Handbook on Africa

Challenges and Issues of the 21st Century

African Political, Economic, and Security Issues

Whitney Sherman
Editor

NOVA

AFRICAN POLITICAL, ECONOMIC, AND SECURITY ISSUES

HANDBOOK ON AFRICA

CHALLENGES AND ISSUES OF THE 21ST CENTURY

AFRICAN POLITICAL, ECONOMIC, AND SECURITY ISSUES

Additional books in this series can be found on Nova's website under the Series tab.

Additional e-books in this series can be found on Nova's website under the e-book tab.

AFRICAN POLITICAL, ECONOMIC, AND SECURITY ISSUES

HANDBOOK ON AFRICA

CHALLENGES AND ISSUES OF THE 21ST CENTURY

WHITNEY SHERMAN
EDITOR

nova publishers
New York

Library of Congress Cataloging-in-Publication Data

Names: Sherman, Whitney, editor.
Title: Handbook on Africa: challenges and issues of the 21st century / editors: Whitney Sherman.
Other titles: African political, economic, and security issues series.
Description: Hauppauge, New York: Nova Science Publishers, Inc., 2016. | Series: African political, economic, and security issues | Includes index.
Identifiers: LCCN 2016037374 (print) | LCCN 2016037555 (ebook) |
ISBN 9781536100631 (hardcover) | ISBN 9781536100761 (eBook)
Subjects: LCSH: Africa--Economic conditions--21st century. | Economic development--Africa--21st century. | Economic development--Africa--International cooperation. | Africa--Social conditions. | Africa--Environmental conditions.
Classification: LCC HC800 .H36132 2016 (print) | LCC HC800 (ebook) | DDC 338.960905--dc23
LC record available at https://lccn.loc.gov/2016037374

Published by Nova Science Publishers, Inc. † New York

CONTENTS

PREFACE

The authors of this handbook provide new research on the challenges and issues of the 21st century in Africa. Some of the topics discussed include the African Development Bank; the PEACE model; environmental developments; waste management; diseases and public health challenges; and education.

Chapter 1 - It is now well-established that Party affiliations tends to dictate the level of commitment and consistency of the U.S. policy towards the multilateral development banks (MDB), which provide financial assistance to promote economic and social development to developing countries. The study uses data on the ADB loan window from 2004 to 2011 to analyze whether the U.S. Congress through the House of Representatives and Senate affect how the U.S. vote in the African Development Bank (ADB). The empirical results uncover overwhelming support of the Congress toward ADB funding, irrespective of party affiliation. This support is less shaped by ideology but more as a way to accommodate resource-constrained ADB's efforts to fund socio-economic projects that improve living conditions of the poorest countries in the continent.

Chapter 2 - This study proposes a model for Alternative Dispute Resolution (ADR) practice, tailored to address the needs of Africans. Specifically, it draws inspiration from Ghanaian visualized philosophical traditions evidenced in Adinkra symbols. It is possible for other African countries to replace the Ghanaian adinkra symbols with their local symbols or maxims with similar meanings that match up with those in the model. The chapter argues that in spite of the usefulness of models imported from developed countries, they lack the ability to make conflict resolution real, concrete, practical and all-encompassing where all, regardless of educational background can identify with, appreciate and understand the process with less effort. Accordingly, ideas are leveraged from the appreciative inquiry theory to develop a PEACE Model using Adinkra Symbols to effectively stimulate peaceful conversations during conflict resolution and human interaction activities in Ghana and Africa as a whole. This chapter emphasizes that indigenous knowledge derived from wisdom refined from the past by African ancestors need to be revisited and employed to empower individuals to lead progressive lives for sustainable peaceful coexistence. It is hoped that this chapter will generate a robust debate into the challenges and opportunities of effectively resolving conflicts in Africa for sustainable results.

Chapter 3 - The energy and development nexus is a strong pillar of sustainable economic development in the 21st century. For countries in sub-Saharan Africa (SSA) wishing to achieve economic growth and meet the sustainable development goals, deployment of modern

energy projects offers potential opportunities. SSA is currently experiencing strong economic growth and showing positive trends in human development indicators. With annual gross domestic product (GDP) growth rates reaching 5% since 2000, more than twice that of the 1980s and 1990s, Africa has become a fast growing continent. Access to morden and sustainable energy will be critical to sustain the growth. About 47% of the population of SSA live on less than US$ 1.25 per day and 27% are hungry or undernourished. A large number of these people depend on agriculture for livelihood. They depend on access to land and traditional forms of bioenergy. Food security and economic development in SSA can be addressed more effectively with morden energy than without it. It is a truism that there is rampant energy poverty in rural areas in SSA. Energy presents both opportunities and risks for sustainable development. Energy is linked to a range of developmental issues such as poverty alleviation and modernization of rural economies. Many developmental activities in SSA such as agriculture, transport, water, education, income generation and health have energy requirements. Taken severally, energy and development represent key issues in SSA today. Holistically, energy and development form an important nexus in SSA. This chapter provides an overview of the energy-development nexus in SSA with the view of supporting sustainable development in the region.

Chapter 4 - Given the nature of water supply related difficulties that so many countries are now facing it is then important to consider the supply of water in most wanting countries such as in Sub-saharan Africa (SSA). The future of water security and related infrastructure, in addition to the possible effects that climate change may have on SSA are all fundamentally in doubt. There is a need to study why so many persons are moving from these countries. The paper shows that while there are many other reasons one of the fundamental is water and food security. The lack of infrastructure and inefficient flow networks of water in countries are also noted and these have to be much improved and moreover guarded against potential loss. The information and critical analysis provided in this paper shows that there is a clear need for the investigation into water availability supply networks security. The fresh and clean drinking water is now to be accepted as on demand by modern consumers given progress of humans over time. This paper reports on the water related difficulties facing some the Sub-saharan African countries where many of dispossessed persons live and this has led to the great movement of people that has occurred in recent times. The unfavourable nature of the climate and agricultural land and the effect of climate change appears to have led to the rural migrating to urban areas; but the difficulty now is maintaining the security of the supply networks as well as for the infrastructure of water lowering risks by the development of appropriate management strategies.

Chapter 5 - This chapter is particularly concerned about the perception of health and diseases held by the communities living in the North of Sierra Leone, specifically in the Koinadugu district. This chapter examines the study of health systems, the ways in which people of Sierra Leone interpret the origins of diseases and how this influences their treatment. Communities think that diseases appear not only because of natural causes: they believe that, behind a disease, the influence of witchcraft or spirits of the jungle may be concealed. Finally, the author makes recommendations for improving the current situation.

Chapter 6 - This briefing contextualises the rumours that circulated during the 2014 Ebola outbreak in Sierra Leone. These rumours were a method of trying to explain the cause of Ebola and understand the responses to it. Analysing these rumours helps the international community to understand Sierra Leonean perceptions of Ebola in order to improve future

emergency health responses in Sierra Leone. These rumours were a product of the initially over stretched and poorly implemented Ebola response and the international communities' attitude towards Ebola, but they were more often linked to long-term issues of structural violence, which also contributed to the unprecedented spread of Ebola in Sierra Leone. Despite the efforts of the World Health Organisation to control the Ebola outbreak, achieving zero cases and providing support for survivors, rumours about the cause of Ebola and the response to it did not abate. Although social mobilisation and sensitisation was important in the short-term, it is the more complex and deeply ingrained issues that the Ebola response and those that dominate the current system of global health governance must grapple with to properly eradicate Ebola now and in the future. Ebola rumours are thus an extremely fruitful way to elucidate both Sierra Leonean perceptions of Ebola and the response to it, and the multiple, global, political, economic and social inequalities that contributed to the outbreak.

Chapter 7 - Arid and semiarid landscapes appear to preserve more evidence of former environmental conditions, although high contemporary erosion rates and the paucity of long terrestrial-sedimentary sequences hinder their complete elucidation. This paper focuses on the late Quaternary environmental change in the Namibia in southern Africa. The Namibia is located at the interface of tropical, subtropical and temperate atmospheric and oceanic systems. Despite the fact that southern Africa was not subject to Quaternary glaciation per se, the influence of variations in amount and seasonality of rainfall has been very marked indeed. The relationship between geomorphology and climate in Namibia reveals the degree and extent to which its landscapes are determined by changing environmental conditions, especially during the Late Quaternary. Case studies of late Quaternary environmental changes in the northern, western and central Namibia are presented. In the western Namibia, over the last 140 ka during the Late Pleistocene, lower leaf-wax δD and higher $\delta^{13}C$ (more C4 grasses) were recorded in a marine sediment core at 23°S off the coast of Namibia, which indicates wetter Southern Hemisphere (SH) summer conditions and increased seasonality, during SH insolation maxima relative to minima and during the last glacial period relative to the Holocene and the last interglacial period. In the central part of the Namibia, the application of OSL dating to both aeolian and fluvial sediments from the Namib Desert is contributing to the understanding of palaeohydrological, palaeoenvironmental and palaeoclimatic change in the region. OSL chronologies from two complex linear dune features close to Gobabeb suggest the current dunes are young (Holocene age), with important messages about the dynamics of the system and migration rates, whilst OSL ages from dunes in the southern part of the Sand Sea suggests older material of up to 24 ka at 5 m depth. The Holocene environmental change in northern Namibia can be deduced from evidences from soils and sediments in the Otjiwarongo thornbush savanna. In this region degradation and desertification (man-made aridification) of drylands are developed during the Holocene. Vertisol–Kastanozem–Calcisol soil associations occur widely (as patches of several hundred hectares in extent). They have formed in fine-grained Mid-Holocene sediments which accumulated on both sides of the subcontinental watershed. Kastanozem formation cannot be explained by the environments that exist at present. The humification suggests open savanna environments in the past and does not accord with the shrublands and thornbush savanna at present. Pedological and geomorphic investigations distinguish separate degradational stages in space and time caused by different periods of human impact. Landscape degradation seems to have started in pre-colonial times (Bantu immigration?) most likely as a consequence of cattle farming, and was increased by farming since the end of the 19th century by European settlers. Degradation of

vegetation and soils, and river channel formation, seem to be the main causes of farmland aridification. These examples from different regions of the Namibia document an increasing intensity of human impact on landscapes to the extent that people now play the dominant geomorphological role, especially in semiarid and coastal areas. The conclusion offers pointers as to how geomorphological evidence of Quaternary change can be used to assist in the better management of contemporary and future environmental conditions.

Chapter 8 - The fluorspar mine at Okorusu, Namibia operated principally from 1988 to 2014 and was a very significant producer of fluorspar used in the chemical industry. It also produced at times several by-products including ground fenite for local road material and magnetite for the cement industry. Together with South Africa the two countries produced as much as 300,000 tons of fluorspar concentrate per year that amounted to 20% of the western world's fluorspar consumption. During 2015 the Okorusu mine has been under care and maintenance.

Okorusu is a carbonatite-related fluorspar mine. Carbonatite is a calcite-rich rock originated in a volcano and derived from the earth's upper mantle. Fluorine-rich fluids developed late in the history of the volcano and fluorine in those fluids combined with calcium in the carbonatites and country-rock marbles to form the fluorspar orebodies. Similar carbonate-related fluorspar ore deposits occur at Amba Dongar in west-central India and at Mato Preto in southern Brazil. Fluorspar deposits at the Kenya Fluorspar mine at Kimwarer in western Kenya and at Hicks Dome in southern Illinois have the geochemical characteristics of carbonatite-related fluorspar deposits.

Several separate orebodies have been mined at Okorusu. The main orebodies were A, B, and D. Mining began at the A deposit. Subsequently both A and B orebodies were mined together. Most recently, significant mining of the D and E orebodies occurred along with continued mining at the B orebody and with minor additional mining at the A orebody. The A and D orebodies owe their genesis mainly to the replacement of carbonatite. The B and C deposits were formed partly by carbonatite replacement and partly by replacement of host rock marble. The carbonatite-replacement fluorspar ores are characterized by elevated deleterious phosphorus contents, elevated amounts of trace rare earth elements, goethite pseudomorphs of magnetite, pyroxene, and pyrrhotite crystals, and by the local presence of replacement remnants of those carbonatite rocks. Carbonatite-replacement fluorspar orebodies transition into unreplaced carbonatite at their margins. Marble-replacement ores are characterized by elevated amounts of silica, banded textures, and gradation into unreplaced marbles at their margins.

The recognition that much of the fluorspar ore at Okorusu had formed as a replacement of carbonatite provided an exploration tool for use in the search for additional fluorspar orebodies. Because the carbonatites at Okorusu contain significant quantities of magnetite they have strong magnetic properties and magnetic anomalies are characteristic of orebodies replacing carbonatite because they contain significant amounts of unreplaced magnetite. Unfortunately, magnetic anomalies also occur for carbonatites that have not been reached by the fluorspar-depositing fluids and especially for syenites in the intrusive complex.

The temperatures of deposition and salinity of the fluorspar-depositing fluids can be measured using small microscopic fluid inclusions within the fluorite. Fluid inclusion analysis of Okorusu fluorite shows that the main purple and green fluorites crystalized at temperatures mostly from 166 to 144ºC, and that later yellow fluorite was deposited from 132 to 128ºC. The salinity ranged 5-1.5 wt percent NaCl equivalent. The salinity is significantly

lower than for Mississippi Valley-type fluorspar ores elsewhere and the temperatures are mostly lower than for epithermal ore fluids.

The Okorusu fluorite mine was the world's largest carbonatite-related fluorspar mine for many years. It serves today as the best example of the characteristics of carbonatite-related fluorspar ores against which fluorspar ore deposits elsewhere in the world can be compared and evaluated for their possible genetic connection to carbonatite intrusions.

Chapter 9 - Rabies remains a common affliction to the African and Asian continents, where more than 59000 people die of the disease every year. In recent years, the social, economic and environmental impacts of this tragic disease on various developing countries and their populace have become better documented. Concertedly, it needs to be reinforced that this very significant burden is completely unnecessary. Rabies can be prevented and even eliminated by practical and cost effective control measures. Although rabies can be transmitted by a variety of terrestrial mammals, canine-transmitted rabies accounts for 99% of the human deaths every year. In consideration, the FAO, OIE, WHO and GARC, at their global rabies meeting in 2015, called for and initiated a framework and strategy towards the elimination of canine-mediated human rabies by 2030.

In Namibia, canine rabies has been present since the 19th century, with cases reported from as early as 1887. While canine rabies, with predominant cycles in dogs and jackals, remains endemic in Namibia, a further development plagued the country in recent decades: a unique and progressive rabies cycle in the antelope species, the Greater Kudu (*Tragelaphus strepsiceros).*

For Namibia, the estimated financial burden related to canine-mediated rabies is US$5 111 282 per annum. However, the inclusion of kudu rabies and the economic impact as it relates to losses in the game farming, trophy hunting and tourism industries would undoubtedly be a significant addition to the total rabies burden estimate.

In a fresh approach to control rabies, the Namibian government elected to develop a strategic plan aimed at producing a controlled and carefully considered approach. Various international collaborators were encouraged to contribute skills and expertise to facilitate the development of a cost-effective, manageable and sustainable National Strategy.

In support of the National Strategy for human rabies elimination in Namibia, various supporting research initiatives have been undertaken, including oral vaccine trials in kudu that endeavour to stop the intra-specific transmission of rabies among kudu. Additionally, an in-depth Namibian epidemiological study of rabies is currently underway in order to infer the transmission and epidemiological cycles of rabies within the country. This study will facilitate the targeted and strategic vaccination of local dog populations to curb, and eventually eliminate, the spread of rabies in Namibia.

The National Strategy has provided a clear and defined guide towards controlling and eliminating rabies and Namibia will greatly benefit from the social and economic implications of such an endeavour. If the strategy is executed vigorously, the authors believe that human rabies elimination can be achieved in Namibia by the year 2030.

Chapter 10 - *Background and objective*. Malaria is a mosquito-borne infectious disease with high morbidity and mortality in tropical regions, caused by Plasmodium parasite and transmitted to humans by female Anopheles mosquitoes. WHO estimates that African households lose about 25% of income to malaria. The aim of this pilot study was to determine the prevalence and socioeconomic impact of malaria on households in the Democratic Republic of Congo (DRC).

Methods. An analytical cross-sectional study was conducted from 16 November through December 2015 in which 152 heads of households took part. They were from a rural (n1=81) and an urban county (n2=71). All participating households made up 1,029 members. The French version of 'Malaria Indicator Survey' questionnaire was completed anonymously.

Results. There were 51.3% of male and 48.7% of female heads of households ($p>0.05$). The mean age was 38.97±9.88, and 22% of them were unemployed. Household size varied from 3 to 18, and more than half (61.7%) of rural households had more than five members (vs. 38.3% for urban households). The estimated household monthly income varied from 10 to 700 $US, and only 10.5% of households earned more than 300 US$ a month (vs. 89.5% earning less than 300US$ and 50.6% less than 100 US$; $p<0.05$). Participants from the urban site had higher level of education, with 37.2% having a college or university degree (vs. 21.6% for rural site); 12.5% either had primary education level or were illiterate. Regarding anti-vector measures for malaria prevention, 15.8% of heads of households reported the existence of a public sanitation activity implemented in their residential area ($p<0.001$); 65.8% used insecticide-treated bed nets (ITN), 13.8% used spray, 0.6% combined ITN and spray, 12.5 used ordinary bed nets, whereas 7.2% did not use any preventive measure. For monthly anti-mosquito expenditure, 50% (76/152) of participants reported that they spent nothing due to lack of money, 24.3% spent 10-20 $US, 15.7% spent 21-30 $US; the remaining participants (9.9%) spent more than 30 $US a month. The availability of nets showed a positive association with socioeconomic status of households. Overall malaria prevalence-rate among heads of households was 92.4% (at least one episode), with an average of 2.5 malaria episodes per person (range: 1–7 episodes). It was equally high in participants from both rural and urban sites, 90.1% and 88.7%, respectively ($p>0.05$). In the group of participants who reported using ITN, malaria prevalence-rate was 89%; it was 90.5% in spray users, 100% in ordinary bed net users and 100% in those who did not use any measure. Heads of households who reported earning less than 300 US$ had 2.76 times malaria risk than those from households with a monthly income of 300 US$ or higher (aOR: 2.76±1.87; 95% CI: 1.73-10.41; $p<0.05$); those who had primary education level (or illiterate) had a 33.87 times risk of developing malaria (vs. higher level; aOR: 33.87±34.42; 95% CI: 2.45-89.49; $p<0.05$); whereas those living in areas without public sanitation program had a 3.01 times malaria risk (aOR: 3.01±2.19; 95% CI: 1.37-24.23; $p<0.05$). Regarding individual malaria care expenditure in the previous 12-month period, the estimated cost was 101.56 ± 10.63 $US per person.

Conclusion. Findings from this pilot study showed high malaria rates in both rural and urban households with a relatively high malaria care expenditure, causing a real socioeconomic burden to Congolese households. There is a necessity to enhance malaria prevention programs with the adoption of an integrated anti-malaria approach aiming at increasing malaria awareness and eliminating its vector in the living environment.

Chapter 11 - The argument that "one in every two urban resident is poor" in cities of the developing world can be articulated in the discussions of social and environmental inequalities occurring in the management of solid waste, particularly in sub-Saharan African countries. This paper discusses environmental justice in the context of solid waste management (SWM) in Kinshasa, the capital of the Democratic Republic of Congo. It is argued that the urban poor in most parts of Kinshasa face serious consequences of poor solid waste management and bear a huge proportion of the environmental burden. It is further argued in the paper that the plight of the poor people in Kinshasa has been worsened by the

accelerated rate of urbanisation which has occurred in the presence of bad urban governance, increased civil conflict and weak institutional framework. A combination of these challenges have resulted in increased injustices in the management of solid waste with poor suburbs poor being exposed to living conditions that are inhumane and demeaning. Using secondary data and other archival records, this chapter argues that solid waste in Kinshasa is not only a health risk, but it also presents issues of environmental injustice. These issues have been analysed within the context of evolving arguments that focus on the need to develop pro-poor approaches in the management of urban solid waste in order to promote urban sustainability.

Chapter 12 - The Democratic Republic of Congo (DRC) is experiencing an unprecedented humanitarian crisis that already affected over 15,000,000 people. The "East-Congo war", a perfect example of 'economic war', is reported to be the deadliest armed conflict since World War II. This paper highlights disasters occurring in DRC, related health issues and the perspectives to ameliorate health care services in affected areas. A review of available literature on disasters and emergency events, enriched by personal experience of authors in humanitarian field within DRC. Recurrent armed conflicts, gender-based violence (sexual violence in particular), climate-related catastrophes, outbreaks of communicable diseases, volcano eruption and, recently, earthquakes are among the most prevalent manmade and natural disasters taking place in DRC. The "Congo war" and the subsequent armed conflicts have already caused over 5,000,000 deaths mainly among civilians, deepened poverty and increased the prevalence of gender-based violence and communicable diseases; it has also rendered the health system dysfunctional in most affected zones. With 200,000–500,000 cases of sexual assault, war and armed conflicts in Congo have been setting scenes of grueling violations of human rights with sexual crime toward women as a weapon war in which foreign and local military forces. Studies on the magnitude of sexual violence in eastern DRC and its impact on mental health of the victims provide alarming results. A population-based survey implemented among 11-23 years old girls from 22 high schools in Bunia, eastern Congo, showed that about one third of adolescent girls were victims of sexual violence, whereas a retrospective study conducted at Panzi hospital in the eastern province of Kivu reported an average of 1,100 rapes per month occurring between 2008 and 2009 and the hospital has treated about 10 cases a day. DRC is facing one of the worse crises in the world. A proportionate response to reduce the human and economic impacts of those multiple disasters can only be possible with the contribution and the involvement of international governmental and non-governmental organizations. Among the strategies to deal with DRC's disasters, a particular focus should be on targeting the real causes of the current DRC crises, mainly the economic interests of countries and companies that sponsor armed conflicts to freely exploit DRC's natural resources, whose main reserves are located in the eastern DRC. More importantly, besides relief services from international organizations and the involvement of competent United Nations' specialized agencies to ensure security, reinforcing the overwhelmed health system through provision of appropriate medical infrastructures and necessary equipment, periodical training of local health care providers and improving their safety and work conditions are among solutions to address health issues arising mainly in conflict zones and ameliorate health care delivery to affected populations.

Chapter 13 - Education is certainly one of the key determinants of income. To understand how education expansion affects income inequality, this paper started out with the observation that the recent economic growth in DRC increased the average income of the population but has left the poor behind due to the lack of industrialisation and redistribution

policies. I then constructed a district-level panel dataset to assess the extent to which education expansion reduces income inequality. I first estimated the impact of educational inequality on income inequality. I found a positive and significant relationship between educational inequality and income inequality. The results are robust across different inequality measures. Then, I went a step further to understand how changes in the average year of schooling affect income inequality. The findings revealed that the increase in the average year of schooling leads to a reduction in income inequality.

Chapter 14 - In the last twenty years, policy makers have come to an understanding that for poverty reduction to be sustainable and welfare benefits distributed evenly, social investments must act as a catalyst. Thus, no meaningful progress in sustainable development can be made when the level of inequality level is continuously rising and benefits of government expenditure unevenly shared. At the moment, Nigeria is one of the twenty poorest, most unequal societies in the world, with just half of the population controlling 5 percent of national resources. Productive sectors in Nigeria have considerably shrunk in size since the 1980s, to the extent that about 70 per cent of the population lives below the poverty line, which is deep, severe and pervasive. This raises concerns and questions on demographic dividends from investments in the social sector. Data for research was obtained from ministries of health as well as private service-providers in the SE region of Nigeria. Marginal Benefit Incidence Analysis was used in estimating the benefits of various quintiles by combining information about unit costs of providing services with information on the use of these services. Thus, this chapter focused on the distribution of beneficiaries across different demographic groups from services rather than measuring the exact value to recipients of government-sponsored services. Results indicate that the states in the South East (SE) Nigeria subsidized the rich in the society. The chapter recommends effective discretionary targeting of expenditure, and the less privileged in government expenditure programmes. This is a potent strategy for curtailing poverty and inequality in the system and would serve as a means of sustaining societal growth and economic progress.

Chapter 15 - The majority of women who participate in South African football (soccer) face a triad of challenges due to their gender, race, and class. Women in general in South Africa continue to fall into the lowest social strata and are considered vulnerable due to poor living conditions, absent fathers, lack of economic opportunities, and poor government infrastructure in terms of education, housing, and health care. Sport participation provides opportunities for women to confront the challenges of poverty, such as traditional gender roles and expectations, avoid deviant behaviours, and become more confident to manage inter-gender power relations. This paper uses comprehensive case studies focused on 21 South African female football players, their significant others, schools and communities. Centered in critical feminism, the case studies in this research reveal how girls can increase their self-confidence and create healthier relationships with boys, leading to better future relationships that reduce the risk of teenage pregnancy, contracting HIV/AIDS, being raped or sexually abused. More research is needed to examine the longer term effects of football participation on gender relations and poverty in South Africa.

In: Handbook on Africa
Editor: Whitney Sherman
ISBN: 978-1-53610-063-1

Chapter 1

US VOTE IN AFRICAN DEVELOPMENT BANK

Djeto Assané [*] ***and Nicole Parks*** [†]
Department of Economics, University of Nevada, Las Vegas,
Las Vegas, NV, US

ABSTRACT

It is now well-established that Party affiliations tends to dictate the level of commitment and consistency of the U.S. policy towards the multilateral development banks (MDB), which provide financial assistance to promote economic and social development to developing countries. The study uses data on the ADB loan window from 2004 to 2011 to analyze whether the U.S. Congress through the House of Representatives and Senate affect how the U.S. vote in the African Development Bank (ADB). The empirical results uncover overwhelming support of the Congress toward ADB funding, irrespective of party affiliation. This support is less shaped by ideology but more as a way to accommodate resource-constrained ADB's efforts to fund socio-economic projects that improve living conditions of the poorest countries in the continent.

1. INTRODUCTION

Once a development bank that only allowed voting rights for its regional members, the African Development Bank (ADB) opened its membership in 1982 to bring in more capital. Within the ADB's Board of Directors there are 20 Executive Directors, 13 of them represent different voting groups of the regional member countries, while the other seven represent the voting groups of non-regional member countries. The only country in the ADB that does not share an Executive Director with another country is the United States. After Nigeria, the U.S. holds the most voting shares in the ADB. The power of the U.S. over the ADB is reflected on the type of project being brought to a vote and the directives enacted by the U.S. President and Congress (Strand, 2001).

[*] Corresponding author: Email: djeto.assane@unlv.edu.
[†] Email: parksn@unlv.nevada.edu.

In efforts to rebuild Europe after World War II, countries came together and created one of the best known multilateral development banks (MDBs), the World Bank. Founded in 1944, the bank is by far the largest lender in the world. From its conception the United States has been involved and invested in the World Bank and many other MDBs. While the World Bank's goal is to help develop and rebuild countries in need, not all countries qualify for assistance; this led to the creation of regional development banks. Some of the most popular regional development banks include the Inter-American Development Bank (IDB), the Asian Development Bank (ASDB), the European Bank for Reconstruction and Development (EBRD) and the African Development Bank (ADB).

When it comes to policy in the many MDBs, the ability of the United States to achieve policy and operational objectives varied from issue to issue and from institution to institution, depending on several factors, especially (i) the level and consistency of the U.S. commitment to a particular objective, (ii) the interests and positions of other key actors and (iii) the individual characteristics of the banks themselves (Mckeown, 2009).

For example, the World Bank is the largest and most important MBD to the U.S., which allocates a vast amount of money into the bank so it could have more power as to how and what projects the World Bank approves. Indeed, the influence of the U.S. over the World Bank lending has evolved overtime, often changing with presidential administrations and depending on economic and political circumstances (Fleck and Kilby, 2006). But, in the case of ADB, the U.S. does not enjoy this same amount of power. While it holds the second largest voting share, and is the only member country with an individual director, it lacks in the voting share that other member countries get from having voting groups (Strand, 2001). Nonetheless, the U.S. still has sway and from time to time does exert its power over the ADB; this depends on the type of project, or issue that is being brought to a vote, which again depends on the policy that is being enacted by Congress and the President in the United States.

The study uses data on the ADB loan window from 2004 to 2011 to analyze the effects of party affiliation of the House of Representative majority and the Senate majority on the U.S. votes in the ADB; the control variables include factors such as types of projects, mode of funding, economic conditions and political, civil and human right records of member African countries. The rest of the study is organized as followed. Section 2 provides institutional background of the ADB, section 3 outlines the empirical model, section 4 describes the data and summary statistical measures, section 5 contains the empirical results and section 6 concludes.

2. INSTITUTIONAL ORGANIZATION

2.1. Overview

The African Development Bank (ADB) came in effect on September 10, 1964 with a mission to spur sustainable economic development and social progress in Africa. Under the parental umbrella of the bank, there are two concessional windows, the African Development Fund (ADF) and the Nigeria Trust Fund (NTF). The ADF became operational in 1972 and serves 40 eligible countries by providing funding for projects and studies through a concessional window. The NTF was created by an agreement between Nigeria and ADB to

assist low-income regional member countries, whose conditions require a concessional financing.

In 1982, the ADB began to allow wealthy countries membership and voting rights 'in an effort to obtain more capital" (Strand, 2014). Prior to this, non-African countries were allowed to contribute, but were not allowed voting rights. This limited the amount of capital because countries were not willing to give as much if they did not have a say in how the money was spent. While the initial idea of an African bank run by Africans for Africans sounds great, the reality of the fact was that it was not sustainable and the ADB had to let in non-regional members in order to remain relevant. As of December 2014, the ADB has 79 member countries, 53 regional member countries and 27 non-regional member countries. All are shareholders except the United Arab Emirates who only contribute to the ADB.

The ADB is the major African development bank that finances socio-economic activities to help alleviate poverty and promote sustainable development of the African countries; ~~B~~ borrowers are mostly low-income countries in the region. The bank finances projects, principally in the areas of road infrastructures, agriculture, health, education and water-related activities. Until recently, the bank was plagued with limited financial resources, accounting only for 6% of the need for development assistance to the continent. For many projects the bank operates in the "shadow" of the World Bank, working jointly on many projects.

Table 1. Voting share in top ten and bottom 10 countries

Exhibit A: Voting share in top ten countries				
Rank	Country	Total shares	Total votes	Voting share
1	Nigeria	595,213	595,838	9.281%
2	United States	420,691	421,316	6.563%
3	Japan	352,069	352,694	5.494%
4	Egypt	344,717	345,342	5.379%
5	South Africa	312,075	312,700	4.871%
6	Algeria	269,575	270,201	4.209%
7	Germany	264,290	264,915	4.126%
8	Canada	243,449	244,074	3.802%
9	France	240,751	241,376	3.760%
10	Cote d' Ivoire	236,085	263,710	3.687%
	Total	3,278,915	3,285,165	51.172%

Exhibit B: Voting share in bottom ten countries				
Rank	Country	Total shares	Total votes	Voting share
1	Comoros	542	1,167	0.018%
2	Djibouti	1,213	1,838	0.029%
3	Guinea Bissau	1,547	2,172	0.034%
4	Seychelles	1,818	2,443	0.038%
5	Somalia	1,941	2,566	0.040%
6	Eritrea	2,003	2,628	0.041%
7	Central African Republic	2,843	3,468	0.054%
8	Mauritania	3,701	4,326	0.067%
9	Lesotho	3,721	4,346	0.068%
10	Sao Tome & Principe	4,335	4,960	0.077%
	Total	23,664	29,914	0.466%

Note: Extracted from ADB 2014 Annual Report.

2.2. Voting Power Scheme

In an effort to maintain the African characteristics of the ADB the bank established a requirement that states overall regional member states must hold 60 percent of the voting share and non-regional member states can hold only 40 percent (Annual Report 163). Beyond this requirement member states receive basic votes and weighted votes on the basis of cumulative financial contribution and commitment to the organization. According to the original agreement each member country receives 625 basic votes. Members receive an extra vote for each share of capital stock they hold (Agreement establishing the African Development Bank). For example, the United States holds 420,691 shares in the ADB, when combined with their basic votes, the U.S. has a total of 421,316 votes and voting share of 6.563%. Table 1 presents the member countries with the highest voting share (exhibit A) and lowest voting share (Exhibit B).

Unlike the top ten member countries, member countries with the least voting share are all regional member countries. Their combined voting share is less than half a percent (0.466%). Therefore their power in having a say in matters at the ADB are extremely limited. If the ADB did not have mandatory basic votes, these countries would have significantly less influence than they actually do. In Comoros case, the basic votes more than double their total votes. Whereas in the case of the top ten countries who own a lot of shares in the ADB, the basic votes barely affect their total voting share.

The ADB has two governing bodies, the Board of Governors and the Board of Directors. The Board of Governors is comprised of a minister of Finance, Planning or Central Bank Government, or an alternate from each member country (Annual Report). The Board of Governors meets once a year to discuss various challenges to the region. This board is in charge of five main actions: The Bureau, the Joint Steering Committee, the Steering Committee on the Election of the President of the Bank, the Standing Committee on the Conditions of Service of Elected Officers and the Governors' Consultative Committee (Annual Report). The Board of Directors is comprised of 20 Executive Directors that are elected by the Board of Governors for 3-year term that can be renewed one time. The Board of Directors handle the day to day operations of the ADB. They are the apex decision-making body as they are in charge of general operations, approval of strategies, policies, loans and grants, equity investments, guarantees and the administrative budget (Annual Report). Thirteen Executive Directors represent the regional member countries while seven Executive Directors are from non-regional member countries. The countries are divided into voting groups, who name the Executive Director and decide where their collective voting share will go. The only country that has its own Executive Director is the United States. The U.S. is the highest shareholder out of all the non-regional member states.

Outside of the United States, most of the voting groups include a county with a high voting share, a mid-level voting share and a low voting share. Every voting group has a dominant country that has the majority of the voting share. The director will often come from the country with the most voting share. For example one voting group is comprised of Algeria, Guinea-Bissau and Madagascar; the Executive Director will more likely come from Algeria whose voting share is 4.209% compared to Guinea-Bissau and Madagascar's 0.034% and 0.652%, respectively (Annual Report). The most interesting voting group is the group of Nigeria and Sao Tome and Principe. Nigeria is the largest shareholder in ADB and Sao Tome and Principe is one of the smallest. In this group the Executive Director has changed ~~3~~ three

times in the last decade, the director was always Nigerian, while the alternate director position has changed as well; it has always been a Sao Tome and Principe candidate in the position. In essence, Sao Tome and Principe will never have a say in how Nigeria uses its large share to exert its power in the ADB.

3. EMPIRICAL MODEL

The empirical model used in our study investigates the factors that contribute to U.S. vote in funding ADB's development projects. The model is specified as:

$$\text{Vote} = X\beta + \varepsilon \quad (1)$$

Vote is the dependent variable coded 1 for support of a given project and 0 for opposition;[1] X is the vector of explanatory variables and ε is the error term. The explanatory variables are grouped into five categories of covariates. The first group of variables is binary and highlights US Congress influence on the vote in the ADB. These include whether or not the house of representatives is a majority Republican *(House)* and whether not the house of senate (*Senate)* is a majority Republicans. Congress uses ideology to express voting preference in most MDBs. "Right-wing" legislators are less likely to support MDB funding on the ground that these projects pay little attention to "market requirements" which insulate them from the risks of their actions. In contrast, the left-leaning legislators tend to focus on market failures and encourage funding that can mitigate pervasive poverty. Moreover, in the case of the IMF funding, Broz (2011) observed that since senators are less sensitive to constituency pressure they tend to support more the IMF financing than their counterpart representatives. The next group of covariates comprise political, civil and human rights conditions in the borrower countries. Poor records of these covariates, adversely affect U.S. support for ADB funding. To mitigate high collinearity among these three variables, we construct a *Freedom House* variable as a simple average of these three covariates where 1 is most free and 7 is least free. Thus, a worsening of the indicator influences negatively the U.S. vote for a given project. Furthermore, the next two variables *Log(Rgdp)* and *log(Trade)* reflect the economic condition of the borrowing African countries. Improvement in both variables is a sign of a healthy economy which increases the opportunity for borrower countries to opt for more diverse, alternative funding sources. Thus, one can expect an inverse relationship between U.S. vote and these economic indicators. Three types of projects financed through the ADB are considered: Road infrastructures *(Transport),* water *(Water)* and health *(Health)* projects are likely to receive a "support vote" since they epitomize ADB's agenda in promoting development. Finally, two modes of funding projects used in the analysis are loan (*Loan)* and grant (*Grant)*. Loans require reimbursement of the fund with interest, whereas a grant is a "gift" that need not be repaid and is based on financial need. Accordingly, a U.S. "opposition vote" is more likely to be associated with a loan than a grant. Table 2 provides the description of the variables.

[1] Initially, vote was coded as no, abstain, or yes. The abstain vote accounted for only 3% of the data. The resulting multinomial logistic regression yield far worse results. It was thus decided to merge the abstained and no vote as just a no vote.

4. DATA AND SUMMARY MEASURES

The data used for this project come from various sources and cover the period 2004 to 2011. The sample was determined by data availability. Information about congressional party affiliation and vote was taken from the U.S. Treasury's Loan Review Votes (2015). Economic condition variables are from the World Bank (2015); the project variables and types of funding were collected from ADB (2015). Freedom House (2009) scores were used to measure extent of political, civil and human rights records.

Table 2. Variables description and definition

Variable name	Acronym	Definition
Vote	*Vote*	1 = Support ; 0 = Opposition
Political Affiliation		
Republican House	*House*	1 if yes, 0 otherwise
Republican Senate	*Senate*	1 if yes, 0 otherwise
U.S. Interests		
Freedom House	*Freedom*	Rated on a scale 1 (High) to 7 (Poor)
Funded Projects		
Road Construction	*Transport*	1 if yes, 0 otherwise
Health	*Health*	1 if yes, 0 otherwise
Water	*Water*	1 if yes, 0 otherwise
Funding Mode		
Loan	*Loan*	1 if yes, 0 otherwise
Grant	*Grant*	1 if yes, 0 otherwise
Economic Conditions		
GDP	*Log(RGDP)*	Log of real per-capita GDP
Trade	*Log(Trade)*	Log of trade volume

Table 3. Descriptive S statistics

Variables	Mean	Standard Deviation	Minimum	Maximum
Vote	.774	.418	0	1
House	.471	.491	0	1
Senate	.209	.500	0	1
Freedom	4.05	1.499	1	7
Transport	.127	1.597	0	1
Water	.091	1.776	0	1
Health	.024	1.309	0	1
Loan	.553	1.499	1	1
Grant	.221	.416	0	1
Log (Rgdp)	1.623	.155	1.012	2.461
Log (Trade)	3.161	.068	2.951	3.290

Descriptive statistic results in Table 3 clearly suggest that the US Congress voted overwhelmingly (77.4%) in support of projects at the ADB lending window. This could suggest that most project proposals were in line with the types of project the bank finances or

that this reflects U.S. attempt to support development effort of the poorest countries in the region. House representatives and senate are 47.1% and 20.5%, respectively. Freedom house score is 4.05, slightly above the mean value which is consistent with African countries' struggle to establish these basic rights. Moreover, funding resources were primarily allocated to road construction. Finally, 55.3% of the funds were in loan compared to 22.1% in grant formats.

5. EMPIRICAL RESULTS

In Table 4, we report the empirical results of the discrete choice models based on the linear probability model, the logit and probit models. For each model we report three types of specification. The first specification is restricted to the effects of the U.S. Congress on vote in ADB financing, whereas the second results add *Freedom* effect to the first specification and finally the third specification controls for all the five groups of variables.

Overall, the interpretation of the findings is straightforward. The coefficients exhibit mostly the correct signs even though many of them are not statistically significant. The positive and insignificant coefficient of the variable *House* and *Senate* suggest that the US Congress is supportive of the ADB's projects irrespective of party affiliation and that senators are more likely to support these projects than their colleague representatives. Moreover, the U.S. congress are also positively responsive to the various types of projects, transport, health, and water which highlight somewhat the mission of the bank in financing projects that improve living conditions of member countries. Turning to factors that identify US foreign policy and financial assistance interests, the coefficient of the variable *Freedom* has the expected sign. In general, violations of these rights result in sanctions that consist of denying funding of projects in most MDBs. Finally, the results of the economic condition variables, real GDP and Trade are consistent with expectation in terms of signs and statistical significance. Improved economic conditions can be an impetus for borrowing countries to expand the source of funding and thus rely less on the ADB's lending window.

Although suggestive, the overall significance of the various specifications accord with the overall conclusion of this study. Indee, the F-statistic test of the LPM model and the log-likehood ratio test of the logit and the probit models point to the same direction of the overall conclusion. That the the U.S. Congress does exert voting preferences in the financing of the ADB's development projects.

CONCLUSION

The purpose of this research was to investigate if party affiliation of the U.S. Congress through the majority of the House of Representatives and the majority of the Senate has an effect on how the U.S. Votes in the ADB. Overall, it was found that projects at the ADB's lending window received an overwhelming support of the U.S. Congress irrespective of party affiliation. In particular projects such as road construction, health and water-related activities are in line with ADB's mission to provide funds that can combat poverty and improve living conditions of the poorest countries in the region.

Table 4. Regression results of the LPM, Logit and Probit models (Vote=1or 0 is the dependent variable)

Variable Name	LPM			LOGIT			PROBIT		
House	.009 (.062)	.008 (.063)	.058 (.062)	.050 (.345)	.038 (.345)	.334 (.389)	.029 (.209)	.021 (.205)	.184 (.227)
Senate	.201** (.077)	.202* (.125)	.153 (.134)	.173** (.658)	1.720 (1.023)	1.445 (1.663)	.916 (.802)	.903 (.897)	.808 (.829)
Freedom		-.009 (.018)	-.002 (.017)		-.055 (.105)	-.013 (.109)		-.034 (.060)	-.013*** (.067)
Transport			.091 (.079)			.513 (.501)			.321 (.924)
Water			.030 (.073)			.403 (.212)			.2076 (.223)
Health			.103 (.203)			.572 (.291)			.342 (.713)
Loan			-.040 (.063)			.503 (.441)			-2.340 (.252)
Grant			.204 (.165)		.265 (.205)	.906 (.381)			.554* (.309)
Log(Rgdp)			-.657*** (.080)		2.136*** (.501)	-4.159*** (1.262)			-2.340*** (.719)
Log(Trade)			-.647*** (.437)		.488 (.511)	-4.312** (2.201)			-2.617*** (1.034)
Constant	.728*** (.036)	.769*** (.085)	4.113*** (.405)	.987*** (.198)	1.233** (.502)	23.449*** (2.683)	.608*** (.118)	.758*** (.288)	13.812*** (4.851)
R_Squared Adjusted	.032	.041	.138						
F-Statistics	5.08***	3.47***	4.11***						
Likelihood Ratio				12.21***	12.49***	36.55***	12.21***	12.53***	36.29***
Number of Observations	244	244	244	244	244	244	244	244	244

Note: Standard errors are in parentheses below each coefficient estimates. The asterisks, *, ** and *** indicate statistical significance at the .1, .05 and .01, respectively.

Although fragile, our results have important implications for the U.S. influence over ADB. Indeed, there is an overwhelming support of the U.S. for ADB which is a relatively small development bank operating in the shadow of the World Bank and lacking financial resources to face the growing financial need of African countries. Perhaps the obvious support is less based on the traditional ideology pursued by the U.S. in other MDB but more as a "genuine" way to contribute to the improvement of the living conditions in Africa.

This study is a first attempt to estimate the U.S. influence through the vote in ADB to finance multilateral development projects of the poorest countries in Africa. Most importantly, we regard this as an interesting topic for future research to explore.

REFERENCES

African Development Bank Group, (2011). Agreement Establishing African Development Bank Group.

African Development Bank Group. (2015). About Us: African Development Bank.

Braaten, D. (2012). Human rights and US foreign policy in the multilateral development banks.

Fleck, R K. and Kilby, C. (2006). World Bank independence: A model and statistical analysis of US influence. *Review of Development Economics*,1 (2): 224- 240.

Kilby, C. (2013). An empirical assessment of informal influence in the World Bank. *Economic Development and Cultural Change*, 61(2): 431-464.

McKeown, T. J. (2009). How US decision-makers assessed their control of multilateral organizations, 1957—1982. *The Review of International Organizations*, 4(3): 269-291.

Schoultz, L. (1982). Politics, economics, and US participation in multilateral development banks. *International Organization*, 36(03): 537-574.

Strand, J. R. (1999). State power in a multilateral context: voting strength in the Asian Development Bank. *International Interactions*, 25(3), 265-286.

Strand, J. R. (2001). Institutional design and power relations in the African Development Bank. *Journal of Asian and African Studies*, 36(2): 203-223.

Strand, J. R. (2014). The Regional Development Banks and Global Governance." Ed. Thomas G. Weiss and Rorden Wilkinson. International Organization and Governance.

In: Handbook on Africa
Editor: Whitney Sherman
ISBN: 978-1-53610-063-1

Chapter 2

THE PEACE MODEL: A SUSTAINABLE APPROACH TO CONFLICT PREVENTION AND RESOLUTION IN AFRICA

Enyonam Canice Kudonoo*, PhD
Ashesi University College, Berekuso E/R, Ghana

ABSTRACT

This study proposes a model for Alternative Dispute Resolution (ADR) practice, tailored to address the needs of Africans. Specifically, it draws inspiration from Ghanaian visualized philosophical traditions evidenced in Adinkra symbols. It is possible for other African countries to replace the Ghanaian adinkra symbols with their local symbols or maxims with similar meanings that match up with those in the model. The chapter argues that in spite of the usefulness of models imported from developed countries, they lack the ability to make conflict resolution real, concrete, practical and all-encompassing where all, regardless of educational background can identify with, appreciate and understand the process with less effort. Accordingly, ideas are leveraged from the appreciative inquiry theory to develop a PEACE Model using Adinkra Symbols to effectively stimulate peaceful conversations during conflict resolution and human interaction activities in Ghana and Africa as a whole. This chapter emphasizes that indigenous knowledge derived from wisdom refined from the past by African ancestors need to be revisited and employed to empower individuals to lead progressive lives for sustainable peaceful coexistence. It is hoped that this chapter will generate a robust debate into the challenges and opportunities of effectively resolving conflicts in Africa for sustainable results.

INTRODUCTION

Alternative Dispute Resolution (ADR) in Ghana is gradually gaining grounds with an Act of Parliament: The Alternative Dispute Resolution Act (Act 798) passed in 2010 to give

* Senior Assistant Professor; E-mail: ekudonoo@gmail.com, Telephone no: +233247105589.

legislative support to the practice with the objective of ensuring its effectiveness. For decades, foreign models mostly from developed countries have been used to resolve conflicts in Ghana. Models including the "PULSE" approach to conflict resolution designed by Love (2008; 2011), Dana's (2005) "Managing Workplace Differences," and Domenici (1996) among others are being used for training and conflict resolution purposes. Although these models are useful and successful to an extent, they lack the local touch of handling conflicts for sustainable results. Moreover, examples and case studies used for illustration in these foreign approaches are based on the cultures of the authors. A typical example is the use of the delta symbol to represent a change agent (mediator or arbitrator), whereas in the proposed PEACE model, the symbol used is more meaningful expressing the way of knowing by Ghanaians (Africans). Accordingly, foreign models lack the ability to make conflict resolution real, concrete, practical and all-encompassing where both literate and non-literates in Ghana (Africa) can identify with, appreciate and understand the process with less effort.

The purpose of the proposed PEACE model is to draw ideas and ideals from values and the existing rich indigenous knowledge of Ghanaian people for effective and sustainable conflict resolution in Ghana and Africa. It employs visualized philosophical traditional knowledge evidenced in Adinkra symbols, with their meanings in concert during conflict resolution and human interaction activities. Both ADR practitioners and disputants in Ghana can easily identify with, and own the process because it is not foreign and thereby indigenizing and concretizing ADR practice in Ghana and Africa.

This chapter makes contributions to the effective practice of ADR in Africa by first, acknowledging that an indigenized approach to conflict resolution contributes to the sustainable success of ADR outcomes. Secondly, this is the first time an attempt is being made to concretize ADR practice in Ghana (Africa) by using local symbols at every stage of the resolution process. Finally, the proposed model makes conflict prevention and resolution easy to both literates and non-literates because both parties are conversant with the symbols and their meanings. Moreover, it is an easy tool for families, clans, chiefs, opinion leaders, colleagues, and organizations to use to prevent or resolve conflicts that crop up during their daily interactions. Also, it is easy to replicate it in other African countries. This can be achieved if practitioners in the African country in question are able to replace the Ghanaian adinkra symbols with local symbols or maxims that have similar meanings like those in the model.

The rest of the chapter is presented in six sections. It starts with a brief discussion on Ghana, the approach to the research, why the use of adinkra symbols for conflict resolution, an explanation of the PEACE model and its elements, and concludes with implications for scholarly and practical contributions.

ABOUT GHANA

Ghana, (formerly known as Gold Coast) with its capital Accra, is a former British colony. It gained independence in 1957. Ghana lies in the center of the world, the closest place where the equator (latitude 0°) and the Greenwich or Prime Meridian (longitude 0°) intersects. It is about the same size of Great Britain or the state of Oregon in the United States of America (Amamoo 2007; Osumanu, Abdul-Rahim, Songsore and Braimah, 2010). Ghana is currently a relatively stable democratic nation made up of ten administrative regions, further divided into

216 metropolitans, municipal and district assemblies for allocation of resources for development and governance. According to Awedoba (2007), more than 50 languages are spoken in Ghana, of which ten (Asante, Fante, Akwapem, Nzema, Ga, and Dangme, Ewe, Dagbani, Gonja, Kasem, and Dagaare) are taught in schools. The Asante, Fante and Akwapim languages are all Akan languages understood by majority of Ghanaians. Despite the diversity in languages, indigenes have managed to learn each other's languages and effectively communicate with one another. English serves as the national language and the main (lingua franca) medium of communication and for instruction in schools.

Ghana has a rich indigenous knowledge, traditionally transmitted orally through stories, folklore, songs, drumming and dancing, games, rituals, laws, proverbs, riddles, and symbols (Gyekye 2003). One of the ways through which this kind of knowledge is documented in Ghana is by means of *adinkra* symbols which encompass its people's belief systems and local cultural practices (Arthur 2001; Asamoah-Hassan 2011). A*dinkra* symbols, according to Vigbedor (2011, 16), "cover all aspects of man's life from history through psychology to philosophy, ranging from rites of passage, love, rivalry (conflict), marriage, bravery, backbiting, advice and consolation." Vigbedor's research revealed that most of the ethnic groups in Ghana, have symbols covering all aspects of their lives. Accordingly, international donor agencies use these symbols – indigenous knowledge to design and implement planned change efforts in communities (Gorjestani 2000). A typical example is the use of the *oware* game in the design and implementation of participatory budget and scored causal diagrams for effective farm management by tomato farmers in the Brong Ahafo region in Ghana (Dorward, Galpin, and Shepherd 2003). Another example is the use of local institutions and practices in the development of the "Community Organization Development Model" (Guri and Laate 2008), which uses local resources, values, ways of knowing, internal dynamics of communities, and external environmental trends for effective management and development in Ghana by the Center for Indigenous Knowledge and Community Organization Development (a non-governmental organization operating in Ghana).

In the same vein, this chapter proposes a PEACE ("People Expressing Accurately Concerns and Emotions") model that is cultural sensitive, comprising six Adinkra Symbols that are vital in facilitating effective conflict resolution for sustainable peaceful coexistence. It serves as a guide for ADR practitioners in Ghana and for replication in other African countries that have symbols or maxims which have similar meanings at each stage of the model.

METHODOLOGY

The approach to this research is conceptual and practical, relying heavily on secondary data from dissertations (Asamoah-Hassan 2011; Danzy 2009; Vigbedor 2011) and other published documents on adinkra symbols (Arthur 2001; Valentina 2009; Willis 1999). Secondary data is complemented with in-depth interview data from 25 individuals who are well versed in Ghanaian traditions and customs, including a scholar in Akan studies who was the former head of department of Linguistics but now dean of the faculty of performing arts at the University of Ghana Legon, Accra. The researcher explained to the 25 interviewees who were participants of an ADR training program organized by Ghana Association of Certified

Mediators and Arbitrators (GHACMA) that, conflict resolution is being studied using adinkra symbols for sustainable results. Participants consented to participate in the research. Accordingly, unstructured interview was conducted using open-ended questions including 1) of what importance are adinkra symbols to you as an individual Ghanaian and Ghanaians in general? 2) Which adinkra symbols are most appropriate for resolving conflicts in Ghana? 3) What are your reasons for choosing such symbols? 4) Compare and contrast the delta (European symbol for change) and mmere dane (Ghanaian (Akan) symbol for change). Background questions included how sustainable will success in conflict resolution be if adinkra symbols are used during conflict resolution in Ghana. The focus of this manner of interview is to find out the detailed meanings of adinkra symbols, their usefulness and effectiveness in sustainable conflict resolution in Ghana. Also, to find ways of indigenizing conflict resolution in order to make it real, concrete, practical and all-encompassing where both literate and non-literates in Ghana can identify with, appreciate and understand the process with less effort.

WHY ADINKRA SYMBOLS FOR CONFLICT RESOLUTION

Adinkra symbols are means by which people in the early 18th century recorded and transmitted ideas during the preliterate era (Arthur 2001). Adinkra symbols are wisdom distilled from experiences of preceding generations, which, when revisited and employed, can empower Ghanaians (Africans) to lead progressive, wise and healthy lives. Several of such symbols emerged in the past, with new ones cropping up in current times. They are used to craft proverbs or maxims in all areas of life, including celebrations, practical wisdom, morals, science, philosophy, conflict resolution and literary principles (Arthur 2001; Vigbedor 2011). They are widely used as designs in fabrics and pottery. Some organizations including educational institutions such as University of Ghana, University of Cape Coast, University of Education, Winneba, Ashesi University College, Ghana Technology University College, and hotels including the Golden Tulip Hotel in Kumasi among others, and corporate bodies use adinkra symbols whose meanings are similar to their values as their logos. Adinkra symbols are also used for advertising in Ghana. They are incorporated into the architectural designs of some hotels and corporate buildings such as the Golden Tulip Hotel building in Kumasi.

The proposed model draws attention to the fact that African countries since the preliterate era have been effectively resolving conflicts using ways similar to modern ADR practices which have been recorded over the years in the form of adinkra symbols. Prior research reveals that the success of change efforts depends on how specific communities use past knowledge to create new knowledge for sustainable change (Kothari 2007; Kudonoo, 2013; Tenkasi and Mohrman 1999; Tripathi and Bhattarya 2004). The word “change” for the purpose of this chapter is used interchangeably in two ways. The mediator is referred to as an agent of change. It is also used for modification, transformation or conversion of disputants’ behavior during conflict resolution for sustainable peaceful coexistence.

Figure 1a. Delta.

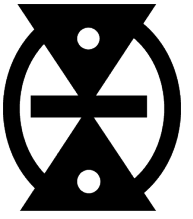


Figure 1b. Mmere dane (Times Change).

> The functions of the human mind are common to the whole of humanity, the reasoning and thinking processes of different people in different cultures do not differ, just their values, beliefs and ways of classifying differ –Boas 1965.

Indeed, the above saying by Boaz aptly sums the view that though different cultures use similar symbols to represent change, values, beliefs systems, and their ways of classifying differ. For example, change in ADR practice is signified by the uppercase delta, the fourth letter of the Greek Alphabet. It is represented by Figure 1a (en.m.wikipedia.org/wiki/Delta_ (letter). The Delta symbol looks like a simple triangle with a thick right side. The Akan (a Ghanaian ethnic group) symbol for change also has two triangles. It is designed out of the maxim "Mmere dane a, wo nso dane bi," which literally means "when times change, you must also change." Accordingly, the symbol is called "mmere dane," which is represented by Figure 1b.

Symbols of Change –*Delta* and *Mmere Dane*

Unlike the Delta, which is similar to a triangle, the symbol 'mmere dane' as depicted by Figure 1b, has several parts. It has two triangles joined by two semi circles. The triangles have white oval shapes inside them, with a rod separating the triangles. The symbol has two colors – white and black. An interview with an Akan cultural expert and a linguistics scholar, revealed that the semi circles joining the triangles symbolize cyclical occurrences in life. The two upside down triangles with their tip touching the rod depict the fact that anything can turn upside down in life. He further explained that there are times in life when people who used to live in harmony become enemies as a result of conflicts. Also, in life, there are times for progress and times for stagnation or retrogression. The rod between the two triangles represent separation, a blockade, or stumbling block, which represent conflict. On the other hand, the separating rod also depicts a conflict situation where a mediator, conciliator, or an arbitrator is (change agent) preventing the two parties (disputants) from clashing. Thus helping parties in dispute to modify their behavior and transform for positive change. The black and white colors depict unity in diversity. White and black are two distinct and

constructive colors that can blend to create not just worlds but best worlds (K. Agyekum, personal communication, January 11, 2016). The complex nature of the 'mmere dane' symbol shows the richness of African indigenous knowledge which need to be taken cognizance of, if Africans must live in harmony for sustainable development.

THE PEACE MODEL

The PEACE model is made up of five carefully selected adinkra symbols based on interview results embedded in a Ewe (Ghanaian ethnic group) adinkra symbol to create a vivid picture of how the conflict resolution process should unfold systematically. The approach though similar to the PULSE (*"People Using Language Skills Effectively)* approach to conflict resolution (Love 2011), is indigenized to suit Ghanaian ways of knowing. The PEACE acronym of "P*eople Expressing Accurately, Concerns and Emotions*" is carefully chosen because the Ghanaian culture value verbal indirectness as a proper way of speaking unlike what pertains in Western cultures which encourage assertiveness and candid expression of views. Consequently, in conflict situations people find it difficult to say exactly what is the root cause of the problem. The model is informed by Appreciative Inquiry theory which centers on human relatedness. The theory emphasizes that "relationships thrive where there is an appreciative eye that focuses on the best in people, when people share their visions and ultimate concerns in affirming ways, when they are connected in full voice to create not just new worlds, but better worlds" (Cooperrider and Whitney 2005:30). The PEACE model weaves ideas and ideals from Ghanaian values, ways of knowing, internal dynamics of local communities, external environmental trends together with principles of the appreciative inquiry theory for sustainable conflict resolution.

The Ewe (a Ghanaian language) symbol that form the foundation of the model is called *"koklostu"* meaning a cock. The symbol depicts two cocks facing each other, as evidenced in Figure 2. The image is derived from the maxim "*when two cocks are fighting, they are mindful of each other's eye"* (Vigbedor 2011:48). The cock in essence, represents a family member, a friend, a colleague in the workplace, a neighbor, a member of a community one lives in, or society. The eye depicts a cordial relationship or common interest shared by a group of people with a common bond. It illuminates the whole body (individual, group or department, or community), enables an individual or a group of people to perceive things in their right perspectives. It is a delicate part of the body, which needs maximum protection. Accordingly, the symbol highlights how people might disagree on certain issues about life, but must be careful not to permanently mar relationships and common interests.

Figure 2. Koklotsu (Cock).

The visualized message in "*koklostu"* runs across all the five stages of the resolution process. The cocks have five feathers each, and each feather represents a stage in conflict resolution. The meaning of the symbol in each feather as depicted in figure 3, communicates the appropriate human behavior that must be exhibited in order to arrive at a sustainable peaceful resolution. The cock at the right side has the stages of conflict resolution embedded in it and the one on the left has corresponding symbols aimed to inform disputants regarding the desired way they should behave. The acronym representing the five stages of the mediation process is "PEACE" (*Prepare, Engage, Analyze, Concerns, Explicate*).

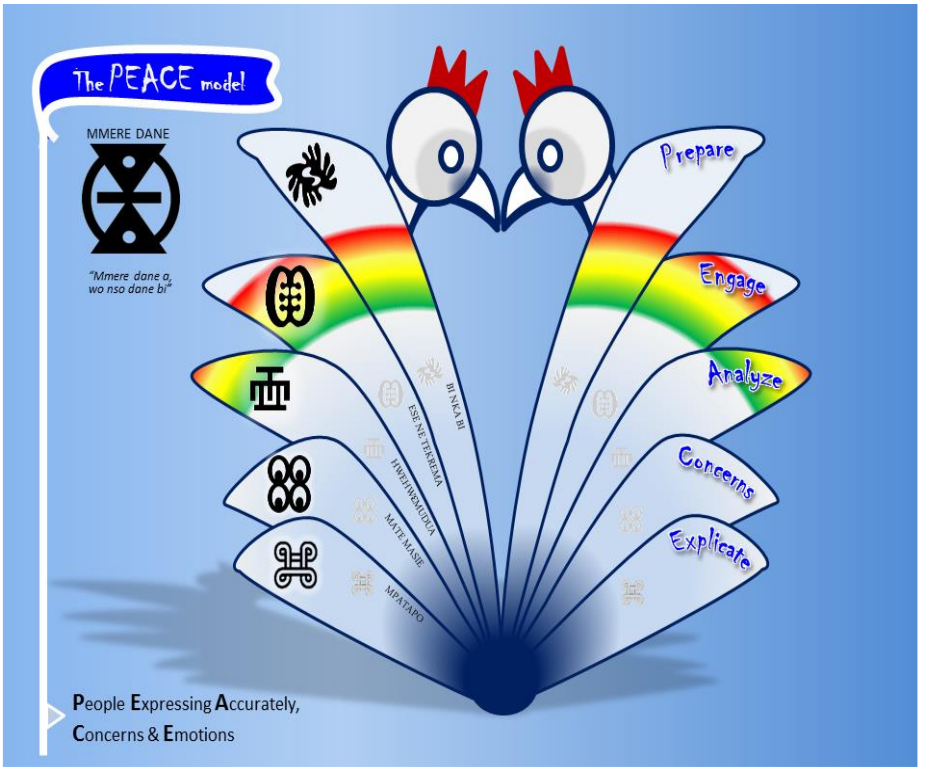


Figure 3. The PEACE Model.

Figure 4. Bi nka bi (Do not bite each other).

The *first stage* of the conflict resolution process starts with "Prepare," which is represented by the adinkra symbol *"Bi nka bi,"* meaning "no one should bite the other" or if you do not wish to be wronged, then do not wrong others. It is a symbol of peace and harmony. This symbol captures the Akan cultural ideal peaceful and harmonious living between and amongst people. It reflects justice and fair play (Willis 1998, 87). A further explanation is that, even though there could be antagonism, such resentment should not lead to inflicting harm. It is represented by Figure 4. At this stage of the mediation process, disputants are encouraged by the mediator to be mindful of their choice of words (thus avoid abusive words) in order to set the right tone for parties to speak to each other amicably and hear from each other what the real issue is. This can be achieved if the mediator carefully explains the whole process (all the stages of the PEACE model) using the corresponding symbols to parties in dispute separately before bringing them together to resolve the conflict. The Prepare stage of the process cannot be over emphasized because it lays the strong foundation needed to resolve the conflict. Disputants should also be assured of confidentiality and impartiality at this stage.

The *second stage* focuses on engaging parties in dispute in a conversation that unearths the root causes of the dispute. To "Engage" in this perspective means the two parties must converse (talk to each other) using words that promote friendship, understanding and cordiality. Emphasis is laid on the use of positive words because according to Cooperrider, and Whitney (2005) words are vehicles that coordinate people's actions with one another, and also enable individuals to share their dreams and ultimate concerns in affirming ways. They further explained that when individuals are helped to connect in full voice with each other, they are able to create better worlds. Accordingly, disputants must be helped to listen to one another and exchange views using positive words that make the conversation interesting in order to unearth the root cause of the problem. This can be achieved if the mediator lays a good foundation during the Preparation stage. Parties must be encouraged to engage with one another for ideas that promote progress. The symbol used to manage this step is the "*ese ne tɛkrɛma,"* symbol; – meaning the teeth and the tongue, which is represented by Figure 5. A further explanation of "*ese ne tɛkrɛma"* symbol is that even though the tongue and the teeth fight, they find amicable ways of resolving issues. The symbol centers around friendship and interdependence. One cannot chew and swallow food without the active use of the tongue and the teeth. There are times when an individual bites his/her tongue when chewing food, he/she is enjoying. When this happens, that individual does not stop eating but continues to eat the food after the pain is gone with the objective of nourishing oneself. The relationship between the tongue and the teeth symbolizes the sign of maturity, progress and improvement. Disputants must be helped to behave maturely towards each other in order to prevent or resolve the conflict. Accordingly, parties at this stage must listen actively (attentively) to each other's submissions and respond rather than react to what is said. To respond in the context of this chapter means to critically analyze what the other party has said (hearing exactly what the other party has said) and give appropriate positive response. To react means forming a response in one's mind while the other party is talking. In this sense, there is the possibility of not hearing exactly what the other party is saying, leading to jumping into premature conclusion without all the facts. Accordingly, the mediator should ensure parties behave maturely and are sensitive to each other's emotions in their choice of words. The symbol represents a picture of the teeth and the tongue within the oral cavity, which can also be used to address situations where the dispute is between a superior and a subordinate (manager and

supervisee, husband wife, leader and followers, etc.) where there is power imbalance (power play). The teeth are hard and look like tools whereas the tongue is soft. Since they live together, there is bound to be conflict. Implying that no matter what, there is bound to be conflict because of differences in nature and functions. When conflict crops up between people of this nature, they are supposed to handle it amicably in order to continue to dwell together in harmony. The teeth and the tongue within the oral cavity situation also depicts internal conflict resolution without a third party, which ensures that the boundaries of conflict are contained between the initial two parties (K. Agyekum, personal communication, January 11, 2016). This self-mediation approach resonates with those proposed by Dana (2005) and Love (2011).

During *the third stage* of the mediation process, the mediator ensures disputants pay attention to the critical analysis of issues before arriving at any final conclusions. This stage is represented by the word "Analyze", with the symbol *"hwehwɛmudua*," which means searching or measuring rod. It is represented by Figure 6. It is a symbol of excellence, superior quality, perfection, knowledge and critical examination. It has to do with careful probing, investigating, or critically analyzing in order to arrive at quality solutions (Willis 1998). In applying this to conflict resolution, the assumption is that no conflict can be resolved without proper scrutiny or investigation to find out the root cause. The *hwehwɛmudua* symbol is elaborated as *wɔse fa na woamfa a, worenhu mu; wohwehwɛ mu a, na wohu mu; wopusu no a, na wote ne pampan.* This is literally translated as "*you miss the opportunity of knowing when you refuse to take it upon request; you know what it entails when you examine it critically; you know the smell when you shake it"* (Arthur 2001, 109). A renowned Akan Scholar gave the following analogy during an interview by the researcher to illustrate his point. "Every roof has two parts. A roof can be called one if the two parts are completed separately before joining them into one with a rod. It is by doing so that it can be called a roof." Meaning critically review each parties' story before you arrive at the final solution (which forms the rod between the two parts of the roof. It is also shown in the 'mmere dane' symbol in the form of the rod separating the two triangles) in order to improve relationships.

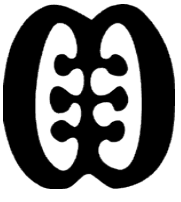


Figure 5. Ɛse ne Tɛkrɛma (The Teeth and The Tongue).

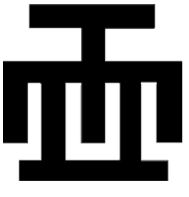


Figure 6. Hwehwɛmudua (Critical Analysis).

The *fourth stage* of the model has to do with confidentiality –thus addressing "Concerns". This is so because critical analysis of an issue unearths the root cause of the issue at stake, which may not necessarily be what disputants initially attributed to as the cause of the issue. At this stage, deep secrets could be revealed. It is important that parties including the mediator treat such revelations as highly confidential as possible, ensuring no one apart from the parties in dispute hears about them. The adinkra symbol appropriate for this stage is known as *"mate masie"* – Figure 7, meaning "I have heard and hidden it, or "*I will adhere to your counsel*" (Willis 1998, 129). The literal understanding of this symbol can be read as: when you encounter challenges, critically reflect on them in silence rather than broadcast it. Have metaphorically heavy lips (K. Agyekum, personal communication, January 11, 2016). This is the stage where disputants are helped to address each other's "Concerns." At this stage, understanding is key to sustainable success. it means the application of wisdom and knowledge to resolve the conflict. Emphasis is laid on ensuring disputants are sensitive to each other's "concerns". Disputants are helped by the mediator to generate options to address their concerns.

"Explicate": "*Mpatapɔ": "Knot of pacification/reconciliation"* is the *final stage* in the model where disputants peacefully, harmoniously reconcile and plan the way forward by selecting the most feasible options generated at the fourth stage. The stage is represented by the symbol "*Mpatapɔ"* - Figure 8. "*Mmpata*" means pacification. "*Pɔ*" means a knot, puzzle, or an enigma, something very difficult to untie. *Mpatapɔ* represents the bond that binds parties into a harmonious, conciliatory reunion. It is a symbol of renewed connection between the parties that were split apart as a result of the conflict. At this stage another symbol known as "*nyansapɔ*" could be used to unravel the "*Mpatapɔ."* This can only be done by someone with wisdom or deep philosophical thought. It is important to unravel the right pacification knot in order to ensure the final decision taken is valuable and affordable for both parties, which needs much wisdom and discretion (K. Agyekum, personal communication, January 11, 2016). "*Nyansapɔ*" is represented by Figure 9. It is the symbol of wisdom, ingenuity, intelligence and patience. It goes with the maxim "*nyansapɔ, yɛde nyansa na Ɛsane*" meaning we use wisdom to untie the knot of wisdom. As Willis (1998) notes, the *Nyansapɔ* symbol is a revered symbol of the Akan people of Ghana. Accordingly, it is only the wise that have the ability to choose the best means to attain a goal. Also, n*yansapɔ* forms part of every step of the stages of the mediation process of the PEACE model. Proverbs are used to communicate wisdom and knowledge in ethnic groups in Africa and it is only the wise that understand them. Accordingly, the mediator is expected to exhibit wisdom during the whole process of mediation as well as guide disputants in the use of wisdom in dealing with each other.

Figure 7. Mate masie (I have heard it and hidden it).

Figure 8. Mpatapɔ (Knot of pacification/reconciliation).

Figure 9. Nyansapɔ (Wisdom Knot).

CONCLUSION

African countries have over the years depended on models designed in developed countries for conflict resolution. Though these approaches are useful, they do not have African cultural practices embedded in them, as a result successes achieved through their use are unsustainable. This chapter draws attention to the richness of Ghanaian indigenous knowledge by proposing a model of conflict resolution using adinkra symbols, showing which behavior to exhibit at each stage of the process. The symbols make the process real, concrete and practical. The symbols used to design the model are *Mmere dane*, *Kolostu*, *Bi nka bi, Ɛse ne tɛkrɛma, Hwehwɛmudua, Mate masie*, *Mpatapɔ,* and *Nyansapɔ*. The proposed model if critically studied, understood and utilized, could immensely reduce conflicts that crop up in everyday human interactions in Ghana and Africa as a whole.

Given the high relevance of the ADR approach to conflict resolution in Ghana, an ADR Act (2010, Act 798) was passed to give legislative support to the practice for its effectiveness and sustainability. As a result, this model is important for ADR practitioners, Ghanaians, and people in other African countries. This is so because it clearly demonstrates the importance of incorporating indigenous knowledge through the use of locally accepted and understood symbols in Ghanaian and African contexts in promoting peaceful coexistence for development. The model could be factored into educational institutions' curricula from basic school level to tertiary level in order to educate students in conflict prevention and resolution. Other African countries can replicate it in their context using symbols or maxims with similar meanings at each stage of a mediation process for sustainable results.

REFERENCES

ADR Act of Parliament of the Republic of Ghana (2010). Act 798.
Amamoo, J. G. (2007). *Ghana, 50 Years of independence*. Accra. Ghana: Jafint Ent.

Arthur, K. G. F. (2001). *Cloth as metaphor*. Legon Ghana: CEFIKS.

Asamoah-Hassan, H. (2011). *Manhyia palace art symbols as a medium for education and information dissemination. (*Doctoral dissertation, the School of Graduate Studies, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana). Retrieved from: http://dspace.knust.edu.gh:8080/xmlui/bitstream/handle/123456789/1442/Project%202.pdf?sequence=1 on January 2012.

Awedoba, A. K. (2007). *Culture and development in Africa: With special reference to Ghana*. Historical Society of Ghana, Project No. 34/2002; ISBN: 9988-0-0843-0.

Cooperrider, D. L. and Whitney, D. (2005). A Positive Revolution in Change: Appreciative Inquiry. In D. Cooperrider, P. Sorensen, T. Yaeger, and D Whitney, (Eds.) *Appreciative inquiry: Foundations in positive organization* d*evelopment* (pp. 9-30). Champaign, IL: Stipes.

Dana, D. (2005). *Managing workplace conflict*. Kansas, USA: MTI.

Danzy, T. (2009). *Adinkra symbols: An ideographic writing system.* (A Master of Arts Thesis submitted to the Graduate School of Stony Brook University). Retrieved from: https://dspace.sunyconnect.suny.edu/handle/ 1951/48176?show=full.

Domenici, K. (1996). *Mediation empowerment in conflict management*. Ill. USA. Waveland Press.

Doward, P., Galpin, M. and Shepherd, D. (2003). Participatory farm management methods for assessing the suitability of potential innovations: A case study on green manuring options for tomato producers in Ghana." *Agricultural Systems,* (*75)*, 97-117.

Guri, B. Y. and Laate, W. (2008). Community organisation development in southwestern Ghana. In D. Millar, A. A. Apusigah, and C. Boonzaaijer (Eds.), *Endogenous development in Africa: Towards a systematization of experiences* (pp. 75-89). Barneveld; the Netherlands: Compas/UDS, BDU.

Gorjestani, N. (2000). Indigenous knowledge for development: Opportunities and challenges. *The World Bank*, Geneva. Retrieved from: http://www.worldbank.org/afr/ik/ikpaper_0102.pdf.

Gyekye, K. (2003). *African cultural values: An introduction*. Accra, Ghana: Sankofa Publishing Company.

Kothari, A. (2007) Traditional knowledge and sustainable development. *International Institute for Sustainable Development (IISD).* pp. 1-11. http://www.iisd.org.

Kudonoo, E. C. (2013) *Success rates of OD and change initiatives in Anglophone West Africa: A meta-analytic review*. Doctoral Dissertation in Organization Development, School of Business, Benedictine University, Lisle, IL. ProQuest, LLC.

Love, N. (2008). *PULSE conversations for change.* Alberta, Canada: The Pulse Institute.

Love, N. (2011). *Complex pulse conversations for change*. Alberta, Canada: The Pulse Institute.

Osumanu, K. I., Abdul-Rahim, L., Songsore, J. and Braimah, F. R. (with M. Mulenga). (2010). Urban water and sanitation in Ghana: How local action is making a difference. *Human Settlement Working Paper Series: Water and Sanitation 25*, IIED.

Tenkasi, R. V. and Mohrman, S. A. (1999). Global change as contextual collaborative knowledge creation. In D. L. Cooperrider and J. E. Dutton (Eds.), *Human dimensions of global change* (pp. 114-136). London, UK: Sage.

Tripathi, N. and Bhattarya, S. (2004). Integrating indigenous knowledge and GIS for participatory natural resource management: State-of-the-practice. *EJISDC, 17*(3), 1-13.

Valentina A. Tetteh (2009). Cultural symbols of the Asante people. Retrieved from: www.stlawu.edu/gallery/education/f/09textiles/adinkra_symbols.pdf.

Vigbedor, D. (2011) *Ewe proverbs – A source of imagery for textile designs.* (Postgraduate thesis submitted to the College of Arts and Social Sciences, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana). Retrieved from: http://ir.knust.edu.gh/ bitstream/123456789/ 1442/1/Project%202.pdf.

Willis, B. W. (1998). *The Adinkra Dictionary: A visual primer on the language of adinkra*. Washington DC. USA. The Pyramid Complex.

In: Handbook on Africa
Editor: Whitney Sherman
ISBN: 978-1-53610-063-1

Chapter 3

THE ENERGY - DEVELOPMENT NEXUS IN SUB-SAHARAN AFRICA

Raphael M. Jingura and Reckson Kamusoko
Chinhoyi University of Technology, School of Agricultural Sciences and Technology, Chinhoyi, Zimbabwe

ABSTRACT

The energy and development nexus is a strong pillar of sustainable economic development in the 21st century. For countries in sub-Saharan Africa (SSA) wishing to achieve economic growth and meet the sustainable development goals, deployment of modern energy projects offers potential opportunities. SSA is currently experiencing strong economic growth and showing positive trends in human development indicators. With annual gross domestic product (GDP) growth rates reaching 5% since 2000, more than twice that of the 1980s and 1990s, Africa has become a fast growing continent. Access to morden and sustainable energy will be critical to sustain the growth. About 47% of the population of SSA live on less than US$ 1.25 per day and 27% are hungry or undernourished. A large number of these people depend on agriculture for livelihood. They depend on access to land and traditional forms of bioenergy. Food security and economic development in SSA can be addressed more effectively with morden energy than without it. It is a truism that there is rampant energy poverty in rural areas in SSA. Energy presents both opportunities and risks for sustainable development. Energy is linked to a range of developmental issues such as poverty alleviation and modernization of rural economies. Many developmental activities in SSA such as agriculture, transport, water, education, income generation and health have energy requirements. Taken severally, energy and development represent key issues in SSA today. Holistically, energy and development form an important nexus in SSA. This chapter provides an overview of the energy-development nexus in SSA with the view of supporting sustainable development in the region.

1. INTRODUCTION

Sub-Saharan Africa (SSA) is a geographical region that covers the area of the African continent that lies south of the Sahara. The region is made up of 49 countries. SSA has 13% of the global population. The region faces multiple challenges which include extreme poverty, under-development and health challenges. SSA is ranked the lowest developing region in the world in terms of growth in gross domestic product (GDP) and modern developmental strides (Mahommed et al., 2013). However, the region has witnessed an encouraging economic growth trend, averaging about 4.5%, with some non-oil exporting countries attaining an average of above 8% over the past 10 years (Chauvin et al., 2012; Pew Research Center, 2015).

With annual GDP growth rate reaching 5% during the past decade, more than twice that of the 1980s and 1990s, SSA has become one of the fastest growing continents. Access to modern and sustainable energy will be critical to sustain these positive signals. The energy and development nexus is a strong pillar of sustainable economic development in the 21st century. It is a truism that access to morden energy services and fuels is a key factor that underpins socio-economic development in modern times. The energy-development nexus is a well known paradigm in contemporary development approaches. For those countries wishing to achieve economic growth as well as meet the goals for sustainable development, the deployment of modern energy projects offers potential opportunities (International Energy Agency (IEA), 2007).

SSA as a region faces multiple challenges reflected by various socio-economic indicators. One of the major challenges in SSA is limited supply of modern energy carriers. Examples of the numerous development challenges in Africa abound in literature. According to some estimates, 47% of the population of SSA lives on less than $1.25 per day and 27% are hungry or undernourished (United Nations (UN), 2012). A large number of people in SSA depend on agriculture for livelihood. They are also largely dependent on access to land and its products, which include traditional forms of bioenergy, to survive (Lynd et al., 2015). The contemporary development narrative posits that food security and economic development in Africa can be addressed more effectively with modern bioenergy than without it (Lynd et al., 2015). Efficient and reliable energy services are scarce in most urban communities, while remote and rural villages have no access to electricity except for few high-income households (Mahommed et al., 2013). The majority of homes in SSA rely on inefficient traditional technologies and fuels, especially biomass to meet domestic energy demands (Schlag and Zuzarte, 2008).

It is worth noting that many SSA countries are rich in both renewable and non-renewable energy sources. SSA is endowed with hydrocarbon energy sources. Natural gas, oil and coal are the main non-renewable sources. Renewables (apart from bioenergy) account for 2% of the regional energy consumption. About 60% of the energy demand is met by bioenergy (IEA, 2014a). The renewable energy sources in the region are solar, hydro, wind and geothermal. The largest coal reserves (90%) are found in South Africa (World Energy Council (WEC), 2005). Namibia has the highest annual multiple potential from renewable energy sources such as solar, wind, hydro, geothermal and biofuels (Deichmann et al., 2011). West Africa, mainly Nigeria, and Angola in southern Africa, have rich oil reserves. Frynas

and Paulo (2007) stated that Africa's oil and gas are its main exceptions to the perceived insignificance of Africa on the global stage.

SSA has the lowest per capita energy consumption as compared to other regions in the world (Deichmann et al., 2011). The global energy consumption grew by 5.4% from 1980 to 2007. SSA accounts for only 1.5% of the global energy consumption (Mohammed et al., 2013). Biomass dominates the bulk of the final per capita energy consumption in SSA. Biomass provides nearly 80% of this energy (Dassapa, 2011). Dassapa (2011) stated that among other resources in a society, access to electricity is considered an important factor in development in any region. The region's access to electricity is estimated at 30% of the population. In SSA, 1% of rural populations have access to electricity (Dassapa, 2011).

Diversifying energy streams is essential for development and energy security in SSA. Intervention strategies must include improved traditional biomass services (Jingura et al., 2013), and utilisation of multiple sources of energy carriers (Grimsby, 2010). Sustainable development and tranformation of SSA can be steered by improvements in energy supply and consumption. Although renewable energy is emerging and promising to be economically viable in future, the use of fossil fuels is unavoidable in present times. In this chapter the energy-development nexus is discussed with a view to promote sustainable development in SSA. It is clear that a connection exists between energy and development issues such as poverty alleviation, education, health and mordenization of poor rural economies.

2. DEVELOPMENT ISSUES IN SSA

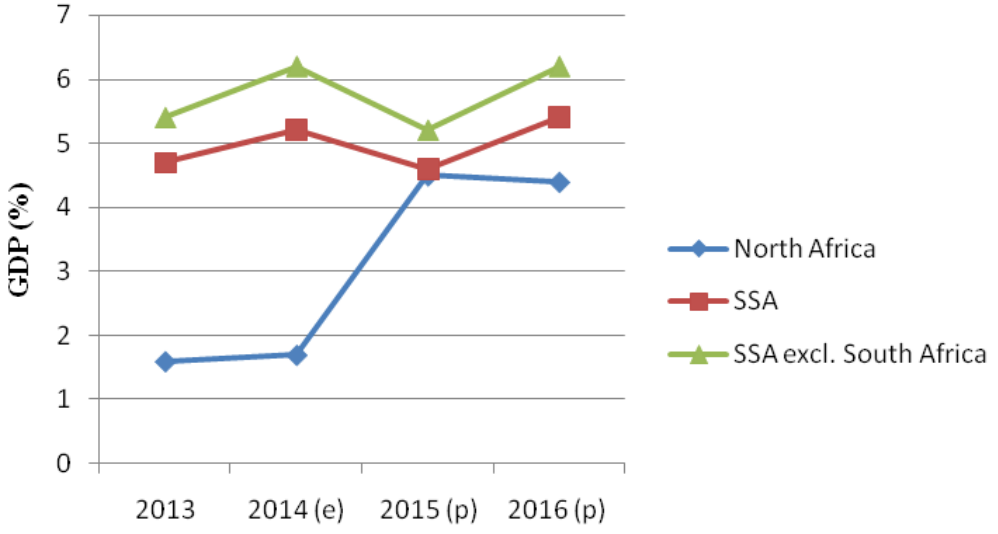
2.1. State of Economies

SSA has reported economic growth trends averaging 5% over the past decade (Chauvin et al., 2012; Pew Research Center, 2015). SSA economies are characterized by exports of primary goods. Nigeria and South Africa are the biggest economies in SSA and account for 75% of the regional GDP (Adu Boahen, 1990). SSA's GDP per capita growth was 1.5% in 2014 (World Bank, 2014). It was expected to rise by 4.6% in 2015 and 5.4% in 2016 (AfDB/OECD/UNDP, 2015). Temporal trends in economic growth in SSA and North Africa between 2013 and 2016 are shown in Figure 1. Sub-regional comparisons in SSA are shown in Figure 2.

Despite the impressive economic performance many people in SSA are exposed to a number of challenges. Prime examples include high levels of unemployment, prevalence of diseases, low levels of education, civic corruption, energy poverty, lack of acces to clean water and sanitation (Pew Research Center, 2015). It can be seen in Figure 2 that East Africa has outstanding progress in terms of economic growth as compared to the other sub-regions of SSA. East Africa has credible systems for regional intergration, major investiments in both national and regional infrastructure, and has remarkable pogress in institutional reforms (Kinyemi and Kibe, 2014). Kenya is the economic powerhouse of this region. It must be pointed out that East African countries have endemic political challenges (Kinyemi and Kibe, 2014).

South Africa is the economic powerhouse of the southern Africa region. South Africa's GDP is projected to grow by an average of 2.8% per annum up to 2020 (Boumphrey, 2014).

Nigeria is the leading economy in SSA ahead of South Africa. The top five economies in SSA are Nigeria, South Africa, Angola, Ethopia and Ghana in descending order. The economies of Nigeria, Ghana and Angola are mainly sustained by the oil sector. The GDP and other data for selected countries in SSA are shown in Table 1.



Note: (e) estimates; (p) projections.

Figure 1. Temporal trends in economic growth in SSA and North Africa (2013-2016) (AfDB/OECD/UNDP.2015).

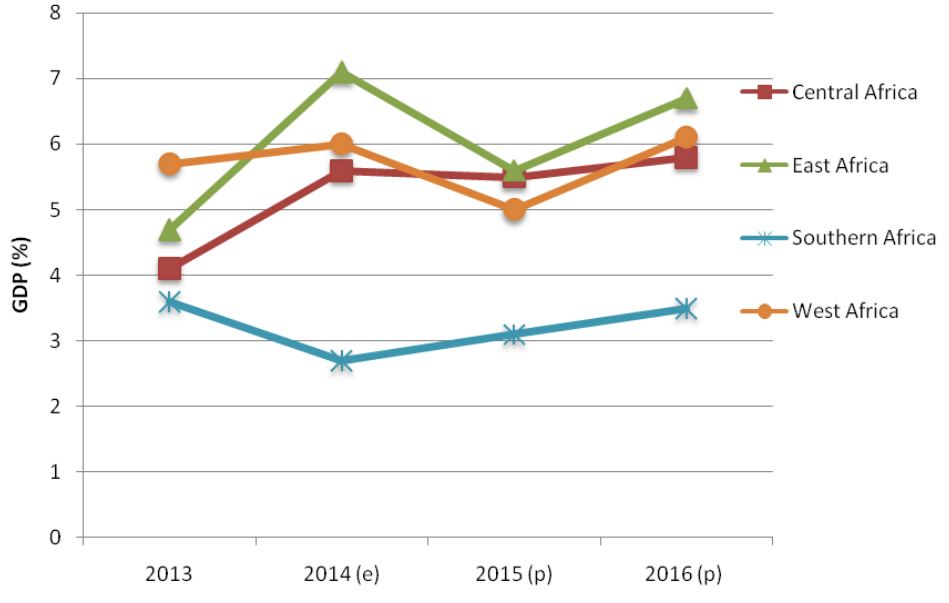


Figure 2. Sub-regional comparisons of economic growth in SSA (AfDB/OECD/UNDP, 2015).

Table 1. GDP, population and povery headcount for selected countries in SSA

Country	Population (million)	GDP (Billion dollars in 2014)	Poverty headcount ratio at national poverty line (% of population)
Central African Republic	4.8	1.72	62.0
Malawi	16.7	4.26	50.7
Rwanda	11.3	7.89	44.9
Zimbabwe	15.3	14.20	72.3
Mozambique	27.2	15.94	54.7
Cameron	22.8	32.05	37.5
Tanzania	51.8	48.10	28.2
Ethiopia	96.9	55.61	29.6
South Africa	54.0	350.10	53.8
Nigeria	177.5	568.50	46.0

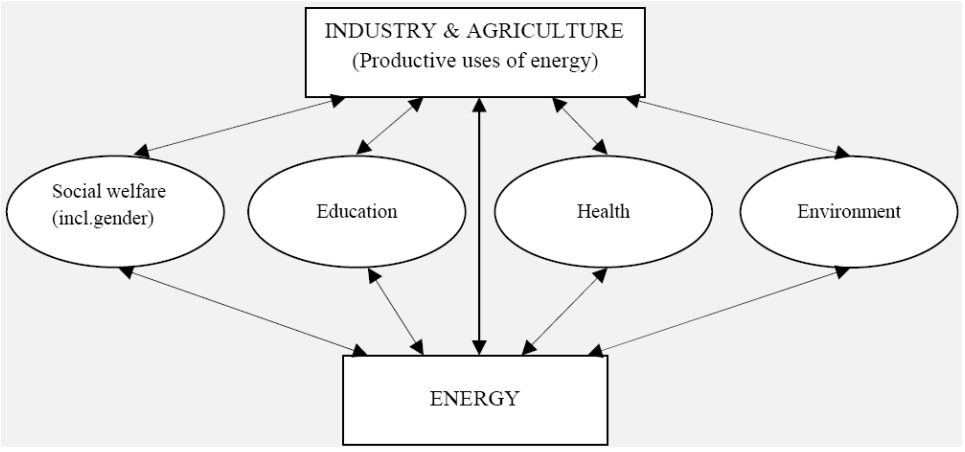
Source: World Bank (2016).

2.2. Energy-Development Nexus

Energy is a core requirement for physical and socio-economic development in both rural and urban areas of SSA (Mohammed et al., 2013). It drives domestic, industrial, commercial and public operations. Kebede et al. (2010) highlighted the centrality of energy supply and consumption for development in SSA. The region is lagging behind in terms of development. Mohammed et al. (2013) attributed this to poor or inadequate acces to morden energy sources. Other factors are at play as well.

Many economists, social scientists and policy analysts are now investigating the link between energy consumption and socio-economic development (Tsani, 2010; Kebede et al., 2010). The economic parameters of interest include gross national product (GNP), GDP, income, jobs and energy costs (Tsani, 2010). Population growth and rates of urbanization are also key social development issues. There is a linkage between energy access, social welfare, and productive uses of energy in agriculture and commercial sectors (Brew-Hammond and Kemausuor, 2009). Brew-Hammond and Kemausuor (2009) presented a graphical conceptual framework for this linkage. The adumbration is shown in Figure 3.

Studies focusing on the energy-development nexus have established a significant positive correlation between development and energy consumption (Kebede et al., 2010). Most of these studies have focused on the linkages between oil prices (oil consumption) and macro-economic indicators. Per capita consumption of energy correlates to development and the social well-being of a country (Kebede et al., 2010). A regression model by Kebede et al. (2010) indicates that energy demand is inversely proportional to the price of petroleum and industrial development, but directly related to GDP, population growth rate, and agricultural development in SSA.



Source: Brew-Hammond and Kemausuor (2009).

Figure 3. A conceptual framework for development benefits from energy access and productive uses of energy.

Energy poverty is quite rampant in SSA. It is conceptualized and measured in terms of the proportion of people without access to modern electricity. This is a crude metric for a region where the majority of people live in rural areas and use a heterogenous mix of energy source. The availability of electricity by itself is not a panacea for the economic and social problems facing Africa (Wolde-Rufael, 2006). However, supply of electricity is nevertheless believed to be a necessary requirement for Africa's economic and social development (Wolde-Rufael, 2006). Approximateley 620 million people in SSA have no access to electricity (IEA, 2014b). The majority are rural people who rely mostly on traditional biomass energy sources. Accesss to electricity in urban areas increased from 22% to 36% between 1980 and 2005 (IEA, 2014b). The electricity challenges are associated with insufficient power generation capacity, low access, poor reliability, and high costs and tarrifs (International Monetary Fund (IMF), 2013).

The overall energy demands in SSA are escalated by expansive urbanization. Forty-eight countries, excluding South Africa, have a combined power generation capacity of aproximately 80 gigawatts. This is lower than that of Spain (IMF, 2013). This is a big challenge that influences economic expansion and improvement in social welfare. As a result, countries that have inadequate supplies of energy or where access to energy is expensive are more likely to have a critically impared economic development and growth is often restricted (World Economic Forum (WEF) and IHS Cambridge Energy Research Associates (IHS CERA), 2012).

The quality and quantum of energy is key to development and eradication of extreme poverty. A predominant reliance on traditional fuels is an indicator of poverty. With a total population of around 600 million, the regional average electricity consumption per capita in 2014 was 440 kWh per annum (Onyeji, 2014). This per capita consumption declines to 160 kWh when South Africa is excluded (Onyeji, 2014). The global average was 3,044 kWh (Onyeji, 2014). There is need to transist from traditional energy forms to morden energy carriers as quickly and cost-effectively as possible. Several social benefits can be derived from this transition. These include better health systems, creation of income-generating opportunities, employment creation, access to education and better quality life.

Human labour, draft power and traditional biomass have low economic viability as compared to electricity and purified petro-chemical products (Kebede et al., 2010). Electricity plays a pivotal role as an enabler of morden livelihoods. SSA is endowed with vast renewable energy resources that are yet to be exploited (Davidson et al., 2007). This potential is a gateway to inclusive socio-economic development. Morden energy supplies play a catalytic role in improving living standards, and meeting the health, education, gender, and environmental rudiments of modern societies. Energy porverty is one of the key factors that depressed the achievement of Millennium Development Goals in SSA (Brazilian et al., 2012).

3. Energy Supply and Consumption

3.1. Energy Supply Mix

3.1.1. Structure of Energy Supply

Hydrocarbon-energy rich countries in SSA are Nigeria, South Africa and Angola. Emerging producers are Mozambique, Ghana and Tanzania. SSA is well endowed with energy resources, but energy supply is very limited. The supply side for a large proportion of the population of SSA is dominated by traditional, inefficient and polluting energy sources (WEC, 2005). The current energy supply mix in SSA consists of both renewables and non-renewables. Renewables are dominated by bioenergy, mainly fuelwood and charcoal. Biomass is by far the most important renewable energy resource in Africa. Bioenergy supplies more than 60% of energy in SSA (IEA, 2014b).

The structure of the energy supply mix in SSA is shown in Figure 4. Primary sources used to generate electricity, supply fuel for transportation, produce heat and cool domestic and commercial buildings are shown. The energy supply mix includes traditional biomass, kerosine for domestic energy use, and petroleum fuels and hydropower for electricity production (IEA, 2014a). Also included are natural gas, coal, solar, geothermal and wind energy. The primary energy supply sources are discussed in detail in subsequent sections.

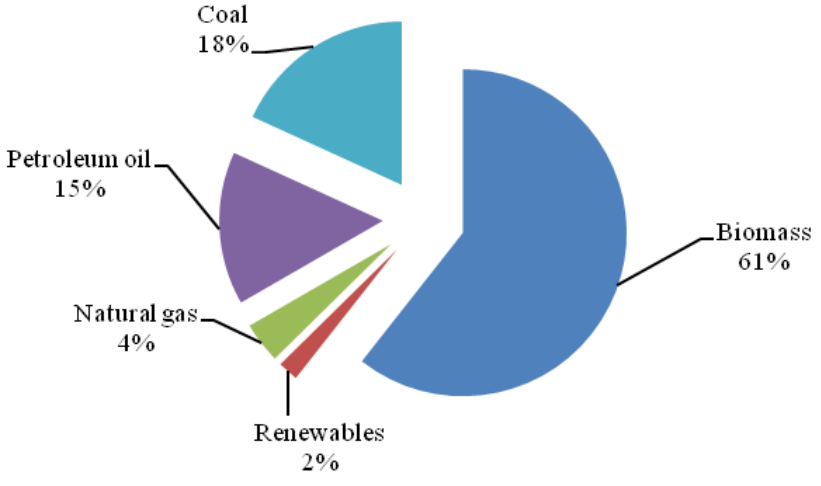


Figure 4. Structure of energy supply mix in SSA (IEA, 2014b).

3.1.2. Fossil Fuel Sources

Fossil fuels play a significant role in energy supply in SSA. They account for 37% of the energy supply mix. Fossil fuels dominate the transport sector, and account for about 73% of electricity production (Obser'Ever, 2013). The main fossil fuels in SSA are coal, crude oil and natural gas.

Coal

Coal is the major hydrocarbon utilized for electricity production in SSA. It is the second major constituent of SSA's energy supply mix after bioenergy. It accounts for 18% of the primary energy supply and 45% of on-grid power generation capacity (Whitley and van der Burg, 2015). Most of SSA's coal fields are located in Southern Africa. South Africa has 90% of the coal reserves in SSA. Botswana, Mozambique, Zimbabwe and Swaziland have the balance of coal deposits (WEC, 2005). Excluding Swaziland, these have estimated coal deposits of 21 billion tonnes, 25 billion tonnes and 25 billion tonnes, respectively. Various projects proposed to expand several coalfields in much of the region have failed to commence. There is lack of exploration in SSA and the construction of infrastructure needed for exports to target markets in Asia is expensive (IEA, 2014a).

Crude Oil

Crude oil is one of the commonly used form of energy in SSA. Over the past decade, oil production in SSA has increased by an annual avarage of 3% (US Energy Information Adminstration (USEIA), 2013). The region has 62.6 billion barrels of confirmed crude oil deposits (USEIA, 2013). In 2012, about 6 million bbl/d were generated, which was approximately 7% of the global oil production (USEIA, 2013). Oil contributes up to 15% of SSA's total energy supply. Nigeria is one of the world's major oil producing countries and is the leading oil producer in SSA, followed by Angola. These two countries make up to 75% of the total oil produced in SSA (USEIA, 2013). Oil production in SSA in 2012 is shown in Figure 5.

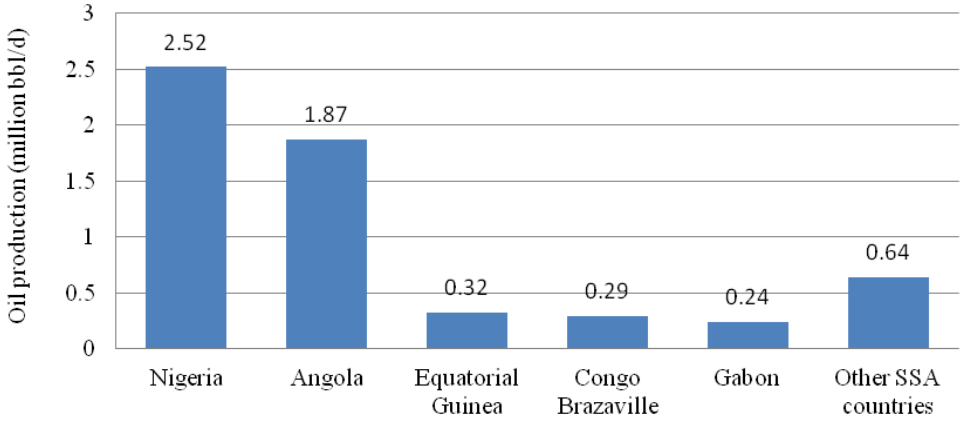


Figure 5. Major oil producers in SSA in 2012
Source: USEIA, 2013

Natural Gas

SSA has vast amounts of proven natural gas reserves with a total amount of 221.6 trillion cubic feet (USEIA, 2013). A total of 1.69 trillion cubic feet was produced in SSA in 2011. This accounts for 1% of the global natural gas supply (USEIA, 2013). Natural gas contributes 4% to the energy supply mix in SSA (USEIA, 2014b). Figure 6 shows the major natural gas suppliers in SSA. The largest gas producer in SSA is Nigeria, followed by Equatorial Guinea. Nigeria represents 66% of the total gas supply in SSA. The other SSA countries contribute only 6% to the regional supply (USEIA, 2013). Recently, significant gas discoveries were made in Mauritania, Mozambique and Tanzania.

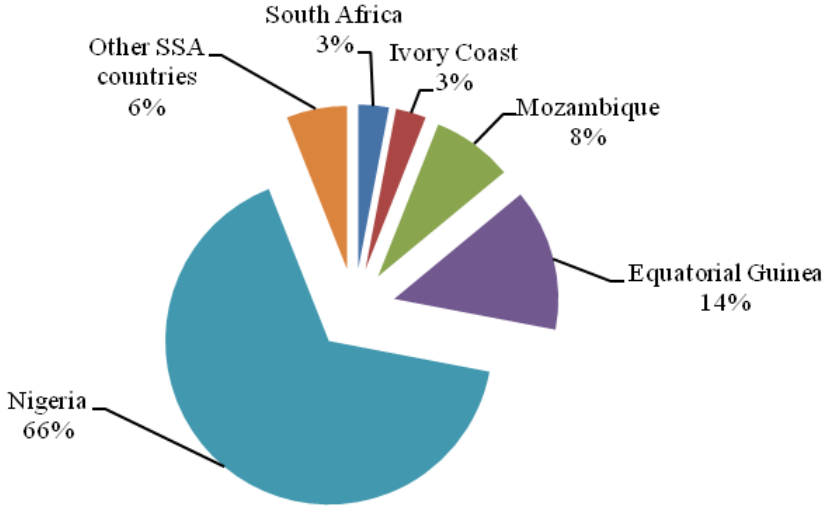


Figure 6. SSA's leading gas producers in 2011.
Source: USEIA, 2013.

3.1.3. Renewable Energy Sources

SSA has considerable amounts of renewable energy resources, the majority of which are under-exploited. Nevertheless, many countries in SSA have embraced the use of renewable energy to improve energy security. The well-known renewable energy resources in SSA are biomass, geothermal, solar, wind, hydro, and geothermal.

Bioenergy

Biomass (mostly fuelwood, charcoal) is the largest component of the energy supply mix in SSA. It is commonly exploited in Mauritius which produces 500 MW of electricity from biomass (Mandelli et al., 2014). It supplies more than 60% of the total primary energy demand in the region (IEA, 2014b). Bioenergy is any form of energy that is produced from biomass. Biomass is generally identified as solid carbonaceous material from plants and animals (Jingura et al., 2013), and includes wood, crops and agricultural wastes. The majority of biomass is consumed by rural communities for domestic cooking, lighting and heating.

Traditional biomass energy is produced from the direct combustion of a variety of solid carbonaceous material. Wood can be processed in specialized furnaces into charcoal. Improvement and modernization of traditional biomass is needed to eliminate environmental

and health problems associated with the use of traditional biomass energy (Jingura et al., 2013). For example, crops and agricultural wastes could be processed into biofuels (biogas, biodiesel and bioethanol). Biogas can be utilized for electricity generation and transport, and bioethanol and biodiesel could replace fossil fuels in transportation.

Approximately 90% of the population in SSA use wood or crop residues as biomass for cooking and heating (Dasapa, 2011). Sixty percent of the rural women face the consequences of fuelwood supply shortage (Dasapa, 2011). Jingura et al. (2013) summarized the use of biomass energy in Zimbabwe. The theoretical total biomass energy value for Zimbabwe was approximated at 409 PJ in Zimbabwe (Jingura et al., 2013). This bioenergy is derived from fuelwood, wood residues, foresty residues, energy crops, agro-residues and municipal wastes (Jingura et al., 2013).

In Mozambique, an estimated 6.7 EJ of bioenergy could be generated annually from agro-technology practices taking into account the food - energy nexus (Dasapa, 2011). The total crop residue energy potential for Ghana and Nigeria were estimated at 75.2 TJ and 697.15 TJ respectively (Mohammed et al., 2013). One-third of SSA is forestry land. Forest forms the bulk of the total biomass stock in SSA, which is estimated at 130 billion tonnes.

Hydroenergy

Hydroenergy (or hydropower) is currently the second most utilized renewable source in SSA. It refers to any form of energy that make use of water stored in dams or flowing rivers to generate electricity in hydropower plants. Hydroenergy is common due to its large-scale of potential development and the lowest average costs of electricity produced. It is a clean and emission free technology and is promoted as an eco-friendly energy option (Karekezi and Kithyoma, 2003). An estimated hydroenergy capacity of 20 GW is installed in SSA (IEA, 2014a).

Hydroenergy resources in SSA account for around 12% of the global technical potential, but only 18% had been tapped (WEC, 2005). Various countries including Mozambique, Democratic Republic of Congo, Uganda and Kenya have enormous potential for hydroenergy generation. Hydroenergy development in some SSA countries is limited as a result of lack of technical expertise and funding, political corruption and small market size (United Nations Environment Programme Finance Initiative (UNEPFI), 2012). In addition, social and environmental constraints often destroy local ecosystems, can lead to massive relocation of people, and may cause regional conflicts over water resources (Kaunda et al., 2012).

Solar Energy

Solar energy is a noticeable natural resource in SSA. Africa's solar power radiation intensity stands at 3,000-7,000 W/h/m^2 (Onyeji, 2014). This range exceeds the requirements to support standard domestic loads (Onyeji, 2014). Southern Africa and Eastern Africa have the maximum levels of solar radiation in SSA (Hogarth et al., 2015). In 2012, solar PV contributed below 1% to the regional electricity grid (Hogarth et al. 2015). Solar electricity generation has high initial costs. The average cost of above $175/MWh to produce electricity from solar PV is high as compared to that of generating electricity from other grid technologies (IEA, 2014a). However, the cost has decreased significantly in recent years and is projected to keep on declining (Hogarth et al. 2015).

The PV technology has been extensively supported in the region, with nearly every SSA country having a major PV project. The major driving forces are reduced production costs

and increased funding for rural solar electrification by bilateral and multilateral donors (WEC, 2005). It is expected that solar will be the least expensive or second cheapest household energy source in more than half of SSA (Hogarth et al. 2015).

Wind Energy

Wind power, which involves using air flow through wind turbines to mechanically drive generators for electricity is currently under-exploited in SSA. The wind potential of the region is estimated at about 1300 GW (Mandelli et al., 2014). At the present moment, wind power contributes a small proportion to the SSA energy supply mix. Thirty-eight wind projects are located in SSA (Mukasa et al., 2015). By 2015 installations were taking place in Cape Verde, Gambia, Namibia, Mauritius, Mozambique, Kenya, Ethopia and Eritrea.

Cabeolica wind farm in Cape Verde is the only project operating at a commercial level in SSA whilst seven of the eight finished projects in the region were at pilot phase (Mukasa et al., 2015). Only 190 MW of wind power have been harnessed in SSA (IEA, 2014a). There are few areas with high quality wind resources in the region. These include the Horn of Africa, eastern Kenya, parts of West and Central Africa sorrounding the Sahara, and parts of Southern Africa. Although, South Africa and parts of East Africa are leading the way to enhance the wind capacity, Somalia remains the country with the greatest onshore potential (AfDB, 2013). By 2020 Kenya will have increased its wind-generated power by 400 MW (IEA, 2014a). Furthermore, Ethopia commissioned its third wind farm (Adam II) in May 2015. Adam II is the biggest (153 MW capacity) in SSA and this has increased the country's installed capacity to 324 MW.

Geothermal Energy

In Africa geothermal energy represents a small proportion in the energy supply mix. It is estimated that 9,000 MW of energy can be generated from geothermal resources on the continent (Karekezi and Kithyoma, 2003). Geothermal resources are common in the East African Rift Valley, particularly in Kenya and Ethopia. Approximately 250 MW of installed geothermal capacity has been identified in Kenya. The total potential capacity of geothermal energy in the East African Rift Valley is calculated at approximately 10 to 15 GW (IEA, 2014a). The Corbetti Power Project is a major geothermal project in Ethopia that will supply 1 GW capacity over the next 10 years (IEA, 2014a). A number of other countries have significant geothermal explorations. These include Zambia, Tanzania, Eritrea, Djibout, Uganda and Rwanda (IEA, 2014a).

3.2. Energy Consumption

All sectors of any economy utilize energy in one form or another. Low energy consumption levels may indicate diminished economic growth and also hinder economic growth (von Maltitz et al., 2009). Global energy consumption grew by 5.4% from 1980 to 2007 (Mohammed et al., 2013). SSA contributed only 1.54% to the universal consumption (Mohammed et al., 2013). Overally, the per capita energy consumption of SSA is very low.

The household sector consumes the largest amount of energy in SSA. Figure 7 compares the per capita energy consumption of rural and urban households in SSA. It is evident that

rural communities consume more energy than urban areas. This is because biomass is highly abundant in rural areas. Per capita energy consumption in selected countries is shown in Table 2.

Fuelwood and Charcoal

Solid biomass provides nearly 80% of the final energy consumption in SSA (Dassapa, 2011; Hogarth et al., 2015). SSA has the greatest regional per capita wood consumption, with an average of 0.69 m^3 per year in 2011 (Cerruti et al., 2015). It is projected that the size of population relying on traditional biomass for cooking will continue to increase up to 2030 (Brew-Hammond and Kemausuor, 2009). Fuelwood energy is utilized by approximately 93% of households in SSA (Cerruti et al., 2015). The use of fuelwood is mainly confined to low income rural people where it is widespread and availabe free of charge (Hogarth et al., 2015). Fuelwood is normally combusted in open stoves. The end result of this combustion is low energy density and low total energy efficiency that normally ranges between 10% and 20% (Schlag and Zuzarte, 2008).

Gender issues are also associated with the use of fuelwood as women spend most of their time collecting the wood (Schlag and Zuzarte, 2008). Charcoal is more common among urban populations due to its higher energy content, easy transport from rural areas and storage, and lower smoke emission than fuelwood. The wood-based biomass energy sector also provides significant employment and remuneration for wood and charcoal producers, transporters, and vendors. Charcoal trade in SSA was estimated to generate US$ 11 billion in SSA in 2012 (Hogarth et al., 2015). Charcoal and other forest product markets create about 30%-32% revenue among rural households in Zambia (Hogarth et al., 2015). In 2007, a total of US$ 122 million was estimated to be generated from fuelwood and charcoal sales in Rwanda (Hogarth et al., 2015).

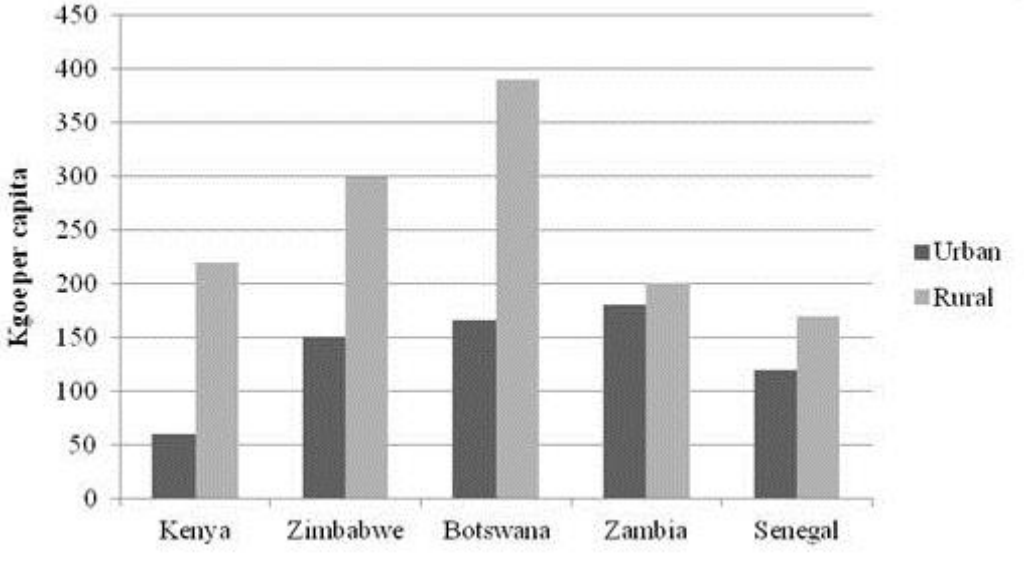


Figure 7. Per capita energy consumption of rural and urban households in SSA-1992.
Source: Karekezi and Kithyoma, 2002.

Table 2. A comparison of the annual energy consumption trends of selected countries in SSA

	Energy use per capita (kgoe)	Total energy from biomass and waste (%)	Electricity consumption per capita (kWh)	Liquid fuel consumption per capita
World	1796	9.7	2678	751
SSA	681	56.3	542	117
Ghana	397	66.0	266	122
Tanzania	530	92.1	61	45
Kenya	484	74.6	138	101
Mozambique	497	85.4	450	39

Source: von Maltitz et al. (2009).

Electricity

Electricity consumption in SSA in 2012 accounted for 7% of the total energy consumed in the region (Hogarth et al., 2015). Half of the electricity is utilized by industry, a fifth by services sector, and consumption by agriculture is insignificant (Hogarth et al., 2015). Hydropower is the principal source of electricity in most SSA countries (excluding South Africa) (Dassapa, 2011). The average per capita annual consumption of electricity in SSA is 536 kWh compared to the world avarage of 3,044 kWh (Onyeji, 2014). These figures are representative of the total electricity consumption in all sectors of the economy.

SSA is the only region in the world where per capita consumption of electricity is declining. It has the lowest electrification rate of around 32% (18% in rural areas) in the developing world (Onyeji, 2014). This can be compared to 92, 70 and 94% in China and East Asia, South Asia and Latin America, respectively (IEA, 2012). Access to electricity in northern Africa, SSA and rural SSA is approximately 90%, 26% and 1%, respectively. An estimated 80% of the people in SSA have no consistent supply of morden electricity. High cost associated with electricity services and limited ease of use of electricity have hindered access to electricity by many SSA countries. The use of electricity is limited even in urban areas where grid network is extensive. Only South Africa, Ghana, Mauritius and Seychelles have more than 50% access to electricity while the remainder of SSA countries have below 25% (Dassapa, 2011). South Africa produces and consumes the bulk of electricity in SSA.

Many countries in SSA face power challenges. At least eight power outages per month, each taking an average of 5.3 hours occur in SSA's electricity grids (Hogarth et al., 2015). These outages destroy equipment and hinder production (Hogarth et al., 2015). Power outages have negative effects on many economic activities.

Liquified Petroleum Gas (LPG)

Many SSA countries are putting effort to substitute traditional biomass consumption for household cooking and space heating with LPG. LPG is used for process heating, as a feedstock (in nitrogenous fertilizer manufacturing, gas-to-liquid) and as a fuel for power production and transportation (Demierre et al., 2014). The consumption of LPG is determined by governement policies and it varies from nation to nation. Botswana has successful programmes to promote the replacement of fuelwood with LPG (Brew-Hammond and Kemausuor, 2009). Senegal started its butanisation programme in the 1970s, and nearly 37% of its population (71% urban households) use LPG as a primary fuel (Schlag and Zuzarte,

2008). To a lesser extent, other Western African countries are also subsidising LPG projects. However, the costs of substitution are high considering the costs of supplying cylinders and stoves to all households using traditional biomass for cooking (Schlag and Zuzarte, 2008).

Biogas

The SSA region is highly endowed with biomass feedstocks that can be effectively utilized for biogas production. However, the technology is not yet fully developed due to several reasons. Biogas production has high capital demand, minimal practical demonstration, technical challenges as well as cultural issues (Mohammed et al., 2013). In SSA, biogas is usually generated at household level for cooking and lighting. The digestate is used as a fertilizer for crop production. The average biogas consumption in SSA is estimated at 490 L/h for a stove and 150 L/h for a lamp (Rupf et al., 2016).

South Africa has demonstrated the first commercial scale biogas production plant at Bronkhorstspruit Biogas Plant using mixed organic wastes as substrates (Rupf et al., 2016). The plant is expected to supply 4.2 MW of electricity. Rwanda is now converting human feacal and urine waste to biogas at various schools and prisons (Rupf et al., 2016).

Bioethanol

Ethanol production in SSA can be dated back to the early 1980s. Successful projects have been demonstrated in Zimbabwe, Kenya and Malawi. Sugar cane molasses is the main source of bioethanol in SSA. In Zimbabwe, sugarcane mollasses has been utilized for bioethanol production at Triangle Ethanol Plant, since 1980. The estimated production capacity at this plant was 120 thousand litres per day and 40 million litres annually for 12 years (Deenanath et al., 2012). The first ethanol-gasoline blend (gasohol) of 12% to 15% (v/v) in SSA was produced at this plant. Nevertheless, the plant was closed due to severe drought in 1992, and lack of government support. It has been revived in recent times.

The Dwangwa Estate Plant and Nchalo Plant are currently producing ethanol from sugar cane mollasses in Malawi, with a 10% (v/v) blending of ethanol and gasoline (Deenanath et al., 2012). Their production capacity are 15-20 million litres, and 12 million litres annually, respectively. A daily production rate of 45 thousand litres ethanol was achieved at Muhoroni Plant in Kenya, with a 10% (v/v) gasohol blend (Deenanath et al., 2012). The plant was shut down in 1992 due to financial constraints, and lack of support from government and oil companies (Deenanath et al., 2012).

Biodiesel

Biodiesel is one of the emerging green fuels. Countries like Zimbabwe, Senegal, Mali, Burkina Faso and Mozambique are promoting and growing Jatropha as a biodiesel plant (Delgado-Ramos, 2015). South Africa promotes use of canola for biodiesel production. Mali has set a target of 2030 to replace 20% of fossil fuel consumption with Jatropha biodiesel. The targets earmarked at producing 84 million litres of refined oil from 50,000 to 70,000 hectares of cultivated land (Favretto and Dyer, 2010).

West African countries have started investing in palm oil as an alternative to petroleum diesel. Nigeria has the major palm oil production activities in SSA but there is limited concentration on its use for biodesel generation (Mohammed et al., 2013). Approximately 3% of oil palm production in the global market comes from Nigeria. Ghana has also invested in

320,000 ha to cultivate oil palm (Mohammed et al., 2013). There are limited commercial production activities for both biodiesel feedstock and biodiesel itself, hence no success stories on large-scale consumption of biodiesel in SSA.

Liquid Fossil Fuels (LFF)

Economies of all countries are highly dependent on LFF such as gasoline, diesel, and kerosine. Transport is the highest consumer of petroleum products, particularly gasoline and diesel in SSA. Approximately 39% of the oil consumed in the region in road transportation is diesel (IEA, 2014a). Sixty-five per cent of the diesel in SSA is consumed by the transport sector (Davidson, 1992). In rural areas diesel is used for small-scale agro-processing such as grain milling (Karekezi and Kithyoma, 2002).

Oil is a good source of eletricity. About 11% of the total electricity produced in Africa in 2007 was from oil (Kojima et al. 2010). The demand for kerosine is steadly increasing and is commonly exploited in households for lighting, cooking and heating (Kojima et al., 2010). Some SSA countries have adopted the use of kerosine for domestic cooking in urban communities. For example, in Kenya, Tanzania and Uganda, kerosine is used by 57%, 15% and 4% urban households, respectively (Schlag and Zuzarte, 2008). Wick stoves and pressurized stoves are the modified stoves that use kerosine for cooking.

4. OPTIMISATION OF ENERGY SUPPLY

4.1. Diversifying Energy Streams

SSA nations are highly susceptable to energy insecurity and power failures. The region is rich in energy resources. Energy security is a prerequisite for democracy, economic development, poverty alleviation and adaptation to climate change. Energy-related crisises in SSA include indoor air pollution, energy poverty, disproportionate gender burden, land degradation, deforestation and climate change (Grismsby, 2010). The majority of SSA's population are rural poor who mostly use traditional biomass to meet their domestic energy needs. Dependence on this sole traditional fuel or technology leaves many households vulnerable. On the other hand, the region is well known for low penetration of morden energy technologies, especially in rural areas. Diversifying energy streams is a strategy that can help to improve energy security in SSA.

4.2. Sources of Energy for Entrepreneurial Activities

Harnessing biomass energy in its traditional unprocessed form is expected to rise in SSA as populations grow. Figure 8 compares information on the number of people per region in the developing world who will rely on traditional biomass between 2000 and 2030. It is clear that SSA will have the largest number of people (nearly 1 billion) depending on traditional biomass by 2030 (Karekezi et al., 2008). It is the peak in 2030 that is worrisome.

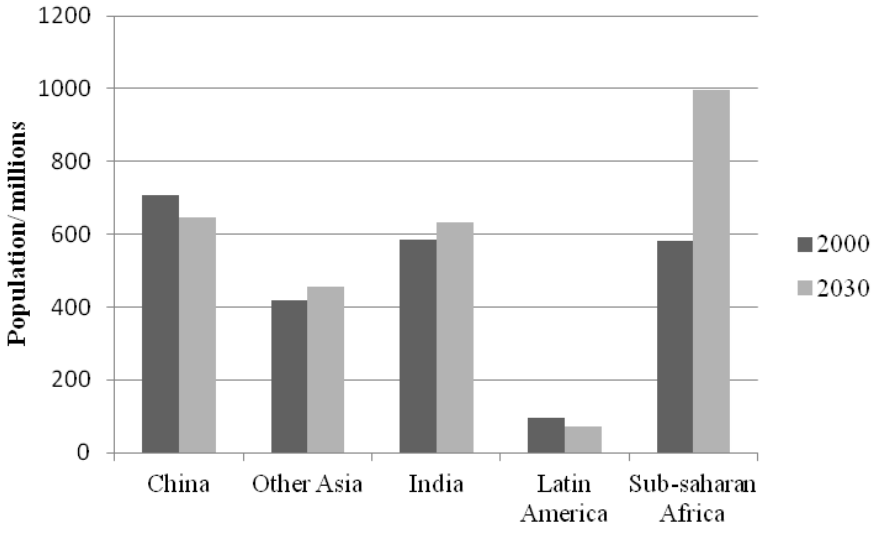


Figure 8. Population using traditional biomass between 2000 and 2030 (Karekezi et al., 2008).

Unprocessed biomass has low energy content per unit volume to make meaningful contribution to industrialisation of rural economies. Energy efficiency is the first line of defence to ensure energy security in modern economies. The application of morden biomass energy services and improved traditional biomass energy services must be common practice in SSA. Improved traditional biomass energy services entail the use of improved and efficient energy services such as improved cook stoves and improved kilns for direct combustion of biomass (Karekezi et al., 2008). Kenya and South Africa had the highest number of improved cook stoves in 2001.

The Ceramic Kenyan Jiko is one of the most successful improved charcoal cook stove in SSA. The stove is appropriate for cooking and space heating, and can direct 25%-40% heat from the fire to the cooking pot (Karekezi et al., 2008). Its production is at moderately established cottage industry (Karekezi et al., 2008). Morden biomass energy services must also include transformation of biomass energy to advanced fuels including electricity, liquid and gaseous fuels (Karekezi et al., 2004). A gamut of technologies available to convert biomass energy into morden energy carriers exist.

Modern energy conversion technologies include combustion, densification, gasification, pyrolysis, liquefaction, fermentation, trans-esterification and anaerobic digestion. Most of these technologies are well established and are at their mature stages (Jingura et al., 2013). The benefits of improved biomass energy and morden biomass energy services are well documented.

Rural electrification is good for broadening entreprenerial opportunities in rural areas. Although it is doubtful that it would solve energy challenges in rural areas, it offers opportunities for industrialisation of such economies. Electrification is a good option for most urban areas as well as high-income rural households. Effective technologies that can rapidly alleviate energy poverty are needed. For example, diesel-based power generation is a broadly accepted solution to service rural areas that are not connected to conventional electricity grids (Dassapa, 2011).

With plentiful solar energy in SSA many households can use solar power. Solar PV is the most attractive option for rural lighting, heating and drying in SSA. The penetration rates of this technology continue to improve. For example, a US$ 7 million co-sponsored project by UNDP and GEF installed more than 10,000 solar systems in Zimbabwe over a period of six years (Karekezi and Kithyoma, 2002). Lighting is a widespread problem in rural areas. This has serious ramifications on many domestic and commercial activities during the night. Alternative power sources such as solar energy are sustainable alternatives. Kerosine, flash lights and candles are also alternatives of light sources in rural communities (Grimsby, 2010).

The greater part of SSA rely on agriculture as a source of food and income. Surprisingly, the region has the lowest agricultural productivity in the world, with per capita output merely 56% of the global average (Sijali and Mwago, 2011). The regional agricultural output is lower than its population growth rate (Sijali and Mwago, 2011). There are reasons for this status quo, but surely energy supply is one of them. Modern agricultural practices rely on mechanization which is a heavy consumer of energy. Grid electricity and petroleum fuels are commonly used in commercial agricultural production and agro-processing activities. Human power and animal traction need to be supported by other forms of power in order to modernize agricultural practices in poor communities. Use of cost-effective machinery is an efficient substitute for human and animal power that can boost agricultural productivity in rural areas.

It is known that irrigation enhances agricultural productivity. This generates more income in contrast to rain-fed conditions. Irrigation schemes require reliable energy for pumping water. Most commercial agricultural producers and agro-processors have irrigation facilities connected to the grid in SSA. This largely excludes smallholder farmers who cannot afford electricity (Karekezi et al., 2005). Such farmers are prone to poor yields and low income levels. Non-electrical renewable energy technologies including wind pumps and ram pumps are cost-competitive options for pumping water and irrigation (Karekezi et al., 2005).

Domestic and livestock supplies, particularly in hilly and mountainous parts of Tanzania have been relying on ram pumps for more than a decade (Karekezi et al., 2005). Wind power provides energy to pump water, and run mills and other machines. Wind pumps are used for household, irrrigation and livestock needs in rural Kenya and Tanzania where there is no provision of clean water to more than 50% of the population (Karekezi et al., 2005). The use of pico- and micro-hydro electricity to provide shaft power for small-scale agro-processing and adding value to agricultural produce has been demonstrated several times in SSA countries (Karekezi et al., 2005). These small grids or off-grids present ideal power solutions to rural off-grids with minimum connectivity or in areas where access to large scale hydro-grids is costly (Kaunda et al., 2012).

Mordenization of poor and marginalized households, small and medium enterprises is not a mission that can be easliy accomblished. Many people in SSA still depend on traditional biomass while a few have adopted the use of improved technologies. Examples of such improved technologies include fish smokers, solar dryers, tea dryers and wood dryers. For instance, low cost solar driers are now popular in countries such as Zambia, Nigeria and Ghana for fish drying and preservation (Mustapha et al., 2014). Their popularity has been derived from their numerous co-benefits over traditional solar drying (Mustapha et al., 2014). The Chorkor Smoker that is now popularized in many SSA countries for improving fish processing was first developed in Ghana two decades ago (Bene et al., 2009). The technology has several advantages as compared to traditional fish smoking (Bene et al., 2009). Solar

dryers reduce post-harvest losses and allow rural farmers to sell their produce whenever they are able to fetch better prices.

CONCLUSION

The role of energy for accelerated socio-economic growth in SSA cannot be overemphasized. Energy is a prerequisite for physical and socio-economic development of rural and urban areas of SSA. Physical and socio-economic development can reduce and eliminate poverty. Economic growth amplifies the tax base and boosts state revenues, which can be utilized for the sustainable financing of social budgets and investment. SSA is characterized by high population growth and low access to affordable energy carriers by the majority. The energy supply mix of SSA is made up of natural gas, oil, coal, bioenergy (fuelwood, charcoal, forests and agricultural residues) and other renewable sources (solar, geothermal, wind and hydro).

The bulk of energy (60%) in SSA comes from biomass resources. Biomass also accounts for around 80% of the total final energy consumption for household cooking, drying and space heating in the region. Modernization and development of cost-effective energy production systems and small-scale, including decentralized systems is a good option to accelerate economic growth in SSA. The discourse on socio-economic development in SSA must be underpinned by a strong narrative on energy and its nexus with development.

REFERENCES

Adu Boahen, A (ed). (1990) *General History of Africa Volume 7: Africa under Colonial Domination 1880-1935 (UNESCO General History of Africa (abridged))*. James Currey Publishers, Carlifornia-UNESCO.

African Development Bank (AfDB). (2013). Development of Wind Energy in Africa. AfDB, Tunis, Tunisia.

Boumphrey, S. (2014). Special report: sub-Saharan Africa's top 5 economies. Available from: http://blog.euromonitor.com/2014/09/special-report-sub-saharan-africas-top-5-economies.html.

Bazilian, M., Nussbaumer, P., Rogner, H., Brew-Hammond, A., Fosterd, V., Pachauri, S., Williams, E., Howells, M., Niyongabo, P., Musaba, L., Ó Gallachóir, B., Radkaj, M. and Kammen, D.M. (2012). Energy access scenarios to 2030 for the power sector in sub-Saharan Africa. *Utilities Policy*, 20, 1-16.

Bene, C., Abban, E.K., Abdel-Rahman, S.H., Brummett, R., Dankwa, H.R., Das, A.K. and Habib, O.A. et al. (2009). Improved fisheries productivity and management in tropical reservoirs. CPWF Project Report, Project number CP34, 30 May 2009. Avaialble from: https://cgspace.cgiar.org/bitstream/handle/10568/3923/PN34_WorldFish_Project%20Report_Jun09_final.pdf?sequence=1.

Brew-Hammond, A. and Kemausuor, F. (2009). Energy for all in Africa — to be or not to be?!. *Current Opinion in Environmental Sustainability*, 1(1), 83-88.

African Development Bank (AfDB)/ Organisation for Economic Co-operation Development (OECD)/United Nations Development Programme (UNDP). (2015). African economic outlook. Available from: file:///C:/Users/user/ Downloads/Overview_AEO2015_EN-web_1.pdf.

Cerutti, P.O., Sola, P., Chenevoy, C., Iiyama, M., Yila, J., Zhou, W. and Djoudi, H et al. (2015). The socioeconomic and environmental impacts of wood energy value chains in Sub-Saharan Africa: a systematic map protocol. *Environmental Evidence*, 4(12), 1-7.

Chauvin, N.D., Mulangu, F. and Porto, G. (2012). Food production and consumption trends in sub-Saharan Africa: Prospects for the transformation of the agricultural sector. Working Paper, United Nations Development Programme, Regional Bereau for Africa. Available from: http://www.undp.org/content/dam/rba/docs/Working%20Papers/Food%20Production%20and%20Consumption.pdf.

Dasapa, S. (2011). Potential of biomass energy for electricity generation in sub-Saharan Africa. *Energy for Sustainable Development*, 15: 203–213.

Davidson, O.R. (1992). Energy issues in Sub-Saharan Africa: Future directions. *Annual Review of Energy and the Environment*, 17, 359-403.

Davidson, O., Chenene, M., Kituyi, E., Nkomo, J., Turner, C. and Sebitosi, B. (2007). Sustainable energy in sub-Saharan Africa. Report approved by the ICSU Regional Committee for Africa, on 5–6 March 2007. Seychelles. Available from: http://www.icsu.org/icsu-africa/publications/ICSUROASciencePlanonSustainable Energy.pdf.

Deenanath, E.D., Iyuke, S. and Rumbold, K. (2012). The bioethanol industry in Sub-Saharan Africa: History, challenges, and prospects. *Journal of Biomedicine and Biotechnology*, Volume 2012 (2012), Article ID 416491, 11 pages.

Deichmann, U., Meisner, C., Murray, S. and Wheeler, D. (2011). The economics of renewable energy expansion in rural sub-Saharan Africa. *Energy Policy*, 39(1), 215-227.

Delgado-Ramos, G.C. (2015). Inequality and Climate Change. Perspectives from the South, Codesria, pp. 88.

Demierre, J., Bazilian, M., Carbajal, J., Sherpa, S. and Modi, V. (2014). Potential for regional use of east Africa's natural gas. Briefing paper, Sustainable Engineering Lab (SEL), The Earth Institute, Columbia University, New York.

Favretto, N. and Dyer, J. (2010). Briefing Note. November 2010. Sustainable biofuels in Africa: cultivation of *Jatropha curcas* in Mali and Malawi. Sustainability Research Institute, University of Leeds.

Frynas, J.G. and Paulo, M. (2007). A new scramble for African oil? Historical, political, and business perspectives. *African Affairs*, 106/423, 229–251.

Grimsby, L.K. (2010). Diversification of the energy use and energy security. Norwegian University of Life Sciences. Norway.

Hogarth, J.R., Haywood, C. and Whitley, S. (2015). Low-carbon development in sub-Saharan Africa: 20 cross-sector transitions. Report, Overseas Development Institute, London.

International Energy Agency (IEA). (2014a). Africa Energy Outlook. A focus on energy prospects in sub-Saharan Africa. World Energy Outlook Special report. Available from: https://www.iea.org/publications/freepublications/ publication/WEO2014_AfricaEnergyOutlook.pdf.

International Energy Agency (IEA). (2014b). World energy outlook 2014 Factsheet. Energy in sub-Saharan Africa today. Available from: http://www.worldenergyoutlook.org/media/weowebsite/africa/Fact_sheet_I_Africa_energy_today.pdf.

International Energy Agency (IEA). (2007). Good practice guidelines: Bioenergy project development and biomass supply. 9, rue de la Fédération,75739 Paris, Cedex 15, France. Available from: < www.iea.org/publications/freepublications/.../biomass.pdf.

International Monetary Fund (IMF). (2013). Energy subsidy reform in Sub-Saharan Africa: experiences and lessons- Washington, D.C, USA.

Jingura, R. M., Musademba, D. and Kamusoko, R. (2013). A review of the state of biomass energy technologies in Zimbabwe. *Renewable and Sustainable Energy Reviews*. 26: 652–659.

Karekezi,S. and Kithyoma,W. (2002). Renewable energy strategies for rural Africa: is a PV-led renewable energy strategy the right approach for providing modern energy to the rural poor of sub-Saharan Africa?. Energy Policy, 30(11-12), 1071-1086. Karekezi, S. and Kithyoma, W. (2003). Renewable energy in Africa –Prospects and limits. The workshop of African energy experts on operationalizing the NEPAD Energy Initiative, 2-4 June 2003. Dakar, Senegal.

Karekezi, S., Lata, K. and Coelho, S.T. (2004). Traditional biomass energy: improving its use and moving to modern energy use. Thematic Background Paper No. 308. In: Proceedings of the international conference for renewable energies, Bonn.

Karekezi, S., Kimani, J., Wambille, A., Balla, P., Magessa, F., Kithyoma, W. and Ochieng, X. (2005). The potential contribution of non-electrical renewable energy technologies (RETs) to poverty reduction in east Africa. Final Regional Report. Nairobi, Kenya.

Karekezi, S., Kithyoma, W., Muzee, K. and Oruta, A. (2008). Scaling up bioenergy in Africa. Presented during the International Conference on Renewable Energy in Africa, 16-18 April 2008. Dakar, Senegal.

Kaunda, C.S., Kimambo, C.Z. and Nielsen, T.K. (2012). Potential of small-scale hydropower for electricity generation in sub-Saharan Africa. *ISRN Renewable Energy*, Volume 2012, Article ID 132606, 15 pages.

Kebede, E., Kagochi, J. and Jolly, C.M. (2010). Energy consumption and economic development in Sub-Sahara Africa. *Energy Economics*, 32, 532-537.

Kinyemi, M.S. and Kibe, J. (2014). Africa's Powerhouse. Available from: http://www.brookings.edu/research/opinions/2013/12/30-kenya-economy-kimenyi.

Kojima, M., Matthews, W. and Sexsmith, S. (2010). Petroleum markets in sub-Saharan Africa. Analysis and assessment of 12 Countries. Extractive Industries for Development Series No. 15. Available from: https://openknowledge.worldbank.org/bitstream/handle/10986/18283/549270NWP0eifd10box349431B01PUBLIC1.pdf?sequence=1.

Lynd, L.R., Sow, M., Chimphango, A.F.A., Cortez, L.A.B., Cruz, C.H.B., Elmissiry, M., Laser, M., Mayaki, I.A., Moraes, M., Nogueira, L., Wolfaard,t G.M., Woods, J. and van Zyl, W,H. (2015). Bioenergy and African transformation. *Biotechnology for Biofuels*, 8, 18.

Mandelli, S., Barbieri, J., Mattarolo, L. and Colombo, E. (2014). Sustainable energy in Africa: A comprehensive data and policies review. *Renewable and Sustainable Energy Reviews*, 37, 656–686.

Mohammed, Y.S., Mustafa, M.W. and Bashir, N. (2013). Status of renewable energy consumption and developmental challenges in Sub-Sahara Africa. *Renewable and Sustainable Energy Reviews*, 27, 453-463.

Mukasa, A, D., Mutambatsere, E., Arvanitis, Y. and Triki, T. (2015). Wind energy in sub-Saharan Africa: Financial and political causes for the sector's under-development. *Energy Research and Social Science*, 5, 90-104.

Mustapha, M.K., Salako, A.F., Ademola, S.K. and Adefila, I.A. (2014) Qualitative performance and economic analysis of low cost solar fish driers in Sub-Saharan Africa. *Journal of Fisheries*, 2(1), 64-69.

http://www.energies-renouvelables.org/ observer/html/inventaire/Eng/

Onyeji, I. (2014). Harnessing and integrating Africa's renewable energy resources. In Jones, L.E (Ed.), Renewable Energy Intergration (pp 27-38). United Kingdom: Elsevier Inc.

Pew Research Center. (2015). Health care, education are top priorities in sub-Saharan Africa. Available from: http://www.pewglobal.org/files/2015/09/ Pew-Research-Center-Development-in-Africa-Report-FINAL-September-16-20151.pdf.

Rupf, G.V., Bahri, P.A., de Boer, K. and McHenry, M.P. (2016). Broadening the potential of biogas in Sub-Saharan Africa: An assessment of feasible technologies and feedstocks. *Renewable and Sustainable Energy Reviews*. 61, 556-571.

Schlag, N. and Zuzarte, F. (2008). Market barriers to clean cooking fuels in sub-Saharan Africa: A review of literature. Working Paper April 2008. Stockholm Environment Institute, Sweden.

Sijali, I.V. and Mwago, M.G. (2011). Money maker pumps: creating wealth in sub-Saharan Africa. In Chuhan-Pole, P. and Angwafo, M (Eds.), Yes Africa Can. Success Stories From A Dynamic Continent (pp. 319-336). Washington D.C: The World Bank.

Tsani S. Z. (2010). Energy consumption and economic growth: A causality analysis for Greece. *Energy Economics*, 32, 582–590.

United Nations (UN) (2012). The millennium development goals report 2012. New York.

United Nations Environment Programme Finance Initiative (UNEPFI), 2012. Financing renewable energy in developing countries. Drivers and barriers for private finance in sub-Saharan Africa. A study and survey by UNEP Finance Initiative on the views, experiences and policy needs of energy financiers. Geneva, Switzerland.

United States Energy Information Adminstration (USEIA). (2013). Oil and Natural Gas in Sub-Saharan Africa. Available from: http://www.eia.gov/pressroom/presentations/ howard_08012013.pdf.

von Maltitz, G., Haywood, L., Mapako, M. and Brent, A. (2009). Analysis of opportunities for biofuel production in sub-Saharan Africa. *CIFOR Environmental Services Briefs*. CIFOR. Available from: http://www.cifor. org/publications/pdf_files/EnviBrief/04-EnviBrief.pdf.

Whitley, S. and van der Burg, L. (2015). Fossil fuel subsidy reform in sub-Saharan Africa: From rhetoric to reality. New Climate Economy, London and Washington, DC. Available from: http://newclimateeconomy.report/ misc/working-papers.

Wolde-Rufael, Y. (2006). Electricity consumption and economic growth: a time series experience for 17 African countries. *Energy Policy*, 34, 1106–1114.

World Bank (2014), Logistics Performance Index 2014 (database), World Bank. Available from: http://lpi.worldbank.org/ (accessed 4 May 2015).

World Bank. (2016). Available from: http://www.worldbank.org/region/SSA.

World Energy Council (WEC). (2005). Regional energy intergration in Africa. A report on the World Energy Council. London, United Kingdom.

World Economic Forum (WEF) and IHS Cambridge Energy Research Associates (IHS CERA). (2012). Energy for economic growth. Energy vision update 2012. Available from: http://reports.weforum.org/energy-for-economic-growth-energy-vision-update-2012/.

In: Handbook on Africa
Editor: Whitney Sherman
ISBN: 978-1-53610-063-1

Chapter 4

THE VULNERABLE NATURE OF WATER SECURITY IN SUB-SAHARAN AFRICA (SSA) – A COUNTRY BY COUNTRY ANALYSIS

Gurudeo Anand Tularam[1] and Omar Moalin Hassan[2]
[1]Senior Lecturer - Mathematics and Statistics, Griffith Sciences (ENV),
Environment Futures Research Institute,
Griffith University, Brisbane, Australia
[2]Research Associate - Environment Futures Research Institute
Griffith University, Brisbane, Australia

ABSTRACT

Given the nature of water supply related difficulties that so many countries are now facing it is then important to consider the supply of water in most wanting countries such as in Sub-saharan Africa (SSA). The future of water security and related infrastructure, in addition to the possible effects that climate change may have on SSA are all fundamentally in doubt. There is a need to study why so many persons are moving from these countries (Myers, 2002). The paper shows that while there are many other reasons one of the fundamental is water and food security. The lack of infrastructure and inefficient flow networks of water in countries are also noted and these have to be much improved and moreover guarded against potential loss (Roca and Tularam, 2012). The information and critical analysis provided in this paper shows that there is a clear need for the investigation into water availability supply networks security. The fresh and clean drinking water is now to be accepted as on demand by modern consumers given progress of humans over time. This paper reports on the water related difficulties facing some the Sub-saharan African countries where many of dispossessed persons live and this has led to the great movement of people that has occurred in recent times. The unfavourable nature of the climate and agricultural land and the effect of climate change appears to have led to the rural migrating to urban areas (Tularam and Krishna, 2009); but the difficulty now is maintaining the security of the supply networks as well as for the infrastructure of water lowering risks by the development of appropriate management strategies (Tularam and Murali, 2015).

Keywords: water stress, water scarcity, Sub-saharan African countries, SSA, water risk, water security, water distribution; human security

INTRODUCTION

Sub-Saharan Africa has been an integral part of the region where many of the recent arrivals of refugees in Europe. There has been a concerted push towards achieving food and water security to eradicate hunger in the region and then even to halve poverty as hard this may be but with today's technology this must be possible. Clearly, water availability has been a challenge to food security in Sub-Saharan Africa (SSA) and this paper reports on water security by analysing in terms of country by country within the region supplementing the earlier major paper the authors (Tularam and Hassan, 2016). The lack of water in fact appears to have led to some social and political instabilities as noted in the region; and there has been a clear push from rural to urban migration and then beyond to other shores, given the nature of the problems faced when arriving in the main urban cities of Sub-saharan Africa.

Much is to do with the consequences of the rapid population growth in SSA. This has been a major problem to the destruction of the natural resources and the distribution of water and its availability. The Sub-saharan Africa population has quadrupled during the past 60 years, increasing from 179 million in 1950 to 830 million in 2010 (DESA, 2013). Also, the productive farming lands have been decreasing over time. The evidence shows a dramatic decline of the renewable fresh water resources (m^3/capita/yr) in SSA and more generally in Africa (Tularam and Hassan, 2016). Water security is the situation where there is sustainable access, on a watershed basis, to adequate quantities of water of acceptable quality, to ensure human and ecosystem health (Tularam and Krishna, 2009; Tularam and Keeler, 2006: Tularam and Murali, 2015).

Moreover, there is a clear connection between water crisis in Sub-Saharan Africa and their food security. Food security is said to exist when all people and at all times have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. This study assesses the relationship between rural migration of eight selected Sub-Saharan African countries and water accessibility. SSA has experienced a large amount of rural migration with the rural SSA population decreasing from 85% in 1962 to 63% in 2012. It is estimated that 50% of SSA population will live in cities by 2020 thus causing major problems for the cities in SSA (Tularam and Marchisella, 2014).

There is now evidence which indicate that agricultural sector has been suffering from receiving adequate water supply, labour shortage and low productivity of lands over recent times in sub-Saharan Africa (Chauvin et al., 2012). Compounding this will be the predicted effects of climate change that will create more difficulties that are yet to be seen. For example, sudden and large increase in rainfall fluctuations and distribution in the region, causing natural disasters such as droughts and floods have been noted (Tularam and Ilahee, 2010; Tularam and Ilahee, 2007a; 2007b, 2007c; Roca, Tularam and Reza, 2015; Tularam and Reza, 2016). Added to this, there is now evidence of more rural to urban migration, which was predicted by Tularam (2012) and Tularam and Properjohn (2011b). Human migration caused by changing water conditions will be one of the major challenges in future

(Tularam and Hassan, 2016). Presently, the capability of SSA cities to deliver expectations of new rural immigrants as they arrive is not achieved and this only means that the arrivals would still need to be on the move. The evidence of Europe refugee crisis shows that are yet unpredictable longer term impacts of water and food security in SSA, and if the major underpinning issues are not addressed there is going to be undesirable outcomes in the future. For example, there may well be further waves of movements of more persons towards the advanced economies and almost certainly this will have major implications to Europe, Italy, Indonesia, and more importantly Australia in terms of the possibility of rather large numbers of environmental refugee arriving into the major cities in the future; as the complexity of the problem increases there may indeed be a second wave of major movement caused by other unforseen events such as wars or conflicts in the region; the complexity theory would suggest that the human movement caused emerging factors that arose from the instability in the environment created by the various interacting agents participating in the Syrian conflict for example (see for complexity theory Hulsman, et al, 2011; 2013).

However even when there is stability amongst countries in SSA (Bob, 2010), as was described in the accompanying paper by Tularam and Hassan (2016). In the paper it was noted that climate change has already affected many rural communities in their ability to navigate a livelihood from their lands (World Bank, 2009; Tularam and Hassan, 2016). Norman (2001) defined as noted in Tularam, 2016) that those people who are forced to leave their original habitat because of some sort of environmental difficulty is called an 'environmental refugee'; which was also put forward by Essam El-Hinnawi in 1985 (United Nations Environmental Programme report, 2005). He defined environmental refugees as "…those people who have been forced to leave their traditional habitat, temporarily or permanently, because of a marked environmental disruption (natural and/or triggered by people) that jeopardized their existence and/or seriously affected the quality of their life" (Khan, 2014; pp.127). Similar definitions exist elsewhere (Ďurková et al., 2012; Myers, 2002)). Environmental refugees are also those "persons who no longer gain a secure livelihood in their traditional homelands because of environmental factors of unusual scope, notably drought, desertification, deforestation, soil erosion, water shortages and climate change, also natural disasters as cyclones, storm surges and floods" (Ďurková et al., 2012; Myers, 2002; Tularam and Hassan, 2016). United Nations use the term "environmentally displaced persons" and this refers to those "who are displaced from or who feel obliged to leave their usual place of residence, because their lives, livelihoods and welfare have been placed at serious risk as a result of adverse environmental, ecological or climatic processes and events" (Ďurková et al., 2012; pp.7).

It is ta fact that the majority of the environmental refugees are from Africa (Myers, 2002). 50 million environmental refugees was noted earlier and it is predicted that there will be around 200 million by 2050 (Myers, 2002; Peters, 2011). It is to be noted that the reduction of poverty in rural communities is an important issue (Diao et al., 2007). Despite the fall of hunger, the SSA poverty levels have not decreased much, and limited reduction of poor people has been noted. According to (DFID, 2004) the number people living under the poverty line has increased significantly due the adoption of a new definition for poverty (Chikaire and Nnadi, 2012). A similar trend is noted in today's figures.

This paper is an accompanying paper to a book chapter by Tularam and Hassan (2016), which also critically reviews the issue of water and food security in SSA using a country by country analysis method. The analyses are in terms of rates of population growth, availability

of water and food resources, and possible effects of climate change factors with regard to water and food resources and their usage. The likelihood of water scarcity or water stress is examined in terms of the migration patterns of recent times (Tularam and Properjohn, 2011a, b).

In the following a country by country analysis is conducted excepting Somalia and Democratic Republic of Congo, which are presented in full in Tularam and Hassan (2016). However, a summary of these two countries is included followed by discussion of the issues examined. A brief summary and conclusion completes this paper. The SSA countries considered in this paper are the following which include some analysis outside of SSA for comparison: Ethiopia, Kenya, Somalia and Tanzania from East Africa, Democratic Republic of Congo in Central Africa region, Nigeria, Niger in West Africa and Republic of South Africa in Southern Africa region. The countries were selected for several reasons and these are: (i) they are in Africa and in SSA; (ii) the high populations and rates of population growth of the countries; (iii) their extreme weather patterns; (iv) including their current and projected water conditions; and finally (v) the lower levels of economic developments in the region.

ETHIOPIA

Ethiopia is the most populated country in Africa after Nigeria with a population of about 81 million in 2010. Only 17% of the population lives in urban areas with most Ethiopians (83%) living in rural areas relying mostly on agriculture (Gebeyehu, 2014). According to Awulachew et al. (2007), about 99.3% of Ethiopia's 1.13 million km^2 is land area and the remaining 0.7% is covered with different types of water bodies specially lakes. Similar to other SSA countries agriculture is the dominant sector contributing around 47.7% to the overall revenue; followed by 39% from services and 13.3% from the industry sector (HEC, 2012). FAO (2005) reported that in 2003 the value added in agriculture (% of GDP) was about 41.8%.

There are 12 river basins in the country with a yearly water flow of about $122km^3$; this is around 3% of Africa's surface water potential and 1% of the world (Mekonen, 2009). Ethiopia has a large amount of surface water but there is limited infrastructure to harvest and store these waters for use. Instead, large volumes of the surface water drains into the wetlands of the central and northern parts. In addition, the country has 2.6 to $6.5km^3$ of ground water, forming per capita share of $1,685m^3$ available water (Awulachew et al., 2007). The total actual renewable water resources per inhabitant has declined from $1,685m^3$/yr in 2004 to $1410m^3$ available water per person (2012); this is due to the population increase from 72.42 million in 2004 to about 86.5 million in 2012 (FAO, 2013). The agricultural production relies on rainfall but the precipitation fluctuates in time and place leading to water shortages in the case of smaller farmers - a category that produces most agricultural products in SSA. The shortages limit crop production and increase crop failures as well as forcing most farmers to only grow one type of crop per year (McCartney et al., 2009). Moreover, severe droughts have hit the country in recent times causing acute food shortage. Table 5 shows that agriculture uses 93.6% of the total water withdrawn in 2002, followed by domestic consumption (6%) while the industrial sector uses 0.4% (FAO, 2005).

In 2006 UNDP (United Nations Development Program) argued that the average water distribution of Ethiopia was on track to meet the MDGs (Millennium Development Goals). In 2005 about 31.4% of the rural people had clean water supply systems; while about 83.1% of those living in cities had clean water supply coverage. The target is to reach 65.5% and 90.9% respectively in 2015 (UNDP, 2006). Most rural Ethiopians source water from the ground using different types of wells such as shallow, spring and deep wells but here are a considerable number who harvest rainwater, or use hand-dug and unprotected wells, or rely on river waters (Awulachew et al., 2007). Only recently there has been some limited attention paid to the ground water development and management programs despite its importance to the population. For example, a scheme has helped some to construct deep, shallow and hand-dug wells (553, 1581 and 150904 respectively) as well as identifying 3,977 spring wells for rural communities (MOFED, 2006).

Ethiopia has the least rate of rural people migrating to urban areas yet the urban population is increasing - 3.8% compared to 2.3% in rural areas. The environmental related difficulties are significant. Geneyehy (2014) noted that around 39.5% of the surveyors migrated because of the lack/shortage of land to make a decent living based on farming, while 16.3% left due to weakening productivity of agriculture, and around 7% migrated because of food shortage (Gebeyehu, 2014).

Table 1. Ethiopia: water sources and use

	Year	**Volume/Ratio**	**Unit**
Renewable water resources			
Average precipitation (in depth)		848	mm/yr
(in volume)		936	10^9 m^3/yr
Internal renewable water resources		122	10^9 m^3/yr
Total actual renewable water resources		122	10^9 m^3/yr
Dependency ratio		0	%
Total actual renewable water resources per inhabitant	2004	1 685	m^3/yr
Total dam capacity	2002	3 458	10^6 m^3
Water withdrawal			
Total water withdrawal	2002	5 558	10^6 m^3/yr
- irrigation + livestock	2002	5 204	10^6 m^3/yr
- domestic	2002	333	10^6 m^3/yr
- industry	2002	21	10^6 m^3/yr
• per inhabitant	2002	81	m^3/yr
• as % of total actual renewable water resources	2002	4.6	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2003	6 600	Million US$/yr
• value added in agriculture (% of GDP)	2003	41.8	%
• GDP per capita	2003	91	US$/yr
Human Development Index (highest = 1)	2002	0.359	

Source: FAO, 2005.

KENYA

Kenya is situated in east Africa and borders the Indian Ocean, Somalia, Ethiopia, South Sudan, Uganda, and Tanzania. Kenya has a population of about 41 million in 2010. The country has a total area 582,646km² including 581,679km² of land and 11,230km² of water. 16% of land are potentially suitable for arable agriculture, while 84% of the land is arid and semi-arid suitable for livestock production and irrigated agriculture (Nyanchaga, 2011). The climate is dry and humid, which is probably why Kenya has critical water crisis issues. Water contamination, poor management, and population increase are some of the issues not well tackled by Kenyans (Marshall, 2011). Out of the 17 million around 41.5% have no access to clean water; while the poor in cities have only access for polluted waters. The rainfall fluctuates from time to time and hence severely affects farm production. Just as in urban areas, there has been minimal government investment on water resources in rural areas (Marshall, 2011). Marshall has argued the effect of climate change has caused severe droughts and floods (Marshall, 2011).

The country is presently under water stress condition in that the renewable freshwater per capita is 718.1m^3/yr, and according to FAO (2013) the total internal renewable water resources per capita was 484.2m^3/inhab/yr (2011), dropping from 3558m^3/inhab/yr in 1962. Equally, the Kenyan population has increased from 5.4 million people in 1948 to 42 million in 2011; in around seven decades with a growth rate of 3% (Nyanchaga, 2011). Not surprisingly, the 2025 estimate of the renewable freshwater per capita is presently at 235m^3/yr. UNEP (United Nations Environmental Programme) has declared the water crisis in Kenya as chronically water scarce (Ogendi and Ong'oa, 2009). The average precipitation in Kenya is 630 mm. It rains heavily in Mt. Kenya (1800 mm per annum) but in northern Kenya the rainfall is less than 200 mm per year (Marshall, 2011). The country did not achieve economic improvements for the last two decades and Kenya is considered to be the poorer on average of the countries in SSA (GDP per capita see Figure 6). In more recent times however, the GDP per capita (US$) has been growing significantly in more recent times US$365 to US$942 in 2012 (World Bank, 2014) and surprisingly, agriculture is a major contributor to the national economy adding about 30% in 2005 (Marshall, 2011).

Figure 1 shows the decline of the percentage of the rural Kenyan population in terms of the total population since 1960; followed by a decline of the percentage of the agricultural value added to GDP in that period. Figure 2 highlights percentages of rural and urban persons with access to improved water resources (Figure 3). The decreased rural population may have been the result of several factors including the declining annual growth rate; which was 2.8% in 1960 increasing to a peak of 3.7% in 1984 but then reduced to about 2.2% in 2012.

Kenya's population has increased but the urban population has been increasing faster than the rural population even though rural population has higher population growth rate than the urban. The population increase has had a significant impact on the population density and the total internal renewable water resources per capita (m^3/inhab/yr).

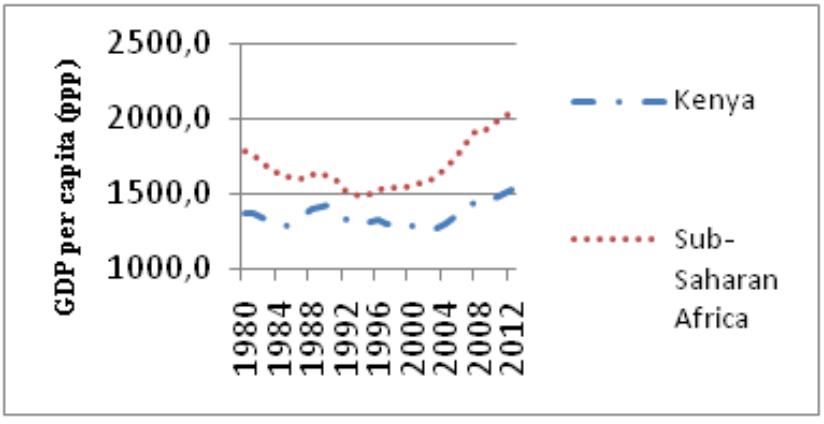


Figure 1. GDP per capita in SSA and Kenya 1980-2012.

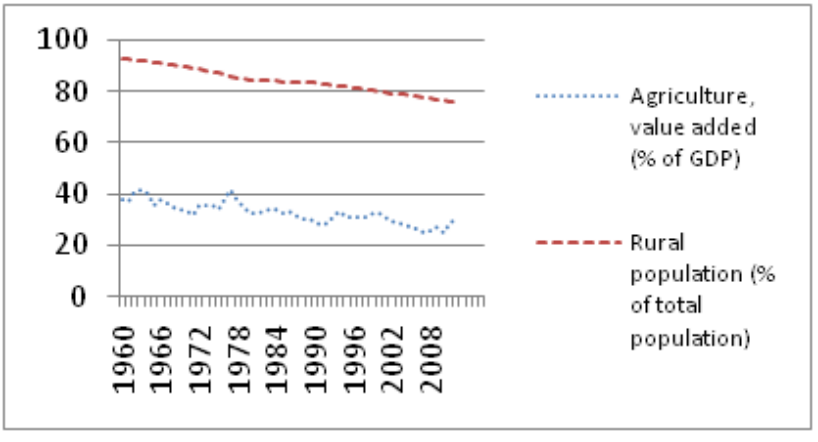


Figure 2. Agriculture contribution to GDP and rural population.

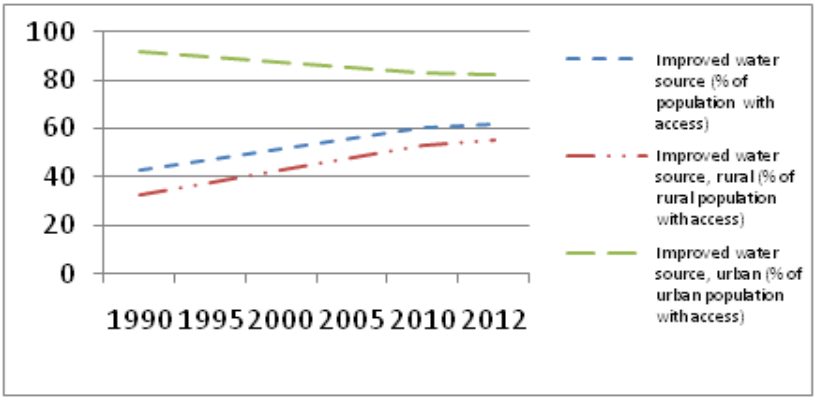


Figure 3. Percentages of improved water sources and access of rural and urban people 1990-2012.

SOMALIA

The following is included in the earlier paper by Tularam and Hassan (2016). "Somalia is an east African country located in the horn of Africa bordering the Indian Ocean, Djibouti, Ethiopia and Kenya. The land area of Somalia is 637,657 km^2 with about 13% being arable land. It has the longest coastline in Africa of around 3333km (Webersik, 2006). The total renewable internal freshwater resource in Somalia is around 6km^3. There has not been census since 1983 but UNICEF (2013) estimated the population to be around 9.3 million in 2008. The World Bank (2014) estimates the present population to be around 10.2 million.

Somalia is a hot country with tropical and semi-tropical, and arid and semi-arid climates. The average temperature is 28^{o}C in coastal areas but the temperature may reach 47^{o}C and yet it can be as low as 0^{o}C in highlands. The precipitation in Somalia is highly variable but low most of the time; many parts of the country receive below 500mm/yr. Coastal areas receive about 50 to 150 mm/yr while some others receive about 584mm/yr (Muchiri, 2007). Somalia is presently under water stress condition and the distribution of water is highly variable. The European Commission Somalia Operations Office (2006) estimated the renewable freshwater per capita to be 1,685 m^3 but the FAO statistics (2013) showed that the actual renewable fresh water per person was 1500m^3 in 2012, dropping from 4980m^3 (1962). Only 30% of the population had access to clean water in 2008, while about 67% and 9% of urban and rural populations had access to improved water sources respectively (UNICEF, 2013). The country has also performed poorly in terms of sanitation -52% of urban and 6% of rural communities have access to adequate sanitation and overall only 23% of Somali population has an access to adequate sanitation (2008) (World Bank, 2014).

According to World Bank (2014), the annual freshwater withdrawal was 54.96% of available water resources. The agriculture water withdrawal was around 99.48%, followed by domestic (0.45%), and then industry with only 0.06%. Figures 4-7 and Tables 2 and 3 summarize trends in population and water resources in Somalia (1958 to 2012). Agriculture has been the major contributor of Somali economy, even though there has not been data available since the collapse of central government in 1991. However, World Bank (2014) shows that agriculture contributed to national economy (about 50% and 71% in 1958 and 1990 respectively).

Somalia seems to have become vulnerable to droughts and floods. A severe Dabadheer drought (1974-1975) resulted in 20,000 people dying due to famine. Climate change has been blamed for other droughts in 1991-1992, more severe than Dabadheer. It is believed that between 300,000 to 500,000 people lost their lives but indirectly the drought also severely affected another 3 million people (Baumann et al., 2003). A large number of drought affected persons moved into relief camps and this led to the spreading of infectious diseases causing many to die as well. Drought continued to hit some parts of the country and the neighbouring countries in 2000 and 2011 (Griffiths, 2003). With similar extremity, the heavy rains caused many floods in 1997 and 2000 destructing many parts of Somalia (Griffiths, 2003). Surprisingly, between 1961 and 2004, 18 floods and 12 droughts were recorded in Somalia (UNEP, 2005). It seems that the rural people are more susceptible to the impact of climate change because of the degradation of ecological systems (Griffiths, 2003). The extreme situation caused many rural people to leave their lands to urban areas (Griffiths, 2003). However, disaster mismanagement, extensive farm production failures and grazing land

overexploitation have also negatively affected the farming lands of Somalia" (pp. 413 – 414; the following figures related to Somalia are also quoted from the Tularam and Hassan, 2016) for completion only.

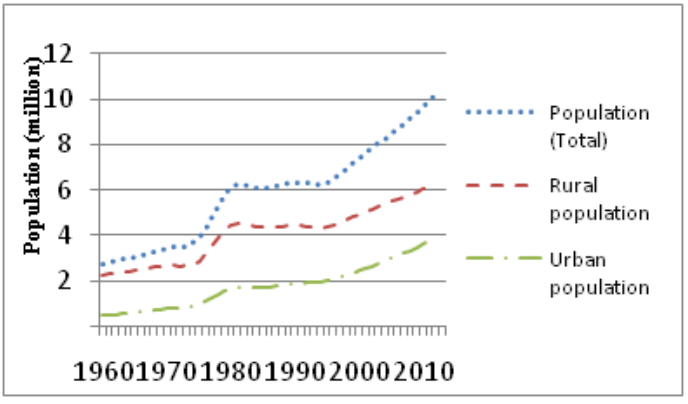


Figure 4. Population trends in Somalia 1960-2012.

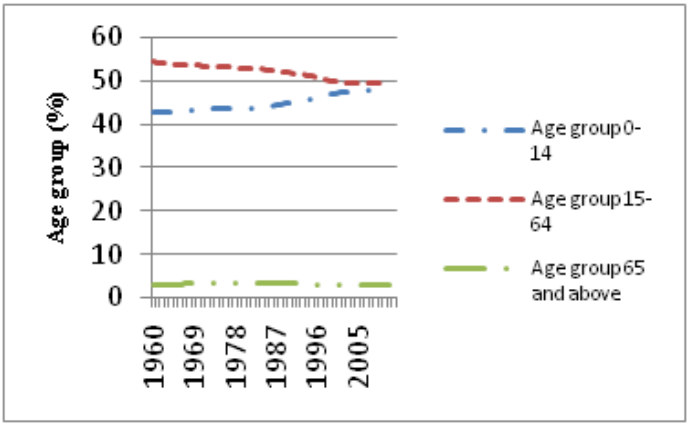


Figure 5. Age groups in Somalia (1960-2012% of total population).

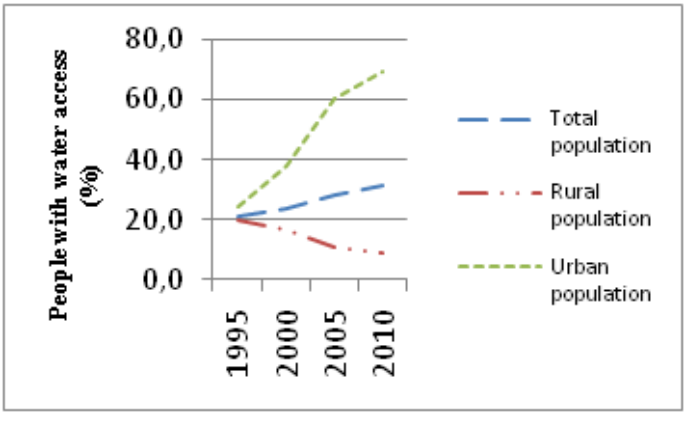


Figure 6. Improved water sources of Somalia during 1995-2010 (% of population with access).

Table 2. Kenyan land, population and water resources 1962-2011

Kenya	**1962**		**1972**		**1982**		**1992**		**1997**		**2002**		**2007**		**2011**	
Land and Population																
Total area (1000 ha)	58037	E	58037	E	58037	E	58037	E	58037	E	58037	E	58037	E	58037	E
Arable land (1000 ha)	3500	E	3500	E	3800	E	5292	E	4814	E	5091	E	5300	E	5500	E
Permanent crops (1000 ha)	405	E	455	E	480	E	480	E	480	E	427	E	500	E	650	E
Percentage of total country area cultivated (%)	6.728	E	6.815	E	7.375	E	9.945	E	9.122	E	9.508	E	9.994	E	10.6	E
Total population (1000 inhab)	8629	E	12083	E	17557	E	25042	E	28945	E	32928	E	37485	E	42749	E
Rural population (1000 inhab)	7949	E	10724	E	14687	E	20393	E	23372	E	26311	E	29515	E	32965	E
Urban population (1000 inhab)	680	E	1359	E	2870	E	4649	E	5573	E	6617	E	7970	E	9784	E
Population density (inhab/km^2)	14.87	E	20.82	E	30.25	E	43.15	E	49.87	E	56.74	E	64.59	E	73.66	E
Rainfall and internal renewable water resources																
Long-term average precipitation in volume (10^9 m^3/yr)	365.6	E	365.6	E	365.6	E	365.6	E	365.6	E	365.6	K	365.6	E	365.6	E
Surface water produced internally (10^9 m^3/yr)	20.2		20.2		20.2		20.2		20.2		20.2		20.2		20.2	
Groundwater produced internally (10^9 m^3/yr)	3.5		3.5		3.5		3.5		3.5		3.5		3.5		3.5	
Overlap between surface water and groundwater (10^9 m^3/yr)	3		3		3		3		3		3		3		3	
Total internal renewable water resources (IRWR) (10^9 m^3/yr)	20.7		20.7		20.7		20.7		20.7		20.7		20.7		20.7	
Total internal renewable water resources per capita (m^3/inhab/yr)	3558	K	2541	K	1749	K	1226	K	1061	K	932.3	K	819	K	718.1	K

Kenya	**1962**		**1972**		**1982**		**1992**		**1997**		**2002**		**2007**		**2011**	
Water withdrawal																
Agricultural water withdrawal (10^9 m^3/yr)							1.566				1.01	L	2.165	I		
Agricultural water withdrawal as % of total water withdrawal (%)							76.43						79.16	I		
Industrial water withdrawal (10^9 m^3/yr)							0.08						0.1			
Industrial water withdrawal as % of total water withdrawal (%)							3.904						3.656	I		
Municipal water withdrawal (10^9 m^3/yr)							0.403						0.47			
Municipal water withdrawal as % of total withdrawal (%)							19.67						17.18	I		
Total water withdrawal (10^9 m^3/yr)							2.049						2.735	I		
Kenya	1962		1972		1982		1992		1997		2002		2007		2011	
Total water withdrawal per capita (m^3/inhab/yr)							81.82	K					72.96	K		
Freshwater withdrawal as % of total actual renewable water resources (%)							6.674	I					8.909	I		

FOA, 2013. E - External data I - AQUASTAT estimate K - Aggregate data L - Modelled data

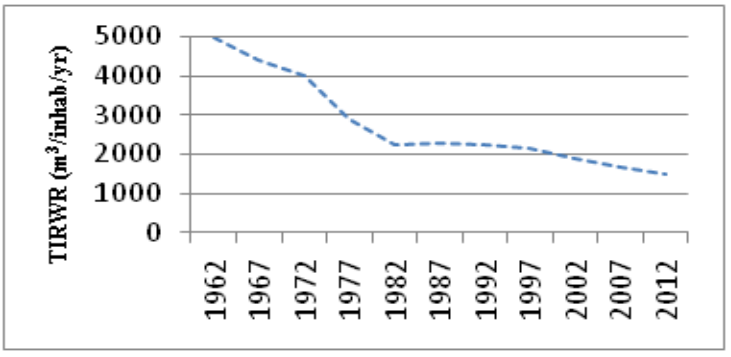


Figure 7. Somalia: Total IRWR per capita in (m^3/inhab/yr) 1962-2012.

TANZANIA

Tanganyika and the islands of Zanzibar and Pemba united in 1964 forming the United Republic of Tanzania. Tanzania is an East African country and has border with Indian Ocean, Mozambique, Malawi, Zambia, Burundi, Rwanda, Uganda and Kenya (ILO, 2004). Tanzania has an area of 947,300 km^2. The population was 10.68 million in 1962 but has increased to 47.66 million in 2012 (FAO, 2013). In 1962, 94.5% of the population lived in rural areas and only 5.5 of the population lived in cities. However after 50 years, 27.35% of the population live in urban while the rural population has dropped to 72.65%. Figure 8 shows the population increase in Tanzania and changes on rural and urban populations over the past five decades.

Agriculture contributes around 45% and 55% to the GDP and foreign exchange earnings respectively. 80% of the work force is employed in the agricultural sector (Noel, Undated). It is clear that the availability of water is crucial for the country's economy because agriculture is a major contributor. Water is also fundamental for other sectors as well such as industry, power and domestic use. The rivers supply water to Tanzania's cities such as Dar es-Salaam, Arusha, Morogoro, Kibaha and Dodoma. These cities are of high economic importance because of the industries. Tanzania also uses water as a source of power and receives about 55% of electricity from hydropower station. The average annual rainfall of the country is 1,015 mm (FAO, 2013). Many parts of the country receive between 500-1,000 mm of rainfall per year. Yet, there are some parts of the country that receive 2,400 mm (Noel, Undated).

The total internal renewable water resources are 84km^3/yr (2002). The agricultural water withdrawal represents 89% whereas the domestic water use is about 10 (2002). As a result of the population increase the total internal renewable water resources per capita has been falling from 9011m^3/inhab/yr in 1962 to 2020m^3/inhab/yr in 2012 (FAO, 2013). Based on these figures the country is not considered as having water scarcity condition; it is slightly above the water scarcity level of 1700 m^3/inhab/yr. During the same period Tanzania doubled its arable land from 5.05 million hectares to 11.6 million hectares. Figure 9 shows the changes on per capita of the renewable water resources, arable land, and land on permanent crops.

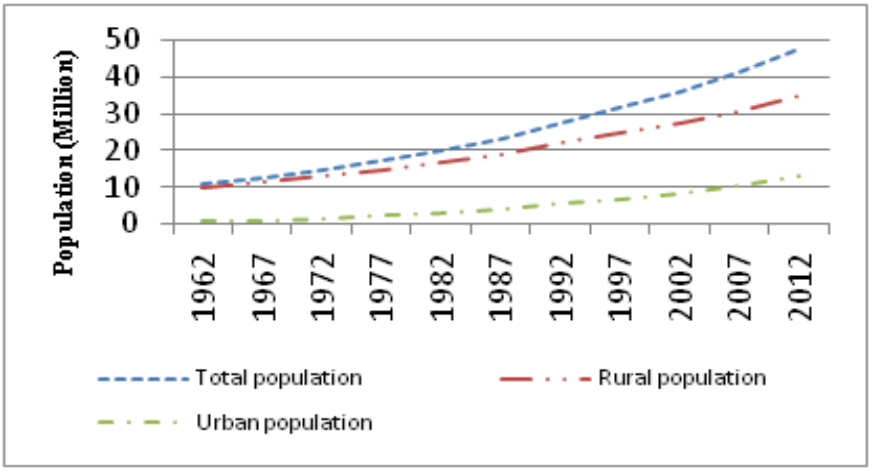


Figure 8. Tanzania: Total, rural and urban populations 1958-2012 (million inhabitants).

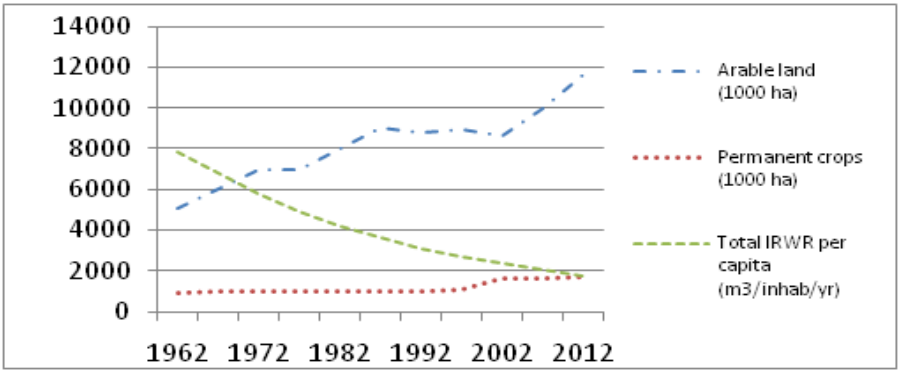


Figure 9. Tanzania: Arable land, permanent crops and per Total IRWR per capita 1962-2012.

DEMOCRATIC REPUBLIC OF CONGO (DRC)

This section is included from Tularam and Hassan (2016) for completion sake. "Democratic Republic of Congo (DRC), often referred as Zaire is located in the African Great Lakes region of Central Africa. DRC is a rich country with many natural resources such as oil, diamond, cooper and cobalt. In addition, DRC is also referred as Africa's water rich country - DRC possesses 52% and 23% of Africa's surface water reserves and internal renewable water resources respectively (UNEP, 2011). Despite this, about 60% on the population live under the poverty line, and it is considered one of world's poorest countries with a ranking 186 out of 186 countries, (also held by Niger in SSA) (UNDP, 2013). DRC is the largest and third most populated in SSA after Nigeria and Ethiopia. The population is growing at a fast rate (see Figure 10); it was around 16.2 million in 1962 and was about 69.57 million in 2012 (FAO, 2013). An interesting changed in composition has been noted in that in 2012, about 45% of the population were below the age of 15 years and about 3% of the population were 65 (Figure 11).

Table 3. Somalia: land, population and water resources (1962-2011): (Copied from Tularam and Hassan 2016)

Somalia	**1962**		**1972**		**1982**		**1987**		**1992**		**2002**		**2007**		**2012**	
Land and Population																
Total area (1000 ha)	63766	E	63766	E	63766	E	63766	E	63766	E	63766	E	63766	E	63766	E
Arable land (1000 ha)	896	E	946	E	994	E	1018	E	1023	E	1200	E	1000	E	1100	E
Permanent crops (1000 ha)	14	E	14	E	16	E	17	E	20	E	26	E	28	E	29	E
Percentage of total country area cultivated (%)	1.427	E	1.506	E	1.584	E	1.623	E	1.636	E	1.923	E	1.612	E	1.771	E
Total population (1000 inhab)	2952	E	3674	E	6608	E	6427	E	6543	E	7791	E	8733	E	9797	E
Rural population (1000 inhab)	2412	E	2796	E	4808	E	4584	E	4557	E	5142	E	5585	E	6030	E
Urban population (1000 inhab)	540	E	878	E	1800	E	1843	E	1986	E	2649	E	3148	E	3767	E
Population density (inhab/km^2)	4.629	E	5.762	E	10.36	E	10.08	E	10.26	E	12.22	E	13.7	E	15.36	E
Rainfall and internal renewable water resources																
Long-term average precipitation in volume (10^9 m^3/yr)	179.8	E	179.8	E	179.8	E	179.8	E	179.8	E	179.8	E	179.8	E	179.8	E
Surface water produced internally (10^9 m^3/yr)	5.7		5.7		5.7		5.7		5.7		5.7		5.7		5.7	
Groundwater produced internally (10^9 m^3/yr)	3.3		3.3		3.3		3.3		3.3		3.3		3.3		3.3	
Overlap between surface water and groundwater (10^9 m^3/yr)	3		3		3		3		3		3		3		3	
Total internal renewable water resources (IRWR) (10^9 m^3/yr)	6		6		6		6		6		6		6		6	
Total internal renewable water resources per capita (m^3/inhab/yr)	4980	K	4001	K	2225	K	2287	K	2247	K	1887	K	1683	K	1500	K
Water withdrawal																
Agricultural water withdrawal (10^9 m^3/yr)							0.786				3.28	L	3.281	I		
Industrial water withdrawal (10^9 m^3/yr)							0				0	L	0.002	I		
Municipal water withdrawal (10^9 m^3/yr)							0.024				0.01	L	0.015	I		
Total water withdrawal (10^9 m^3/yr)							0.81				3.29	L	3.298	I		
Agricultural water withdrawal as % of total water withdrawal (%)							97.04				99.7	L	99.48	I		
Industrial water withdrawal as % of total water withdrawal (%)							0				0	L	0.061	I		
Municipal water withdrawal as % of total withdrawal (%)							2.963				0.304	L	0.455	I		
Total water withdrawal per capita (m^3/inhab/yr)							126	K			422.3	K	377.6	K		
Freshwater withdrawal as % of total actual renewable water resources (%)							5.51				22.38	I	22.44	I		

FOA, 2013. E - External data I - AQUASTAT estimate K - Aggregate data L - Modelled data

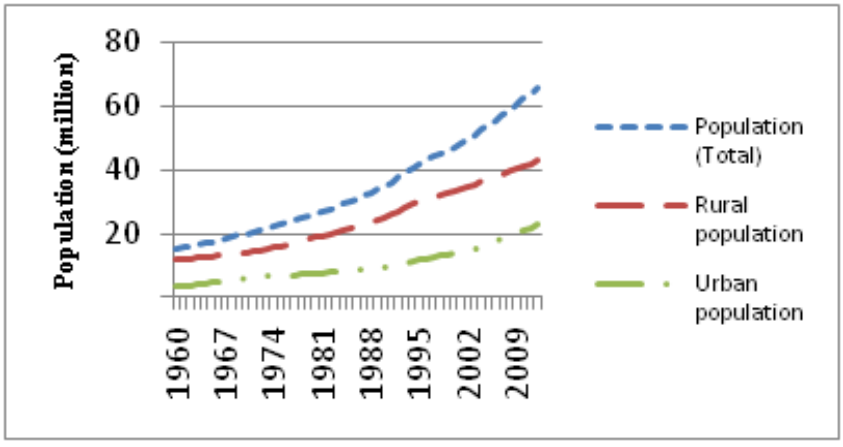


Figure 10. Population trends in DRC 1960-2012 (Tularam and Hassan, 2016).

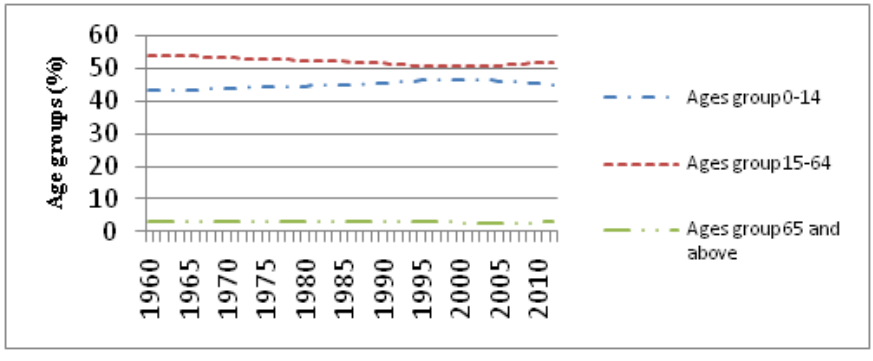


Figure 11. DRC: Trends of age group percentages in 1960-2012 (% of total population) (Tularam and Hassan, 2016).

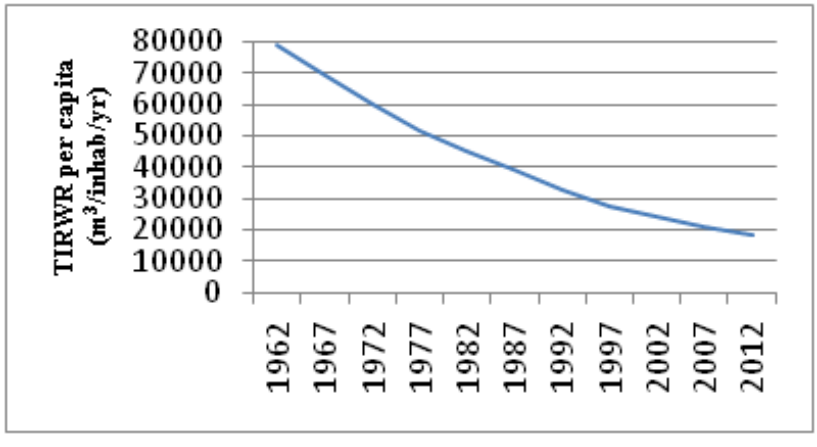


Figure 12. DRC: Total IRWR per capita in (m^3/inhab/yr) 1962-2012 (Tularam and Hassan, 2016).

Table 4. Tanzania: land, population and water resources (1962-2011)

Tanzania	**1962**		**1972**		**1982**		**1992**		**2002**		**2011**	
Land and Population												
Total area (1000 ha)	94730	E	94730	E	94730	E	94730	E	94730	E	94730	E
Arable land (1000 ha)	5050	E	7000	E	8000	E	8800	E	8600	E	11600	E
Permanent crops (1000 ha)	950	E	1000	E	1000	E	1000	E	1600	E	1700	E
Percentage of total country area cultivated (%)	6.334	E	8.445	E	9.501	E	10.35	E	10.77	E	14.04	E
Total population (1000 inhab)	10684	E	14505	E	19897	E	27231	E	35832	E	47656	E
Rural population (1000 inhab)	10099	E	13193	E	16805	E	21899	E	27575	E	34623	E
Urban population (1000 inhab)	585	E	1312	E	3092	E	5332	E	8257	E	13033	E
Population density (inhab/km^2)	11.28	E	15.31	E	21	E	28.75	E	37.83	E	50.31	E
Rainfall and internal renewable water resources												
Long-term average precipitation in volume (10^9 m^3/yr)	1015	E	1015	E	1015	E	1015	E	1015	E	1015	E
Surface water produced internally (10^9 m^3/yr)	80		80		80		80		80		80	
Groundwater produced internally (10^9 m^3/yr)	30		30		30		30		30		30	
Overlap between surface water and groundwater (10^9 m^3/yr)	26		26		26		26		26		26	
Total internal renewable water resources (IRWR) (10^9 m^3/yr)	84		84		84		84		84		84	
Total internal renewable water resources per capita (m^3/inhab/yr)	9011	K	6637	K	4838	K	3535	K	2687	K	2020	K
Water withdrawal												
Agricultural water withdrawal (10^9 m^3/yr)									4.632	K		
Industrial water withdrawal (10^9 m^3/yr)			0.024						0.025	I		
Municipal water withdrawal (10^9 m^3/yr)			0.101						0.527	K		
Total water withdrawal (10^9 m^3/yr)									5.184	K		
Water withdrawal for irrigation (10^9 m^3/yr)									4.425	I		
Agricultural water withdrawal as % of total water withdrawal (%)									89.35	K		
Industrial water withdrawal as % of total water withdrawal (%)									0.482	K		
Municipal water withdrawal as % of total withdrawal (%)									10.17	K		
Total water withdrawal per capita (m^3/inhab/yr)									144.7	K		
Freshwater withdrawal as % of total actual renewable water resources (%)									5.385	K		

FOA, 2013. E - External data I - AQUASTAT estimate K - Aggregate data L - Modelled data

The population increase has resulted in a significant drop of total renewable water resources per capita -79,291m^3/yr (1962) to 18,441m^3/yr (2011) (Figure 12). The annual average precipitation is 1,543m^3 (FAO, 2013) with the minimum rainfall in some parts of about 800m^3/yr and maximum around 1,800m^3 in other parts. The DRC's total actual renewable water resource is 1,283km^3 (FAO, 2013; UNEP, 2011).

The percentage of the population that have access to clean water is low (23%) compared to other Sub-Saharan African countries. As shown in Figure 12, Congo has not progressed in terms of water improvements and the people with access to clean water appears to be stable and low – there has been a 10% decline in the number of urban population with access to clean water during the past two decades. Similar to other Sub-Saharan African countries, agriculture is a major contributor to the GDP. In 2006, 47.7% of the GDP came from agriculture, forestry, fishing and hunting sector; however, this has fallen to 39.4% in 2011. In the same period, the sectors like Mining and quarrying, and Finance, real estate and business services have showed a slight increase overall (AfDB, 2012).

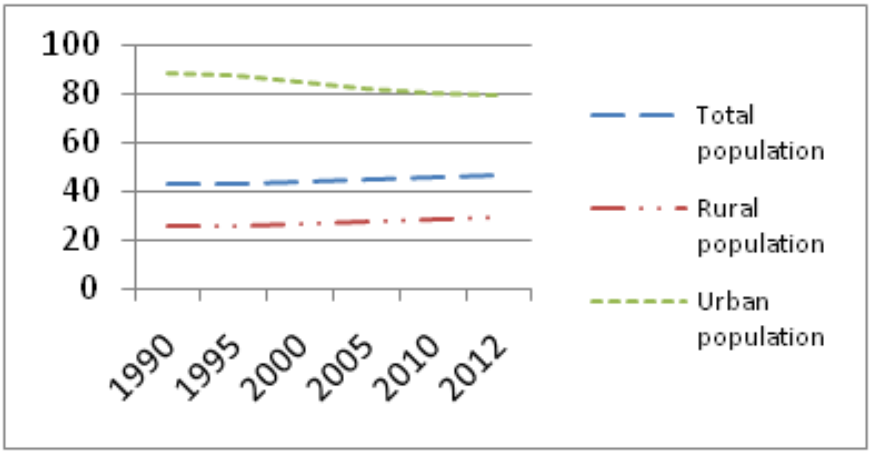


Figure 12. Improved water sources in DRC 1990-2012 (% of population with access) (Tularam and Hassan, 2016).

Table 4 shows the arable land in DRC has not increased significantly from 6.4 million hectares in 1962 to only 6.8 million hectares in 2012. FAO (2013) also noted that other agricultural improvement measures such as percentage of total area cultivated remained almost unchanged during this period. The area of permanent crops was 0.57 million hectares in 1962 and peaked at 1.2 million hectares in 1992, dropping to 0.755 million hectares in 2012. This shows that the country has not responded to the dramatic increase in its population in terms of agricultural production and food security. In contrast to other SSA countries, DRC's agricultural sector consumes the least amount of water when compared to domestic and industry sectors. However, as there are huge amounts of water resources in DRC the pressure on water is significantly low - only 0.053% in 2007 (FAO, 2013)" (pp. 414-415).

NIGERIA

Nigeria is the most populated country in Africa with an estimated population of 168.8 million (2012) (World Bank, 2014). Around 200 ethnic groups live in Nigeria, speaking about 500 indigenous languages. Figure 13 shows the population has been increasing dramatically for the last 50 years in both urban and rural areas but the urban population has been growing twice as much as rural population. Data also shows that the urbanization in Nigeria is faster than other Sub-Saharan African countries (World Bank, 2014). As a result of lack of consideration and negligence of the government to rural communities, Nigeria's rural people have become more disadvantageous than the urban people; and this has caused a number of rural people to migrate to cities searching for a better life (Nwokocha, 2012). In terms of food security when the productive people leave from the rural areas it will affect the agricultural production as labour shortage emerges and consequently on food security (Ofuoku, 2012). In Delta Niger, for example, one of the important factors was the discovery of oil that undermined the agricultural production causing farmers to migrate to cities for employment (Ofuoku, 2012). In other parts of the country, rural youths became less interested in farming and migrating to cities hoping for a better life (Olajide and Udoh, 2012).

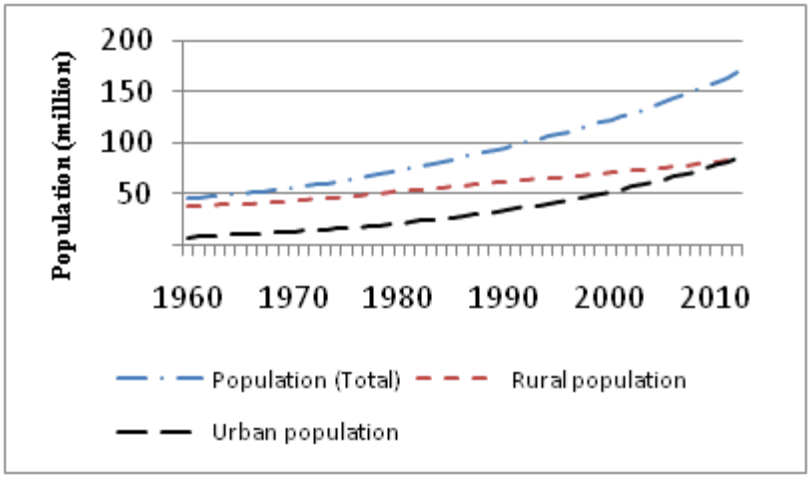


Figure 13. Population trends in Nigeria 1960-2011.

Nigeria is considered as the second largest economy in SSA. The Nigerian economy relies mainly on oil. Oil contributes about 41% of the GDP, and accounts 97.5% and 81% of the export and government revenues respectively (EPRI, 2011). Recently, the contribution of agriculture to GDP has experienced fluctuations mainly due to water availability. The available freshwater resources in Nigeria come from rivers, lakes, streams and flood basins that are distributed evenly in the country. However, precipitation is Nigeria has significant variability ranging from around 250mm/yr in country's far north parts to 500mm/yr in southern parts of the country (Orubu, 2006). Rainfall amounts affect the quality and volume of surface water in rivers, lakes, streams and flood basins as well as groundwater (Tularam, 2010; Tularam and Singh, 2009; Indraratna, et al., 2001a, Indraratna et al, 2001b).

Table 5. Democratic Republic of Congo: land, population and water resources 1962-2012 (Tularam and Hassan, 2016)

Democratic Republic of Congo	**1962**		**1972**		**1982**		**1992**		**2002**		**2007**		**2012**	
Land and Population														
Total area (1000 ha)	234486	E	234486	E	234486	E	234486	E	234486	E	234486	E	234486	E
Arable land (1000 ha)	6400	E	6500	E	6640	E	6700	E	6700	E	6700	E	6800	E
Permanent crops (1000 ha)	570	E	850	E	1030	E	1200	E	750	E	750	E	755	E
Percentage of total country area cultivated (%)	2.972	E	3.135	E	3.271	E	3.369	E	3.177	E	3.177	E	3.222	E
Total population (1000 inhab)	16181	E	21431	E	28551	E	39444	E	52491	E	60772	E	69575	E
Rural population (1000 inhab)	12378	E	14916	E	20445	E	28411	E	36409	E	40547	E	44150	E
Urban population (1000 inhab)	3803	E	6515	E	8106	E	11033	E	16082	E	20225	E	25425	E
Population density (inhab/km2)	6.901	E	9.14	E	12.18	E	16.82	E	22.39	E	25.92	E	29.67	E
Rainfall and internal renewable water resources														
Long-term average precipitation in volume (109 m3/yr)	3618	E	3618	E	3618	E	3618	E	3618	E	3618	E	3618	E
Surface water produced internally (109 m3/yr)	899		899		899		899		899		899		899	
Groundwater produced internally (109 m3/yr)	421		421		421		421		421		421		421	
Overlap between surface water and groundwater (109 m3/yr)	420		420		420		420		420		420		420	
Total internal renewable water resources (IRWR) (109 m3/yr)	900		900		900		900		900		900		900	
Total internal renewable water resources per capita (m3/inhab/yr)	79291	K	59867	K	44937	K	32527	K	24442	K	21112	K	18441	K
Water withdrawal														
Agricultural water withdrawal (109 m3/yr)									0.072	L	0.072	L		
Industrial water withdrawal (109 m3/yr)							0.058		0.123	L	0.147	L		
Municipal water withdrawal (109 m3/yr)							0.216		0.389	L	0.465	L		
Total water withdrawal (109 m3/yr)									0.584	L	0.684	L		

Table 5. (Continued)

Democratic Republic of Congo	**1962**		**1972**		**1982**		**1992**		**2002**		**2007**		**2012**	
Water withdrawal for irrigation (109 m3/yr)									0.072	L	0.072	L		
Agricultural water withdrawal as % of total water withdrawal (%)									12.31	L	10.52	L		
Industrial water withdrawal as % of total water withdrawal (%)									21.04	L	21.47	L		
Municipal water withdrawal as % of total withdrawal (%)									66.65	L	68.01	L		
Total water withdrawal per capita (m3/inhab/yr)									11.13	K	11.25	K		
Freshwater withdrawal as % of total actual RWR (%)									0.045	I	0.053	I		

FOA, 2013. E - External data I - AQUASTAT estimate K - Aggregate data L - Modelled data.

Surface water produced internally in Nigeria is 214km^3/yr plus 87km^3/yr of internally produced groundwater. However, Nigeria's total internal renewable water resources (IRWR) are 221km^3/yr - about 80km^3/yr of overlapping waters. Orubu (2006) noted that agriculture consumes about 34.2% of the available water followed by industries (25%) and domestic – (12.4%) with 28.2% being wasted. Figure 14 shows that agricultural contribution has slightly increased from 28% in 1981 to 32% in 2011 peaking in 2003 to about 50% of the GDP (World Bank, 2014). In fact Olajide and Udoh (2012) noted that agriculture employed 70% of workforce and accounted for 66% of non-oil sector foreign exchange.

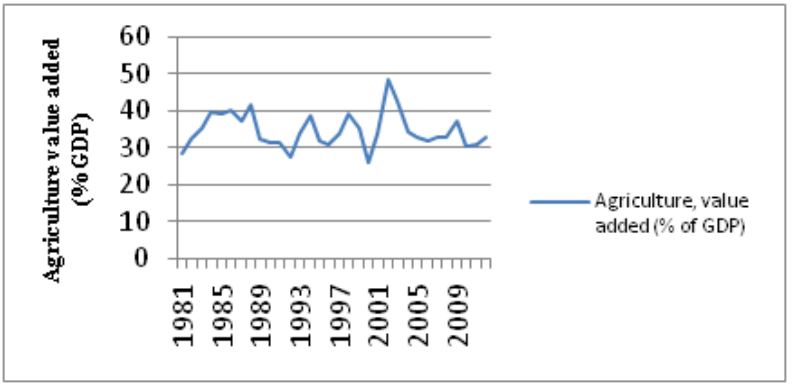


Figure 14. Nigeria: Agriculture, value added (% of GDP) 1981-2011.

World Bank (2014) noted that Nigeria had progressed in that about 64% of Nigerians had access to improved water resources in 2012, including 78.84% of the urban population and 49.1% of the rural people (Figure 15).

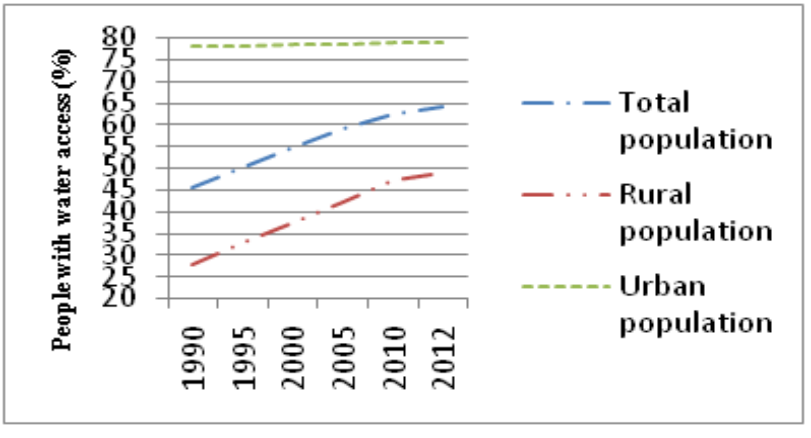


Figure 15. Improved water sources in Nigeria 1990-2012 (% of population with access).

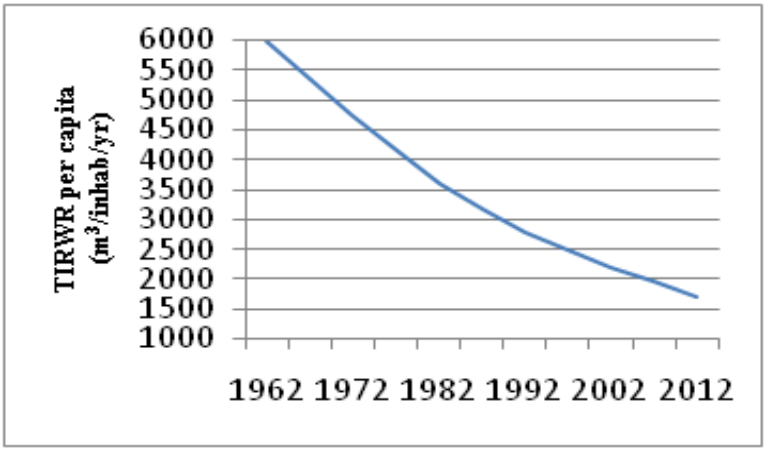


Figure 16. Nigeria: Total internal renewable water resources per capita (m^3/inhab/yr) 1962-2012.

In 1991, 79% (25 million) of Nigerian people living in cities had access to clean water, but 17 years later this has fallen to 75% (55 million) of people living in urban areas of Nigeria. The country doubled the number of people with access to fresh water but the higher rate of population growth has resulted in the water demand exceeding the water supply (World Bank, 2012). As the population increased the total internal renewable water resources per capita has been decreasing significantly from 4129m^3/inhab/yr in 1967 to 1326m^3/inhab/yr in 2012. Due to this fact, people have lost about 68% of their water share during the last half century (Figure 16).

NIGER

Niger is a West African country, with a population of about 17.15 million (2012) (World Bank, 2014). It is one the fastest growing countries in terms of population. Figure 23 shows that the population increased from 3.33 million in 1960 to 17.15 million in 2012 (World Bank). However, out of 186 countries studied Niger was the poorest country worldwide holding the 186th position with DRC (UNDP, 2013). About 61% of the population live with less than a dollar per day. Agriculture is the dominant sector of the economy accounting about 39% of the GDP (2009). Therefore level of agricultural production has a great impact on annual growth of the economy. The variability of farming conditions and country's economic growth is highly volatile, for example in 2007, 2008 and 2009 the economic growth was 3.2%, 9.3% and -1.2% respectively (EPRI, 2011). Desertification and frequent drought are two major factors that affect the agricultural production in the country (EPRI, 2011). The rural and urban population growth is different from other SSA countries - the urban population has been increasing slowly during the last 50 years, while the rural population rose remarkably as well in this period.

Table 6. Nigeria: land, population and water resources (1962-2012)

Nigeria	**1962**		**1972**		**1982**		**1987**		**1992**		**2002**		**2007**		**2012**	
Land and Population																
Total area (1000 ha)	92377	E	92377	E	92377	E	92377	E	92377	E	92377	E	92377	E	92377	E
Arable land (1000 ha)	26500	E	27420	E	28013	E	28947	E	29922	E	32000	E	37500	E	36000	E
Permanent crops (1000 ha)	2400	E	2480	E	2535	E	2535	E	2535	E	2800	E	3000	E	3200	E
Percentage of total country area cultivated (%)	31.28	E	32.37	E	33.07	E	34.08	E	35.14	E	37.67	E	43.84	E	42.43	E
Total population (1000 inhab)	47936	E	60192	E	79624	E	90364	E	102445	E	129832	E	146951	E	166629	E
Rural population (1000 inhab)	39299	E	45874	E	55848	E	60368	E	64843	E	72732	E	76955	E	81254	E
Urban population (1000 inhab)	8637	E	14318	E	23776	E	29996	E	37602	E	57100	E	69996	E	85375	E
Population density (inhab/km^2)	51.89	E	65.16	E	86.19	E	97.82	E	110.9	E	140.5	E	159.1	E	180.4	E
Rainfall and internal renewable water resources																
Long-term average precipitation in volume (10^9 m^3/yr)	1062	E	1062	E	1062	E	1062	E	1062	E	1062	E	1062	E	1062	E
Surface water produced internally (10^9 m^3/yr)	214		214		214		214		214		214		214		214	
Groundwater produced internally (10^9 m^3/yr)	87		87		87		87		87		87		87		87	
Overlap between surface water and groundwater (10^9 m^3/yr)	80		80		80		80		80		80		80		80	
Total internal renewable water resources (IRWR) (10^9 m^3/yr)	221		221		221		221		221		221		221		221	

Table 6. (Continued)

Nigeria	**1962**		**1972**		**1982**		**1987**		**1992**		**2002**		**2007**		**2012**	
Total internal renewable water resources per capita (m^3/inhab/yr)	5970	K	4755	K	3594	K	3167	K	2794	K	2204	K	1948	K	1718	K
Water withdrawal																
Agricultural water withdrawal (10^9 m^3/yr)							1.96				5.51	L	7.047	L		
Industrial water withdrawal (10^9 m^3/yr)							0.545				1.554	L	1.965	L		
Municipal water withdrawal (10^9 m^3/yr)							1.125				3.242	L	4.099	L		
Total water withdrawal (10^9 m^3/yr)							3.63				10.31	L	13.11	L		
Agricultural water withdrawal as % of total water withdrawal (%)							53.99				53.44	L	53.75	L		
Industrial water withdrawal as % of total water withdrawal (%)							15.01				15.07	L	14.99	L		
Municipal water withdrawal as % of total withdrawal (%)							30.99				31.45	L	31.27	L		
Total water withdrawal per capita (m^3/inhab/yr)							40.17	K			79.41	K	89.21	K		
Freshwater withdrawal as % of total actual RWR (%)							1.268	I			3.602	I	4.581	I		

FOA, 2013. E - External data I - AQUASTAT estimate K - Aggregate data L - Modelled data

During the past four decades the average temperature has increased about 0.6ºc and after 30 years of decreasing annual precipitation during 1990-2000 there was a significant recovery of the overall rainfall averages. Niger has a total internal renewable water resources (TRWR) of 3.5km^3. The TRWR per capita has been falling dramatically from 9771m^3/inhab/yr in 1962 to 2022m^3/inhab/yr in 2012. This seems to be directly related to the rapid population growth. The pressure on freshwater withdrawal is low as the country withdraws about 2.9% of the actual renewable water resources. Surprisingly, Niger has higher percentage of people with access to clean water compared to SSA countries - about 98.7% of urban and 42.1% of the rural has access; in fact, 52.3% of the total population has access to improved water. Niger has 15% of arable land but in contrast to DRC it increased the permanent cropped land from 1,000ha in 1962 to 60,000ha in 2011 (FAO, 2013).

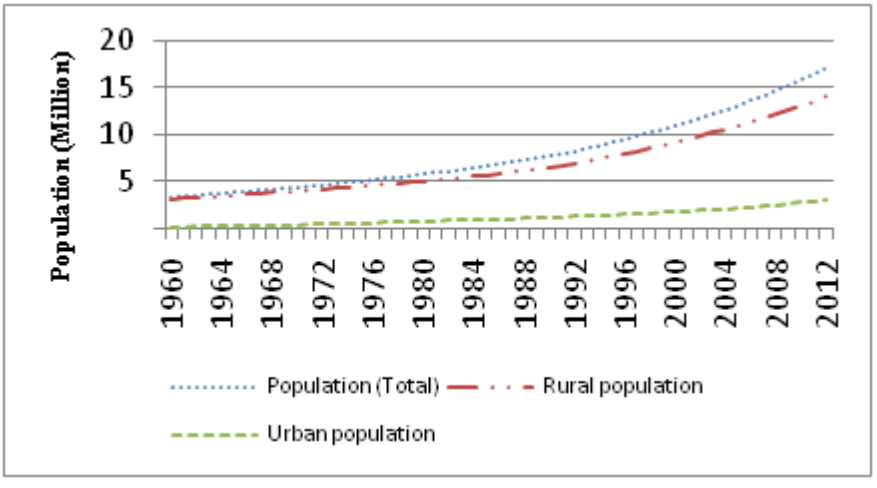


Figure 17. Population trends in Niger 1960-2012.

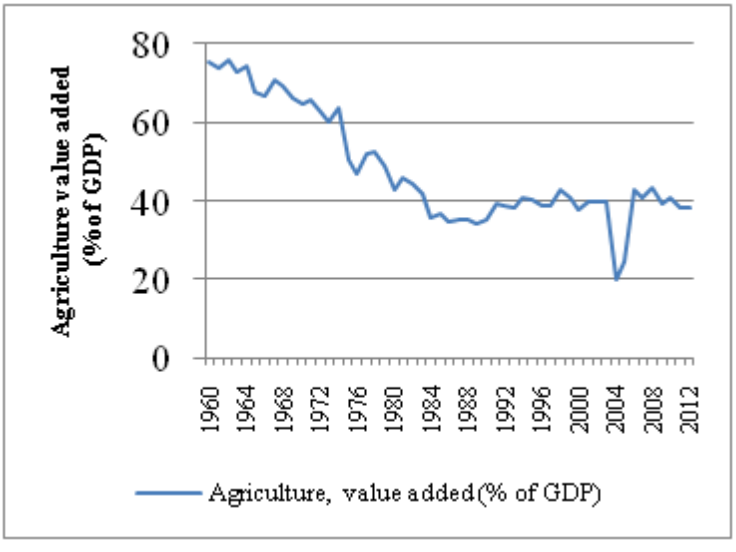


Figure 18. Niger: Agriculture, value added (% of GDP) 1960-2011.

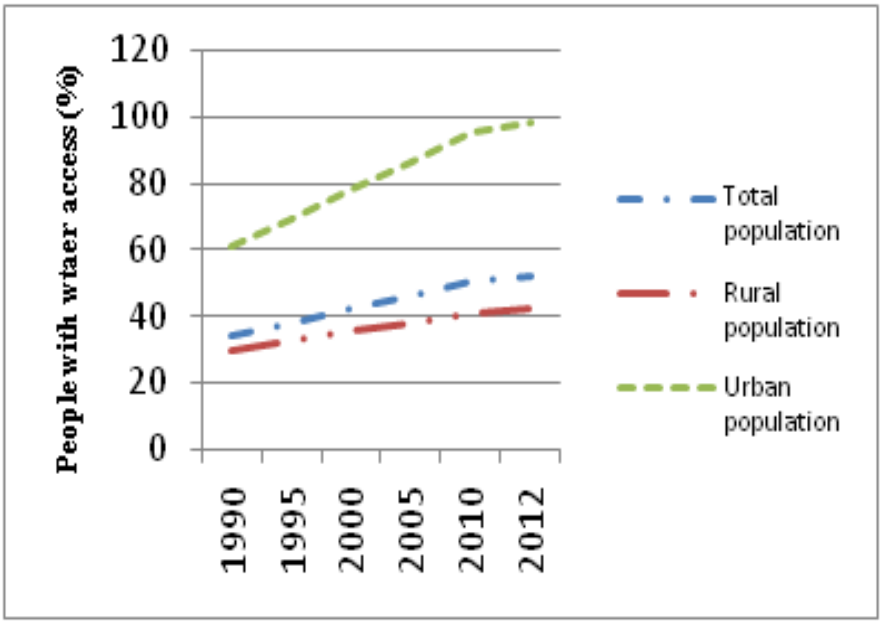


Figure 19. Niger: Improved water sources 1990-2012 (% of population with access).

REPUBLIC OF SOUTH AFRICA

South Africa has been under water stress since 1982 since rainfall has been insufficient and unreliable and evaporation rates are high (FAO, 2013; UNEP, 2009).). Climate change effects may be to blame but these factors have led to a number of river basins having a demand that exceeds the available water. Most of the country falls into arid and semi-arid regions with around 70% receiving less than 500mm of rainfall per year while about 20% receiving 200mm/yr or less (Binns et al., 2001). In dry land regions 200mm/yr is the minimum amount of precipitation for crop production.

South Africa is 495mm/yr and this is 40% less than the average annual rainfall worldwide (Mukheibir and Sparks, 2003). Although the actual renewable water resources are 50km^3, 95% of the population had access to clean water in 2012 (Figure 20). Moreover, the coastline areas do receive reliable rainfall while the forest and sugar cane plantations extract large amounts of rain water reducing the amount of water that rivers receive to only 9% of the available water (Mukheibir and Sparks, 2003). As noted, the evaporation rate also plays a part; for example, 2750mm/yr occurs in the hot dry northwest of South Africa and 1250mm/yr in south and southeast (Binns et al., 2001).

Table 7. Niger: land, population and water resources (1962-2012)

Niger	**1962**		**1972**		**1982**		**1992**		**2002**		**2007**		**2012**	
Land and Population														
Total area (1000 ha)	126700	E	126700	E	126700	E	126700	E	126700	E	126700	E	126700	E
Arable land (1000 ha)	11499	E	11173	E	9852	E	12987	E	13970	E	14958	E	14940	E
Permanent crops (1000 ha)	1	E	4	E	8	E	13	E	30	E	42	E	60	E
Percentage of total country area cultivated (%)	9.077	E	8.822	E	7.782	E	10.26	E	11.05	E	11.84	E	11.84	E
Total population (1000 inhab)	3444	E	4641	E	6208	E	8300	E	11706	E	13946	E	16644	E
Rural population (1000 inhab)	3236	E	4185	E	5341	E	7008	E	9791	E	11604	E	13748	E
Urban population (1000 inhab)	208	E	456	E	867	E	1292	E	1915	E	2342	E	2896	E
Population density (inhab/km^2)	2.718	E	3.663	E	4.9	E	6.551	E	9.239	E	11.01	E	13.14	E
Rainfall and internal renewable water resources														
Long-term average precipitation in volume (10^9 m^3/yr)	191.3	E	191.3	E	191.3	E	191.3	E	191.3	E	191.3	E	191.3	E
Surface water produced internally (10^9 m^3/yr)	1		1		1		1		1		1		1	
Groundwater produced internally (10^9 m^3/yr)	2.5		2.5		2.5		2.5		2.5		2.5		2.5	
Overlap between surface water and groundwater (10^9 m^3/yr)	0		0		0		0		0		0		0	
Total internal renewable water resources (IRWR) (10^9 m^3/yr)	3.5		3.5		3.5		3.5		3.5		3.5		3.5	
Total internal renewable water resources per capita (m^3/inhab/yr)	9771	K	7251	K	5420	K	4054	K	2875	K	2413	K	2022	K
Water withdrawal														
Agricultural water withdrawal (10^9 m^3/yr)							0.41				0.6565	L		
Industrial water withdrawal (10^9 m^3/yr)							0.01		0.0284	L	0.0327	L	0.0137	
Municipal water withdrawal (10^9 m^3/yr)							0.08		0.2554	L	0.2944	L	0.0617	
Total water withdrawal (10^9 m^3/yr)							0.5				0.9836	L		
Agricultural water withdrawal as % of total water withdrawal (%)							82				66.74	L		
Industrial water withdrawal as % of total water withdrawal (%)							2				3.325	L		
Municipal water withdrawal as % of total withdrawal (%)							16				29.93	L		
Total water withdrawal per capita (m^3/inhab/yr)							60.24	K			70.53	K		
Freshwater withdrawal as % of total actual RWR (%)							1.538				2.923	I		

FOA, 2013. E - External data I - AQUASTAT estimate K - Aggregate data L - Modelled data

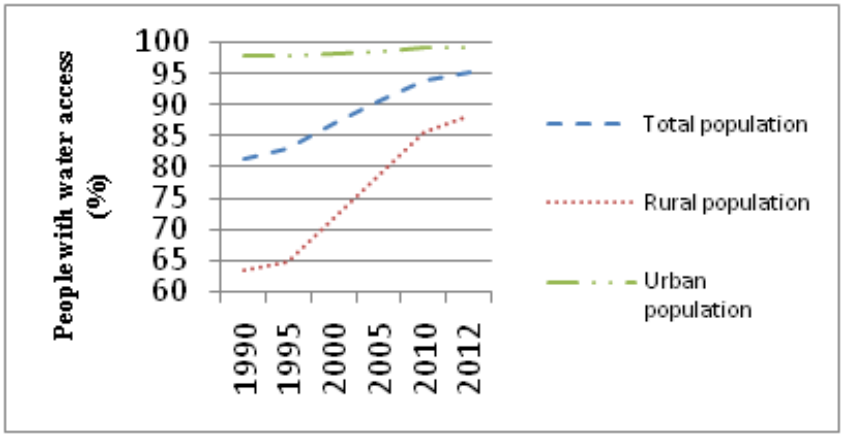


Figure 20. South Africa: Improved water sources 1990-2012 (% of population with access).

South Africa has 13.7% of arable land and agriculture is the major water withdrawer at about 59%, followed by urban (25%) and industry (6%) respectively. Yet, agriculture accounts for only 2.5% of the GDP (2012) and Figure 27 shows that it is the lowest in SSA (World Bank, 2014). The irrigated farming sector employs only 2% of country's workforce with 8% employed by those in the rain-fed agriculture (Mukheibir and Sparks, 2003).

The Department of Water Affairs and Forestry acknowledges that climate change is challenging the South Africa's water supply sustainability. As temperature rise, increasing amounts of water are required for crop production (Steele and Schulz, 2012). The projected natural disasters such as flood and droughts will affect food security. There is increasing evidence that rain-fed agriculture particularly maize production will fall to half in 2020 (Wassung, 2010).

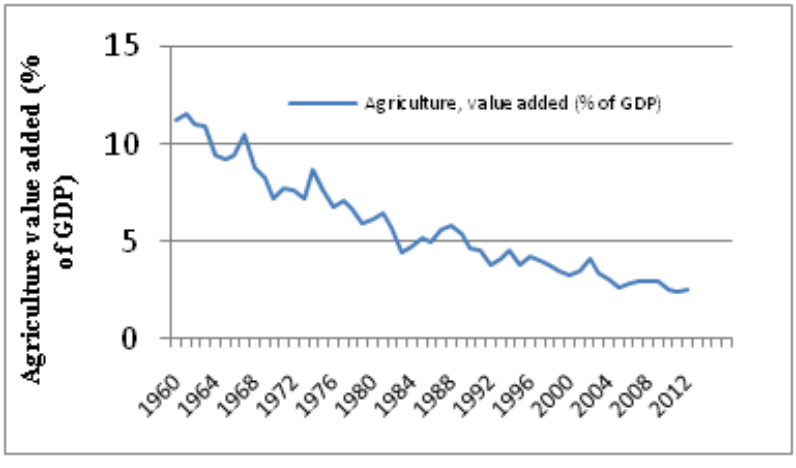


Figure 21. South Africa: Agriculture, value added (% of GDP) 1960-2012.

Africa has a population of 52.2 million, out of which 62.4% (32.63 million) live in cities and the remaining 37.6% (19.6 million) live in rural areas. South Africa has experienced rapid urbanization and expansion of cities in mid 1980s and early 1990s (Figure 21). Therefore, the water demand is increasing and fuelling the water supply crisis that already exists (Binns et al., 2001).

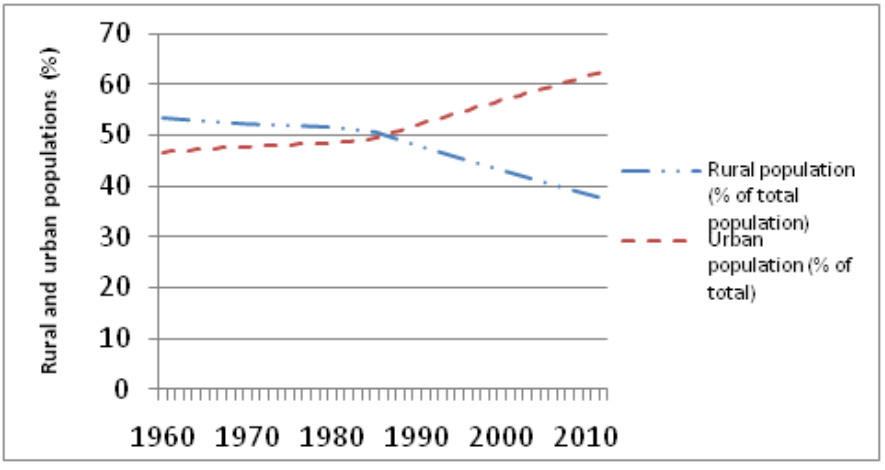


Figure 22. Changes in percentages of South African rural and urban populations 1960-2012.

DISCUSSION

Evidently, the Sub-Saharan African countries are in deep trouble when water and food security are considered. The data shows that population growth in SSA in general is rather high and this in turn has led to high levels of poverty. SSA is rapidly urbanizing at a faster rate than others in the globe with the rural population is decreasing due to several reasons such as movement with an aim to gain a better lifestyle. As noted in the earlier paper (Tularam and Hassan, 2016), the Sub-Saharan Africa has quadrupled since 1960; while Kenya and Niger, and Tanzania increased around 4.7 times. South Africa, Nigeria and Somalia have tripled over time. In Nigeria and Tanzania the percentage of rural population has declined about 34% and 22% respectively, while Ethiopia, Niger and DRC decreased about 12%. Overall, a 22% decline in rural population has been noted in SSA since 1960 (see Table 8). This was a serious aspect of movement of persons from Africa to Europe and for this reason the changes in the rural and urban population numbers have also been included in this paper (Tularam and Hassan, 2016; Tularam and Murali, 2015).

Fourteen SSA countries have water stress with 11 predicted to be water stressed by 2025 (Abel Mejía et al., 2012; UN, 2008). Kenya is under water scarcity and Somalia, Ethiopia and South Africa are already in stress situation. South Africa has made better use of their water resources to deal with the water issue. Table 9 shows changes in the Total Renewable Water Resources per capita (TRWR) in terms of the percentage of water share lost – there is a relationship between TRWR and the population growth yet clearly there could other factors affecting it as well such as inappropriate management.

Table 8. Changes in total and rural populations in SSA (Tularam and Hasssan, 2016)

Population by Region/Country	Population (Millions)		Folds increased	Rural population (%)		Rural population decrease (%)
	1960	2012		1960	2012	
Ethiopia	22	92	4.1	94	83	11
Tanzania	10	48	4.7	95	73	22
South Africa	17	52	3.0	53	38	16
Somalia	3	10	3.7	83	62	21
Kenya	8	43	5.3	93	76	17
DRC	15	66	4.3	78	65	13
Nigeria	45	169	3.7	84	50	34
Niger	3	17	5.1	94	82	12
SSA	228	911	4.0	85	63	22

Table 9. Total renewable water resources (TRWR) per capita in SSA (Tularam and Hassan, 2016)

Item	TRWR 1962	TRWR 2012	TRWR lost 1960-2012	TRWR lost 1962-2012	Freshwater withdrawal as % of TARWR**	
Country	m^3/capita/yr	m^3/capita/yr	m^3/capita/yr	%	year	%
Ethiopia	2017*	1410	607	30	2002	4.56
Tanzania	9011	2020	6991	78	2002	5.39
South Africa	2805	1013	1792	64	2000	24.28
Somalia	4980	1500	3480	70	2003	22.44
Kenya	3558	718.1	2839.9	80	2003	8.91
DRC	79291	18441	60850	77	2005	0.05
Nigeria	5970	1718	4252	71	2005	4.58
Niger	9771	2022	7749	79	2005	2.92

* 1997 data

** Freshwater withdrawal as % of total actual renewable water resources (TARWR) (%)

Table 9 shows that freshwater withdrawal as percentage of total actual renewable water resources varying from 0.05% in DRC, and 22.44% and 24.28 in Somalia and South Africa respectively. In Nigeria many now have the access to clean water but this process has been stifled by the steady increase in the population. The overall percentage with access to potable water however has been falling overall.

The steady availability of arable land in the face of increasing population has led to a decrease in agricultural activities and thus lowering the levels of food production in SSA. Figure 23 shows the changes on arable land in SSA since 1962 with some countries increasing the availability. There are a number of reasons such as the poor land quality and rather low level of agricultural productivity; there has been a lowering of manpower in general caused by the migration of young looking for better opportunities and thus a significant lowering of the existing work force; this has been compounded by the varying rainfall levels in SSA, with many areas experiencing significant water shortage; also there has been a clear lack of attention in terms of research development in the agricultural sections of

many countries by focus retained on arrivals at major cities of each of the countries involved. All of this ultimately leads to food security of the region.

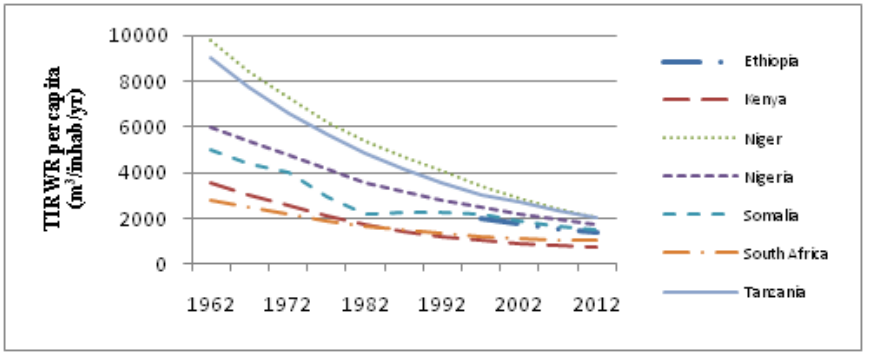


Figure 23. Total internal renewable water resources per capita (m^3/inhab/yr; Tularam and Hassan, 2016).

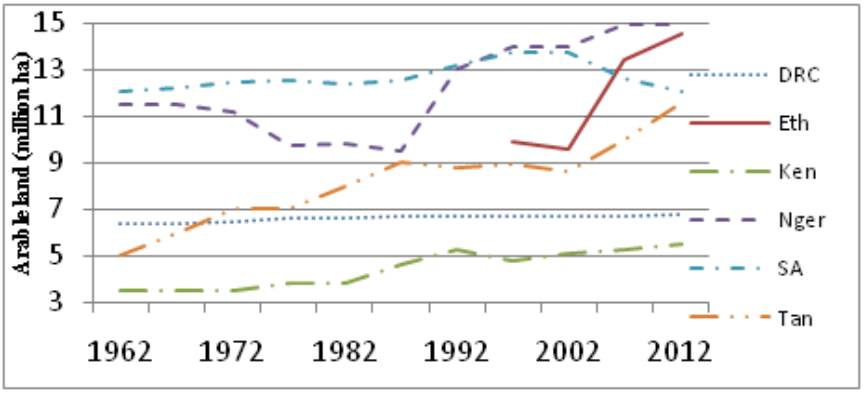


Figure 24. Changes on arable land of six selected countries (million ha) 1962-2012 (Tularam and Hasssan, 2016).

Apart from Niger, Tanzania and Ethiopia most other countries show a very steady level of arable land availability in SSA, over a long period of time with a slight trend; which does not seem significant given the population increases in the countries concerned (Figure 23). For example, DRC has almost no change in arable land over 50 years. Therefore it is not surprising at all to note that SSA is net food importer of food. However, in SSA, agriculture is important and has accounted for 20% of GDP with 15% in 2012. In Niger, Nigeria, DRC and Ethiopia it is around 40% and 50% in 2012. Tanzania has had a gradual lowering to 2012. In general, the levels are steady but there is an overall decline over time (Figure 24).

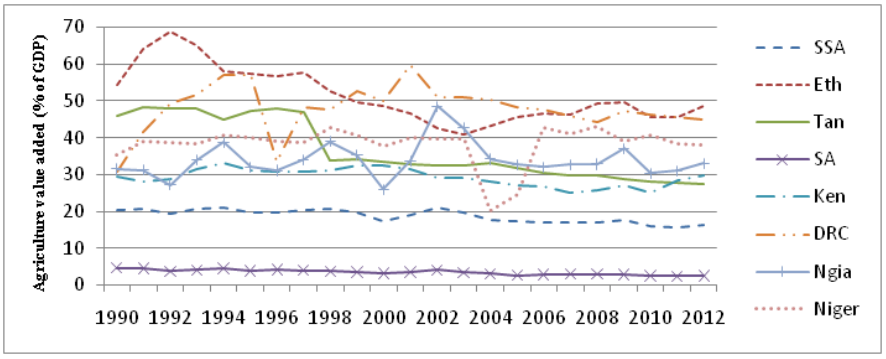


Figure 25. Agriculture value added (% of GDP) (Tularam and Hassan, 2016).

The floods and droughts in Somalia, Kenya and Ethiopia were not helpful in the recent times but it was noted that Somalia experienced a lack of rainfall and then droughts in 1992 and again in 2011 causing their population many more difficulties than others in SSA. In fact it was noted that in 1992 there was no agricultural production at all in Ethiopia and the lack of food led to many deaths leading to famine that was well reported. Indeed, the water condition in the SSA has led to conflicts in the past with a well reported case in DRC for example – their internal disruptions erupted in 1990's. There have been a number of other disputes regarding boarder water in rivers etc. (Tularam and Hassan, 2016; Tularam, 2012; Tularam 2014).

CONCLUSION

This study examined water availability and stress in Sub-Saharan Africa and related water and food security. The SSA countries (Ethiopia, Kenya, Somalia, Tanzania, Democratic Republic of Congo (DRC), Niger, Nigeria and South Africa) were studied in relation to specific factors such as population, water resources availability, agricultural production as well as the nature of their economic developments. Evidently, SSA has a number of water and food security challenges. The data presented in the accompanying paper of Tularam and Hassan (2016) show that around 63% of SSA population were in rural areas (2012). It is now been predicted that about a half of the SSA population will be living in cities by the year 2020. SSA has a high level of population growth with equally high level of poverty and the rural youth perceive themselves being disadvantaged. Not surprisingly, there is a high level of migration to major cities with evidence showing that the main cities are expanding; and thus themselves experiencing a number of complex issues relating to this migration from rural areas. In fact SSA is urbanizing at a faster rate than the rest of the world with the rural population declining steadily during the past fifty years. Many have attributed this move to the very low availability of arable land, fresh and domestic water and thus food security and this has all compounded into the mass flow of refugees that has been recently noted in Europe.

The data shows that SSA has not been spared the effects of climate change. Many in SSA rely on the rain-fed agriculture and rainfall has not been consistent but in addition it seems that the population have tended to have poor adaptive capacity when compared with the Asian

populations (Tularam and Murali, 2015) which were in a similar position many years ago (IPCC, 2007; Cooper et al., 2008; Ringler et al., 2010). Essentially, the study reveals a lack of clean water access for rural areas, which has been compounded by the largely variable rainfall. Altogether the impact on SSA agricultural activities and thus food production has been great (see Amikuzuno and Donkoh, 2012; and also Wroblewski and Wolff, 2010). A move away towards the urban from villages is also due to the fact that the agricultural production is not at all improving over time as noted in the graphs and this may then be directly related to water security. Thus, rather than being self-sufficient in their food production SSA is a net food importer that is not a good position given there is so much land and water in the continent.

REFERENCES

Abel Mejía, M. N. H. Enrique, R. S. and Miguel, D. (2012). Water and Sustainability: A Review of Targets, Tools and Regional Cases. United Nations World Water Assessment Programme, Side Publications Series 03. United Nations World Water Assessment Programme. pp.8.

AfDB, (2012). African Economic Outlook 2012: Democratic Republic of the Congo. African Development Bank. Tunis, Tunisia.

Amikuzuno, J. and Donkoh, S. A. (2012). Climate Variability and Yields of Major Staple Food Crops in Northern Ghana. African Crop Science Journal, Vol. 20, Issue Supplement s2, pp. 349 – 360.

Awulachew, S. B. Yilma, A. D. Loulseged, M. Loiskandl, W. Ayana, M. and Alamirew, T. (2007). Water Resources and Irrigation Development in Ethiopia. International Water Management Institute. 78p. (Working Paper 123). Colombo, Sri Lanka.

Baumann, R. F. Yates, L. A. and Washington, V. F. (2003). "My Clan Against the World" US and Coalition Forces in Somalia 1992-1994. Combat Studies Institute Press Fort Leavenworth, Kansas.

Binns, J. A. Illgner, P. M. and Nel, E. L. (2001). Water shortage, deforestation and development: South Africa's `Working for Water' programme. Land Degradation and Development, 12 (4), 341-355.

Bob, U. (2010). Land-related conflicts in Sub-Saharan Africa, African Journal on Conflict Resolution Vol. 10(2), 2010. pp. 49-64.

Chauvin, N.D., Mulangu, F. and Porto, G., 2012. Food production and consumption trends in sub-Saharan Africa: Prospects for the transformation of the agricultural sector. *United Nations Development Programme*, pp.4-29.

Chikaire, J. and Nnadi, F. N. (2012). Agricultural biotechnology: A panacea to rural poverty in sub-Saharan Africa (Review). Prime Research on Biotechnology (PRB) ISSN: 2251-1261 Vol. 2(1), pp. 6-17.

Cooper, P. J. M., Dimes, J., Rao, K. P. C., Shapiro, B., Shiferaw, B. and Twomlow, S. (2008). Coping better with current climatic variability in the rain-fed farming systems of sub-Saharan Africa: An essential first step in adapting to future climate change? Agriculture, Ecosystems and Environment, 126(1–2), 24–35.

DESA, (2013). World population prospects: the 2012 revision. *Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, New York*.

DFID, (2004). Agriculture, growth and poverty reduction. UK Department for International Development.

Diao, X. Hazell, P. Resnick, D. and Thurlow, J. (2007). The Role of Agriculture in Development Implications for Sub-Saharan Africa, International Food Policy Research Institute, Washington, D.C. U.S.A.

Ďurková, P. Gromilova, A. Kiss, B. and Plaku, M. (2012). Climate refugees in the 21st century. Regional Academy on the United Nations, December 2012. pp. 7.

EPRI, (2011). Country profiles: Chapter 36. Country profile: Niger. Economic Policy Research Institute, Cape Town, South Africa.

EPRI, (2011). Country profiles: Chapter 37. Country profile: Nigeria. Economic Policy Research Institute, Cape Town, South Africa, 2011.

FAO, (2005). Irrigation in Africa in figures – AQUASTAT Survey 2005, Ethiopia. FAO Land and Water Division, Food and Agriculture Organization of the United Nations. pp. 2-4.

FAO, (2013). AQUASTAT database - Food and Agriculture Organization of the United Nations (FAO). Website accessed on [22/03/2014 2:51].

Gebeyehu, Z. H. (2014). Rural-Urban Migration and Land and Rural Development Policies in Ethiopia. 2014 World Bank Conference on Land and Poverty." The World Bank - Washington Dc, March 24-27, 2014.

Griffiths, D. (2003). Forced Migration Online Country Guide: Somalia.

HEC, (2012). Environmental Impact Assessment. Highway Engineers and Consultants (HEC) PLC, Ethiopian Roads Authority, Federal Democratic Republic of Ethiopia, E2986 v5.

Hulsman, K, Tularam, G. A, Willett, G. 2011. The application of reductive methods to study Complex- and Complex-Adaptive Systems in Ecology. IJEES 37(3): 93-104. http://www.nieindia.org/Journal/index.php/ijees/ issue/archive.

Hulsman, K, Tularam, G. A, Willett, G. 2013. Evolutionary processes which organise ecological systems as nested hierarchies. IJEES 39(2): 69-77. http://www.nieindia.org/ Journal/index.php/ijees/issue/archive.

ILO, (2004). United Republic of Tanzania Country Profile: Employment of People with Disabilities: The Impact of Legislation (East Africa). International Labour Office, Geneva.

Indraratna, B., Tularam, G.A. and Blunden, B (2001a). Reducing the impact of acid sulphate soils at a site in Shoalhaven Floodplain of New South Wales, Australia. *Quarterly Journal of Engineering Geology and Hydrogeology*, 34, pp.333-346.

Indraratna, B, Glamore, W, Anand Tularam, G, Blunden, B and Downey, J. (2001b). Engineering strategies for controlling problems of acid sulphate soils in low-lying coastal areas, Environmental Geotechnics, 2001, 133-146, Newcastle, Australia: Australian Geomechanics Society Inc.

IPCC, (2007). Climate Change 2007: The Physical Science Basis. Contribution of Working Group 1 to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. In: Solomon, S., Quin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M., Miller, H.L. (Eds), Regional Climate Projections. Cambridge University Press, Cambridge, UK. pp. 996 (Chapter 11).

Khan, M. R. (2014). Routledge Advanced in Climate Change Research: Toward a Binding Climate Change Adaptation Regime, A proposed framework, 2014. Pp. 127.

Marshall, S. (2011). The Water Crisis in Kenya: Causes, Effects and Solutions. *Global Majority E-Journal, Vol. 2, No. 1 (June 2011), pp. 31-45.*

McCartney, M. Smakhtin, V. Fraiture, C. and Awulachew, S. B. (2009). Flexible Water Storage Options and Adaptation to Climate Change: WATER POLICY BRIEF. (Eds.) Clayton T. and Fernando, S. Issue 31, 2009. International Water Management Institute, Colombo, Sri Lanka.

Mekonen, A. (2009). Multiple uses of rural household water supplies for livelihood in Ethiopia. Water, sanitation and hygiene: sustainable development and multisectoral approaches. (Eds) Shaw, R. Proceedings of the 34th WEDC International Conference, United Nations Conference Centre, Addis Ababa, Ethiopia, 18-22 May 2009 pp. 462-465.

MOFED, (2006). Ethiopia: Building on Progress, A Plan for Accelerated and Sustained Development to End Poverty (PASDEP) 2005/06-2009/10. Ministry of Finance and Economic Development, September, 2006, Addis Ababa: Ethiopia. P. 10-11.

Muchiri, P.W. (2007). Climate of Somalia. Technical Report No W-01, FAO-SWALIM, Nairobi, Kenya.

Mukheibir, P. and Sparks D. (2003). Water resource management and climate change in South Africa: Visions, driving factors and sustainable development indicators. Energy and Development Research Centre, University of Cape Town, Cape Town, South Africa.

Myers, N. (2002). Environmental refugees: a growing phenomenon of the 21st century. The Royal Society, *Phil. Trans. R. Soc. Lond. B* (2002) 357, 609–613, DOI 10.1098/rstb.2001.0953.

Noel, S. (Undated). THE ECONOMICS OF CLIMATE CHANGE TANZANIA: WATER RESOURCES. Stockholm Environment Institute, SEI-Africa Centre and Institute of Resource Assessment, University of Dar es Salaam.

Norman M. (2001). Environmental refugees: a growing phenomenon of the 21st century. The Royal Society.

Nwokocha, E. E. (2012). Engaging the Burden of Rural-Urban Migration in a non-regulatory System: the Case of Nigeria. Department of Sociology, University of Ibadan, Nigeria.

Nyanchaga, E. N. (2011). Importance of Water in Kenya: Challenges and Reforms, Tampere University of Technology and Department of Civil and Construction Engineering University of Nairobi, Kenya, 19th August 2011.

Ofuoku, A. U. (2012). Urban-Rural Migration in Delta State, Nigeria: Implications for Agricultural Extension Service. Global Journal of Science Frontier Research Agriculture and Veterinary Sciences. Vol.12 Issue 6 Version 1, 1-5.

Ogendi, G. M. and Ong'oa, I. M. (2009). Water Policy, Accessibility and Water Ethics in Kenya. Santa Clara Journal of International Law. Vol. 7(1) (2009) pp. 177-196.

Olajide, A. and Udoh, G. (2012). Rural-Urban Migration: Migrants Perceptions of Problems and Benefits in Oyo State Nigeria. International Conference on Humanities, Economics and Geography (ICHEG'2012) March 17-18, 2012 Bangkok, Thailand, 187-191.

Orubu, C. O. (2006). Water Resources, Environment and Sustainable Development in Nigeria. J. Hum. Ecol., 19(3): 169-181.

Peters, K. L. (2011). Environmental Refugees. Social Sciences Department, College of Liberal Arts, California Polytechnic State University.

Reza, S. R. Roca, E. and Tularam, G. A. (2013). Fundamental Signals of Investment Profitability in the Global Water Industry (December 22, 2013). Available at SSRN: http://ssrn.com/abstract=2371115 or http://dx.doi.org/10.2139/ssrn.2371115.

Ringler, C. Zhu, T. Cai, X. Koo, J. and Wang, D. (2010). Climate Change Impacts on Food Security in Sub-Saharan Africa: Insights from Comprehensive Climate Change Scenarios. Environment and Production Technology Division, International Food Policy Research Institute, IFPRI Discussion Paper 01042, December 2010. pp. 10.

Roca, E. D. and Tularam, G.A. (2012). Which way does water flow? An econometric analysis of the global price integration of water stocks. Applied *Economics,* 44(23), 2935-2944.

Roca, E., Tularam, G. A., and Reza, R. (2015). Fundamental Signals of Investment Profitability in the Global Water Industry. *International Journal of water*, 9 (4), 395-424.

Steele, M. and Schulz, N. (2012). Water hungry coal burning South Africa's water to produce electricity. (Eds.) Musana, F. and Schulz, N.

Tularam G. A. (2010). Relationship between El Nino, southern oscillation index and rainfall. International Journal of Sustainable Development and Planning, 5(4), 378-391.

Tularam G. A. (2014). Investing and water for a green economy. Australian Planner, 51(4), 372-373.

Tularam G.A. and Hassan, O.M. (2016). Water availability and food security - impact on people's movement and migration in Sub-Saharan Africa (SSA), In M. Thangarajan and V. Singh (Eds.) Groundwater Assessment, Modeling, and Management. pp. 405-427. *CRC press – Taylor Francis.*

Tularam, G. A (2012). Water security Issues of Asia and their implications for Australia. *Fifth International Groundwater Conference*, Artworks, India.

Tularam, G. A and Illahee, M. (2010). Time Series Analysis of Rainfall and Temperature Interactions in Coastal Catchments. *Journal of Mathematics and Statistics*, 6(3), 372-380.

Tularam, G. A. and Ilahee, M. (2007a). Environmental concerns of desalinating seawater using reverse osmosis. *Journal of Environmental Monitoring*, Vol.9, No.8, pp.805-813. Royal Society of Chemistry, Cambridge: UK. High Impact: included in South Australian Parliamentary report on Desalination.

Tularam, G. A. and Ilahee, M. (2007b). Initial loss estimates for tropical catchments. Environmental Impact Assessment Review 27 (6), 493-504.

Tularam, G. A. and Ilahee, M. (2007c). Baseflow separation using exponential smoothing and its impact on continous loss estimates. MODSIM 2007 International Congress on Modelling and Simulation. Modsim: NZ: http://www. mssanz. org. au/.

Tularam, G. A. and Keeler, H. P. (2006). The study of coastal groundwater depth and salinity variation using time-series analysis. *Environmental Impact Assessment Review*, Vol.26, No.7, pp.633-642. Elsevier: United States.

Tularam, G. A. and Krishna, M. (2009). Long term consequences of groundwater pumping in Australia: A review of impacts around the globe. *Journal of Applied Sciences in Environmental Sanitation*, vol.4, no.2, Inst of Technology, Surabaya and Indonesian Soc of Sanitary and Env Engineers.

Tularam, G. A. and K. K. Murali. (2015). Water security problems in Asia and longer term implications for Australia. In W. Filho and V. Sumer (Eds.) Sustainable Water Use and Management, 119-149. Springer: NY.

Tularam, G. A. and Marchisella, P. (2014). Water scarcity in Asia and its long term water and border security implications for Australia. In *International Practices for Protecting*

Water and Wastewater Infrastructure (Eds. Robert M Clark and Simon Hakim p. 189 - 212). Springer: NY.

Tularam, G. A. and Murali, K. K. (2014). Water security problems in Asia and longer term implications for Australia. Environmental Futures Centre, Faculty of Science Environment Engineering and Technology, Griffith University, Brisbane, Australia. pp. 1.

Tularam, G. A. and Properjohn, M. (2011a). An investigation into modern water distribution network security: Risk and implications. *Security Journal, 24*(4), pp.283-301.

Tularam, G. A. and Properjohn, M. (2011b). An investigation into water distribution network security: Risk and implications. *Security Journal, Vol.* 4, pp.1057-1066.

Tularam, G. A. and Reza, R. (2016). Water exchange traded funds: A study on idiosyncratic risk using Markov switching analysis. *Cogent Economics& Finance* (2016), 4: 1139437, 1-12.

Tularam, G. A. and Singh, R. (2009). Estuary, river and surrounding groundwater quality deterioration associated with tidal instrusion. Journal of Applied Sciences in Environmental Sanitation, Vol.4, No.2, Inst of Technology, Surabaya and Indonesian Soc of Sanitary and Env Engineers.

Tularam, G. A. and Singh, R. (2009). Estuary, river and surrounding groundwater quality deterioration associated with tidal intrusion. *J Appl Sci Environ Sanitation*, *4*, pp.141-150.

UN (2008). Trends in Sustainable Development: Africa Report. Division for Sustainable Development, Department of Economic and Social Affairs, United Nations. pp. 38.

UNDP, (2006). Getting Africa on Track to Meet the MDGs on Water Supply and Sanitation: A Status Overview of Sixteen African Countries. United Nations Development Programme. pp. 19-25.

UNDP, (2013). Human Development Report 2013: The Rise of the South: Human Progress in a Diverse World. United Nations Development Programme, New York, USA, 2013. 139-197.

UNEP, (2005). The State of the Environment in Somalia: A Desk Study. United Nations Environment Programme.

UNEP, (2009). Chief Liquidity Series: Chapter 9. Water sustainability of agribusiness activities in South Africa. United Nations Environmental Programme, Chief Liquidity Series, Issue 1, 2009. pp. 42-46.

UNEP, (2011). Water Issues in the Democratic Republic of the Congo: Challenges and Opportunities. United Nations Environment Programme, Nairobi, Kenya.

UNICEF, (2013). Somalia: Fast facts. Unicef Somalia Support Centre, The United Nations Children's Fund, 2013.

Wassung, N. (2010). Water Scarcity and Electricity Generation in South Africa. Part 1: Water use in the coal-to-electricity process. School of Public Management and Planning, University of Stellenbosch. pp. 4.

Webersik, C. (2006). Fighting for the plenty – The banana trade in southern Somalia, Paper presented to the Conference on Multinational Corporations, Development and Conflict, Queen Elizabeth House, Oxford, Saturday 6th December 2003.

World Bank (2009). South Asia: Shared Views on Development and Climate Change, Chapter 10. The Social Dimensions of Climate Change. South Asia Region Sustainable Development Department, World Bank, 2009. pp. 131-137.

World Bank, (2012). The Future of Water in African Cities: Why Waste Water? Chapter 1. Africa's Emerging Urban Water Challenges. Jacobsen, M. Webster, M. Vairavamoorthy, K. (eds.). The World Bank, Washington DC, USA.

World Bank, (2014). World Development Indicators 1960 – 2013. The World Bank, 09-Apr-2014Wroblewski, J. and Wolff, H. (2010). Risks to Agribusiness Investment in Sub-Saharan Africa. Evans School of Public Affairs, University of Washington.

Wrobleski, J. and Wolff, H. (2010). *Risks to Agribusiness Investment in Sub-Saharan Africa* (No. UWEC-2011-02). University of Washington, Department of Economics.

In: Handbook on Africa
Editor: Whitney Sherman
ISBN: 978-1-53610-063-1

Chapter 5

BETWEEN WIZARDS AND DEVILS OF THE FOREST ON DEVELOPMENT, HEALTH AND DISEASES IN SIERRA LEONE

Javier Rodríguez Mir*
Autonomous University of Madrid, Madrid, Spain

ABSTRACT

This chapter is particularly concerned about the perception of health and diseases held by the communities living in the North of Sierra Leone, specifically in the Koinadugu district. This chapter examines the study of health systems, the ways in which people of Sierra Leone interpret the origins of diseases and how this influences their treatment. Communities think that diseases appear not only because of natural causes: they believe that, behind a disease, the influence of witchcraft or spirits of the jungle may be concealed. Finally, the author makes recommendations for improving the current situation.

Keywords: Sierra Leone, development, health, witchcraft, devils, medical anthropology

"While some medical professionals in developing nations still complain of their patients 'ignorance,' many are becoming aware of their own ignorance of their patients' cultural perspectives." (Opala and Boillot, 1996)

INTRODUCTION

Sierra Leone is classified by the UN as one of the least developed countries. In 2008, Sierra Leone ranked 178 out of 178 in the UN Human Development Index. Sierra Leone has

* Javier Rodríguez Mir: Autonomous University of Madrid, Spain. E-mail: www.palabrasdelplata.com.

some of the poorest health indicators in the world, and healthcare payments are a substantial burden on households which can constitute a problem for the rural population because of the risk of further impoverishment. Childhood mortality is high in Sierra Leone: currently, 89 children per 1,000 live births die before their first birthday. About one child out of seven die before reaching age five. Maternal mortality is also extremely high in Sierra Leone: of the total deaths of women aged 15-49, more than one-quarter of deaths (27%) are due to maternal causes (SSL-ICF Macro, 2009).

Most deaths can be attributed to nutritional deficiencies, pneumonia, anemia, malaria, tuberculosis, and now HIV/AIDS. Diarrheal diseases and acute respiratory infections are also major causes of outpatient care and illness in the country. According to Musa et al. (2014), contaminated water causes a range of life-threatening diseases, and children are the population that is most affected by them. Children's well-being is directly dependent on both the availability and the quality of water. Childhood diarrhea is closely associated with insufficient water supply, contaminated water, inadequate sanitation, and poor hygiene.

Six of the seven diseases targeted by USAID's NTDs Program, including lymphatic filariasis, onchocerciasis, schistosomiasis, and three soil-transmitted helminthes, are endemic in Sierra Leone. Non-communicable diseases like diabetes, cancer, hypertension, cardiovascular disease, and chronic kidney disease are on the increase, and now account for a significant proportion of morbidity and mortality among the population. The nation continues to struggle with a low life expectancy of 47 years; an infant mortality rate of 89 per 1,000 live births; an under-five mortality rate of 140 per 1,000 live births; and a maternal mortality rate of 857 per 100,000 births (GHI Strategy, 2011, SSL-ICF Macro, 2009).

A majority of the causes of illness and death in Sierra Leone are preventable, with most deaths attributable to nutritional deficiencies, pneumonia, anemia, malaria, tuberculosis, and now HIV/AIDS. Malaria remains the most common cause of illness and death in the country. In Sierra Leone, malaria is one of the major causes of morbidity and mortality in children under five years old. The country has a poor health status, mainly due to a high disease burden caused by environment-related communicable diseases and aggravated by poor nutrition. Children in Sierra Leone are generally malnourished. Among children, malnutrition, stunting, and poor immunization coverage are still significant problems. Malnutrition is the leading cause of death among children under five years old. Prevalence of anemia is high among both children and women. In 2008, 21% of children under age 5 were found to be underweight or too thin for their age, 36% were stunted or too short for their age, and 10% were weakened or too thin for their height (SSL-ICF Macro, 2009).

Another major factor affecting the health status of the population is poor access to clean water, which is closely related to diarrheal illnesses. Scarce availability of clean water and safe sanitation is a major factor affecting the health status of the population. Almost half of the population have no access to safe drinking water, and only 13% have access to improved non-shared sanitation facilities. The situation is worse in rural areas than in urban communities: in rural communities, up to 66% of the people do not have access to safe water. In addition, the country suffers from epidemic outbreaks of certain diseases, such as yellow fever, cholera, Lassa fever, and meningitis (GHI Strategy, 2011).

The country's health service delivery system is pluralistic. The government, religious missions, local and international NGOs, as well as the private sector provide health services. There are public, private for profit, private non-profit and traditional medicine practices. The private sector is underdeveloped compared to countries in the subregion, such as Ghana, and

involves mainly curative care for inpatients and outpatients on a fee-for-service basis. Private health facilities operate under the authority of individual owners and/or boards of directors, mainly in urban areas. The non-poor tend to use private health facilities more often than the poor. Traditional healers and Traditional Birth Attendants (TBAs) are reported to be providing a significant amount of health care, with TBAs attending to almost 90% of the deliveries at the community level (NHSSP 2010-2015, 2009).

Traditional healers in African societies are frequently ignored in studies. African traditional medicine is part of the African people's culture and is therefore closely linked to their beliefs. In their traditional cultural belief system, they may include an illness which combines religion, sorcery, health, and interpersonal conflict into a single form of belief and practice. As shown by Gessler et al. (1995a) in relation to malaria in Tanzania, it is important to evaluate the potential of the contribution of traditional healers to improve the conditions of the population's health care. Also, a study conducted in Nigeria about malaria and traditional healers showed that traditional healers are seen as specialists in the treatment of severe diseases, especially convulsions. It also suggested that, for any program to have an impact on malaria-related morbidity and mortality, it will have to include the support of traditional healers in an effort to improve referral practices for the treatment of severe malaria. The potential for successful collaboration with traditional healers in public health interventions has been demonstrated in several African countries (Okeke et al., 2005). According to Gessler et al. (1995b), traditional healers can undoubtedly contribute positively to the population's health, and not only with herbal remedies. In this regard, Hoff (1992) suggests that traditional healers are valuable resources for providing primary care to communities, and in countries where needs are great and resources are scarce, traditional practitioners can play a significant role in helping people from rural communities to improve their life in a broad sense. It is also important that health workers understand the patterns of self care and traditional care in the area where they want to work. Health workers should look carefully at the resources in the traditional health sector. For instance, Langwick (2008) reported that, among hospital practitioners in East Africa, traditional medicine interfered with modern medicine on hospital grounds every day. In response, nurses and nurse's aides have developed innovative ways of combining diverse therapies with the knowledge, practices, desires, and medicines of which they consist. Thus, nurses are at the heart of this change.

GEOGRAPHICAL AREA

Sierra Leone is in the sub-Saharan region and has an area of 72,325 km^2. Its international boundaries are Guinea Conakry and Liberia. The approximate population of Sierra Leone is 5,485,000 inhabitants. Various ethnolinguistic groups live in Sierra Leone, although the predominant ones are the Mende in the south and the Temne in the north. Together, they account for more than 60% of the population. Other ethnic groups in the country are the Fullah, the Limba, the Locko, the Susu, the Mandingo, the Koranko, and the Yalunka.

Sierra Leone is divided into thirteen districts: Kailahun, Kenema, Kono, Bombali, Kambia, Koinadugu, Port Loko, Tonkolili, Bo, Bonthe, Pujehun, Moyamba, and the Western Area. The present study was developed in the Koinadugu district, in the north of the country. The district has an area of 12,121 km^2 and about 282,000 inhabitants. The ethnic groups

found in the region are the Koranko, the Limba, the Yalunka, the Fullah, the Mandingo, the Mende, the Temne, the Locko, the Susu, and the Kono. The Koinadugu district is bordered to the north by the Republic of Guinea. The region is one of the most depressed in the country: it has a subsistence economy, scarce agricultural production, and a marked lack of consumer goods in the households. The road that links the Koinadugu district with Freetown is 175 miles long, and some parts are in such bad conditions that vehicles cannot travel on it. The problem of communication by road affects the entire country, and it is estimated that only 8% of national roads are paved. The roads of the Koinadugu district are, in general, deficient and they limit access to the communities. The capital of the Koinadugu district is Kabala, with a population of, approximately, 13,000 people. Kabala has a referral hospital and, when patients cannot be properly treated at the community health centers, the health workers usually refer the patients to the government hospital in Kabala.

PROCESS AND METHODOLOGY OF THE SURVEY

This research was conducted in the context of Doctors of the World projects and executed in the Koinadugu district, in order to improve the quality and level of assistance regarding health services, with a special interest on sexual and reproductive health, from a gender perspective. So as to carry out a diagnosis with regard to access to health services by the communities involved, we have applied a qualitative methodology, typical of anthropology, which considers the use of extensive and intensive interviews. The research lasted from May 15, 2010, to December 31 of the same year. The first phase of the project was developed from May to August. During that time, we held multiple interviews in the villages of the chiefdom of Diang. The second phase of the anthropological research was carried out from June to December, and we devoted those months to visiting the towns of the chiefdoms of Wara Wara Yagala and Sengbe.

Interviews aimed specifically at detecting problems of access to health in the various regions have been designed and implemented. The questionnaire covered subjects related to diseases in general and treatments in particular. Emphasis was placed on the diseases and the population's preferences for Western or traditional medicine. Another large section of the questionnaire was aimed at detecting problems related to discrimination and gender violence, with a special interest on female genital mutilation (FGM). These semi-structured interviews were applied in the countries of the Koinadugu district. Many villages are fairly accessible, but some other regions are quite isolated and can only be reached by walking from three to eight miles. Moreover, the bridges are often in bad conditions or even inexistent, which turns the journey impossible. On more than one occasion, the team had to turn back because problems of this type made the villages unreachable.

The flexibility and reflexivity of the research were some of the principal characteristics that defined the anthropological fieldwork and the subsequent drafting of the results (Rodríguez Mir, 2006). The interviews were modified and broadened as they were applied in the various communities (Rodríguez Mir, 2011). They were open and flexible, thereby enabling the addition of new questions and lines of research that emerged throughout the course of the investigation. The dynamics of the interviews was very important and it was aimed at eliminating gender bias. In that respect, before starting group interviews, men and

women were divided into two groups, each quite distant from the other, in order to prevent that the nearby presence of people of the opposite gender conditioned the answers of the group. So as to address the gender issues, we had to hire two interpreters (a man and a woman) who translated from English into Koranko or Krio. Only rarely did we visit communities which spoke Limba, where most people did not speak Krio. In those cases, there was always a person of the community who kindly offered to translate from Krio into Limba, and the interviews were carried out without much difficulty.

Apart from the group and focus interviews in the communities, we had to interview the traditional healers (TH). In order to do so, we designed semi-structured interviews, without neglecting the gender issue. We chose both male and female THs, in order to have a broader perspective and observe the gender differences, if any, between the THs. Lastly, we interviewed the nurses from most of the health centers. The interviews were quite open, so that the nurses could talk frankly about the problems associated with access to health, infrastructure in health centers, and current health policies.

DISEASES AND CONDITIONS

Diseases afflicting the population are diverse and different in terms of importance and origins. Malaria appears as one of the most recurrent diseases. It is associated with fever, and constitutes the main cause of morbidity and mortality. Although this disease affects the entire population, the most vulnerable groups are children under five and pregnant women. The interviewed communities related the transmission of the disease to mosquito bites. However, they also identified other causes: they indicated that malaria may be transmitted because of the poor sanitary conditions, the lack of good bathrooms, or through urine. For example, people can be infected with malaria if they stand in a place where someone infected with malaria has urinated before. The symptoms that communities identify with malaria are fever; vomiting; general body weakness; muscle pain; tremors; loss of appetite; change in the color of the eyes, which turn yellow; and change in the color of urine, which turns bright yellow.

Another disorder found in all the communities is stomachache, which communities associate with poor water conditions. It is worth mentioning that access to drinking water is very limited in the villages. In most communities, obtaining drinking water is a recurring difficulty, a problem that is especially serious during the dry season. Many communities do not have wells; others do have them, but they are not enough to serve the needs of the all the people who live in the village. Sometimes, they have three or four wells, but most of them do not work and are abandoned by the community itself; some other times, when the wells work properly, the community lacks the necessary elements to chlorinate them. On the other hand, the groups identified other reasons for the propagation of stomachaches: coughing and sexual relations. They also mentioned that stomachaches could be transmitted by mothers who are breastfeeding their children.

Fever and cold are also mentioned as frequent disorders, especially when working in farms during the rainy season. Other diseases that are prevalent in the visited villages are skin problems. Measles is mentioned permanently, while chickenpox and smallpox are mentioned sporadically. As regards measles, it is believed that the person can be cured if the disease affected only the skin; however, the person will inevitably die if the disease spreads and

affects the stomach. Other disorders identified during the interviews were convulsions (especially in children); dizziness; vomiting (including vomiting blood); epilepsy; headaches; backaches; hernias; pneumonia; asthma; eye problems; river blindness (onchocerciasis); hypertension; coughing (including coughing up blood); muscle problems; general weakness; cholera; dysentery; chest pain; paralysis; intestinal parasites; scabies; rheumatism; gastritis and ulcers; hemorrhoids; diabetes; dental problems; fluid retention (blockage); leprosy; gonorrhea; HIV; syphilis; elephantiasis; impotence and hydrocele in men; as well as vaginal infections and loss of menstruation for long periods in women. Diarrhea is common, especially among children under five years old. The lack of latrines in the communities was among the problems cited by the respondents of the survey, as well as in the forum group discussions.

The research was conducted in 2010, before the outbreak of the Ebola virus. Surprisingly, within the interviewees, no-one mentioned Ebola virus as a disease from which the population could suffer. The Ebola virus disease spread to Sierra Leone by May 2014.

INTEGRATING MODERN MEDICINE WITH TRADITIONAL MEDICINE

In this chapter, the term "modern medicine" refers to an approach based on scientific evidence and includes government operated hospitals, health centers, health posts, and clinics. We use the "traditional medicine" term, although we know that research indicates that the tradition involves a creative role, improvisation in social life, inventiveness, dynamism, imaginative recreation, exploration of a subject, medium, and innovation (Murphy, 1998). Traditional medicine has its roots in the societies' culture, folk knowledge, tradition, and values, whereas modern medicine comes from distant societies and cultures. In short, traditional medicine consists of health practices, approaches, knowledge, and beliefs, with the addition of animal or herbal remedies, as well as mineral-based medicines and spiritual therapies, either used independently or in combination to treat, diagnose, and prevent illness to maintain well-being (Tabi et al., 2006). The people who practice traditional medicine are those who have sufficient knowledge and mastery of the properties of the herbs found in the forest, who are capable of diagnosing the cause of diseases and who rely on other techniques —such as massage and dreams— to restore the patient's health. These people are known as "traditional healers." As Rekdal (1999) has pointed out, a common characteristic of many of the practices of African traditional healers is that they are not "traditional" at all. African traditional healers may well be transmitters of ancient and powerful knowledge, but they are also — and, sometimes, solely— inventors of medical tradition, agents who facilitate the incorporation of new ways of thinking and acting. However, there are other people (the moreh men) who do not only master herbs, but also know how to read, write, and interpret the Koran (The Book of Koran, also called "Sam-Suru"). These men are not only consulted by common people to cure diseases, but also by politicians to obtain political gain during electoral campaigns or elections. The moreh men are respected by the entire population and, in some cases, elected Town Chiefs of the community. Depending on the type of consultation, the moreh men generally charge much more for their services than the traditional healers. Only men can be moreh men. In contrast, traditional healers can be either men or women. The term "traditional healer" is misleading and naïve because it suggests that there is a more or less

homogeneous body of medical thought. Such a body does not examine the types of medical practitioners; you can find an extreme diversity both in theories and practices (Van der Geest, 1997). There are different types of healers. Some healers focus on one or a few illness, while others are generalists. Among their specializations are bone setting, childcare delivery, and psychotherapy.

When someone is ill, a key factor is who decides whether to go to a traditional healer, a moreh man, or a health center. Generally speaking, that decision is made by the patients themselves and their relatives. Sometimes, the patient's neighbors and friends may also decide on that matter. In some communities, the decision may be made by motivators trained by Doctors of the World, by the traditional birth attendant (TBA), or even by the Town Chief. Social pressure plays an important role in these cases, and it is not easy for the patient to make a decision (Burstcher, 2004). Married women, in particular, need their husbands' permission. The husband has to cope with the expenses of the health center, but if he does not have enough funds, his wife will contribute the remaining amount. On some occasions, the wife may pay for the entire cost of the treatment.

In the treatment of a disease, it is crucial to know the causes of the disease, since this will determine whether it can be treated by modern medicine or traditional medicine. The traditional healers and the moreh men could identify the cause of diseases. The cause of the illnesses directly conditions their treatment. Thus, the communities declared that an important cause of illnesses is found in witchcraft. Witches can cause different illnesses which, in no circumstances, can be cured by modern medicine. Also, the existence of many evil spirits living in the woods creates different types of illnesses that cannot be cured by modern medicine. Depending on its causes, the illness should be treated either with modern medicine or with traditional medicine. However, the population does not have absolute certainty of the cause of diseases. In fact, people usually engage in a kind of "trial and error" process, recurring to one system first and, if the problem continues, then they try the other one.

The interviewees declared that, in general, they prefer modern medicine to traditional medicine. Among their reasons they mentioned, firstly, that modern medicine has up-to-date equipment to examine patients and to know exactly what they are suffering from (contrary to the traditional healers, who use their hands to examine them). Secondly, in modern medicine, there are specific drugs for specific problems, so doctors may prescribe the exact dose (whereas traditional healers do not have a system of doses). Lastly, modern medicine is much more efficient and cures rapidly; in fact, the interviewees declared that modern medicine cures automatically, almost instantaneously, and that the healing rhythm of traditional medicine is much slower and more gradual. It is worth mentioning that this last point is a double-edged sword: on the one hand, the treatment effectiveness increases public confidence in modern medicine and encourages people to attend health centers; on the other hand, it might be a drawback in long-term treatments because, if the patients see that their condition persists for too long, they will probably abandon the treatment and consult the traditional healer. At the beginning, some people are willing to start treatment at the health centers, but then they come up against countless obstacles which hinder access to health services (economic difficulties, long distances, improper treatment of patients on the part of the nurses, etc.). In this respect, traditional healers are always available to the community, they do not charge an excessive cost, and they give the patient a much more personalized treatment. As Labhardt et al. (2010) noted, traditional healers focused more on psychosocial topics and on issues of daily life than on purely medical questions and, in particular, they

more often asked for the patient's opinion and frequently discussed their concept of illness. This could impact positively on the effectiveness of treatment. Although there is no consensus regarding this topic, to determinate the efficacy of specific treatments in any medical system is problematic both conceptually and methodologically, since efficacy must be viewed as something that is essentially negotiated, in part, in each encounter of a patient and a traditional practitioner (Waldram, 2000).

The cause of diseases directly conditions their treatment (either in modern medicine or traditional medicine). Diseases may have their origin in God's will. In this case, they are very difficult to treat. It is worth mentioning here that populations are, for the most part, Muslim and Christian. Another possible cause of diseases is the natural one. These natural causes are the first ones mentioned in all the group interviews carried out, both by men and women. In general, they said that diseases appear because of lack of drinking water, poor sanitary conditions, lack of latrines, environmental pollution, bad weather, poverty (which forces them to work hard on the farms), insects (especially mosquito bites), parasites, inadequate diet, and through sexual intercourse. In some cases, they referred to the terrible hygiene conditions in the village. However, the communities consider the existence of two other causes that originate diseases which are hard to treat. An important cause is found in witchcraft: wizards are able to cause different diseases that, in no circumstances, can be cured by modern medicine. The wizards live near the villages, but the diseases they cause cover considerable distances, going beyond the limits of the village to affect distant communities. And the last cause of disease is found in the woods. The existence of many evil spirits living in the woods gives rise to different types of diseases. These spirits are given different names according to each ethnolinguistic group (in Koranko, "Nyenne"; in Limba, "Wali"; in Krio, "Devils"), but the differences lie only in their names, since all the spirits share the same way of acting and living. The good spirits do not cause any diseases and actually help the traditional healers to cure them. In order to achieve this, at night, the traditional healer or moreh man will begin the oracle ceremony to establish a dialogue with the good spirits of the forest. During this period, the traditional healer will describe the disease affecting his patient and Nyenne will explain everything that has to be done in order to restore the patient's health.

These four causes of diseases (God's will, natural causes, witchcraft, and evil spirits) cause many and diverse disorders. Just as, at the hospital, they cannot cure the conditions caused by wizards and evil spirits, the traditional healers cannot cure diseases attributed to natural causes. The most important thing is to know the exact cause of the disease, in order to know where to begin treating the condition. The cause of the condition determines the existence of "diseases to be treated at the hospital" and "diseases to be treated by the traditional medicine." For instance, among the Mende, the fear of wizards, juju curses, and other supernatural activities is widespread, and it is believed that certain precautionary measures must be taken to safeguard the mother and fetus against them (West, 1981:75). As far as traditional medicine is concerned, the traditional healers or the moreh men specialize in the treatment of different ailments caused by the activities of wizards or spirits of the woods. These social actors specialize in different conditions and problems that afflict the communities, such as fractures, skin problems, poisoning caused by wizards, wizard gun, earache, chest ache, convulsions, fainting, urinary retention, dysentery, epilepsy, diarrhea, impotence, chronic cough, eye problems, nose bleeds, hydrocele, rheumatism, pneumonia, as well as menstrual problems and infertility in women. Moreover, they can give protection against wizards and spirits, and help to solve problems at work or disputes.

THE WORLD OF WIZARDS AND EVIL SPIRITS

There follows a description of the two most important unnatural causes of diseases which affect the local population. This is a simplified description because, in fact, these causes interact: wizards and spirits enter into alliances and they even work together with the strongest traditional healers, setting up agreements and pacts to treat the diseases. On some occasions, the wizards or spirits may threaten the traditional healer to have him stop treating the patient.

The interviewees declared that wizards usually live near the towns and cities. They like to live close to areas crowded with children and prefer large trees, such as the cotton tree and the papaya tree. They cause different diseases in people: anemia, malaria, fever, stomachache, measles, skin infections, elephantiasis, blindness, impotence, and infertility, among others. They are also blamed for people's poverty conditions. No matter how hard people might work on their farms: if wizards are against them, they will never have enough food to feed their families. Wizards are active at night, and they cannot be seen, except by the traditional healers or the moreh men, who use herbs mixed with water to wash their faces and put drops in their eyes. Thanks to these herbs, they can contact the wizards through their dreams. The average people cannot see the wizards, but they only see their transformations, since wizards can turn into different animals to harm people. The most common is the transformation into a snake, but they can also turn into dogs, cats, pigs, birds, crocodiles, monkeys, leopards, and tigers, among others. If somebody kills one of these animals — which are, in fact, transformed wizards—, the wizard also dies. When a wizard turns into a snake and bites someone, the victim dies, as there are no effective treatments, not even at the hospitals.

Some interviewees believe that wizards suck the blood of human beings when they are sleeping. They also extract people's blood with instruments which are similar to those used in hospitals, and these procedures can cause anemia or malaria in people. They can also suck blood by turning into a tsetse fly. A traditional healer told us that a woman in Lengekoro suffered greatly because a wizard used to suck her blood continuously. She had frequent nose bleeds and visited different health centers, but could not be cured. The woman finally recovered when she was treated by a traditional healer. Moreover, wizards feed on human flesh. They have a system, called "Sukereh" in Koranko and "Kadilih" in Mandingo, which consists of holding frequent meetings with several wizards. In these meetings, the wizards take turns to provide with a person to eat: in a given meeting, one wizard will contribute a person so that the others can eat; in the next meeting, it will be another wizard's turn to contribute a person to feed the group; and so on. It is said that wizards can eat papaya without opening it. They eat the interior of the papaya and then, when people want to eat it, they find it empty. The interviewees stated that this is the way that wizards eat people: from within. In the communities, they also said that wizards have two stomachs: a normal one, to eat during the day, and another one, to eat human flesh at night. In fact, at night wizards undergo a transformation and duplicate their entire body.

The practice called "wizard gun" deserves a special mention. The communities consider that wizards have special guns to shoot at people. If they shoot from short distances, they will probably kill the person, but if they shoot from longer distances, only the after-effects will be evident. These after-effects consist of a burning sensation in the skin and a severe pain that keeps people from carrying out their normal activities. The traditional healers can cure these

ailments by applying specific herbs and soaps which allow them to see and extract the gunshots. Another technique used to cure the effect of the wizard gun is to boil medicinal herbs and use the resulting steam. Applying the steam from the herbs over the affected areas makes the bullet marks visible in the body. Nobody can see or hear the shot; all that can be sensed is the smell of gunpowder. The gun they use is very small, easy to hide, and hard to see at night, but very powerful. Some of the interviewees said that wizards sometimes put poison in the bullets before shooting at people.

Local people expressed that wizards can take some persons' belongings (watches, clothes, caps, chains) and destroy them. When they do so, the owner dies automatically. Wizards, as well as the evil spirits of the woods, may attack and hit people. In the most extreme cases, they may even cause death. Wizards can also push people off palm trees when they climb in search of oil or wine; trap flying insects and give them different diseases, so that they will infect people; or spread diseases through the air, so as to affect distant communities. In order to prevent the diseases the wizards send through the air, the village elders advise children not to leave their rooms in the afternoon, which is when the wizards spread their diseases. Wizards' actions may be motivated by feelings of envy and hate. If a person is very rich and has access to good clothes and good food, this might bring about feelings of resentment in some wizards. This is also true when a woman has a beautiful child: the wizard might kill the mother so that the child will suffer.

From the local population's point of view, wizards are also constantly poisoning the population. They usually put different types of poison in food and water. These poisons create stomach dilation, and the person will have to go to a traditional healer to get herbs. Once the herbs are processed, the person will have to drink them in order to vomit. If the person vomits, he/she may be cured, but if the traditional healer cannot induce vomiting, the person might die. Wizards can obtain poison in many ways: one of them is in the pancreas of a crocodile. They mix this poison with other herbs, and the mixture becomes a highly dangerous toxin. They can also extract it from the heart of different birds, some fish, frogs, and snakes. The poison extracted from the pancreas of a crocodile is greatly feared and difficult to cure. When a crocodile is killed in the village, the Town Chief, the Section Chief, or the Paramount Chief has to be informed about it, so that they remove the pancreas and avoid poisonings in the population. Wizards can also poison the waters of a stream and cause great damage to the entire village; they can put poison on the ground, so that when people stands there, they will get elephantiasis; they can turn into a snake and spit the poison directly into people's eyes to blind them; or, at night, when people are sleeping, they can put some drops in their eyes to blind them. Wizards can also participate in the FGM and cause intense bleeding in young girls, which is difficult to staunch. In those cases, all women get together and call the most powerful traditional healers (women), search for medicinal herbs in the woods, and go to the nurse at the health center. In order to avoid witchcraft, people put medicinal herbs on their skin and wash their clothes with a special soap mixed with herbs from the woods. The affected person must wash himself/herself and his/her clothes with these soaps every day for one week. The traditional healer can also build defensive barriers against wizards by placing certain herbs in the house, which will keep the wizards out and protect the entire family from the diseases caused by them.

The interviewees also declared that spirits live in the forests. There are different habitats: many spirits live in areas close to large rivers or streams; others, around large trees; and many live near rocky areas, in mountains, caves, or on hills. Those spirits living near rivers,

streams, and waterways are the most powerful and feared. Evil spirits can cause different ailments which affect human beings. The diseases caused by them are varied, but among the most typical are loss of speech, generalized pain in the entire body —especially when they attack and hit a person hard in the forest—, fainting, convulsions, epilepsy, paralysis, mental disorders (accompanied by a strong desire to go to the forest), trembling, headaches, infertility in women, colds, river blindness, feet problems, inability to walk, and elephantiasis. Nyenne can turn into a human being. This creates difficulties when trying to establish whether a person is really a human being or a spirit that has turned into a human being. The interviewees stated that only specialized people, such as some traditional healers, can tell the difference. However, during the interviews, some hints appeared as to how to tell the difference. When Nyenne turns into a human being, the resulting person will have an asocial behavior, will not talk to anyone and, when asked a question, will not answer. Some pointed out that people may see it, but when they draw close to it, it will suddenly disappear. The interviewees said it is also possible to identify a spirit through their eyes (since they look like cat's eyes), or because, sometimes, they are missing some fingers or move in strange ways. Moreover, they are either very tall or very short.

Local populations believe that some people can make pacts with Nyenne. Not everyone can see the spirits, but those who can see them can form alliances with them. People can ask for money, power, wealth, good harvests, or economic success. In exchange, Nyenne will ask for kola nuts, chickens, goats and, lastly, human beings. Nyenne can present himself in people's dreams in order to come to an agreement with them, offering them wealth in exchange for human beings. On some occasions, Nyenne can refuse human sacrifices because he only wants the person who made the pact with him. In those cases, Nyenne will unfailingly kill the person by hitting him/her violently and sucking out all his/her blood. If people do not fulfill the agreement, the spirit can also kill them by hitting them until they die or drowning them while they are bathing in the river.

The interviewees consider that Nyenne can cause paralysis (when he goes in the opposite direction to a person) and feet problems (when a person stands in a place recently occupied by him). Evil spirits can also cause mental problems that are very difficult to treat. Nyenne causes infertility in women when they bathe in streams or waterways in the afternoon or at nightfall. If women dream of having sex with Nyenne, he can cause infertility in them. Nyenne can turn into a man and have sex with the women who are bathing in the streams, or he can change the baby in the mother's womb, causing the child to be born with deformities or diseases (paralysis, mental problems, dumbness, etc.). There are ways to protect oneself against the evil spirits. In order to do so, people must go to a traditional healer who is an expert on Nyenne. The practitioner will gather specific herbs in the woods and mix them with a sweet smelling soap. The person must bathe every day with the mixture, thereby avoiding attacks by Nyenne.

IMPLICATIONS AND RECOMMENDATIONS FOR PRACTICE

It is difficult to draft recommendations for several reasons. Firstly, because of some limitations that were inherent to the project carried out by Doctors of the World (little time, the need to cover broad areas, the need to visit villages of three different chiefdoms);

secondly, because of obstacles that were beyond our control (weather, rainy season, illness, inaccessibility to villages, vehicle breakdowns); and lastly, because of our own limitations (problems with language, etc.). However, despite these difficulties, we will try to suggest some practical recommendations.

A general recommendation, especially for those organizations working on issues related to the right to health, is that they communicate previously with the different agencies and NGOs operating in the region, in order to be informed about the projects they are carrying out in the area, so as not to overlap programs and objectives, as well as to work in a coordinated and joint manner. It is important to maintain an open and fluid dialogue with the different organizations carrying out tasks in the entire area.

It is important that NGOs and the various ministries of Sierra Leone who work in the health field have an overview of the perceptions of the communities living in Koinadugu about diseases and health. A worldwide view is the key to understanding the patients' behavior in developing countries and to devising strategies to communicate with them more effectively. In addition, to increase the effectiveness of public health programs, a better understanding of the reasons why patients consult a traditional healer first seems warranted (Labhardt et al., 2010). This will enable a better understanding of people's attitudes and the development of more suitable projects to improve the situation. For example, if a project is aimed at sexually transmitted diseases, it is important that the agency carrying out the project is aware of the fact that interviewees identify gonorrhea and syphilis as STDs, but they also believe that stomachache and hernia can be contracted sexually. At this point, it is worth mentioning that stomachache and malaria are pointed out by the interviewees as the most frequent and recurrent disorders in their communities. In some cases, communities are more concerned about how to avoid and prevent stomachaches caused by sexual intercourse than, for example, about HIV, which they consider a distant disease, since they said that there was no HIV in their villages. As for the prevention of STDs, they stated that the main method is to maintain a stable relationship with one person, something very difficult to achieve when men are allowed to have more than one wife.

Populations are open to incorporate the Western medical system and integrate it with their own cultural and social ideas about health. Opala and Boillot (1996:16) remind us that the Limbas have adopted modern drugs because they found them to be more effective, but they have not changed their traditional ideas about diseases. This is a good opportunity for the populations to use health systems and to shape a message that is consistent with their way of thinking, but we should not underestimate the obstacles and barriers that impede people's access to health centers. A major barrier is economic conditions, and despite the efforts made by the Sierra Leone government —which implemented a free health care for pregnant women, nursing mothers, and children—, the economic barriers are still present. The free access to health for these three categories brought the population closer to health services, but there are still many technical problems to solve (cost of medicines not covered, lack of medicines at health centers, not enough health workers, inadequate structures, etc.). It is also necessary that the Western medical system integrates with the local health system, in order to achieve real and effective complementarities. This is also important to influence the health workers' attitudes, because they are often against other health systems, do not treat patients who have already visited the traditional healer adequately, or do not speak well of specialists in traditional medicine. Opala and Boillot (1996:4) have stated that an in-depth understanding of Limba ideas can be used to improve communication between health providers and Limba

patients. We must change the vision: we should not see health systems as incompatible or competing with each other, but as complementary systems. This way, people will have more confidence and become closer to the Western health systems. This is possible. For instance, Hoff (1986) reported that, in Swaziland, a pilot project has successfully brought together nurses and traditional healers, who in the past mistrusted one another. Joint training workshops have led to a marked improvement in attitudes and to the involvement of traditional healers in an effort to promote good health practices and prevent disease. A good understanding of traditional preventive issues on the part of nurses and policy makers could have enormous public health benefits.

Another aspect is related to formal education. Health standards and conditions will improve if a better knowledge about personal hygiene, food care, etc. is diffused. Maternal education may be one of the most important determinants of mortality in childhood. A reduction in infant-child mortality was brought about by rural development, an improvement on medical facilities, and an increase in female education (Bailey, 1989:105-106). Sometimes the distance to the health center is too long, the conditions of the roads are terrible, and there is no way of hiring another means of transport (motorbikes or cars). A possible alternative would be building sanitary rooms, which would have the basic elements and essential medicines, and which could be controlled and managed by a doctor or a nurse, if possible. The first step would be identifying those communities that are more than five miles from the referral hospital of the catchment area and propose nodes which would concentrate the largest possible amount of regions near the sanitary rooms. These sanitary rooms would bring the populations closer and act as a link with the referral hospitals of each catchment area.

One element that might dissuade people from going to the health center is the medical staff. On some occasions, people who are ill and weak and cannot walk long distances make an extraordinary effort to reach the health center, which perhaps is five or more miles away. When they arrive, they have to pay for the medicines out of their own pocket. And to make matters worse, the attention they receive is not adequate. All of this leads to the patient having no desire to return to the health center. Training and awareness workshops for medical and health workers have to be organized, with special emphasis on the patients' care:

1. Patients should be given top priority. The staff's personal activities should not take precedence over caring for the patient.
2. Medical attention should be flexible. If an adult goes to a health center on a day programmed for pregnant women, that person should not leave the center without having received adequate medical attention.
3. Patients should be treated politely. Health workers should not shout nor ask why the patient has not come to the center sooner or why he/she has gone to a traditional healer.

Often the attitude of the medical staff has a twofold effect: first of all, the patients will not say they went to traditional healers, which means losing valuable information to diagnose and treat the patients; secondly, it influences traditional healers, who might have reservations about sending new patients to the health centers. But training should also be given to TBAs (or traditional midwives). The most serious consequence of TBAs non-scientific understanding of childbirth and care of the newborn is seen in the cutting and dressing of the umbilical cord. Neonatal tetanus is a major cause of perinatal death. Recognition and

acceptance of the TBAs by the traditional providers of health care have been already put into practice in Sierra Leone (West, 1981:80, 92). In Sierra Leone, constraints to ideal maternal health require a primary healthcare approach that includes collaboration with traditional midwives (Jambai and MacCormack, 1996).

Finally, in many health centers we have visited, we observed that they did not have drinking water, sanitary conditions were poor, and sometimes they did not have electricity or refrigerators. We must not forget that without clean water, proper hygiene, and sanitation facilities, diseases cannot be effectively eradicated.

CONCLUSION

As we have seen in this report, the cause of diseases is a factor that determines whether a person should be treated by traditional medicine or at a health center. Integration and cooperation between both health systems is important, so that health workers can have access to those patients who believe the cause of their disease lies in witchcraft or evil spirits. In brief, the integration and complementarities of the two systems would be beneficial for all the local communities. It is not a matter of changing health concepts, or instilling or imposing the Western ones, but rather of aiming at a mutual adaptation between both health systems, which would translate into a general benefit to the entire local population.

Integration of both health systems is fundamental. Asymmetric relations have been established in that the health workers, who are familiar with Western medicine, disqualify or minimize the importance the traditional medicine system has for the local communities. We have to change the perception of the traditional health system, because the medical workers at the health centers often see the traditional healer as an "adversary" or "enemy" to the Western system. This perception should be replaced by symmetric relations, which take into account the reciprocity and mutual collaboration between both systems. Regular workshops and meetings should be organized, where members of both systems (medical workers of health centers and traditional medicine) can participate to create symmetric relations, and where they can state their problems and the way in which they could work in complementary or joint manners. Integration and cooperation between both health systems will enable Western medicine to have access to patients who resort to traditional medicine because they believe that their disease was caused by witchcraft or evil spirits. According to Hoff (1992), given the major status and influence of most traditional practitioners among their own people, their role in providing sound and culturally appropriate primary health care should not be underestimated.

REFERENCES

Bailey, M. (1989). Female Education and fertility in Rural Sierra Leone: A Test of the Threshold Hypothesis. *Canadian Studies in Population* 16(1), 87-112.

Burstcher, D. (2004). *Coming late or not at all. Perception of and access to Primary Healthcare: The Mende and Kissi in Sierra Leone*. Technical Report, MSF, Paris.

Gessler, M. C., Msuya, D. E., Nkunya, M. H., Schär, A., Heinricch, M., and Tanner, M. (1995a). Traditional Healers in Tanzania: the perception of malaria and its causes. *Journal of Ethnopharmacology* 48, 119-130.

Gessler, M. C., Msuya, D. E., Nkunya, M. H., Schär, A., Heinricch, M. and Tanner. M. (1995b). Traditional Healers in Tanzania: sociocultural profile and three short portraits. *Journal of Ethnopharmacology* 48, 145-160.

GHI Strategy. (2011). Global Health Initiative Strategy for Sierra Leone. August 7, 2012, US State Department. US Embassy Freetown. http://www.ghi.gov/documents/organization/188011.pdf.

Hoff, W. (1992). Traditional healers and community health. *World Health Forum*, vol. 13, 182-187.

Hoff, W. and Nhlavana Maseko, D. (1986). *World Health Forum*, vol. 7, 412-416.

Jambai, A. and MacCormack, C. (1996). Maternal health, war, and religious tradition: Authoritative knowledge in Pujehun district, Sierra Leone. *Medical Anthropology Quarterly* 10(2), 270-286.

Labhardt, N., Aboa, S., Manga, E., Bensing, J. and Langewitz, W. (2010). Bridging the gap: how traditional healers interact with their patients. A comparative study in Cameroon. *Tropical Medicine and International Health*. Vol. 15(9), 1099-1108.

Langwick, S. A. (2008). Articulate(d) bodies: Traditional medicine in a Tanzanian hospital. *American Ethnologist*, Vol. 35, No. 3, 428-439.

Murphy, W. P. (1998) The Sublime dance of Mende politics: An African aesthetic of charismatic power, *American Ethnologist* 25(4), 563-582.

Musa, Joseph Alex; B. Eng; M. Eng. (2014). Water Sanitation and Hygiene in Sections of Bo District: Problems, Challenges, and Recommended Solutions, *Research in Sierra Leone Studies (RISLS): Weave* Vol. 2 No 1, 1-24.

NHSSP 2010-2015. (2009). National Health Sector Strategic Plan 2010-2015. August 7, 2012, Government of Sierra Leone. Ministry of Health and Sanitation. http://www.whosierraleone.org/1_docs/mohspartnersdocs/nhssp_2010_15.pdf.

Okeke, T. A., Okafor, H. U. and Uzochukwu, B. S. C. (2005). Traditional Healers in Nigeria: perception of cause, treatment and referral practices for severe malaria. *J. biosoc. Sci*. 38, 491-500.

Opala, J. and Boillot, F. (1996). Leprosy among the Limba: Illness and Healing in the Context of World, *View. Soc. Sci. Med*. 41(1), 3-19.

Rekdal, O. B. (1999). Cross-Cultural Healing in East African Ethnography. *Medical Anthropology Quarterly* 13(4), 458-4.

Rodríguez Mir, J. (2006). *Los wichí en las fronteras de la civilización. Capitalismo, violencia y shamanismo en el Chaco Argentino* (The wichí on the borders of civilization. Capitalism, violence and shamanism in the Argentine Chaco). *Una aproximación etnográfica*. Ecuador: Abya Yala.

Rodríguez Mir, J. (2011). *Brujos, espíritus y sacrificios humanos en África* (Warlocks, spirits and human sacrifice in Africa). *Un antropólogo en Sierra Leona*. Spain: Círculo Rojo.

Tabi, M. M., Powell, M. and Hodnicki, D. (2006). Use of traditional healers and modern medicine in Ghana. *International Nursing Review* 53, 52-58.

Statistics Sierra Leone (SSL) and ICF Macro. (2009). *Sierra Leone Demographic and Health Survey 2008*. Calverton, Maryland, US: Statistics Sierra Leone (SSL) and ICF Macro.

Van der Geest, S. (1997). Is there a role for traditional medicine in basic health services in Africa? A plea for community perspective. *Tropical Medicine and International Health*. Vol. 2(9), 903-911.

Waldram, J. B. (2000). The Efficacy of Traditional Medicine: Current Theoretical and Methodological Issues. *Medical Anthropology Quarterly, New Series, Vol. 14, No. 4, Theme Issue: Ritual Healing in Navajo Society*, 603-625.

West, K. M. (1981). Sierra Leone: Practices of Untrained TBAs and Support for TBA training and utilization. In: A.M. Maglacas and H. Pizurki (Eds.), *The Traditional Birth Attendant in Seven Countries. Case Studies in Utilization and Training* (pp. 71-95), England: World Health Organization.

BIOGRAPHICAL SKETCH

Javier Rodríguez Mir

Professional data
Phone: 91 947 30 90
Office 210
Mod. VI Bis.
Facultad de Filosofía y Letras (UAM)

javier.rodriguez@uam.es
rodriguezmir@yahoo.es

Education And Training

- PhD in Social Anthropology. Cum Laude.
Autonomous University of Madrid (UAM). Spain, 2005.

- Master in Native American Studies.
Complutense University of Madrid (UCM). Spain, 2003.

- Specialist in Culture, Society and Development in Latin America.
Autonomous University of Madrid (UAM). Spain, 2002.

- Certificate in Native American Studies. Organized by Casa de América in Madrid and sponsored by UNESCO. Spain, 2001.

- Degree in Social Anthropology. National University of La Plata (UNLP, Buenos Aires, Argentina). 1989.

Research
Anthropology
Health.

Development.
Cooperation.
Human rights.
Public politics.

Current Professional Status

Professor, Department of Social Anthropology and Spanish Philosophical Thought. Faculty of Arts. Autonomous University of Madrid.

Coordinator of external practices Grade Social Anthropology at the Autonomous University of Madrid (UAM)

Consultant and Adviser as anthropologist in Doctors of the World.

External evaluator in journals specializing in Social and Cultural Anthropology.

External evaluator in Social Science Projects.

Consulting

2010. Advice for Doctors of the World project "Strengthening the Primary Health Care in the Region of Diang" and "Strengthening of Sexual and Reproductive Health Services in Koinadugu District." Both projects implemented in Sierra Leone. May-December 2010.2010.

2016. Advice on the project "Intercultural Health Care Protocol for Wixárika with type 2 diabetes," University of Guadalajara (Mexico).

Publications

Books

2013. Spirits and demons in the Argentine Chaco. Reflections from fieldwork... Twenty years later. Publisher Red Circle. Spain. ISBN 97884 9050 4758.

2011. Witches, spirits and human sacrifice in Africa. An Anthropologist in Sierra Leone. Publisher Red circle. 104 pp. Seville (Spain). ISBN: 978-84-9991-559-3.

2011. Violence and Environmental Racism in Argentina. Resistance and Mobilization of Indigenous Peoples in the Chaco. Ethnography Wichí from the Conflict. Publisher Spanish Academic Publishing. 240 pp. ISBN: 978-3-8465-7014-2.

2006. The Wichí in the Frontiers of Civilization. Capitalism, Violence and Shamanism in the Argentine Chaco. An Ethnographic Approach. Abya Yala, Quito, Ecuador. 416 pp. ISBN: 978-9978-22-628-5.2011.

Chapters of Books

2011. The Funeral Variability in the Southern Chaco, Chapter 9, with the collaboration of Guillermo Lamenza, Horacio Calandra and Susana Salceda; In Humans, the Middle East and its Relations, compilation num. 1. Faculty of Natural Sciences. National University of Catamarca. San Fernando del Valle de Catamarca; Argentina; p. 177-189.

2007. Political Strategies of Indigenous Peoples in the Context of Globalization. The Case of Argentina, in: Neoliberalism, NGOs and Indigenous Peoples in Latin America, (Oscar Calavia, Juan Carlos Gimeno and Maria Eugenia Rodriguez eds.), publisher SEPHA, Madrid, pp: 153-175.

Dossier

2012. Analyst and editor of the Report "Social and Intercultural Coexistence in Areas of High Diversity," under the scientific direction of Carlos Giménez Romero. Obra Social "la Caixa," Barcelona, Spain.

2011. Analyst and editor of the series that presents the results of the survey 2010 on intercultural coexistence at the local level in the field of Intercultural Community Intervention Project. 17 vol., publisher Obra Social "la Caixa," Barcelona (Spain).

2009. Ethnology of the Chaco, Javier Rodríguez Mir and Guadalupe Barúa (eds.), in Spanish Magazine of American Anthropology, number 39-2, Complutense University of Madrid.

Papers

2015. Indian public and political mobilizations on the Argentine Chaco: Dynamics of Identity and Otherness Wichí Social Confrontation. Magazine of Public-oriented Anthropology.

2013. Joint health Systems in Sierra Leone: Perspectives from Medical Anthropology. Gazeta Anthropology, No. 29 (1), Article 01.

2012. The Winding Roads of Racism: Environmental Racism in Argentina. Journal of Experimental Anthropology, No. 12, text 4, pp. 43-59.

2011. Transforming Otherness. Scope and Limitations of Development Projects in the Native Societies of the Argentine Chaco. Gazeta of anthropology, number 27/1, Article 17, University of Granada, Spain.

2009. The Symbolic Ownership as a form of Power. The Necessary and Feared Wichí otherness between the Argentine Chaco, Spanish Journal of American Anthropology, Number 39-2, Universidad Complutense de Madrid.

2009. Presentation of Dossier Ethnology of Chaco, in collaboration with Guadalupe Barua, Spanish Journal of American Anthropology, Number 39-2, Universidad Complutense de Madrid.

2008. Otherness and Imaginary Social in the Argentine Chaco Matacos groups. Conflict, Resistance, War and Negotiations. American Acta, Vol. 16, num. 1 Swedish Society of Americanists.

2008. Indigenous movements in Latin America. Resistance and Otherness in a Globalized World. Gazeta of anthropology, number 24, item 24-37, University of Granada, Spain.

2008. Complexity, Diversity and Social Heterogeneity. Bolivia and Multicultural implications from an Anthropological perspective. Journal of Experimental Anthropology, No. 8, Text 25: 341-349, University of Jaen, Spain.

2007. The Argentine Chaco as a border region. Boundaries, Wars and Indigenous Resistance (1865-1935). Hispania Nova. Journal of Contemporary History. Vol. 7, Spain.

2006. The boundaries of the Empire of Civilization. Genesis of Ethnic Categories in Latin America. Journal of Experimental Anthropology, no. 6, text 16: 235-250. University of Jaen, Spain.

2006. Nous et les autres: Hostile relations conflictuelles et dans les sociétés des Matacas Las Lomitas (Argentina Rep.). Civilisations, LV (1-2): 89-100. Brussels, Belgium.

2006. Resistance and Confrontation in Argentina: Denial and Exclusion of Indigenous Peoples. Gazeta Anthropology, No. 22, text 22 to 22, Granada, Spain.

Communications and Conferences

2015. "Female Genital Mutilation. Dilemmas and Debates on Body Rituals and Health," organized by the African Group for Research on Migration in Argentina and Chair of Methods and Techniques of Social and Cultural Research, Faculty of Natural Sciences of the National University of La Plata, Argentina. Dec. 21.

2015. Anthropology of Health in the framework of the course "Health and Pharmaceutical Care in Cooperation and Humanitarian Action" organized by Farmamundi from 23 to 27 November. Pharmacy Faculty. Complutense University of Madrid.

2015. The Dark Side of Social Inclusion: Female Genital Cutting, Rituals and Health. IV International Congress of University Students (CIJU). University of Guadalajara (Mexico) and UNESCO. October 14, Mexico.

2015. Social Inclusion and Bodily Transformations. About Rituals, Traditions and Female Genital Cutting. Anthropological Conference VIII Sierra de San Vicente. Almendral de la Cañada, Toledo. Anthropological Association organized by Sierra de San Vicente. September 27th.

2015. Ownership of Patients, Knowledge and Power: a Critical Perspective Anthropology of Health. Congress Medicines and Bodies in Latin America. Anthropological Debates from Health and Multiculturalism. 27 February. Department of History of America II (Complutense University of Madrid) and National Museum of Anthropology.

2014. Anthropology of Health in intercultural contexts. The case of Sierra Leone. I Conference: NGO, Intercultural Perspectives and New Challenges in the Social Field of Health. XI edition of the Week of Solidarity. Autonomous University of Madrid. November 26. Madrid.

2014. Latin American Indigenous Movements in a Globalized World. Dynamic Resistance and Otherness. Congress: Territories and Threatened in the Amazon Bodies. Casa de Velázquez. Mar. 24, Madrid.

2013. Terror and Violence in Predatory Systems: the Fight for the Capital and the Struggle for Survival (The case of the Wichi of Argentina). X Week of Solidarity. Autonomous University of Madrid. November 25. Madrid.

2010. Contemporary Humanities Course: What is Anthropology? Theories and Practices of the Professionalization of Anthropology, with the paper: "Engaged Anthropology: Advice on Intercultural Projects Development," in Madrid, on December 15.

2010. Change and Continuity: mortuary practices in the Southern Chaco, in collaboration with Guillermo Lamenza and Horacio Calandra, National Congress of Archaeology Argentina (CNAA) from 11 to 15 October, Mendoza.

2009. Course Social Transformations and Development in Latin America. Challenges for Cooperation 200 years of American Independence, with the conference "The Indigenous

Ownership of Development: the case of Social Movements in the Argentine Chaco," held in Madrid on December 12.

2009. Workshop: Social Movements and Ethnicity in the context of Globalization, funded by the National Agency for Scientific and Technological Promotion, between 22 and June 26 in the Auditorium of the Faculty of Natural Sciences of the National University La Plata (Argentina).

2008. An Anthropological Perspective of Social Movements in Latin America. Resistance and Otherness in a Globalized World, inaugural conference of the summer course "The possibility of another world in Latin America: collective responses to exclusion" held between 7 and 11 July at the University of Alcala de Henares, Spain.

2006. Wichí Argentine Chaco: Consolidation, Design and Scope of Otherness and Imaginary Social in Latin American Conference on Indigenous Cultures, November 27 to December 1, 2006. Madrid.

2006. The Power of Otherness: Violence, Fear and Negotiation between the Argentine Chaco Wichí in 52 International Congress of Americanists, 17 to 21 July 2006. Spain.

2005. Political Strategies of Indigenous Peoples in the context of Globalization. The case of Argentina in First State Meeting of Anthropology and Development, 14 and 15 November 2005, Madrid.

2005. The Chaco as a border region. War, Repression and Territorial Appropriation, International Colloquium: The Wars of Paraguay, 17 to 19 November 2005. Paris, France.

Organization of Events

2015. Director, with Juan Carlos Gimeno Martin, of course, "Horizons for a Reformulation of the Spanish International Cooperation in Latin America." Autonomous University of Madrid, from 13 to 28 October 2015. Madrid.

2014. Director of the I Conference: NGO, Intercultural Perspectives and new challenges in the Social Field of Health. XI edition of the Week of Solidarity. Autonomous University of Madrid. November 26. Madrid.

Participation in Projects

2013-5 Participatory Design Continental Master Studies in African Descent in Latin America. Director: Juan Carlos Gimeno Martin. Members: Theophile Ambadiang; Alicia Campos Serrano; Javier Rodríguez Mir; Alta Hooker; William Oswaldo Flores López; Daniel Mato; Ramón Grosfoguel; Cyril Omier; Leticia Castillo; Diego Buffa; Maria José Becerra; Maguemati Wabgou; Aura Marina Chojlan. January 2013-February 2015.

2011. Intercultural Community Intervention Project. Funded through collaboration with Foundation "la Caixa" Social Work.

2010. Conflict and Migration in Local Contexts. A Theoretical and Practical Approach to Coexistence and Mediation, Ministry of Science and Innovation, Spain.

2006. Migration and Multiculturalism Programme. Autonomous University of Madrid.

2004. Politics and Actions. Integration and Intercultural Relations. Autonomous University of Madrid.

2004. Orientations of Young Men and Women to Citizenship and European Identity. European Union.

2003. Latin American Intellectuals and Projection of Hispanic and Regenerationism in American Space Networks. Autonomous University of Madrid.

2002. Analysis and Diagnosis of the Situation of the Colony Colombian in Spain, Embassy of Colombia in Spain, University Autonomous of Madrid and University of Comillas.

2001. Multilingual Cities Project, Centre for Research Education (CIDE) of the Ministry of Education, Culture and Sport and the General Directorate of Educational Promotion of the Community of Madrid.

Director of Doctoral Theses

In Progress

- Mobility and Identities of Young European. Candidate: Simone Lamanna. Autonomous University of Madrid.
- Obstetric Violence and Gender Violence. Candidate: Eva Margarita Garcia. Autonomous University of Madrid.

Master Works

2015. Master in Public-oriented Anthropology. Department of Social Anthropology and Spanish Philosophical Thought. Autonomous University of Madrid. Student: Inmaculada Fernández. "Two perspectives Intercultural Birth Bolivia: from Development Cooperation" (Medicus Mundi) and Anthropology (Kallawaya Traditional Medicine).

2008 European Masters in Latin American Studies: Cultural Diversity and Social Complexity (MLSS) Zarina Estela Aguirre Lozano on "Global and Local Factors and Processes that influence the Reconstruction of Multicultural Identities Colotlán Case Analysis (Mexico)."

2008 European Masters in Latin American Studies: Cultural Diversity and Social Complexity (MLSS) Manuela Bianchi on the Issue of Social Resilience of Communities of African origin in Latin America.

2008 European Masters in Latin American Studies: Cultural Diversity and Social Complexity (MLSS) Chiara Lilli on Cuban Santeria comparison with Candomble of San Salvador de Bahia (Brazil).

Thesis in Social Anthropology Graduate Students

2015. Degree in Social and Cultural Anthropology. Autonomous University of Madrid. Student: María del Mar Labian Serrano. Anthropological Study of Episiotomy and Female Genital Mutilation: The exercise of Power through Biomedicine and Culture.

2015. Degree in Social and Cultural Anthropology. Autonomous University of Madrid. Student: Elena Abraham. Poverty and Hunger in Spain: An anthropological analysis.

In: Handbook on Africa
Editor: Whitney Sherman
ISBN: 978-1-53610-063-1

Chapter 6

EBOLA AND RUMOURS IN SIERRA LEONE: CONTEXTUALISING AND ELUCIDATING PERCEPTIONS OF EBOLA THROUGH RUMOURS

Rosie Wigmore
University of Sussex, Brighton, UK

ABSTRACT

This briefing contextualises the rumours that circulated during the 2014 Ebola outbreak in Sierra Leone. These rumours were a method of trying to explain the cause of Ebola and understand the responses to it. Analysing these rumours helps the international community to understand Sierra Leonean perceptions of Ebola in order to improve future emergency health responses in Sierra Leone. These rumours were a product of the initially over stretched and poorly implemented Ebola response and the international communities' attitude towards Ebola, but they were more often linked to long-term issues of structural violence, which also contributed to the unprecedented spread of Ebola in Sierra Leone. Despite the efforts of the World Health Organisation to control the Ebola outbreak, achieving zero cases and providing support for survivors, rumours about the cause of Ebola and the response to it did not abate. Although social mobilisation and sensitisation was important in the short-term, it is the more complex and deeply ingrained issues that the Ebola response and those that dominate the current system of global health governance must grapple with to properly eradicate Ebola now and in the future. Ebola rumours are thus an extremely fruitful way to elucidate both Sierra Leonean perceptions of Ebola and the response to it, and the multiple, global, political, economic and social inequalities that contributed to the outbreak.

In May to June 2015 I returned to Sierra Leone to research the rumours that circulated about the cause of the 2014 Ebola outbreak and the response to it – Ebola rumours. These

rumours were a product of the initially over stretched Ebola response,[1] as well as the international communities attitude towards the outbreak, but were more often linked to long-term issues of structural violence[2] that also contributed to Ebola's unprecedented spread in Sierra Leone, and also Guinea and Liberia. Thus, I found that Ebola rumours were an extremely fruitful way to elucidate both Sierra Leonean perceptions of Ebola and the reactions to it, and issues of structural violence that contributed to the outbreak.

Analysing and contextualising Ebola rumours is important because they show that although social mobilisation, sensitisation and an effective health response was important in the short-term, it was and is the more long-term and deeply ingrained social, political and historical problems that the international community needs to grapple with to ensure that Ebola outbreaks in Sierra Leone are controlled in the future. Sensitisation was necessary to demystify Ebola and reduce conflict because it was the first known outbreak of Ebola in Sierra Leone.[3] However, sensitisation was also a contentious issue. Many involved in the response argued that focussing on problematic behaviours distracted from larger issues that caused the Ebola outbreak, such as poverty, inadequate public health facilities, the role of the international community and the fraught relationship between the Sierra Leonean government and its citizens (Abramowitz, 2014; Benton, 2014; Bloom et al., 2015; Fairhead, 2015).

Furthermore, many of these issues are not produced internally but also interlinked with *global* political, economic and social inequalities. Accordingly, the current system of global health governance (GHG)[4] needs to undergo a period of self-reflection and transformation to ensure that countries such as Sierra Leone can expect to receive the same level of care and attention as their Western counterparts during outbreaks of disease. The deeply inadequate health care system that Sierra Leoneans encounter on a day-to-day basis and the causes of its inadequacy must also be considered.

Scrutinising Ebola rumours also has the ability to make people's perceptions, and their experiences of Ebola and the response to it, understood. A limited understanding of Sierra Leonean perceptions undermined health measures, as often they were often contradictory to people's needs and beliefs and were therefore resisted. Resistance included: concealing, washing and burying dead bodies in compliance with traditional practices, hiding contacts,[5] escaping quarantine, denying the virus, physically or verbally abusing those linked to the response, traditional healing, and rumours that contradict the nature of the virus, the reason for its dispersion and the response to it. All forms of resistance greatly exacerbated the spread of Ebola. Consequently, appreciating people's perceptions must be an essential part of any future emergency health responses in Sierra Leone.

This contextualisation of rumour is based on research conducted in ten different districts: Bo, Bombali, Kailahun, Kenema, Kono, Koinadugu, Moyamba, Port Loko, Western Urban

[1] Mainly, but not limited to the Sierra Leonean government and the international communities' (NGOs, countries closely involved in West Africa, such as France, the UK and the US, the World Health Organisation (WHO) and the United Nations (UN)) public health measures to stop Ebola.

[2] Structural violence is violence that is not a random occurrence, but a result of historically given, or economically driven processes that prevent people from escaping poverty, racism and political violence (Farmer, 1997: 263).

[3] Some samples suggest that Ebola has been present in Sierra Leone since at least 2006 (EurekAlert, 2014).

[4] Global health occurs when the causes and consequences of ill health 'are oblivious to the territorial boundaries of states and, thus, beyond the capacity of states to address effectively through state institutions alone (Buse et al, 2002: 5).' This results in a global, rather than a national response to outbreaks of disease, such as Ebola. The WHO and its biggest funders, such as the UK and the USA, are generally considered to be the leaders of GHG.

[5] People who have been in contact with a confirmed Ebola case and therefore need to be monitored for symptoms either in a holding centre or a quarantined house.

and Western Rural. Each district experienced Ebola differently. Accordingly, the rumours and the intensity of them were slightly altered depending on the district. For example, treating Ebola and conducting sensitisation was harder in districts that have a lot of inaccessible areas, such as Port Loko and Kabala. In these districts, rumours that blamed Ebola on witchcraft were more prevalent, as the Ebola response found it harder to access them to dissociate Ebola and witchcraft. In districts bordering Liberia and Guinea, for instance Kambia and Kailahun, inevitably rumours concerning their neighbours were more common. Districts that experienced the outbreak earlier had more rumours regarding the origin of Ebola. In Kenema and Kailahun there were many rumours linked to the Ebola infected *Sowei*[6] who first brought Ebola from Guinea to Sierra Leone.

Nevertheless, knowledge of most Ebola rumours were known across the country regardless of their originating source. Thus, considering the majority of the rumours confronted people's frustration with either the Ebola response or their government, this suggests that the health response and people's relationship with their government was problematic across the country.

To get a varied perspective of Ebola rumours, numerous one to one interviews and focus group discussions were undertaken with a wide range of Sierra Leoneans and stakeholders in the Ebola response. These included doctors and nurses in Ebola Treatment Centres (ETCs) and Community Care Centres (CCCs),[7] the NERC, NGOs, social mobilisers,[8] traditional healers, chiefs, Muslim and Christian groups, youths, women and men. I attempted to gather information from a variation of people and from across Sierra Leone due to the immense spatial spread of Ebola, Ebola rumours and because it impacted all Sierra Leoneans.

For Sierra Leoneans, rumours caused hysteria, and increased the fear of foreigners, the government, the Ebola response and even fellow citizens. For example, misunderstandings surrounding Ebola survivors left thousands of Sierra Leoneans isolated from and within their own communities. The consequences of Ebola for Sierra Leoneans, fuelled by rumours and dissonance, were endless. They included: losing friends and relatives, disrupted education, economic hardship, the disintegration of basic social practices, such as physically caring for loved ones or even shaking hands with acquaintances, and the moratorium of traditional practices, such as washing the dead. The suffering that Ebola caused intensifies the importance of listening to people's experiences of the outbreak to overcome the likelihood of a future outbreak.

Ebola rumours arose from, although they were by no means limited to, three main sources. Firstly, many rumours were reactions to the originally, poorly funded and over stretched health response to Ebola. For example, on March 31st 2014 at the start of the outbreak, Medecins Sans Frontieres (MSF), who were at the time the sole organisation leading the response on the ground, declared the outbreak 'unprecedented.' The World Health Organisation (WHO), however, denied this and accused MSF of exaggerating. Consequently, GHG failed to react, which ensured that MSF was unable to provide a 'full range of

[6] A senior member of all women societies that help girl's transition into womanhood. They also controversially lead the ritual known as Female Genital Mutilation (FGM).

[7] CCCs are setup within communities so that anyone suspected of having Ebola can receive basic care close to home until they are transferred to an ETC, which reduces the chance of Ebola being spread further afield (Plan, 2015).

[8] Social mobilisers work as intermediaries between organisations fighting Ebola and the community to educate people about Ebola and the measures implemented to stop it.

containment activities in all areas.' The lack of facilities meant nurses and patients died rapidly (MSF Report, 2015: 6-7).

As a result, Sierra Leoneans often did not trust Ebola Treatment Centres (ETCs) and the general response, as very few people were surviving and returning to their communities from which they had, at times, been forcibly removed. In reactions to this, a consortium of rumours concerning ETCs and health staff began to arise.

Many of these rumours arose in Kenema. Kenema is one of Sierra Leone's poorest provinces largely because it is the political opposition party stronghold, the Sierra Leone's People Party (SLPP), and therefore receives less funding than government supporting provinces. Consequently, many Sierra Leoneans are notably sceptical of the government in Kenema. Kenema was also the location of a Lassa fever laboratory that spawned a highly prevalent rumour – the USA paid the Sierra Leonean government in order to test bioweapons on monkeys in Kenema, which escaped and infected people with Ebola. Widespread corruption in Sierra Leone has led many Sierra Leoneans to believe that their government cares more for money than its people, which reflects this rumour.

Other rumours accused health workers of bringing Ebola to communities on purpose. A nurse that I spoke to in Kenema who had been heavily involved in the Ebola response described how children would run away from her shouting "Ebola nurses are coming" if she was spotted in her work uniform. After, she was careful to always wear plain clothes outside of the ETCs and even moved away from her family in case she infected them. This precautionary measure reveals the rationality of this rumour: during the start of the outbreak due to the lack of resources health workers *were* contaminating communities with Ebola, as many infected their own family members.

Figure 1. Health workers dressed in the outlandish looking PPE. Available From: http://www.huffingtonpost.com/kim-yi-dionne/what-we-know-and-dont-kno_b_5752226.html.

Other more 'fantastical' rumours, for example that health workers were stealing blood and organs to sell or were performing cannibal rituals within the ETCs (Reuters, 2014), are less so when people's experiences of the outbreak are carefully considered. The outlandish appearance of health workers dressed in Personal Protective Equipment (PPE) (see Figure 1) and ambulance sirens that people in remote areas had never heard before induced fear and panic, particularly because both were connected to the removal of sick family members.

ETCs also had a strange and hostile appearance. When I spotted my first ETC I initially thought it was a military camp and imagined the apprehension I would feel if I knew that I was to enter that place (see Figure 2). Thus, organ-stealing rumours that are arguably more extreme than other Ebola rumours are understandable when considering the unusualness and extremity of the situation to many.

Figure 2. (My own). Sierra Leoneans are often very afraid of being taken to Ebola Treatment Centres (ETCs). This image shows why this fear is quite understandable, as many ETCs look more like army camps than health facilities. I myself felt the ETC looked ominous and would have felt afraid if I had been admitted to it for treatment.

Some rumours were more directly aimed at the inadequate response to Ebola. For example, in Wellington, a community in the eastern suburbs of Freetown, a rumour suggested that sachets found in rice rations provided by the Ebola response, which were perhaps a desiccant used to keep the rice fresh, were in fact sachets of poison intended to contaminate the food. This caused people to resist quarantine measures. However, after speaking to a couple of families that had been previously quarantined, I discovered that their rations had included turned fish, which could have initiated the poison rumour. These rations were the family's only source of food, as the Ebola response was unable to provide more as their neighbours were avoiding their quarantined home.

Many families had endured a deeply traumatic experience with the Ebola response team. An adolescent girl from one family told me how she watched her dead mother rot because the burial team took five days to collect her mother. The quarantine team also refused to extend the quarantine fence that surrounded their house to the full length of their garden and therefore significantly reduced the space in which they were forced to live in for 42 days. She now cares for two younger siblings with the intermittent help of her aunty. Her other family members, at the time, had stayed away due to fear of Ebola. She asked the quarantine officials: "what will I gain from surviving this quarantine? I have no future, I can't go to school; we have no money." The other family that I spoke to described how the burial team

threw their deceased family members into the back of an ambulance. Thus, with such little respect shown to needs, feelings and deceased family members, a poison rumour is arguably not so implausible.

An understandable lack of faith in health facilities and health workers greatly reduced patient referral. Consequently, sick and highly contagious people were treated in communities instead of ETCs. This spread the virus infinitely, which made rumours hugely complicit in heightening the impact of Ebola. Accordingly, understanding the causes of these rumours one of the most important parts of the Ebola response.

These rumours generally dissipated when the WHO and the international community began to react and the response accordingly improved. Survivors returning to their communities was a crucial turning point, which significantly altered people's perceptions of ETCs and their willingness to use them. Therefore, when people's practical and emotional needs were met, rumours and resistance diminished. Taking these rumours seriously explained people's anxieties concerning health facilities and ensured the Ebola response could implement suitable health measures that were utilised and trusted by Sierra Leoneans.

The second source of Ebola rumours were Western theories or rumours that attempted to explain the cause of epidemic, which also shaped the Ebola outbreak, the responses to it and even fuelled more rumours. Throughout the outbreak Western media and environmental science accepted the idea that Ebola was caused by deforestation, eating bush meat and bats (Drakeley, 2015; Ginsburg, 2014; Glasgow and Pirages, 2001; McCoy, 2014). Despite these tenuous linkages, these ideas are not labelled as rumours, but as not-yet-proven scientific 'facts.' Here we are dealing with a 'hierarchy of knowledge,' whereby information from the Western world is more respected than knowledge produced in Sierra Leone.

This approach overlooked useful and existing capabilities in Sierra Leone that could have been enhanced to create a more effective and trusted response to Ebola. For example, Community Care Centres (CCCs)[9] were a hugely effective way to reduce transmission, as CCCs included and therefore motivated local people and were far more reactive to local needs. It was found that local people often trusted and willingly utilised CCCs more than internationally run ETCs. However, the leadership capabilities of Sierra Leoneans and therefore the implementation of CCCs was recognised very late in the response. This undoubtedly cost many lives and increased tensions between Sierra Leoneans and the international community, as local perceptions were often overlooked in favour of solely Western led solutions.

Western theories or rumours about the cause of the Ebola outbreak also distracted from other key issues, such as the initially poor and often unsuitable way that the international community responded to the outbreak and enduring political, social and economic issues. Instead, the international community, for example the WHO, frequently promoted 'behavioural change capacities' to overcome resistance and rumours (WHO, 2015: 3-4). This approach was problematic as it focussed the causation of Ebola's rapid spread on individuals rather than the general context.

Some 'behavioural change capacit(ies)' even spawned additional rumours. Due to the theory that bush meat was a likely cause of initial infection, the WHO and the Sierra Leonean

[9] CCCs were health centres setup within communities and ran by community members so that anyone suspected of having Ebola can receive basic care close to home until they were transferred to an ETC. This reduced the chance of Ebola being spread further afield (Plan, 2015).

government advised Sierra Leoneans to halt their consumption of bush meat (see Figure 3). However, many Sierra Leoneans interpreted this as proof that Americans had brought Ebola to Sierra Leone. Many Sierra Leoneans believe that the USA was testing bioweapons on monkeys in a laboratory studying Lassa fever in the region of Kenema. The rumour suggested that the monkeys escaped and infected locals with Ebola and explains why their government has ordered them to stop eating monkeys, a type of bush meat that has been a vital source of food for hundreds of years. GHG's faith in science and 'facts' meant that the context in which resulting protocols were implemented were not understood. In the long run, removing a valuable food source caused more harm than good as it angered locals and encouraged people to resist other health measures connected to the response.

Figure 3. A health poster informing Sierra Leoneans that they must avoid eating bush meat. Available From: https://twitter.com/marionkoopmans/status/ 452331256068726784.

In preparation for future outbreaks GHG must focus on the dangers of misinformation and its role in causing resistance. For instance, at the start of the outbreak the Ebola response misleadingly informed Sierra Leoneans that there was no cure for Ebola, which again prevented people from using ETCs. This is technically true because initially there was no vaccination. Nonetheless, this particular strain of Ebola is certainly treatable if attended to early and if a person is young and healthy.[10]

Thus, the inequalities ingrained in global transactions of knowledge that can characterise one set of ideas as 'traditional' and another as 'fact' must be acknowledged. Failing to do so overlooked useful and existing capabilities in Sierra Leone that should have been enhanced much earlier to create a more effective Ebola response, one that respected Sierra Leoneans

[10] According to the head doctor of Emergency USA's Goderich ETC.

and their perceptions of Ebola. *All* interpretations of Ebola, from witchcraft to hemorrhagic fever, are socially conditioned and a product of some sort of 'tradition.'

Lastly, a considerable number of Ebola rumours emerged from the everyday experience of structural violence in Sierra Leone and there are countless rumours that embody this: Americans testing harmful bioweapons, the government released Ebola in the southern, SLPP stronghold to eliminate the opposition, the government was injecting people with Ebola to increase the number of cases to get more money from the international community, and foreign health workers are stealing and selling organs and blood in ETCs.

These rumours derived from an unequal social and economical relationship with the West and an equally problematic relationship that Sierra Leoneans have with their government. They betrayed how foreign actions could negatively affect people at a local level by holding people in poverty and causing violence.

Foreign companies who extract mineral resources from Sierra Leone's impoverished and rural areas are one such example. The profits of the mining companies benefit their foreign owners and Sierra Leone's elite in Freetown who condone the mining due to the private gain they receive (Keen, 2005; Richards, 1996). Despite the harm caused to people's land and the environment, those living in areas close to the mines receive little to none of the profits, have no share in the resources, and are often living without schools and health facilities. Consequently, rural Sierra Leoneans are frequently alienated from and mistrustful of their government. These same issues also contributed to the anger and frustration felt amongst Sierra Leoneans, which fuelled a ten-year civil war that ended in 2002. Furthermore, the war also destroyed Sierra Leone's already precarious health care system, which was a core reason for the unprecedented spread of Ebola.

The Sierra Leonean government's treatment of its people is also to blame for the antipathy of the population. Sierra Leoneans know not to rely on their government for healthcare, jobs, economic stability or an education. Instead, Sierra Leoneans see politicians grow richer, and obtain healthcare and their children's education from abroad, which prevents them from improving Sierra Leone's own health and education services.

Corruption is undoubtedly rife amongst Sierra Leone's elite. However, the causes of corruption and the government's failure to provide basic social services are complex and sustained by foreign relationships. Foreign mining companies, for example, do not let go of resources like Sierra Leone's easily and inevitably their payoffs are handed to the elite to continue invasive mining and not to the Sierra Leonean people. Sierra Leone's poor economic climate also reduces the wages paid to government officials, which increases temptation, as the pressure to provide for family members and supporters is high whilst in government.

Another reason for low social spending originates in the financial protocols of financial organisations, such as the International Monetary Fund (IMF) and the World Bank. After the civil war in particular the IMF and the World Bank supplied Sierra Leone with large loans to recover from the conflict. However, accepting these loans also requires Sierra Leone to accept the IMF and World Bank's policies, in this case the IMF and the World Bank's Poverty Reduction and Growth Facility (PRGF), which focussed on macroeconomic stability and reduced spending, for example the government wage bill (IMF/World Bank, 2002: 29, 36 in Hanlon, 2007; 463).

Thus, when the WHO attributed the unprecedented scale of the outbreak to West Africa's weak health systems, a lack of resources and to the unfamiliarity of Ebola to the West African

region, the WHO was massively undermining the causes of the unprecedented spread of Ebola (WHO, 2014).

To understand why Ebola spread so far and killed so many we need to look at *why* Sierra Leone's health system is so poor and *why* there are so few social resources. If GHG explores these issues it will realise that an essential part of preventing another outbreak reoccurring involves confronting the current world system that prioritises the economic desires and health of the Western world. It is no coincidence, for instance, that the USA launched a militarised response in the seventh month of the outbreak and only after an American contracted Ebola (Mark, 2014). The irony of this was not lost on Sierra Leoneans and many debated why it is Ebola and not malaria that has acquired so much attention. One woman in Kissy asked me "why have they come now, people are always dying of disease in Sierra Leone?"

Accordingly, the Ebola response has a responsibility to contextualise rumours and other reactions to Ebola from a social, political and historical perspective. This ensures that people's reactions and the reasons for the outbreak are understood, which avoids simplifying future health measures and explanations for the cause of the outbreak itself. If not, rumours, resistance and Ebola will return, as will the complex factors that caused the outbreak.

For instance, in Port Loko, a witch plane crash rumour[11] was often treated facetiously and sensitisation was encouraged to overcome it. However, in certain contexts, this rumour was inherently political and therefore increased sensitisation was irrelevant. For example, this rumour confronted deep-rooted issues concerning chiefs in Mamasa, Port Loko. In this case, the witch plane crash rumour stemmed from a conflict between two chiefs after an election. One chief, annoyed at having lost the election, sent a witch plane to his opponents, which caused a sickness named 'Ebola.' Here, but also across Sierra Leonea, many find chiefs problematic. A social mobiliser in Mamasa felt that democracy did not work in Sierra Leone: "when one chief is elected, one group will always be unhappy and will react." Moreover, chiefs are frequently implicated in corruption. Some *okada*[12] drivers in Mamasa complained that when their chief needs money he detects faults on their bikes to confiscate their licence, which they then have to buy back.

Tensions between Sierra Leoneans and their chiefs can be traced back to the colonial era during which the British listlessly installed democracy. Instead, the British ruled through loyal chiefs and patronage. Consequently, the chiefs largely answered to the British instead of the people. Forced labour, unfair land reform and taxes became rife and reoccurred more recently under President Siaka Stevens in the 70's and 80's when patronage and corruption was commonplace (Keen, 2005: 9-10).

Overall, Ebola rumours are a way for Sierra Leoneans to grapple with the outbreak in relation to previous problematic political, economical and social experiences, which most Sierra Leoneans have a very good awareness and knowledge of. These rumours therefore tell us that the GHG must aim for enduring solutions to Ebola that confront these problems. However, this is difficult to achieve considering the ephemeral nature of development programmes.

[11] Witch planes are tiny aeroplanes that are used to transport witches from one place to another. Some suggest a groundnut shell or animals can be used as witch planes. Occasionally, in the 'astra' world, the magic world, there are accidents: a witch plane could crash and bring a sickness or the people involved will fall sick. In this instance, a witch plane crashed in Port Loko and brought Ebola.

[12] Motorbike taxis.

Already there is anger amongst Sierra Leoneans over promises of better healthcare and most importantly free healthcare for Ebola survivors. Despite the government promoting Ebola survivors as 'heroes' in attempt to reduce the stigma that the survivors face in their communities, the government has failed to deliver on its promise of free healthcare for survivors. The government willingly admits that the medicines are not available to treat the many ailments, such as loss of sight and aching joints that plague those who overcome Ebola (Acland, 2016).

This proves that systematically little has changed. Sierra Leone still lacks resources and is unable to provide for its people. Thus, Sierra Leone's deep-rooted and prevailing political, economic and social issues need to be reiterated to those who lead GHG to ensure that a sustainable approach to development, an approach that deals with *systematic* causes of poverty and violence, is achieved. This new approach must also ensure that it is Sierra Leoneans and their government who take control of development, as the Ebola outbreak has proved how important local direction and ownership of disaster response is. A panoptic meditation of a 'global system' and its ramifications is admittedly difficult, but Ebola rumours are moving insights into sections of the reality of our current world system and must not be overlooked.

Thus, Ebola rumours do not exist in a vacuum and are intertwined with the social, political and historical world in which they emerge and therefore allow us to apprehend people's interpretations of events in which rumours arise. Consequently, rumours are an important and insightful vehicle for understanding people's lived experience of challenging and ambiguous circumstances that are catalysts for rumours. History has shown that Sierra Leoneans have justifications for their scepticism of their corrupt government, the international community and its exploitative connotations, and the systematic categorisation of Sierra Leoneans as 'traditional' people that need educating.

The post-recovery phase is dealing with some of these issues. For example, a lot of emphasis has been placed on strengthening health structures and ensuring they feed into the Ministry of Health and Sanitation, rather than focussing on individual development projects. But this focus on structure must be sustained and go much deeper to ensure that Sierra Leone is able to fund and manage a health system that works, and this involves confronting some extremely complex and long-term problems.

As the recent Ebola outbreak has shown, when people's perceptions and the reasons for people's reactions are respected, the health response will also be more successful. Analysing rumours is not the only solution to overcoming Ebola, but they provide insights into all of these problems, which makes them a powerful medium in which to bring the Ebola response and the subsequent healing process to a more equal and effective level.

REFERENCES

Abramowitz, S. (2014) How the Liberian health sector became a vector for Ebola. *Cultural Anthropology*. [Online] 7th October. Available From: http://www.culanth.org/fieldsights/598-how-the-liberian-health-sector-became-a-vector-for-ebola.

Acland, O. (2016) Ebola leaves a painful legacy for survivors in Sierra Leone. *The Guardian.* [Online] 28th April 2016. Available From: http://www. theguardian.com/global-development/2016/apr/28/ebola-survivors-sierra-leone-painful-legacy.

Benton, A. (2014) Ebola, mistrust and humanitarian mobility? *Mats Utas.* [Online] 17th April. Available From: https://matsutas.wordpress. com/2014/08/18/ebola-mistrust-and-humanitarian-mobility-by-adia-benton/.

Bloom, G. et al., (2015) Strengthening health systems for resilience. *Institute of Development Studies.* [Online] 24th Febuary. Available From: http://www.ids.ac.uk/publication/ strengthening-health-systems-for-resilience.

Buse, K., Fustukian, S. and Lee, K. (2002) An Introduction to Global Health Policy. In Buse, K., Fustkian, S. and Lee, K. (eds.). *Health Policy in a Globalising world.* Cambridge: Cambridge University Press.

Drakeley. (2015) Defining the biomedical, environmental and social risk factors for human infection with Plasmodium knowlesi; opportunity. *London School of Hygiene and Tropical Medicine.* [Online] NERC Science of the Environment. Available From: http://www.nerc.ac.uk/ research/funded/programmes/esei/drakeley/.

EurekAlert. (2014) *Sierra Leone samples: Ebola evidence in West Africa 2006.* [Online] 14th July. Available From: http://www.eurekalert.org/pub_releases/2014-07/uamr-sls071414.php.

Fairhead, J. (2015) *Understanding Social Resistance to Ebola Response in Guinea.* [Working Paper].

Farmer, P. (1997) On Suffering and Structural Violence: A View from Below. In Das, V., Kleinman, A. and Lock, M. (eds.). *Social Suffering.* Berkeley and London: University of California Press. pp. 261-283.

Ginsburg, J. (2014) How saving West African forests might have prevented the Ebola epidemic. *The Guardian.* [Online] 3rd October. Available From: http://www.theguardian. com/vital-signs/2014/oct/03/ebola-epidemic-bats-deforestation-west-africa-guinea-sierra-leone-liberia.

Glasgow, S. and Pirages, D. Microsecurity. In Price-Smith, A. (ed.). *Plagues and Politics: Infectious Disease and International Policy.* Basingstoke: Palgrave Macmillan.

Hanlon, J. (2007) Is the International Community Helping to Recreate the Preconditions for War in Sierra Leone? *Routledge.* [Online] The Round Table: the Commonwealth Journal of International Affairs Volume: 94 No:381. pp. 459-472. Available From: http://www.tandfonline.com.ezproxy.sussex.ac.uk/doi/pdf/10.1080/00358530500243641.

Keen, D. (2005) *Conflict and Collusion in Sierra Leone.* New York: Palgrave.

Mark, M. (2014) Soldiers deployed in Sierra Leone and Liberia to contain Ebola outbreak. *The Guardian.* [Online] 5th August. Available From: http://www.theguardian.com/ world/2014/aug/05/soldiers-sierra-leone-liberia-ebola.

McCoy, T. (2014) How deforestation shares the blame for the Ebola epidemic. *The Washington Post.* [Online] 8th July. Available From: http://www. washingtonpost.com/ news/morning-mix/wp/2014/07/08/how-deforestation-and-human-activity-could-be-to-blame-for-the-ebola-pandemic/.

MEDECINES SANS FRONTIERES. (2015) *Pushed to the limit and beyond: a year into the largest ever Ebola outbreak.* [Online] 23rd March. Available From: http://www.msf.org. uk/sites/uk/files/ebola_-_pushed_to_ the_limit_and_beyond.pdf.

Plan. (2015) *How Ebola community care units are helping to stop the spread of Ebola.* [Online]. Available From: http://plan-international.org/about-plan/resources/news/how-ebola-community-care-units-are-helping-to-stop-the-spread-of-ebola/.

Reuters. (2014) *Ebola center in Sierra Leone under guard after protest march.* [Online] 27th July. Available From: http://af.reuters.com/article/topNews/idAFKBN0FW04D20140727.

Richards, P. (1996) *Fighting for the Rainforest: War, Youth and Resources in Sierra Leone*. London: Heinemann.

WORLD HEALTH ORGANISATION. (2014) *WHO statement on the meeting of the International Health Regulations Emergency Committee regarding the 2014 Ebola outbreak in West Africa,'* [Online] 8 August 2014. Available From: http://www.who.int/mediacentre/news/statements/2014/ ebola-20140808/en/.

World Health Organisation. (2015) *WHO Strategic Response Plan 2015: West Africa Ebola Outbreak.* [Online] WHO Press. Available From: http://apps.who.int/iris/bitstream/10665/163360/1/9789241508698_eng.pdf?ua=1&ua=1.

In: Handbook on Africa
Editor: Whitney Sherman
ISBN: 978-1-53610-063-1

Chapter 7

LATE QUATERNARY ENVIRONMENTAL CHANGE IN THE NAMIBIA OF SOUTHERN AFRICA

Bingqi Zhu[1], Xunming Wang[1], Jingjie Yu[1], Patrick Rioual[2], Yichi Zhang[1] and Ping Wang[1]

[1]Key Laboratory of Water Cycle and Related Land Surface Processes,
Institute of Geographic Sciences and Natural Resources Research,
Chinese Academy of Sciences, Beijing, China
[2]Key Laboratory of Cenozoic Geology and Environment,
Institute of Geology and Geophysics,
Chinese Academy of Sciences, Beijing, China

ABSTRACT

Arid and semiarid landscapes appear to preserve more evidence of former environmental conditions, although high contemporary erosion rates and the paucity of long terrestrial-sedimentary sequences hinder their complete elucidation. This paper focuses on the late Quaternary environmental change in the Namibia in southern Africa. The Namibia is located at the interface of tropical, subtropical and temperate atmospheric and oceanic systems. Despite the fact that southern Africa was not subject to Quaternary glaciation per se, the influence of variations in amount and seasonality of rainfall has been very marked indeed. The relationship between geomorphology and climate in Namibia reveals the degree and extent to which its landscapes are determined by changing environmental conditions, especially during the Late Quaternary. Case studies of late Quaternary environmental changes in the northern, western and central Namibia are presented. In the western Namibia, over the last 140 ka during the Late Pleistocene, lower leaf-wax δD and higher $\delta^{13}C$ (more C4 grasses) were recorded in a marine sediment core at 23°S off the coast of Namibia, which indicates wetter Southern Hemisphere (SH) summer conditions and increased seasonality, during SH insolation maxima relative to minima and during the last glacial period relative to the Holocene and the last interglacial period. In the central part of the Namibia, the application of OSL dating to both aeolian and fluvial sediments from the Namib Desert is contributing to the understanding of palaeohydrological, palaeoenvironmental and palaeoclimatic change in the region. OSL chronologies from two complex linear dune features close to Gobabeb

suggest the current dunes are young (Holocene age), with important messages about the dynamics of the system and migration rates, whilst OSL ages from dunes in the southern part of the Sand Sea suggests older material of up to 24 ka at 5 m depth. The Holocene environmental change in northern Namibia can be deduced from evidences from soils and sediments in the Otjiwarongo thornbush savanna. In this region degradation and desertification (man-made aridification) of drylands are developed during the Holocene. Vertisol–Kastanozem–Calcisol soil associations occur widely (as patches of several hundred hectares in extent). They have formed in fine-grained Mid-Holocene sediments which accumulated on both sides of the subcontinental watershed. Kastanozem formation cannot be explained by the environments that exist at present. The humification suggests open savanna environments in the past and does not accord with the shrublands and thornbush savanna at present. Pedological and geomorphic investigations distinguish separate degradational stages in space and time caused by different periods of human impact. Landscape degradation seems to have started in pre-colonial times (Bantu immigration?) most likely as a consequence of cattle farming, and was increased by farming since the end of the 19th century by European settlers. Degradation of vegetation and soils, and river channel formation, seem to be the main causes of farmland aridification. These examples from different regions of the Namibia document an increasing intensity of human impact on landscapes to the extent that people now play the dominant geomorphological role, especially in semiarid and coastal areas. The conclusion offers pointers as to how geomorphological evidence of Quaternary change can be used to assist in the better management of contemporary and future environmental conditions.

Keywords: quaternary, palaeoclimate change, landform evolution, geomorphology, human impact

1. INTRODUCTION: THE IMPORTANCE OF THE NAMIBIA QUATERNARY

One of the reasons for the Quaternary environment research is that it is an imperative to understand environmental changes of the past as a key to more appropriate management of changes evidently occurring at present and in the future (Meadows, 2011). The historical (documentary) record of climate change is impossibly short and a full comprehension of the dynamics of contemporary environmental systems, i.e., distinguishing 'noise' from 'oscillations' and 'trends' requires a much longer-time perspective. Study of the Quaternary not only confirms the ubiquity of change but also the detailed responses of the flora and fauna (including our own species) to such change. In short, the Quaternary is the archive against which is measured the nature, causal factors, frequency and magnitude of contemporary environmental dynamics.

But what of the Namibia Quaternary in particular is? The territory of Namibia is located in Southern Africa of the southern hemisphere, an area of the African continent south of approximately 19°S (19-29°S, 12-21°E) (Figure 1) and a subcontinent with a varied but coherent set of physical geographical characteristics.

In a global scale, the southern hemisphere occupies a key position in the global climate system because, in comparison to the northern hemisphere, it is much more oceanic in character and therefore plays the dominant global role in redistributing solar radiation energy. Climate is closely linked to oceanic circulation, a linkage that is manifested in the salinity and

temperature gradients producing the thermohaline circulation, or conveyor, which ultimately transfers North Atlantic Deep Water to the southern oceans and in the process impacts on global energy distribution (Broecker et al., 1985). An understanding of Quaternary environmental changes within and offshore southern Africa becomes a significant element in the reconstruction of the dynamics of this thermohaline conveyor (the return limb of which passes offshore of the subcontinent from east to west), which has been held responsible for sub-Milankovitch scale global climate changes, such as the Younger Dryas at the end of the last glacial (Broecker and Denton, 1990). Changes in the southern African environment arguably are also of significance to the understanding of environmental perturbations at lower latitudes in inter-tropical Africa.

Figure 1. The geographical distribution of the Namibia.

Tropical to sub-tropical southwestern Africa (between about 17◦S and 30◦S) experiences semi-arid to hyper-arid conditions (Tyson, 1986) due its position in-between the influence of precipitation from low-latitude tropical climate systems in the north and mid-latitude climate systems in the south. The climate of southern Africa is inherently variable on a wide range of time scales (Tyson, 1986), through seasonal, annual, decadal up to millennial and beyond. This manifests itself particularly in terms of fluctuations in the amount and seasonality of rainfall. For example, Tyson et al. (1975) have described the importance of a spatially

coherent 18-year oscillation in rainfall values over the summer rainfall region for the meteorological record (1910 to 1972). The existence of such fluctuations over longer time periods is also apparent and it becomes clear that significant variations in the patterns of precipitation and temperature, some of which are in phase with global climate-forcing factors, such as the perceived solar radiation changes due to orbital eccentricities (Partridge, 1997), are a key component of southern Africa's environmental situation and one that needs to be elucidated as far as possible. Unfortunately, due to this aridity, long terrestrial palaeoclimate records are rare and thus our understanding of past changes in precipitation remains incomplete.

Integral to the variability of rainfall and other climate elements is the issue of natural resource management. The economy of southern African nations (Namibia) is based primarily on resource extraction, the agricultural and pastoral component of which is strongly responsive to climate variability. A comprehensive understanding of the details and mechanisms underlying environmental change is essential in order to manage more reliably these increasingly stressed agricultural resources. Comprehending the regional and subcontinental scale environmental changes in the context of General Circulation Models, which generate scenarios of future climate conditions, is an important goal; Quaternary data play a significant part in achieving that goal. A resource-related issue is the problem of desertification in southern Africa.

The aim of this paper is to present a strong case in the southern hemisphere for a consideration of Quaternary events in understanding the landscapes of Namibia and, furthermore, to argue that such an understanding is vital to the appropriate management of its environments. There are a number of important underlying reasons why a more comprehensive understanding of Quaternary environmental changes in this subcontinent should be an important goal, and why geomorphologists need to practice their science with these changes in mind.

2. REGIONAL SETTING AND METHODOLOGY

The mean elevation of the African continent is higher than the mean elevations of the other continents. It is characterized by a bimodal topography with long wavelength reliefs in plateau in the south and in cuvette in the north (Partridge and Maud, 1987; Doucouré and de Wit, 2003). The South African Plateau (SAP) is a major morphological feature that affects nearly one third of the continent. The South Namibian Plateau, which belongs to the South African Plateau, is situated between 25°-29°S and 15°-20°E.

2.1. Topographical, Geomorphological and Geological Setting of the Namibia

Topographically, the Namibia, particularly the South Namibian Plateau (SNP) which is the major part of the South African Plateau, is strongly contrasted with a relief that varies between 0 and 2183 m (Owono et al., 2016). The Namibian margin is characterized by a coastline that has evolved in a large escarpment with a difference in level of more than 1000 m, a coastal plain approximately 150 km wide and an inner flank. Two deserts surround this

vast plateau: the Kalahari Desert to the east and the Namib Desert to the west. Four major morphological provinces or domains were spatially defined according to their relative reliefs, directions and senses of surface water flow, depth incision and lateral tilting (Owono et al., 2016). They are (1) the coastal province (CP), (2) the intermediate province (IP), (3) the upper province and (4) the lower province or Kalahari province (LP). In drainage pattern, South Namibia presents two types of drainage system: one on the coastal plain and the other in the inner plateau (Owono et al., 2016). The coastal plain is crossed by numerous rivers with courses roughly orthogonal to the coast. Some of rivers are thrown directly into the sea, but the majority is lost in the Namib dunes before reaching the sea. Overall, the coastal networks are more or less dendritic, and all of the rivers have temporary flows. Therefore, the external network could be a young network in the process of installing (Owono et al., 2016). The internal network in the inner plateau is the oldest network with a moderate incision. This network is characterized by a dendritic pattern around a main collector, the Orange River (458 km), and becomes more parallel towards the north.

The geological history of South Namibia includes the formation of the Damara chain during the Pan-African, the opening of the South Atlantic Ocean and the Cenozoic evolution (Owono et al., 2016).

The Namibia landscape was shaped during the opening of the Atlantic Ocean, which took place progressively from the breakup of the Pangea supercontinent in the Jurassic, and that of the Gondwana during the Cretaceous (Scotese et al., 1988). The rifting associated with the opening of the Atlantic Ocean was accompanied by two continental volcanic episodes (Storey, 1995): the Karoo volcanism in the Jurassic at the early stages of continental breakup between Africa and South America (Cox, 1992) and the trapp volcanism of Etendeka in the Cretaceous (Wilson, 1992; Storey, 1995). The opening of the South Atlantic led to an uplift of the Namibian border parallel to the rift. This uplift generated the "Great Escarpment," a 1000 m high cliff that has continued to retreat eastward due to erosional activities (Ollier and Marker, 1985).

The Cenozoic history of Namibia has been mainly sedimentary. On the coastal plain currently occupied by the Namib Desert (Ward, 1987), the "Namib unconformity surface" separates the older rocks of the Precambrian basement from the Cenozoic deposits. On this surface lies the oldest unit, the "Tsondab Sandstone" Formation of early Palaeocene age (Ward, 1987). More recent conglomerates (Karpfen cliff Conglomerates) confirm the erosion of the escarpment during the Miocene (Ward, 1987). To the east of the scarp, sedimentation is continental (fluvio-lacustrine) with the deposits of the Kalahari Sequence being the most recent (Cretaceous to Tertiary) (Miller, 1992). The development of the cold Benguela current since the late Miocene led to arid conditions responsible for the current climate of the Namib Desert. The Kalahari basin was developed during the Tertiary due to the alternations of dry and humid periods. It was also during this period that most of the canyons were formed.

The tectonic setting is marked by two extensional phases of deformation that have affected the South African Plateau (SAP) during the Cenozoic (Mvondo et al., 2011). The characteristics of these deformations are consistent with mantle dynamics that acted on the lithosphere of the SAP and impacted the landscape evolution during the Late Cenozoic (Forte et al., 2010).

2.2. Climate Setting of the Namibia (Southwestern Africa)

Southwestern Africa experiences arid conditions due to the South Atlantic Anticyclone, which is strongest and furthest south during SH winter (e.g., Tyson, 1986). The western part of Namibia experiences the most pronounced aridity due to the cold sea surface temperature of the Benguela upwelling region, which stabilizes air and prevents convection (e.g., Eckardt et al., 2013). Most precipitation delivered to southwestern Africa is tropical convective precipitation, which is delivered by the southernmost extension of the East African monsoon in SH summer (the northerly East African monsoon), resulting in decreasing precipitation amounts from NE to SW. SH summer rainfall is associated with Tropical-Temperate Troughs (TTTs), the Congo Air Boundary (CAB) and the Angola Low (Eckardt et al., 2013). TTTs form when tropical systems connect with mid-latitude low pressure systems and form cloud bands which move eastward across southern Africa and are thought to be the most important source of moisture in southern Africa (Harrison, 1984; Todd et al., 2004). As well as tropical systems, the mid-latitude westerly winds bring a limited amount of moisture to the very south of southwestern Africa when they shift northward during the SH winter season. Finally, in the hyper-arid Namib Desert, fog constitutes a regular but minor source of moisture (Olivier, 1995). Most of the moisture delivered to southwestern Africa originates from the Indian Ocean (Tyson, 1986; Rouault et al., 2003; Gimeno et al., 2010). The Atlantic Ocean also contributes some moisture to this region: to the north of the cold Benguela Upwelling, the SE trade winds are deflected clockwise (e.g., Leroux, 1983; Servain and Legler, 1986), carrying some moisture on-land (e.g., Rouault et al., 2003; Eckardt et al., 2013), and the winter westerlies also source moisture from the Atlantic Ocean (Rouault et al., 2003).

The arid west coast of the southern African subcontinent is rarely disturbed by rain events. Arid regions such as the Namib are the result of dry descending air as part of the Global Hadley Circulation. A strong NE-SW rainfall gradient across southern Africa results in the semi-arid Kalahari and Karoo and ultimately the hyper-arid Namib coast. The subsidence associated with the South Atlantic High Pressure (anticyclone), along with the stable air generated by the cold sea surface temperatures, introduces stability which effectively suppresses convection along the southern African west coast (Logan, 1960; Pietruszka and Seely, 1985) which is further accentuated by a shallow surface temperature inversion.

Rainfall in the Namibia is spatially and temporally highly variable (Mattes and Mason, 1998; Tyson, 1986; Eckardt et al., 2013). Central southern African and in particular Namib rainfall is subject to both inter- and intra-annual variations (Seely, 1978; Mason and Jury, 1997). Average precipitation in the Namib ranges from 50 to 100 mm in the far south, 5-18 mm in the central Namib and less than 50 mm along the Angolan coast in the north. Furthermore, there is an increase in rainfall from west (~10 mm at the coast) to east (~60 mm at 100 km inland) (Seely, 1978; Lancaster et al., 1984; Pietruszka and Seely, 1985; Southgate et al., 1996; Hachfeld and Jurgens, 2000; Henschel and Seely, 2008) producing a steep but variable rainfall gradient from the desert interior to the Namibian highland.

The Namib only covers the western fifth of Namibia, and thus a small portion of southern Africa, however many of the climatic systems which bring rain to the surrounding regions also have the potential to influence rainfall along the west coast. Atmospheric moisture availability is dependent on sea surface temperature variability in the south east Atlantic beyond the Benguela upwelling, the western Indian Ocean as well as the tropical Pacific in

particular El Nino Southern Oscillation (ENSO) (Shannon et al., 1986; Walker and Shillington, 1990; Mason, 1995; Mason and Jury, 1997; Lindesay, 1998; Landman and Mason, 1999; Todd and Washington, 1999; Cook, 2000; Reason, 2002; Reason et al., 2000; Tyson and Preston-Whyte, 2001; Rouault et al., 2003; Reason et al., 2006). Namibian precipitation largely occurs during convective thunderstorms, common throughout the region (Tyson and Preston-Whyte, 2001), including the Namib (Gamble, 1980; Hachfeld and Jürgens, 2000; Lancaster et al., 1984; Sharon, 1981).

2.3. Material and Methods

Reliable chronologies are essential for the paleoenvironmental interpretation of landforms but the absence of closed geochemical systems and fossilized organic remnants or strata in arid regions (such as in the southwestern Kalahari Desert) makes it very difficult to contribute to paleoclimatic reconstructions. Due to repeated cycles of carbonate mobilization ^{14}C-dating is often not able to produce reliable age data in desert areas. Similar problems can occur using U/Th-dating methods (Geyh, 1995). During the last few years optical- and thermo-luminescence (OSL and TL) dating of quartz and feldspar bearing sediments led to new progress in paleoclimatic research in arid regions: If carefully applied, luminescence dating techniques provide the possibility to date a mineral grain's last exposure to sun light. In many studies these techniques have successfully been used on aeolian sediments during the last decade (e.g., Wintle, 1993). In the northern, western and southeastern Namibia, some researchers presented OSL and TL results from aeolian and fluvial sediments (Buch and Zoller, 1992; Eitel and Zoller, 1995, 1996; Blumel et al., 1998; Lancaster, 2002; Stone and Thomas, 2013; Stone, 2013). This study combines these results to assess the paleoenvironmental evolution of landforms in the Namib Desert.

Besides chronologies, geomorphology is emphatically used as a method for its qualitative and quantitative approaches, all based on the principle of Tricart and Cailleux (1963) that any bedrock/sediment deformation or any variation of lithology has a morphological signature. The morphological analysis of Namibia combines (1) a literature survey, (2) analysis of geological maps at multiple scales, such as 1:250,000, and (3) digital elevation model (DEM) analysis within ArcGIS.

Literature data and information from geological maps allowed us to highlight the nature and the path of the geomorphological processes. The SRTM-3 data were used by Owono et al. (2016) to produce DEM of the south Namibia. The results of their work were highly evaluated and cited in this study. The importance of SRTM data for the environment, geomorphology or tectonic studies has been widely recognized. Rabus et al. (2003) showed that SRTM-3 data are of high quality and can be used to replace the DEM from 1:250,000 scale topographic maps in many studies (including geomorphology, tectonics, ecology and hydrology).

Geomorphologic assessment through morphometric indices can be used to constrain the role of lithology, tectonics and base level and to characterize and discriminate key geomorphic processes in an arid context (Owono et al., 2016). Table 1 summarizes the formulas, equations and parameters used for the calculation or computation and the threshold values interpretation. Concerning landform analysis, relative relief (R) (Partsch, 1911; Mark, 1975; Rowberry, 2012), elevation–relief ratio (E) (Rowberry, 2012) and hypsometric integral

(HI) (Pike and Wilson, 1971) are used as powerful tools to identify denudation processes and measure the degree of landscape dissection (Evans, 1972). Hypsometric curves provide additional arguments on the morphology of landforms and their relationship with tectonics. Young basins are characterized by convex curves, mature basins with S-shapes and peneplains by concave ascending shapes (Strahler, 1952).

Table 1. Morphometric indices used for the landscape analysis: formulas and equations used for their calculation or computation and threshold values interpretation (cited from Owono et al., 2016)

Morphometric indices	Formulas and parameters	Threshold values interpretation
Relative relief (R)	R = (ΔH/P) × 100 ΔH: difference between the highest and the lowest altitude of a given area; P: perimeter of the same area.	R>0.5: high relative relief; R<0.5: low relative relief;
Elevation-relief ratio (E)	E = (Me - me) / (Ma - me) Me, me and Ma: mean, minimum and maximum elevation.	E nearer 0: concave or broad flat terrain with isolated peaks; E nearer 1: convex or broad flat terrain with deep incision;
Hypsometric integral (HI)	HI = (Hmean–Hmin)/(Hmax–Hmin) Hmean, Hmin and Hmax: mean, minimum and maximum elevation.	HI>0.6: younger stages of basin development, most of the topography is high relative to the mean;
Morphometric indices	Formulas and parameters	Threshold values interpretation 0.3<HI<0.6: mature basins, extensive and long term erosion, associated with dissected drainage basins; HI<0.3: older basins, such as peneplains.
Valley floor width to valley height ratio (Vf)	Vf = 2Vfw/((Eld ld Vfw/((EErd rd Vfw/(Vfw: width of the valley floor; Eld and Esc: elevations of the left and right valley divides	Vf > 1: broad valleys and low uplift rates; Vf <1: V-shaped valleys, actively incising and high uplift rates.
Drainage basin asymmetry (Af)	Af = 100 (Ar/At) Ar: area of the basin to the right (facing downstream) of the trunk stream; At: total area of the drainage basin	Af > 50: the main channel has shifted towards the downstream left side of the drainage basin; Af < 50: the channel has shifted towards the downstream right side of the drainage basin.
Transverse topographic symmetry factor (TTSF)	TTSF = Da/Dd Da: distance from the channel to the basin midline, Dd: distance from the lateral basin margin to the basin midline.	TTSF N 0.5: the drainage basin is influenced by the tilting of the terrain due to tectonic activity; TTSF b 0.5: the tilting does not have an influence on the drainage;
Scarp front sinuosity (Sf)	Sf = Lf/Lr Lf: Length of the scarp front from a point; Lr: Length of the straight line from the same point to the same end point.	Sf low: active scarp fronts; More Sf high: older is the scarp.
Longitudinal profiles of rivers	(1) y - y0 = (y1 - y0)/(x1 - x0) ∗ (x - x0) y: elevation in normal range; x: distance in logarithmic scale; (2) AN=Am + [((AH – AL)/(LogLm – LogLM)) * (LogLi – Log LM)] AN: equilibrium normalised altitude value; AH and AL: highest and lowest altitude; LM and Lm: maximum and minimum length; Li = length value calculated for each considerate point in relation with the upstream	Concave longitudinal profiles are characteristics of old rivers, in equilibrium state; Convex longitudinal profiles are characteristics of young river or old rivers reactivated by fault or affected by uplift.

Morphometric indices	Formulas and parameters	Threshold values interpretation
Concavity index (IC)	IC = 2 A/H A: difference of altitude between the middle profile and a straight line joining the two ends of the profile; H: difference in height between the channel head and the outlet.	IC close to 0: the form of the profile is close to a straight line; IC close to 1: the profile is L shaped.
Dimensionless curves (ratio of altitude-ratio of distance)	H/Ho o of alH and Ho: stream altitudes at the point of measurement, and from the mouth at the headwaters respectively; L and Lo: stream distances at the point of measurement, and from the river mouth at the headwaters respectively.	Help to superpose and compare profiles of different river lengths
Stream-length index (SL)	SL = (ΔH/ΔL)∗L ΔH: difference in elevation between the ends of the considered reach; Δl: length of the reach; L: distance between the measured reach and the drainage divide.	Very high or very low SL values reveal tectonic distortions if there is no correlation with lithologic factors
Drainage density (Dd)	Dd =ΣLi/A Li: length of river; A: watershed area	The more a system is uplifting, the more the drainage density decreases

3. RESULTS AND DISCUSSION

3.1. Geomorphological and Palaeoclimatic Evolution of the South Namibia

The geomorphological and palaeoclimatic evolution of the south Namibia has been systematically reviewed by Owono et al. (2016). In their document, the geomorphological evolution of south Namibia dates essentially from the Jurassic-Cretaceous monoclinal folding of the southern African continental margin in response to the fragmentation of Gondwana. Later on, the region underwent a significant flattening (Owono et al., 2016). King (1956) described three main planation surfaces in South Africa: the Gondwana Surface (Jurassic), the African Surface (late Cretaceous to early Tertiary) and the Post-African Surface (late Tertiary). King (1962) showed that the establishment of these surfaces was related to a large denudation that occurred in the region after the breakup of Gondwana. The event affected all Africa and impacted its landscape; King (1963) extrapolated those surfaces to the entirety of Africa. This denudation was explained to have been due to a pediplanation with associated cycles of river incision, scarp retreat and pedimentation (King, 1955). After this event, the formation of laterite occurred in Namibia during the late Cretaceous-middle Eocene (Pickford and Senut, 1999). Another well-described event affecting the morphology of the region is the uplift of the South Namibia Plateau (SNP). Burke and Gunnell (2008) proposed a post-Oligocene age for the uplift and tied it to the mantle-related "swell" dynamics of the African continent, which appear to have promoted large-scale plateau uplift. Partridge and Maud (1987) suggested a very recent age of uplift (late Pliocene).

Climate change has also greatly impacted the landscape of the south Namibia. The available data are at the scale of the African continent. Three periods are well constrained: Cretaceous, Eocene and Miocene to Present (Owono et al., 2016). Nevertheless, there are no continuous data for the Palaeocene and the Oligocene (Owono et al., 2016). The Cretaceous was semi-arid to arid approximately 130 Ma and 85 Ma (Gomez et al., 2002; Sandersen,

2006). The second half of the late Cretaceous up until the middle Eocene (85–40 Ma) was very humid along the Atlantic coast (De Villiers, 1999; Sandersen, 2006). This humid period coincided with the formation of the laterite in Namibia (Pickford and Senut, 1999), a widespread process across Africa with well constrained age brackets for Burkina Faso (West Africa) between 59 and 45 Ma (Beauvais et al., 2008). The early Miocene was humid (Bamford and de Wit, 1993; Bamford, 2000). After the middle Miocene, South Namibia and particularly the coastal plain became and remained arid (Pickford and Senut, 1999).

A morphological analysis of the modern landscapes in the South Namibia Plateau based on geometrical parameters (as listed in Table 1) through the DEM, slope map and transverse profiles was conducted by Owono et al. (2016). The results showed that the modern-scale landscape of the SNP is controlled primarily by tectonics and also by the lithology, base level and climate.

3.1.1. Tectonics and Base Level Control

For example, the negative and very low ICs (<0.3) combined with low values of TTSF (<0.5) and the Af (Table 1), imply that the region of the SNP underwent an inhomogeneous uplift or several episodes of uplift. According to Hack (1973), when the fluvial incision rate exceeds the uplift or base level lowering rates, the profile goes to a steady state with a smooth downstream concavity. This is not the case for either of the coastal network profiles in the south Namibia, where very important jumps and numerous knickpoints have been observed and the internal network rivers have almost convex profiles (Owono et al., 2016). To attain a steady state, a profile needs a long time, and the response time is on the order of 1 Ma in tectonically active regions under detachment-limited conditions and during periods of climate stability (Whipple, 2001) and at least 3 Ma under stable tectonic conditions. However, all of the rivers of the internal network and their tributaries in the SNP are over 3 Ma, at least upper Cretaceous to Eocene for the Orange, the Fish and the Konkiep (Mvondo et al., 2011), and consequently should be in a dynamic equilibrium state. That is not the case in the SNP. Therefore, it can be concluded that vertical movements in the SNP exceed the rate of incision. The rivers and their tributaries cannot develop an equilibrium profile. The long stream profiles are the result of continuous adjustment at least since the Eocene until the present day (Owono et al., 2016).

The hypsometric integral values (Table 1) for the different watersheds and sub-watersheds in SAP are approximately 0.5. It means that there are still 50% of the original non-eroded masses (Owono et al., 2016). This result reflects the maturity of the SNP basins, but do not entirely reflect the hypsometric curves, whose forms according to Strahler (1952) should be exclusively “S”-shaped. The hypsometric curves of the different basins that constitute the different planation surfaces of the SNP show various and complex forms that combine concave patterns, S-shapes and more convex trends (Owono et al., 2016). This reflects an evolution marked by an alternation of several tectonic and erosive episodes. The model of cyclic erosion leading to the formation of a peneplain (Davis, 1930) cannot explain the geometry of these curves according to the variable types of surfaces encountered in the SNP. The model of Penck (1924) suggests a prolongated uplift during which erosion registers one or many flattenings at the periphery of the elevated area according to the variation of the uplift velocity. Yet, in the SNP, several phases of uplift have been described (Dauteuil et al., 2015) and reveal the shortcomings of this model. However, the models of King (1962) and Grandin and Thiry (1983) that are based respectively on pediplanation and etchplanation

seem to be more adapted (Owono et al., 2016). The model of King (1962) reflects a punctuated evolution of tectonic pulsations followed by incision and flattening phases and a retreat of scarps or backwearing. These processes lead to the coalescence of the pediments (Cooke et al., 1993) and the reduction in the reliefs of the hillocks and inselbergs are well described in the coastal surface. Etchplanation appears to be especially characteristic of the ancient and stable rocks where deep weathering occurred. The Kalahari, high and low surfaces are the best examples in the SNP (Owono et al., 2016). Finally, according to the hypsometric curves and hypsometric integral, the South Namibia landscapes consist of coalescence surfaces of different ages that have undergone a polycyclic evolution marked by more than one pediplanation and or etchplanation processes due to the different phases of uplift.

3.1.2. Tectonic and Lithology Controls

The drainage patterns in a region are an important clue for identifying the tectonic and lithology controls and also for quantifying the base level action (Owono et al., 2016). The inner streams in the SNP display convex profiles with a few knickpoints (Owono et al., 2016). Some of them are located in the contact of two lithologies, and others are related to the presence of faults, which coincide in certain cases with the contact of the different lithologies (Owono et al., 2016). The SL-index values (see Table 1 for its interpretation) are also high, conveying tectonic effects (Owono et al., 2016). The equilibrium longitudinal profiles give straight lines when they are plotted on a semilogarithmic scale (Hack, 1973). The deviations D (see Table 1 for its interpretation) measured at the outlet towards the downstream with respect to this straight line allow the type of control, either lithological or base level changes, to be determined. According to Goldrick and Bishop (1995), a variation of the base level involving a retreat of knickpoints is verified when the main course and its tributaries have the same value of D. However, in the SNP, the values of D of the tributaries are higher than those of the main courses (Owono et al., 2016). That implies that the control exerted by the base level is less significant. For the rivers that cross several lithologies, the D values are high. That is observed for the Orange and Konkiep Rivers tributaries. The rivers of the inner plateau in the SNP are then controlled by lithology, tectonics and climate acting together.

3.1.3. Tectonic and Sea Level Control

Although the long profiles of the coastal rivers are globally concave, they are not smooth (Owono et al., 2016). All of these rivers display knickpoints. In particular, the Isurub River in the SNP presents a concave upstream portion and a linear profile downstream (Owono et al., 2016). This could be interpreted as the recording of a reactivation of a system partially in balance. Apart from Kp7 in the Koichab River and Kp1 in the Tsaris River, which coincide with the contact of two different lithologies, some of the streams flow on uniform lithologies. The SL-index values for the main rivers of this area in the SNP are very high and above 200 (Owono et al., 2016). Such values, in the absence of any correlation with lithology, show that these knickpoints are due to tectonics (Hack, 1973; Keller and Pinter, 1996, 2002). However, these profiles have numerous downstream knickpoints of large magnitude and large jumps (Owono et al., 2016). This probably reflects the recent responses of relative sea level or the recent reactivations of faults, which are probably buried under theNamib Dunes (Owono et al., 2016). It can finally be assumed that the coastal surface is controlled by tectonics and sea level.

3.1.4. Climate and Eustasy Control

As above mentioned, the tectonic controls on the landscapes of the SNP are especially dominated by uplifts. Dauteuil et al. (2015) have identified in the southern part of the SNP, close to the Orange River, three episodes of uplift: a slow uplift (10 m/Ma), followed by a second interval of uplift involving a cumulative magnitude of at least 200 m and the third stage of uplift of 60 m magnitude occurred after the Middle Miocene. Two types of networks are described in this place: one in the coastal plain, which is temporary, mainly dendritic, young or in the process of being emplaced or resulting from a series of reactivations of a system partially in equilibrium, and the other in the inner plateau, which is permanent, dendritic with a parallel trend, old and marks a continuous adjustment at least since the Eocene until the present day.

The genesis and the evolution of the coastal surface are controlled by climate, eustasy and deformation, whereas climate, lithology and deformation control the interior plateau (Owono et al., 2016). The climate-controlled processes appear to be the leading factors for the flattening of the inner plateau, whereas the coastal area seems to be more subject to eustatic variations. The longitudinal profiles of coastal rivers, which are concave with numerous knickpoints and large jumps at the end of the profiles in contrast to those of the interior plateau, which are convex, with few knickpoints, well attest to this dichotomy (Owono et al., 2016).

3.2. Glacial-Interglacial Control on Hydroclimate of the West Namibia during the Late Quaternary

There is presently debate regarding the behavior of hydroclimate in southwestern Africa in response to precessional (19–23 kyr cycle) insolation variations (Collins et al., 2014). Increased local summer insolation is expected to increase the land–ocean pressure gradient, bringing more warm, moist air on land and increasing precipitation delivered by the summer monsoon, as has been shown in the northern hemisphere (NH; e.g., Pokras and Mix, 1985; Rossignol-Strick, 1985). In line with this, a 200 ka long sedimentological record from Lake Tswaing in southeastern Africa, suggests that precipitation increased during precessional Southern Hemisphere (SH) summer insolation maxima (Partridge et al., 1997), due to an enhancement of the SH summer East African Monsoon. Similarly, a leaf-wax hydrogen isotope record from the Zambezi River (Schefuß et al., 2011) suggests relatively dry conditions during the mid-Holocene SH summer insolation minimum, relative to the deglacial and late Holocene. In contrast, a hyrax-midden record from the Namib Desert, spanning the last 11.7 ka (one half of the last precessional cycle), suggests a progressive drying from the mid to late Holocene, i.e., wetter rather than drier conditions during the mid-Holocene SH summer insolation minimum (Chase et al.,2009). It was thus suggested that southwestern Africa responds in phase with NH summer insolation (Chase et al., 2009). As such, on precessional time scales it is not yet clear whethe the hydrology of southwestern Africa is controlled by NH or SH summer insolation variations (Collins et al., 2014).

In addition to precessional insolation control, the effect of glacial versus interglacial boundary conditions on the hydroclimate of southwestern Africa is also under debate (Collins et al., 2014). For example, more desert and semi-desert vegetation points to drier conditions

during the last glacial period relative to the Holocene and last interglacial period (Shi et al., 2001; Collins et al., 2011). In contrast, a marine grain-size record (Stuut et al., 2002) and a collection of terrestrial records (Chase and Meadows, 2007) suggest wetter conditions in southwestern Africa during the last glacial period. Depleted isotopes in precipitation would also point to wetter glacial conditions (Collins et al., 2013a). Wetter glacial conditions in southwestern Africa have been interpreted to reflect a northward shift of the SH mid-latitude westerly wind belt during the last glacial period (Cockcroft et al., 1987; Stuut et al., 2002; Chase and Meadows, 2007). However, an alternative mechanism is a southward shift of tropical rain-producing systems due to the expanded NH ice sheets, as is sometimes simulated by climate models (e.g., Kageyama et al., 2013). In summary, studies disagree whether southwestern Africa was wetter or drier during the last glacial period and, for those that do agree on the sign of the changes, different mechanisms have been invoked.

Researchers have investigated the effect of precessional insolation changes and glacial–interglacial boundary conditions on the climate of southwestern Africa using the hydrogen and carbon isotopic composition of terrestrial plant leaf-wax n-alkanes taken from a marine sediment core (Collins et al., 2011, 2013a, 2013b, 2014). n-Alkanes are straight chain hydrocarbon compounds produced as part of the protective layer on terrestrial plant leaves (Koch and Ensikat, 2008; Eglinton and Hamilton, 1967). The hydrogen isotopic composition (δD) of leaf wax n-alkanes is taken as a recorder of the hydrological history of precipitation (e.g., Sachse et al., 2012). The carbon isotopic composition ($\delta 13C$) of leaf-wax n-alkanes reflects the photosynthetic pathway of the plants i.e., the relative contribution of C3 versus C4 vegetation (e.g., Castañeda et al., 2009).

Today the central Namibia is partly savanna vegetated, partly barren. Instrumental data indicate that during 2011, the wettest year on record (since 1962), most of the rain was delivered in a few rainy days and this transformed the barren gravel plains into savanna grassland (Eckardt et al., 2013). Collins et al. (2014) suggested an analogous scenario to have taken place in southwestern Africa in the past: higher $\delta 13C$ values during the last glacial period and insolation maxima indicate an expansion/thickening of C4 grasses across barren areas of the Namib Desert, Namibian Plateau and Kalahari Desert due to increased SH summer rainfall. These periods hence represent maxima in seasonality, in line with Daniau et al. (2013). The dominance of C4 grasses over C3 vegetation throughout the record suggests that semi-arid conditions and high seasonality were a persistent feature of southwestern African climate over the past 140 ka. This is in line with indications of the persistence of aridity based on sedimentary landforms in this region (Lancaster, 2002; Stone and Thomas, 2012).

On precessional timescales, increased summer precipitation in south western Africa during SH summer insolation maxima is in a greement with the record from Lake Tswaing in South Africa (Partridge et al., 1997), and with relatively dry conditions during the mid-Holocene insolation minimum with in the Zambezi River catchment in southeastern Africa (Schefuß et al., 2011). Together these records would suggest that SH summer insolation maxima resulted in wetter conditions throughout most of southern Africa. However, our record contrasts with the Spitzkoppe hyrax-midden record from the Namib Desert (Chase et al., 2009), which indicates wetter conditions during the mid-Holocene SH summer insolation minimum. Although the Holocene is less well-resolved in our record, it is clear for the rest of our record that SH summer insolation minima were drier. One possible explanation for the mismatch may relate to the source areas of the two records. The hyrax-midden record reflects

the climate of the hyraxes' habitat (in close proximity to the midden), situated in the Namib Desert. Our record reflects a wider catchment including material from the Namibian plateau (Eckardt and Kuring, 2005) and the Kalahari Desert (Prospero et al., 2002), further east of the Namib. Consequently, climate in the Namibian Desert may indeed respond in phase with NH summer insolation, perhaps via a control on upwelling intensity, while the Namibian plateau and the Kalahari Desert respond in phase with SH summer insolation. Further records or model simulations are needed to verify this hypothesis.

On glacial–interglacial timescales, our data suggest increased summer precipitation during the last glacial period relative to the Holocene and last interglacial period. This is consistent with the deposition of river-derived silts (the 'Homebsilts') in the Namib Desert during the LGM, thought to indicate increased flow of ephemeral rivers due to wetter conditions on the Namibian plateau (Heine and Heine, 2002). Our record is also in agreement with the grain-size record (Stuut et al., 2002) from the Walvis Ridge which indicates the deposition of finer material during the last glacial period, thought to reflect increased river-derived material and perhaps also attributable to increased flow of ephemeral rivers. Enhanced tropical precipitation in southern Africa during the last glacial period is also in agreement with climate models (e.g., Kageyama et al., 2013) and this would explain lower leaf-wax δD in other southwestern African cores during the LGM relative to the Holocene (Collins et al., 2013a).

In order to understand the interplay between the climate of southwestern African and tropical central Africa, we also compare our record with a record of major-element composition (Schneider et al., 1997) from a site at 6◦S which reflects Congo River discharge and hence wetness in central Africa. The Congo River record indicates wetter conditions during NH summer maxima (i.e., during SH summer insolation minima), and also during the Holocene and last interglacial period, relative to the last glacial period. This response is hence in antiphase to our leaf-wax δD record from further south (23◦S). This implies that SH summer insolation maxima and glacial boundary conditions acted to cause an (albeit minor) enhancement of precipitation in southwestern Africa coeval with drier conditions in central Africa.

In terms of the effect of precessional insolation variability, more humid periods during SH summer insolation maxima likely represent enhanced northerly East African monsoon, which would have brought more moisture into southern Africa, enhancing precipitation. This mechanism would also explain the precessional-timescale antiphase between central Africa and southwestern Africa: in central Africa NH insolation is thought to control the on-land moisture flux (Schneider et al., 1997).

The effect of glacial boundary conditions is more complicated. One explanation for wetter conditions is that winter westerlies shifted north during the last glacial period (Chase and Meadows, 2007; Cockcroft et al., 1987; Stuut et al., 2002). However, lower leaf-wax δD values argue against a shift towards more proximal Atlantic Ocean-sourced westerly precipitation. Moreover, westerly-influenced C3 vegetation (Boom et al., 2014; Carr et al., 2014) did not shift northward during the last glacial period. Additionally, the strong precessional signal throughout our record suggests a continuous influence of the summer monsoon. SH summer insolation was at a maximum in southwestern Africa at the LGM: a simultaneous influence of precipitation from mid-latitude winter westerlies and the summer monsoon at the LGM would have required extreme seasonal shifts in the climate belts. Overall, it is unlikely that a wetter glacial was due to increased precipitation from the winter

westerlies. We suggest that the increased glacial wetness was due to more tropical summer precipitation, mainly from TTTs.

Although wetter conditions during the last glacial period in southwestern Africa were coeval with drier conditions in the Congo Basin, this is unlikely to be due to a straightforward displacement of the tropical precipitation from the Congo Basin towards southwestern Africa because the southern boundary of the rainforest belt was shifted equatorward in western Africa during the LGM (Collins et al., 2011; Dupont et al., 2008; Ning and Dupont, 1997; in turn suggesting a wider SH savanna belt during the last glacial period). Instead, the glacial–interglacial antiphase may represent an increase of the northerly East African monsoon (Indian Ocean) at the expense of the central African monsoon (Atlantic Ocean) similar to the mechanism on precessional timescales. This was perhaps associated with the relatively cold glacial SE Atlantic Ocean (Jansen et al., 1996; Kim et al., 2003) compared with the relatively warm glacial Indian Ocean (Sonzogni et al., 1998).

3.3. Late Quaternary Environmental Change in the Central and Southeastern Namibia: Namib Desert and Kalahari Desert

Today the Namib and Kalahari Deserts are partly savanna vegetated, partly barren. Instrumental data indicate that during 2011, the wettest year on record (since 1962), most of the rain was delivered in a few rainy days and this transformed the barren gravel plains into savanna grassland (Eckardt et al., 2013).

3.3.1. Late Quaternary Environmental and Landscape Change in the Namib Desert

The Namib Desert stretches ~2000 km from the Olifants River in South Africa (32°S) to the Carunjamba River in Angola (14°S), forming a narrow strip, 120-200 km wide, bounded inland by the Great Escarpment. It has been subdivided into four regions: the southern, or transitional, Namib; The Namib Sand Sea, covering 34,000 km^2 and containing extensive dunefields (Lancaster, 1989a); the central Namib Plains, including a rocky gravel plain, the Brandberg mountains and inselbergs; and the northern Namib and Skeleton coast, comprising dissected sandstones, lava-capped plateaux (the Kaokeveld), loess-filled basins and coastal dunefields. The Namib Desert is located at the interface of tropical, subtropical and temperate atmospheric and oceanic systems (Tyson and Preston-Whyte, 2000) and extends over more than 10° of latitude. The region is hyper-arid to arid with lowest rainfall at the coast, owing to subsiding anticyclonic air, the cool offshore Benguela current (Dingle et al., 1996; Eckardt et al., 2013) and the permanent, but not stationary, South Atlantic high-pressure cell along the Namib coast (Tyson and Preston-Whyte, 2000).

Quaternary climatic fluctuations in the Namib Desert should have been linked to variations in above-mentioned atmospheric and oceanic circulations. However, Quaternary palaeoenvironmental and palaeoclimatic reconstruction in the Namib Desert has been limited by a paucity of sites, access difficulties, discontinuous records, difficulties of dating and uncertainty in interpreting the climatic signals from certain proxies (Chase and Meadows, 2007; Gasse et al., 2008; Lancaster, 2002; Stone and Thomas, 2013; Stone, 2013). Since the

latest detailed review for the region by Lancaster (2002), Stone and Thomas (2013) have further performed a synthesis of past environmental and climatic change over the past 128 ka for Namib Desert, by concentrating on the advances made through the application of OSL: to complex linear dunes in the northern Namib Sand Sea (Bristow et al., 2005, 2007), fluvial deposits from five of the west coast ephemeral river catchments (Bourke et al., 2003; Brook et al., 2006; Eitel et al., 2005; Srivastava et al., 2004, 2005; 2006) and sands interdigitated with water-lain interdune deposits in the northern Namib Sand Sea (Stone et al., 2010; Stone, 2013).

The age compilation from cosmogenic-nuclide burial dating and optically stimulated luminescence dating indicates that the Namib Sand Sea is in excess of a million years old (Stone, 2013). Initial data from luminescence dating yields depositional ages for dune sediments from three broad areas of the sand sea that include MIS 5, later in the Pleistocene around the Last Glacial Maximum and the Holocene. Detailed dating and application of ground penetrating radar in the far northern reaches reveals extensive dune migration and deposition during the Holocene (Stone et al., 2010; Stone, 2013). Ewing et al. (2006) provide age estimates for three dune types in the Namib Sand Sea based on pattern analysis and pattern evolution, linked to self-organization (without radiometric age control from the Namib Sand Sea). The boldest attempt at a landscape development model for the Namib Sand Sea comes from Bubenzer and Bolten (2008) for the southern Namib, which divides development into distinct phases relating to changing wind regimes. It is suggested that during the first phase (>20 cal. kyr B.P.) the draa (or mega linear dunes, with dates of 22.5 ka at 5 m depth) accumulated under strengthened trade winds, owing to increased pole-to-tropics temperature and pressure gradients (Sarnthein, 1978; Lancaster et al., 2002). The second-phase of the model suggests that strong westerly winds at the end of the Pleistocene and start of the Holocene, picked up sediment from the western flank of the draas and deposited it on the eastern flanks (with OSL ages from the eastern flank dated by Bubenzer et al. (2007) spanning 10.4–8.8 ka).

In general, the Namib Sand Sea is now digitally recorded by Livingstone et al. (2010). The digital atlas draws attention to the new chronological data available, which although limited in coverage, represents some significant developments (Stone, 2013):

1) Cosmogenic nuclide burial dating of surface samples (Vermeeschet al., 2010) suggest a residence time of at least 1 million years, which accords with previous estimates of sand sea age based on sand volume, and influx, of ~2–3 Ma.
2) OSL dating of sediment burial indicates Pleistocene deposition in MIS 5 (110±5 ka) for one site in the north of the sand sea (Stone et al., 2010) and ages of 18–22.5 ka for two drill holes in the southern part of the sand sea (Bubenzer et al., 2007).
3) OSL data also reveal Holocene activity in the southern sand sea (at 10–8.5 ka) (Bubenzer et al., 2007) and northern extreme, with west–east migration and extensive reworking of a complex linear dune over 6 ka (Bristow et al., 2007) and active superimposed features on the southern tip of a linear dune from 1.4 ka (Bristow et al., 2005).
4) The OSL chronologies are in broad accordance with earlier estimates based on dune-patterning by Ewing et al. (2006).

5) It is important to recognize that OSL ages will only record depositional events that are preserved (and will miss events that have been reworked or removed) (Stone, 2013).

3.3.2. Late Quaternary Environmental Change in the Namibian Part of the Kalahari Desert

South of the Congo-Zambezi watershed the Kalahari Desert covers central parts of the large inner-continental basin of southern Africa. The Kalahari climate is generally semi-arid becoming sub-humid in the northern parts (northern Namibia, northern Botswana, Western Zimbabwe). Ideas of climatic changes in Kalahari of southern Africa have occurred at least since Schwarz (1920) concept of a Kalahari irrigation scheme, which was based on the assumption of an aridification of the Kalahari since the beginning of the 19th century. Studies concerning the paleoclimatic significance of Kalahari landforms especially the 'mekgacha' (dry valleys), the pans and associated lunette as well as the linear dunes--have been intensified since the study by Grove (1969). A short state-of-the-art is given in Thomas and Shaw (1991) and Shaw and Thomas (1996). But until now only a small number of results of geomorphic and (paleo-) environmental studies have been presented from the Namibian part of the southwestern Kalahari (see, for instance, Leser, 1971; Heine, 1981: Lancaster, 1989b; Eitel and Blumel, 1997; Blumel et al., 1998).

The Namibian Kalahari is situated in the transition zone to the hyper-arid Namib Desert in the west and the semiarid Karoo in the south. The aridification of this area is relatively old: First evidence derives from the Miocene layers of the Kalahari Group sediments (Blumel et al., 1998). The Proto-Fish, Proto-Auob and Proto-Nossob River (Wellington, 1955) transported widespread flashflood fan deposits from the Windhoek Highlands and from the central Great Escarpment to the subsiding Nama basin (Eitel and Zoller, 1996) where they covered a lower Tertiary planation surface (Blumel and Eitel, 1994). Due to the glaciation of the Antarctic and the formation of the Benguela upwelling, the aridification led to ubiquitous calcrete complexes containing high amounts of authigenic palygorskite (Watts, 1980; Eitel, 1995). The pedogenic synthesis of this fibrous clay mineral indicates former dry conditions with ca. 150-300mm mean annual precipitation (Paquet and Millot, 1972) during the calcretization. Since this 'Mega Kalahari phase' (Thomas, 1987), knowledge of paleoenvironmental changes of the southwestern Kalahari (Namibia), documented in Pliocene and Quaternary landforms, has remained highly speculative, Even the effects of Late Pleistocene and Holocene climatic fluctuations are uncertain (Blumel et al., 1998).

Thomas et al. (1997) and Stokes et al. (1997) present a suite of OSL data for the southwestern Kalahari Desert (Botswana and R.S.A.). Blumel et al. (1998) used the TL data of linear dunes from the Keetmanshoop-Tses-Aroab triangle and to contribute to the knowledge of Late Quaternary paleoenvironmental changes in the southwestern Kalahari (Namibia). They thought that linear dunes in the southwestern Kalahari Desert provide evidence of the nature of paleoclimates.

It is remarkable that all typical linear dunes in the Grootpan, Swartput se Pan and the vicinity of Aroab in the Namibia Kalahari shifted during the early Holocene (TL ages: 9.5±1.8 ka at Grootpan; 8.8±1.2 ka north of Swartput se Pan; 8±0.6 ka and 17.5±8.1 ka east of Gaukabpan) (Blumel et al., 1998). This points to a younger period of intensive dune remobilization than in the regions further east (Stokes et al., 1997). The high coincidence of

the TL ages of the linear dune complexes over a distance of about 150 km suggests that dune activation in the southwestern Kalahari was not the result of local effects but due to subcontinental climatic changes (Blumel et al., 1998). Taking into account that the vegetation cover does not respond instantly to excess and deficits of rainfall, due to the annual and perennial savanna grassland species, but reflects moisture availability over a number of preceding years (Bullard et al., 1997), the modification of the environment was fundamental in southeastern Namibia.

The early Holocene age of the linear dunes (Blumel et al., 1998) contrasts with the hypothesis that many of the dunes were stabilized by vegetation prior to 33 ka (Lancaster, 1989). Radiocarbon data of calcretized dune sands at Soudpan (33.5±0.88 ka, Lancaster, 1989) may overestimate the age of the dune formation due to carbon exchange in the open systems of the sandy sediments (Blumel et al., 1998). Lancaster (1989) suggested that the last major phase of dune initiation and extension took place during the Late Pleistocene dry period, which may have persisted from ca. 20 to 12 ka. However, a check of all available data shows that "with the exception of the dunebase peat date of 19,680 + 100 at Tsoi, in the Makgadikgadi, the only absolute dates available for dune forms at present are of Holocene age" (Thomas and Shaw, 1991). This fact points to an early Holocene phase of dune activity.

Compared with the aeolian archives of Blumel et al. (1998), a fluvial phase of the Molopo River ended about 14 ka (Heine, 1982), which correlates with features of a great number of pans in the central Kalahari indicating moist conditions after the Late Glacial Maximum (17-12ka, Thomas and Shaw, 1991; Shaw and Thomas, 1996). In the southern Botswana and the R.S.A. a major period of linear dune activity occurred at 17-10 ka (Stokes et al., 1997). An aridification around 12 ka is documented at Kathu Pan by decreased runoff and reduced organic deposition and at Wonderwerk Cave (southeastern Kalahari) by the shifts in species composition of micromammals (Beaumont et al., 1984). Both sites show signs of subsequent moister conditions between 8 and 5 ka (=postglacial global climatic optimum). The suggested arid period in the southeastern Namibia between 4.5 and 3.5 ka (Heine, 1982) may have been regional only because several indications from ancient lake levels (compilation in Thomas and Shaw, 1991) point to more humidity in the northern and central Kalahari (Blumel et al., 1998).

It is obvious that the linear dunes in the southwestern Kalahari are younger than the main stages of pan development. The pan activity has been reduced at least since the early Holocene. Shifting sands filled up several smaller pans or buried large parts of them (Blumel et al., 1998). As shown by the young dunes in Pan 1073 (TL ages: 1.1_+0.1 and 0.1_+0.01 ka, Blumel et al., 1998) this process may have continued in short dry phases during the Holocene. This youngest aeolian activity seems to correspond with data from other parts of the southern Kalahari (R.S.A. and Botswana) published by Thomas et al. (1997). Unfortunately, until now it cannot be decided if the aridity was interrupted by more humid phases (Blumel et al., 1998).

3.4. Holocene Environmental Change and Desertification in the Northern Namibia

The Holocene environmental change in northern Namibia can be deduced from evidences from soils and sediments in the Otjiwarongo thornbush savanna. In this region degradation

and desertification (man-made aridification) of drylands are developed during the Holocene (Eitel et al., 2002). Vertisol–Kastanozem–Calcisol soil associations occur widely (as patches of several hundred hectares in extent). They have formed in fine-grained Mid-Holocene sediments which accumulated on both sides of the subcontinental watershed (Eitel et al., 2002). Kastanozem formation cannot be explained by the environments that exist at present. The humification suggests open savanna environments in the past and does not accord with the shrublands and thornbush savanna at present. Using AMS 14C and OSL data (Eitel et al., 2002), it is possible to distinguish two periods of soil degradation during the recent past. Initially, most of the Kastanozems and Vertisols were buried by slope wash sediments to a depth of several decimetres. This process started in the mid-19th century at the latest. In a second phase, the soils were affected by rill and gully erosion, indicating increased runoff. This occurred during the last decades of the 19th and the first decades of the 20th century, probably as a result of intensified cattle farming. In contrast to other parts of Namibia, the prominent river channels of the Otjiwarongo region, most of them up to 20 m wide and 3–4 m deep, are a result of recent erosion (Eitel et al., 2002).

In the Otjiwarongo region, the fine-grained Mid-Holocene sediments and related soils rich in organic matter are an important natural resource. Work from Eitel et al. (2002) shows that the dark surface soil horizons of Vertisols, Kastanozems and Calcisols were formed under open grasslands in shallow valleys which existed until the 19th century. At present, most of the soils are affected by erosion. Pedological and geomorphic investigations distinguish separate degradational stages in space and time caused by different periods of human impact. Landscape degradation seems to have started in pre-colonial times (Bantu immigration?) most likely as a consequence of cattle farming, and was increased by farming since the end of the 19th century by European settlers. In contrast to former ideas that the incised river channels are a natural feature of the Otjiwarongo region, there is pedological and geomorphic evidence that they result from these recent changes in settlement and land use patterns. The fertile soils on Mid-Holocene sediments, especially the Kastanozems and the Calcisols with thick Ah horizons, are water retentive and therefore provide good grazing for cattle and game. With erosion and river channel formation, drainage is intensified and subsequent aridification of the farmland sets in, which is probably documented by reduced growth of trees since the end of the 19th century (Huss, 1944). Therefore, aridification is not only a result of grazing-induced vegetation types (Skarpe, 1986), but is also caused by increased runoff, as suggested by Walter (1940). River channel formation and soil loss is not reversible. In areas which have not been greatly affected by erosion, removal of acacia bushes and trees can assist the re-establishment of natural grassland, which would stabilize the soil surface. However, this is costly as it is heavy labour and it would require a reduction of cattle stocks for several years at least. Degradation of vegetation and soils, and river channel formation, seem to be the main causes of farmland aridification.

A resource-related issue is the problem of modern desertification in Namibia. In southern Africa, the drylands of two countries are most affected by this process (UNEP, 1992), one is the Namibia and the other is the Republic of South Africa.

Since the beginning of the 20th century, white settlers have recorded increasing aridification in Namibia. This seems to reflect grazing-induced vegetation types, which frequently indicate drier conditions than those recorded by meteorologists (Acocks, 1975; Skarpe, 1986). The evidence for climatic or anthropogenic causes of landscape degradation is based on detailed sedimentological, palynological, pedological, geomorphological and

ecological studies (e.g., Vogel, 1983; Sugden and Meadows, 1989; Sugden, 1989). Environmental studies in the Karroo show that in the Late Holocene the first degradation of the natural vegetation was initiated in pre-colonial times by hunting and gathering Khoi San and Khoi Khoi herders (Meadows et al., 1994). Signs of recent environmental change exist in Namibia as well (e.g., Walter, 1954; Seely and Jacobson, 1994; Maurer, 1995; Sander et al., 1998). There does not appear to have been a significant change in precipitation over the period of rainfall record since the 19th century. Walter (1940, 1954) suggested that landscape aridification in Namibia is primarily an anthropogenic effect on savanna ecosystems induced by intensified cattle farming. The environmental change is characterized by the transformation of open savanna grasslands to shrublands (Kempf, 1994) caused by heavy stocking with cattle or increasing human population pressure (Sander et al., 1998) and concomitant accelerated erosion (Brunotte and Sander, 2000).

CONCLUSION

This paper focuses on the late Quaternary environmental change in the Namibia in southern Africa. The Namibia is located at the interface of tropical, subtropical and temperate atmospheric and oceanic systems. The relationship between geomorphology and climate in Namibia reveals the degree and extent to which its landscapes are determined by changing environmental conditions, especially during the Late Quaternary. In the central part of the Namibia, OSL chronologies from two complex linear dune features close to Gobabeb suggest the current dunes are young (Holocene age), with important messages about the dynamics of the system and migration rates, whilst OSL ages from dunes in the southern part of the Sand Sea suggests older material of up to 24 ka at 5 m depth. Linear dunes in the southwestern Kalahari Desert provide evidence of the nature of paleoclimates. These dunes have special significance because their alignments indicate a previous circulation pattern with prevailing northwesterly winds. In contrast to previous suggestions final dune stabilization took place before about 9-8 ka. This corresponds to reduced wind velocities accompanied by more humid conditions. This seems to be the last important environmental change recorded by significant landforms in the southwestern Kalahari. Since about 8 ka the region remained more or less semi-arid: The long distance to seasonal south-shifting humid tropic air masses (Innertropical Convergence Zone, ITCZ) and the climatic barrier of the Namib and the Karas Mountains against Atlantic influences allowed only minor fluctuations. The Holocene is a period of reduced pan development. Collins et al. (2014) present a record of leaf-wax δD and δ13C taken from a marine sediment core at 23◦S off the coast of Namibia to reconstruct the hydrology and C3 versus C4 vegetation of southwestern Africa over the last 140,000 years (140ka). They found lower leaf-wax δD and higher δ13C (more C4 grasses), which they interpreted to indicate wetter Southern Hemisphere (SH) summer conditions and increased seasonality, during SH insolation maxima relative to minima and during the last glacial period relative to the Holocene and the last interglacial period. Nonetheless, the dominance of C4 grasses throughout the record indicates that the wet season remained brief and that this region has remained semi-arid. This research data suggest that past precipitation increases were derived from the tropics rather than from the winter westerlies. Comparison with a record from the Congo Basin indicates that hydroclimate in southwestern Africa has evolved in

antiphase with that of central Africa over the last 140 ka. The Holocene environmental change in northern Namibia can be deduced from evidences from soils and sediments in the Otjiwarongo thornbush savanna. In this region degradation and desertification (man-made aridification) of drylands are developed during the Holocene. Vertisol–Kastanozem–Calcisol soil associations occur widely. They have formed in fine-grained Mid-Holocene sediments which accumulated on both sides of the subcontinental watershed. The humification suggests open savanna environments in the past and does not accord with the shrublands and thornbush savanna at present.

REFERENCES

Acocks JPH. Veld types of South Africa. *Mem. Bot. Surv. S. Afr.*, 1975, 40, 1– 128.

Beaumont PB, Van Zinderen Bakker EM, Vogel JC. Environmental changes since 32000 BP at Kathu Pan, Northern Cape. In: Vogel JC (Ed.) Late Cainozoic Palaeoclimates of the Southern Hemisphere. Balkema, Rotterdam, 1984. pp. 329-338.

Blumel WD, Eitel B. Tertifire Deckschichten und Kalkkrusten in Namibia: Entstehung und geomorphologische Bedeutung. *Zeitschrift fur Geomorphologie,* 1994, 38, 385-403.

Blumel WD, Eitel B, Lang A. Dunes in southeastern Namibia: evidence for Holocene environmental changes in the southwestern Kalahari based on thermoluminescence data. Palaeogeography *Palaeoclimatology Palaeoecology,* 1998, 138, 139-149.

Boom A, Carr AS, Chase BM, Grimes HL, Meadows ME. Leaf wax nalkanes and δ13C values of CAM plants from arid southwest Africa. *Organci Geochemistry,* 2014, 67, 99–102.

Bourke MC, Child A, Stokes S. Optical age estimates for hyper-arid fluvial deposits at Homeb, Namibia. *Quaternary Science Reviews,* 2003, 22 (10-13), 1099-1103.

Bristow CS, Lancaster N, Duller GAT. Combining ground penetrating radar surveys and optical dating to determine dune migration in Namibia. *Journal of the Geological Society,* 2005, 162 (2), 315-321.

Bristow CS, Duller GAT, Lancaster N. Age and dynamics of linear dunes in the Namib Desert. *Geology,* 2007, 35, 555-558.

Broecker WS, Denton GH. What drives glacial cycles? *Scientific American,* January 1990, 43–50.

Broecker WS, Peteet DM, Rind D. Does the ocean–atmosphere system have more than one stable mode of operation? *Nature,* 1985, 315, 21–25.

Brook GA, Srivastava P, Marais E. Characteristics and OSL minimum ages of relict fluvial deposits near Sossus Vlei, Tsauchab River, Namibia, and a regional climate record for the last 30 ka. *Journal of Quaternary Science,* 2006, 21, 347-362.

Brunotte E, Sander H. Bodenerosion in loßartigen Sedimenten Nordnamibias (Becken von Opuwo) hervorgerufen durch Gullybildung und Mikropedimentation. *Zeitschrift fur Geomorphologie,* 2000, 44, 249–267.

Bubenzer O, Bodeker O, Besler H. A transcontinental comparison between the southern Namib Erg (Namibia) and the southern Great Sand Sea (Egypt). *Zentralblatt fur Geologie und Palaontologie Teil,* 2007, 1, 7–23.

Bubenzer O, Bolten A. The use of new elevation data (SRTM/ASTER) for the detection and morphometric quantification of Pleistocene megadunes (draa) in the eastern Sahara and the southern Namib. *Geomorphology*, 2008, 102, 221–231.

Buch MW, Zoller L. Pedostratigraphy and thermoluminescence chronology of the western margin- (lunette-) dunes of Etosha Pan/Northern Namibia. *Warzburger Geograph Arb*, 1992, 84, 361-384.

Bullard JE, Thomas DSG, Livingstone I, Wiggs GFS. Dunefield activity and interactions with climatic variability in the southwest Kalahari Desert. *Earth Surface Processes and Landforms*, 1997, 22, 165-174.

Burke K, Gunnell Y. The African erosion surface: a continental-scale synthesis of geomorphology, tectonics, and environmental change over the past 180 million years. *Memoir of the Geological Survey of Namibia*, 2008, 201, 66.

Carr AS, Boom A, Grimes HL, Chase BM, Meadows ME, Harris A. Leaf wax nalkane distributions in arid zone South African flora: environmental controls, chemotaxonomy and palaeoecological implications. *Organic Geochemistry*, 2014, 67, 72–84.

Castañeda IS, Mulitza S, Schefuss E, Lopes RA, Damste JSS, Schouten S. Wet phases in the Sahara/Sahel region and human migration patterns in North Africa. *Proc. Proceedings of National Academy of Sciences USA*, 2009, 106, 20159–20163.

Chase BM, Meadows ME. Late Quaternary dynamics of southern Africa's winter rainfall zone. *Earth-Science Reviews*, 2007, 84 (3-4), 103-138.

Chase BM, Meadows ME, Scott L, Thomas DSG, Marais E, Sealy J, Reimer PJ. A record of rapid Holocene climate change preserved in hyrax middens from south western Africa. *Geology*, 2009, 37, 703–706.

Cockcroft MJ, Wilkinson MJ, Tyson PD. The application of a present-day climatic model to the late quaternary in southern Africa. *Climatic Change*, 1987, 10, 161–181.

Collins JA, SchefuB E, Heslop D, Mulitza S, Prange M, Zabel M, Tjallingii R, Dokken TM, Huang E, Mackensen A, Schulz M, Tian J, Zarriess M, Wefer G. Interhemispheric symmetry of the tropical African rainbelt over the past 23000 years. *Nature Geoscience*, 2011, 4, 42–45.

Collins JA, SchefuB E, Mulitza S, Prange M, Werner M, Tharammal T, Paul A, Wefer G. Estimating the hydrogen isotopic composition of past precipitation using leaf-axes from western Africa. *Quaternary Science Reviews*, 2013a, 65, 88–101.

Collins JA, Govin A, Mulitza S, Heslop D. Abrupt shifts of the Sahara–Sahel boundary during Heinrich stadials. *Climate of the Past*, 2013b, 9, 1181–1191.

Collins JA, Schefub E, Govin A, Mulitza S, Tiedemann R. Insolation and glacial–interglacial control on southwestern African hydroclimate over the past 140 000 years. *Earth and Planetary Science Letters*, 2014, 398, 1-10.

Cook KH. The south Indian convergence zone and interannual rainfall variability over southern Africa. *Journal of Climate*, 2000, 13, 3789-3804.

Cox KG. Karoo igneous activity, and the early stages of the break-up of Gondwanaland. In: Storey D et al., (Eds.) Magmatism and Causes of Continental Break-up. *Geological Society Special Publications*, London. 1992. pp. 137–148.

Daniau AL, Goni MFS, Martinez P, Urrego DH, Bout-Roumazeilles V, Desprat S, Marlon JR. Orbital-scale climate forcing of grassland burning in southern Africa. *Proceedings of National Academy of Sciences USA*, 2013, 110, 5069–5073.

Dauteuil O, Bessin P, Guillocheau F. Topographic growth around the Orange River valley, southern Africa: a Cenozoic record of crustal deformation and climatic change. *Geomorphology*, 2015, 233, 5–19.

Davis WM. Rock floors in arid and humid climates. *Journal of Geology*, 1930, 38, 1-27.

Dingle RV, Giraudeau J, Buhmann D, Bremner JM. Modern and palaeooceanographic environments under Benguela upwelling cells off southern Namibia. *Palaeogeography Palaeoclimatology Palaeoecology* 1996, 123, 85-105.

Doucouré CM, de Wit MJ. Old inherited origin for the present near-bimodal topography of Africa. *Journal of African Earth Sciences*, 2003, 36 (4), 371–388.

Dupont LM, Behling H, Kim JH. Thirty thousand years of vegetation development and climate change in Angola Ocean Drilling Program Site 1078). *Climate of the Past*, 2008, 4, 107–124.

Eckardt FD, Kuring N. SeaWiFS identifies dust sources in the Namib Desert. *International Journal of Remote Sensing*, 2005, 26, 4159–4167.

Eckardt FD, Soderberg K, Coop LJ, Muller AA, Vickery KJ, Grandin RD, Jack C, Kapalanga TS, Henschel J. The nature of moisture at Gobabeb, in the central Namib Desert. *Journal of Arid Environment*, 2013, 93, 7-19.

Eglinton G, Hamilton RJ. Leaf epicuticular waxes. *Science*, 1967, 156, 1322–1335.

Eitel B. Kalkkrusten in Namibia und ihre palaoklimatische Interpretation. *Geomethodica*, 1995, 20, 101-124.

Eitel B, Zoller L. Soils and sediments in the basin of Dieprivier-Uitskot (Khorixas District/Namibia): age, geomorphic and sedimentological investigation, paleoclimatic interpretation. *Palaeoecology of Africa*, 1996, 24, 159-172.

Eitel B, Bliimel WD. Pans and dunes in the southwestern Kalahari (Namibia): Geomorphology and paleoclimatic evidence. Zeitschrift fur Geomorphologie, *Supplement band*, 1997, 111, 73-95.

Eitel B, Eberle J, Kuhn R. Holocene environmental change in the Otjiwarongo thornbush savanna (Northern Namibia): evidence from soils and sediments. *Catena*, 2002, 47, 43-62.

Eitel B. Environmental history of the Namib Desert. In: Smith M, Hesse P (Eds.) Degrees South: Archaeology and Environmental History of the Southern Deserts. National Museum of Australia, Canberra, 2005. pp. 45-55.

Ewing RC, Kocurek G, Lake LW. Pattern analysis of dune-field parameters. *Earth Surface Processes and Landforms*, 2006, 31, 1176–1191.

Forte AM, Quéré S, Moucha R, Simmons NA, Grand SP, Mitrovica JX, Rowley DB. Joint seismic–geodynamic-mineral physical modelling of African geodynamics: a reconciliation of deep-mantle convection with surface geophysical constraints. *Earth and Planetary Science Letters*, 2010, 295, 329–341.

Gamble FM. Rainfall in the Namib Desert Park. *Madoqua*, 1980, 12 (3), 175-180.

Gasse F, Chalié F, Vincens A, Williams MAJ, Willamson D. Climatic patterns in equatorial and southern Africa from 30,000 to 10,000 years ago reconstructed from terrestrial and near-shore proxy data. *Quaternary Science Reviews*, 2008, 27 (25-26), 2316-2340.

Geyh MA, Eitel B. Radiometric dating of young and old calcrete. *Radiocarbon*, 1998, 40, 795–802.

Gimeno L, Drumond A, Nieto R, Trigo RM, Stohl A. On the origin of continental precipitation. *Geophysical Research Letters*, 2010, 37, L13804.

Goldrick G, Bishop P. Differentiating the roles of lithology and uplift in steepening bedrock river long profiles: an example from Southeastern Australia. *Journal of Geology*, 1995, 103, 227-231.

Grove AT. Landforms and climatic change in the Kalahari and Ngamiland. *Geographical Journal*, 1969, 135, 191-212.

Hachfeld B, Jurgens N. Climate patterns and their impact on the vegetation in a fog driven desert: the Central Namib Desert in Namibia. *Phytocoenologia*, 2000, 30, 567-589.

Hack JTT. Stream-profile analysis and stream-gradient index. *Journal of Research U.S. Geological Survey*, 1973, 1, 421-429.

Harrison M. A generalized classification of South African summe rrain-bearing synoptic systems. *International Journal of Climatology*, 1984, 4, 547–560.

Heine K. Aride und pluviale Bedingungen wahrend der letzten Kaltzeit in der Siidwest-Kalahari (sadliches Afrika). *Zeitschrift fur Geomorphologie, Supplement band*, 1981, 38, 1-37.

Heine K. The main stages of late Quaternary evolution of the Kalahari region, southern Africa. *Palaeoecology of Africa*, 1982, 15, 53-76.

Heine K, Heine JT. A paleohydrologic reinterpretation of the Homeb Silts, Kuiseb River, central Namib Desert (Namibia) and paleoclimatic implications. *Catena*, 2002, 48, 107–130.

Henschel JR, Seely MK. Ecophysiology of atmospheric moisture in the Namib Desert. *Atmospheric Research*, 2008, 87, 362-368.

Huss W. Jahresringuntersuchungen an Acacia giraffae und Copaifera coleosperma und ihre Auswertung fupr die Frage einer Klimaanderung in Deutsch-Sudwestafrika. Dissertation, Stuttgart, 1944. 234 pp.

Jansen JHF, Ufkes E, Schneider RR. Late quaternary movements of the Angola–Benguela front, SE Atlantic, and implications for advection in the equatorial ocean. In: *The South Atlantic. Springer*, Berlin, Heidelberg, 1996. pp. 553–575.

Kageyama M, Braconnot P, Bopp L, Caubel A, Foujols MA, Guilyardi E, Khodri M, Lioyd J, Lombard F, Mariotti V, Marti O, Roy T, Woillez MN. Mid-holocene and last glacial maximum climate simulations with the IPSL model – part I: Comparing IPSL_CM5A to IPSL_CM4. *Climate Dynamics*, 2013, 40, 2447–2468.

Keller EA, Pinter N. *Active Tectonics: Earthquakes, Uplift and Landscape.* Prentice Hall, Upper Saddle River, New Jersey, 1996. 338 pp.

Keller EA, Pinter N. *Active Tectonics: Earthquakes, Uplift and Landscape (Second Edition).* Prentice Hall, Englewood Cliffs, New Jersey, 2002. 362 pp.

Kempf J. Probleme der Land-Degradation in Namibia: Ausmaß, Ursachen und Wirkungsmuster. *Wurzburger Geograph. Manuskr*, 1994, 31, 164 pp.

King LC. *Morphology of the Earth: A Study and Synthesis of World Scenery*. Oliver and Boyd, Edinburgh, 1962. 726 pp.

Kim JH, Schneider RR, Mulitza S, Müller PJ. Reconstruction of SE trade-wind intensity based on sea-surface temperature gradients in the Southeast Atlantic over the last 25 kyr. *Geophysical Research Letters*, 2003, 30, 2144.

Koch K, Ensikat HJ. The hydrophobic coatings of plants urfaces: epicuticular wax crystals and their morphologies, crystallinity and molecular selfassembly. *Micron*, 2008, 39, 759–772.

Lancaster J, Lancaster N, Seely MK. Climate of the central Namib Desert. *Madoqua,* 1984, 14 (1), 5-61.

Lancaster N. The Namib Sand Sea: Dune Forms, Processes and Sediments. Balkema, Rotterdam. 1989a.

Lancaster N. Late Quaternary palaeoenvironments of the southwestern Kalahari. *Palaeogeography Palaeoclimatology Palaeoecology,* 1989b, 70, 367-376.

Lancaster N. How dry was dry? - Late Pleistocene palaeoclimates in the Namib Desert. *Quaternary Science Reviews,* 2002, 21 (7), 769-782.

Lancaster N, Kocuerk G, Singhvi A, Pandey V, Deynoux M, Ghienne JF, Lo K. Late Pleistocene and Holocene dune activity and wind regimes in the western Sahara Desert of Mauritania. *Geology,* 2002, 30 (11), 991–994.

Landman WA, Mason SJ. Change in the association between Indian Ocean sea-surface temperatures and summer rainfall over South Africa and Namibia. *International Journal of Climatology,* 1999, 19, 1477-1492.

Leroux M. The Climate of Tropical Africa. Atlas, vols. 3–9. Champion, Paris, 1983. pp.39–45.

Leser H. Landschafts0kologische Studien im Kalaharisandgebiet um Auob und Nossob (rstliches Sfidwestafrika). Erdwiss. Forsch., vol. 3. *Springer,* Wiesbaden, 1971. 243 pp.

Lindesay JA. Present climates of southern Africa. In: Hobbs JE, Lindesay JA, Bridgman HA (Eds.) Climates of the Southern Continents: Present, Past and Future. *John Wiley and Sons, Chichester,* 1998. pp. 5-62 (Chapter 2).

Livingstone I, Bristow C, Bryant RG, Bullard J, White K, Wiggs GFS, Baas ACW, Bateman MD, Thomas DSG. The Namib Sand Sea digital database of aeolian dunes and key forcing variables. *Aeolian Research,* 2010, 2, 93–104.

Logan RF. The Central Namib Desert, South West Africa. *National Research Council Publication,* 1960, 758, Washington D.C.

Mason SJ. Sea-surface temperature e South African Rainfall Associations, 1910-1989. *International Journal of Climatology,* 1995, 15, 119-135.

Mason SJ, Jury MR. Climatic variability and change over southern Africa: a reflection on underlying processes. *Progress in Physical Geography,* 1997, 21, 25-50.

Mattes M, Mason SJ. Evaluation of a seasonal forecasting procedure for Namibian rainfall. *South African Journal of Science,* 1998, 94, 183-185.

Maurer U. Nutzungspotential und Landdegradation im semi-ariden Namibia—Ein Beitrag zur Desertifikationsforschung. *J. Agric. Trop. Subtrop.* (Der Tropenlandwirt), Beiheft, 1995, 55, 195 pp.

Meadows ME, Milton SJ, Dean WRJ, Hoffman MT. Desertifikation im Bereich der semiariden Karoo, Sudafrika. *Geookodynamik* XV, 1994, 219– 242.

Meadows ME. The role of Quaternary environmental change in the evolution of landscapes: case studies from southern Africa. *Catena,* 2001, 42, 39-57.

Miller RM. The stratigraphy of Namibia, 33 pp. Ministry of Mines and Energy, Geological Survey of Namibia, 1992.

Mvondo F, Dauteuil O, Guillocheau F. The Fish River canyon (Southern Namibia): a record of Cenozoicmantle dynamics? *Comptes Rendus Geoscience,* 2011, 343, 478–485.

Ning S, Dupont L. Vegetation and climatic history of southwest Africa: a marine palynological record of the last 300,000 years. *Vegetation History Archaeobotany,* 1997, 6, 117–131.

Olivier J. Spatial distribution of fog in the Namib. *Journal of Arid Environment*, 1995, 29, 129–138.

Ollier CD, Marker ME. The Great Escarpment of southern Africa. *Zeitschrift fur Geomorphologie, Supplement band*, 1985, 54, 37–56.

Owono FM, Ntamak-Nida MJ, Dauteuil O, Guillocheau F, Njom B. Morphology and long-term landscape evolution of the South African plateau in South Namibia. Catena, 2016, 142, 47-65.

Paquet H, Millot G. Geochemical evolution of clay minerals in the weathered products in soils of Mediterranean climate. *Proc. Int. Clay Conf., Madrid*, 1972. pp. 199-206.

Partridge TC. Cainozoic environmental change in southern Africa, with special emphasis on the last 200,000 years. *Progress in Physical Geography*, 1997, 21, 3–22.

Partridge TC, Demenocal PB, Lorentz SA, Paiker MJ, Vogel JC. Orbital forcing of climate over South Africa: a 200,000-year rainfall record from the pretoria saltpan. *Quaternary Science Reviews*, 1997, 16, 1125–1133.

Partridge TC, Maud RR. Geomorphic evolution of southern Africa since the Mesozoic. *South African Journal of Geology*, 1987, 90 (2), 179–208.

Pickford M, Senut B. Geology and palaeobiology of the Namib desert Southwest Africa. *Memoir of the Geological Survey of Namibia*, 1999, 18. 155 pp.

Pietruszka RD, Seely MK. Predictability of two moisture sources in the Namib Desert. *South African Journal of Science*, 1985, 81, 682-685.

Pokras EM, Mix AC. Eolian evidence for spatial variability of late Quaternary climates in tropical Africa. *Quaternary Research*, 1985, 24, 137–149.

Prospero JM, Ginoux P, Torres O, Nicholson SE, Gill TE. Environmental characterization of global sources of atmospheric soil dust identified with the Nimbus 7 Total Ozone Mapping Spectrometer (TOMS) absorbing aerosol product. *Review of Geophysics*, 2002, 40, 31.

Reason CJC. Sensitivity of southern African circulation to dipole sea-surface temperature patterns in the south Indian Ocean. *International Journal of Climatology*, 2002, 22, 377-393.

Reason CJC, Allan RJ, Lindesay JA, Ansell TJ. ENSO and climate signals across the Indian Ocean basin in the global context: Part 1, Interannual composites patterns. *International Journal of Climatology*, 2000, 20, 1285-1327.

Reason CJC, Landman W, Tennant W. Seasonal to decadal predictability/prediction of southern African climate and its links with variability of the Atlantic Ocean. *Bulletin of the American Meteorological Society*, 2006, 87, 941-955.

Rossignol-Strick M. Mediterranean quaternary sapropels, an immediate response of the African monsoon to variation of insolation. *Palaeogeography Palaeoclimatology Palaeoecology*, 1985, 49, 237–263.

Rouault M, Florenchie P, Fauchereau N, Reason CJ. South East tropical Atlantic warm events and southern African rainfall. *Geophysical Research Letters*, 2003, 30(5).

Sachse D, Billault I, Bowen GJ, Chikaraishi Y, Dawson TE, Feakins SJ, Freeman KH, Magill CR, Mclnerney FA, van der Meer MTJ, Polissar P, Robins RJ, Sachs J, Schmidt HL, Sessions A, White JWC, West JB, Kahmen A. Molecular paleohydrology: interpreting the hydrogen-sotopic composition of lipid biomarkers from photosynthesizing organisms. *Annual Review of Earth and Planetary Sciences*, 2012, 40, 221–249.

Sander H, Bollig M, Schulte A. Himba paradise lost. Stability, degradation and pastoralist management of the Omuhonga Basin (Namibia). *Die Erde*, 1998, 129, 301– 315.

Sarnthein M. Sand deserts during glacial maximum and climate optimum. *Nature* 1978, 272, 43–46.

Schefuß E, Kuhlmann H, Mollenhauer G, Prange M, Patzold J. Forcing of wet phases in southeast Africa over thepast 17000 years. *Nature,* 2011, 480, 509–512.

Schneider RR, Price B, Muller PJ, Kroon D, Alexer I. Monsoon related variations in Zaire (Congo) sediment load and influence of Fluvial silicate supply on marine productivity in the East Equatorial Atlantic during the last 200,000 years. *Paleoceanography,* 1997, 12, 463–481.

Schwarz EHL. The Kalahari, or Thirstland Redemption. Maskew Miller, Cape Town/Blackwell, 1920. Oxford.

Scotese RC, Cahagan LM, Larson RL. Plate tectonics reconstruction of the Cretaceous and Cenozoic ocean basins. *Tectonophysics*, 1988, 155, 27-48.

Seely MK. Standing crop as an index of precipitation in the central Namib grassland. *Madoqua*, 1978, 9 (3), 5-13.

Seely MK, Jacobson KM. Desertification and Namibia: a perspective. *Journal of African Zoology*, 1994, 108, 21– 36.

Servain J, Legler DM. Empirical orthogonal function analyses of tropical Atlantic sea surface temperature and wind stress: 1964–1979. *Journal of Geophysical Research - Oceans*, 1986, (1978–2012) 91 (C12), 14181–14191.

Shannon LV, Boyd AJ, Brundrit GB, Taunton-Clark J. On the existence of an El-Nino-type phenomenon in the Benguela system. *Journal of Marine Research,* 1986, 44, 495-520.

Sharon D. The distribution in space of local rainfall in the Namib Desert. *International Journal of Climatology*, 1981, 1, 69-75.

Shaw PA, Thomas DSG. The Quaternary palaeoenvironmental history of the Kalahari, Southern Africa. *Journal of Arid Environment,* 1996, 32, 9-22.

Shi N, Schneider R, Beug HJ, Dupont LM. Southeast trade wind variations during the last 135 kyr: evidence from pollen spectra in eastern South Atlantic sediments. *Earth and Planetary Science Letters,* 2001, 187, 311–321.

Skarpe C. Plant community structure in relation to grazing and environmental changes along a north–south transect in the western Kalahari. *Vegetatio,* 1986, 68, 3– 18.

Sonzogni C, Bard E, Rostek F. Tropical sea-surface temperatures during the last glacial period: a view based on alkenones in Indian Ocean sediments. *Quaternary Science Reviews*, 1998, 17, 1185–1201.

Southgate RI, Masters P, Seely MK. Precipitation and biomass changes in the Namib Desert dune ecosystem. *Journal of Arid Environments*, 1996, 33, 267-280.

Srivastava P, Brook GA, Marais E. A Record of fluvial aggradation in the Northern Namib Desert during the Late Quaternary. *Zeitschrift fur Geomorphologie, Supplement band*, 2004, 133, 1-18.

Srivastava P, Brooke GA, Marais E. Depositional environment and luminescence chronology of the Hoarusib River Clay Castles sediments, northern Namib Desert, Namibia. Catena, 2005, 59, 187-204.

Srivastava P, Brook GA, Marais E, Morthekai P, Singhvi AK. Depositional environment and OSL chronology of the Homeb silt deposits, Kuiseb River, Namibia. *Quaternary Research*, 2006, 65, 478-491.

Stokes S, Thomas DSG, Shaw PA. New chronological evidence for the nature and timing of linear dune development in the southwest Kalahari Desert. *Geomorphology*, 1997, 20, 81-93.

Stone A.C, Thomas DSG. Linear dune accumulation chronologies from the southwest Kalahari, Namibia: challenges of reconstructing late Quaternary palaeoenvironments from aeolian landforms. *Quaternary Science Reviews*, 2008, 27, 1667-1681.

Stone AEC, Thomas DSG, Viles HA. Late Quaternary palaeohydrological changes in the northern Namib Sand Sea: new chronologies using OSL dating of interdigitated aeolian and water-lain interdune deposits. *Palaeogeography Palaeoclimatology Palaeoecology* 2010, 288, 35–53.

Stone AEC. Age and dynamics of the Namib Sand Sea: A review of chronological evidence and possible landscape development models. *Journal of African Earth Sciences*, 2013, 82, 70-87.

Stone AEC, Thomas DSG. Casting new light on late Quaternary environmental and palaeohydrological change in the Namib Desert: A review of the application of optically stimulated luminescence in the region. *Journal of Arid Environments*, 2013, 93, 40-58.

Storey M. Timing of hot spot-related volcanism and the breakup of Madagascar and India. *Science*, 1995, 267, 852–855.

Strahler AN. Hypsometric (area-altitude) analysis of erosional topography. *Geological Society of American Bulletin*, 1952, 63, 1117–1142.

Stuut JBW, Prins MA, Schneider RS, Weltje GJ, Jansen JHF, Postma G. A 300-kyr record of aridity and wind strength in southwestern Africa: inferences from grain-size distributions of sediments on Walvis Ridge, SE Atlantic. *Marine Geology*, 2002, 180, 221–233.

Sugden JM. Late Quaternary palaeoecology of the central and marginal uplands of the Karoo, South Africa. Unpublished PhD thesis, University of Cape Town, South Africa, 1989. 384 pp.

Sugden JM, Meadows ME. The use of multiple discriminant analysis in reconstructing recent vegetation changes on the Nuweveldberg, South Africa. *Review of Palaeobotany and Palynology*, 1989, 60, 131– 147.

Thomas DSG. Discrimination of depositional environments, using sedimentary characteristics, in the Mega KalaharL central southern Africa. *Geological Society of London Special Publications*, 1987, 35, 293-306.

Thomas DSG, Shaw PA. The Kalahari Environment. Cambridge Univ. Press, 1991. 284 pp.

Thomas DSG, Stokes S, Shaw PA. Holocene aeolian activity in the southwestern Kalahari Desert, southern Africa: significance and relationships to late Pleistocene dune building events. *Holocene*, 1997, 7(3), 273-281.

Todd M, Washington R. Circulation anomalies associated with tropical temperate troughs in southern Africa and the southwest Indian Ocean. *Climate Dynamics*, 1999, 15, 937-951.

Todd MC, Richard W, Palmer PI. Water vapour transport associated with tropical–temperate trough systems over southern Africa and the southwest Indian Ocean. *International Journal of Climatology*, 2004, 24, 555–568.

Tricart J, Cailleux A. *Première partie: Géomorphologie structurale, cicule II type de bordure de massifs anciens avec travaux pratiques*. Documentation Universitaire, 1963, 5. Place de la Sorbonne, Paris V.

Tyson PD. Climatic Change and Variability in Southern Africa. Oxford University Press. Cape Town. 1986.

Tyson PD, Dyer TGJ, Mametse MN. Secular changes in South African rainfall: 1880–1972. *Quarterly Journal of the Royal Meteorological Society*, 1975, 101, 817–833.

Tyson PD, Preston-Whyte RA. TheWeather and Climate of Southern Africa. Oxford University Press, Cape Town, 2000.

Tyson PD, Preston-Whyte RA. The Weather and Climate of Southern Africa. Oxford University Press, England, 2001.

UNEP. World Atlas of Desertification. Arnold, London, 1992. 32 pp.

Vermeesch P, Fenton CR, Kober F, Wiggs GFS, Bristow CS, Xu S. Sand residence times of one million years in the Namib Sand Sea from cosmogenic nuclides. *Nature Geoscience*, 2010, 3, 862–865.

Vogel JC. Isotopic evidence for the past climates and vegetation of southern Africa. *Bothalia*, 1983, 14, 391–394.

Walker ND, Shillington FA. The effect of oceanographic variability on South African weather and climate. *South African Journal of Science*, 1990, 86, 382-386.

Walter H. Die Farmwirtschaft in Deutsch-Sudwestafrika. Ihre biologischen Grundlagen. Zweiter Teil: Die Weidewirtschaft. Verbesserung der Weide, Wassererschließung und Bekampfung der Bodenerosion. Parey, Berlin, 1940. 98 pp.

Walter H. Grundlagen der Weidewirtschaft in Su¨dwestafrika. Ulmer, Stuttgart, 1954. 182 pp.

Ward JD. The Cenozoic succession in the Kuiseb Valley, central Namib Desert. Mem, Geol. Surv. S. West Afr. Namibia, 1987, 9. 124 pp.

Watts NL. Quaternary pedogenic calcretes from the Kalahari (southern Africa): mineralogy, genesis and diagenesis. *Sedimentology*, 1980, 27, 661-686.

Wellington JH. Southern Africa, a Geographical Study, Vol. 1: Physical Geography. *Cambridge University Press*, 1955. 528 pp.

Whipple KX. Fluvial landscape response time: how plausible is steady-state denudation? *American Journal of Science*, 2001, 301, 313–325.

Wilson M. Magmatism and continental rifting during the opening of the South Atlantic Ocean: a consequence of Lower Cretaceous super-plume activity? *Geological Society of London Special Publications*, 1992, 241-225.

Wintle AG. Luminescence dating of aeolian sands: an overview. *Geological Society of London Special Publications*, 1993, 72, 49-58.

In: Handbook on Africa
Editor: Whitney Sherman
ISBN: 978-1-53610-063-1

Chapter 8

FLUORSPAR DEPOSITS AT OKORUSU, NORTH-CENTRAL NAMIBIA: ECONOMIC IMPORTANCE, HISTORY OF MINING AND GEOLOGY

Richard D. Hagni*
Curators' Professor of Geology Emeritus
Department of Geosciences and Geological and Petroleum Engineering
Missouri University of Science and Technology
Rolla, Missouri, US

ABSTRACT

The fluorspar mine at Okorusu, Namibia operated principally from 1988 to 2014 and was a very significant producer of fluorspar used in the chemical industry. It also produced at times several by-products including ground fenite for local road material and magnetite for the cement industry. Together with South Africa the two countries produced as much as 300,000 tons of fluorspar concentrate per year that amounted to 20% of the western world's fluorspar consumption. During 2015 the Okorusu mine has been under care and maintenance.

Okorusu is a carbonatite-related fluorspar mine. Carbonatite is a calcite-rich rock originated in a volcano and derived from the earth's upper mantle. Fluorine-rich fluids developed late in the history of the volcano and fluorine in those fluids combined with calcium in the carbonatites and country-rock marbles to form the fluorspar orebodies. Similar carbonate-related fluorspar ore deposits occur at Amba Dongar in west-central India and at Mato Preto in southern Brazil. Fluorspar deposits at the Kenya Fluorspar mine at Kimwarer in western Kenya and at Hicks Dome in southern Illinois have the geochemical characteristics of carbonatite-related fluorspar deposits.

Several separate orebodies have been mined at Okorusu. The main orebodies were A, B, and D. Mining began at the A deposit. Subsequently both A and B orebodies were mined together. Most recently, significant mining of the D and E orebodies occurred

* E-mail address: rhagni@mst.edu.

along with continued mining at the B orebody and with minor additional mining at the A orebody. The A and D orebodies owe their genesis mainly to the replacement of carbonatite. The B and C deposits were formed partly by carbonatite replacement and partly by replacement of host rock marble. The carbonatite-replacement fluorspar ores are characterized by elevated deleterious phosphorus contents, elevated amounts of trace rare earth elements, goethite pseudomorphs of magnetite, pyroxene, and pyrrhotite crystals, and by the local presence of replacement remnants of those carbonatite rocks. Carbonatite-replacement fluorspar orebodies transition into unreplaced carbonatite at their margins. Marble-replacement ores are characterized by elevated amounts of silica, banded textures, and gradation into unreplaced marbles at their margins.

The recognition that much of the fluorspar ore at Okorusu had formed as a replacement of carbonatite provided an exploration tool for use in the search for additional fluorspar orebodies. Because the carbonatites at Okorusu contain significant quantities of magnetite they have strong magnetic properties and magnetic anomalies are characteristic of orebodies replacing carbonatite because they contain significant amounts of unreplaced magnetite. Unfortunately, magnetic anomalies also occur for carbonatites that have not been reached by the fluorspar-depositing fluids and especially for syenites in the intrusive complex.

The temperatures of deposition and salinity of the fluorspar-depositing fluids can be measured using small microscopic fluid inclusions within the fluorite. Fluid inclusion analysis of Okorusu fluorite shows that the main purple and green fluorites crystalized at temperatures mostly from 166 to 144ºC, and that later yellow fluorite was deposited from 132 to 128ºC. The salinity ranged 5-1.5 wt percent NaCl equivalent. The salinity is significantly lower than for Mississippi Valley-type fluorspar ores elsewhere and the temperatures are mostly lower than for epithermal ore fluids.

The Okorusu fluorite mine was the world's largest carbonatite-related fluorspar mine for many years. It serves today as the best example of the characteristics of carbonatite-related fluorspar ores against which fluorspar ore deposits elsewhere in the world can be compared and evaluated for their possible genetic connection to carbonatite intrusions.

INTRODUCTION

The Okorusu Alkaline Igneous Carbonatite Complex is a vertical igneous intrusion derived from the upper mantle. It is circular in plan view, and about 8 km in diameter (Van Zijl, 1962). It was intruded during early Cretaceous time (125 Ma) (Milner et al., 1995) into late Precambrian Damara Series regional metasediments. In the vicinity of the complex and especially along its southern margin the Precambrian rocks have been highly metasomatized to green, dense, fine-grained, aegirine-rich sodic fenites. Fenitization resulted from early sodic and potassic fluids introduced into the complex prior to the intrusion of carbonatites and alkaline silicate magmas. The resultant fenites were brecciated prior to the introduction of the carbonatites producing large fenite blocks cemented by carbonatites. Introduced silicate igneous rocks at Okorusu include nepheline syenite, foyaite, tinguaite, and monzonite.

The fluorspar mine at Okorusu, Namibia is located approximately half way between the capital city of Windhoek and the famous mining town of Tsumeb to the north (Figure 1). It is about 20 miles west of highway B1 that links Windhoek with Tsumeb. The initial open pit mine (A pit) was located about 2/3 of the way to the summit of Okorusu Mountain (Figures 2 and 3). Okorusu Mountain is about 48 km north of Otjiwaromgo, or 30 km north of the small town of Okahandja, and it is 1,484 meters high. The second open pit (B pit) was placed at the

summit (Figure 4). Seven additional fluorspar deposits were either mined by open pits mines or subjected to exploratory drilling and they were located on Okorusu Mountain and elsewhere in the Okorusu Alkaline Igneous-Carbonatite Complex.

PRODUCTION HISTORY

Although minor mining at Okorusu occurred after fluorspar was first discovered there in the early German colonial era, the most significant mining at Okorusu occurred from 1988 through 2014. Financial funding for Okorusu Ltd. initially came from the Iron and Steel Corporation (ISCOR) of the Republic of South Africa, but the company has been under contract with Solvay International Corporation of Brussels, Belgium since 1997. Okorusu reached its greatest productivity under Solvay funding (Figure 5). Okorusu was the world's third largest producer of acid grade fluorspar. For a long time, Okorusu supplied 50% of Solvay's fluorspar needs. Okorusu, together with the Witkop fluorspar mine of South Africa, supplied about 20% of the western world's fluorspar in 2005 (Lanham, 2005). Finally, for mineral collectors, Okorusu is said by many to be the world's top fluorspar mine for top quality fluorspar mineral specimens. As a result of low commodity prices, lower grades from some open pits, and greater distance of transportation from other deposits, Okorusu was placed on care and maintenance in Octobrt, 2014.

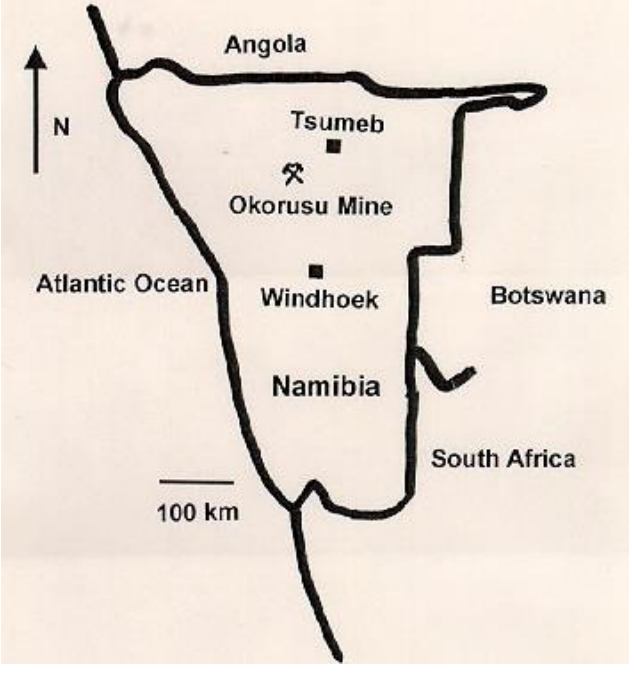


Figure 1. Index map showing location of Okorusu mine.

Figure 2. View of Okorusu Mountain and A open pit mine taken from access road to east of Okorusu mine.

Figure 3. View from an airplane of A open pit in 2008.

Figure 4. View from an airplane of B open pit at the summit of Okorusu Mountain.

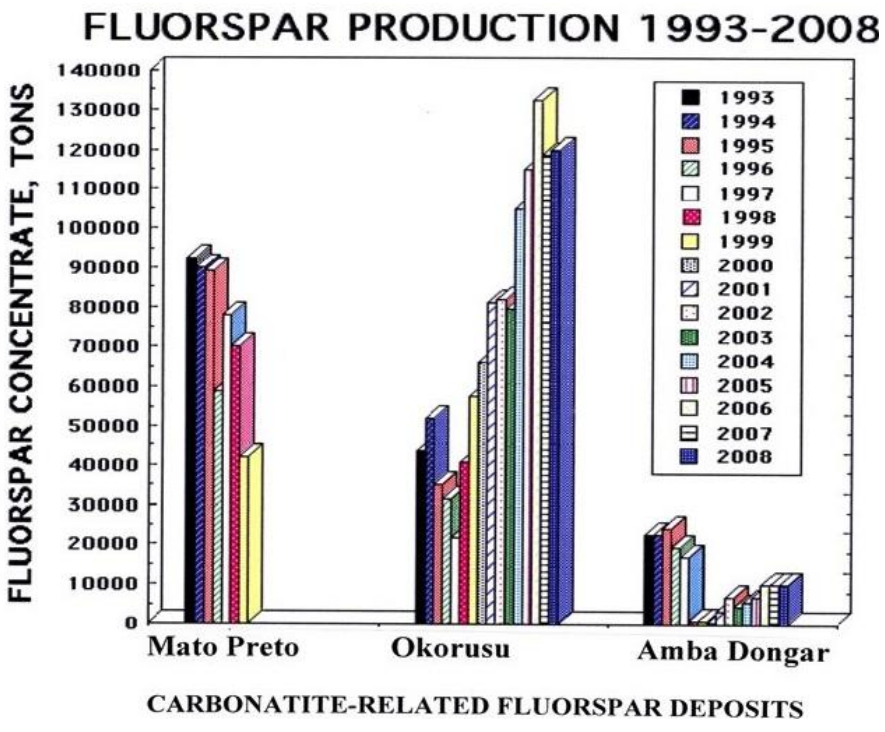


Figure 5. Production graph for Mato Preto, Okorusu, and Amba Dongar carbonatite-related fluorspar mines, 1993-2008, in tons concentrate.

Among carbonatite-related fluorspar (CaF_2) deposits, Okorusu has been the world largest producer. Although a fluorspar deposit at Mato Preto in southern Brazil formerly produced as much as 90,000 tons of fluorspar concentrate per year (Figure 5), that open pit mine was closed in 1999, and the mine area was subsequently converted into a park. A carbonatite-related fluorspar deposit at Amba Dongar in west-central India had been mined as early as 1993 (Hagni and Viladkar, 2004). That mine was shut down for a period of time after 1999 because the national government was concerned with deforestation in the general region around Amba Dongar (Figure 5). After the company planted a large number of trees to replace those previously cut down, mining was allowed to resume. Fluorspar concentrate production at Amba Dongar has always been rather small and usually amounted to about 20,000 tons fluorspar concentrate per year, but it has been closed since 2011 (Table 1).

Two fluorspar deposits that have not previously been considered to be of carbonatite origin have been interpreted by the present writer (Hagni, 2015) to exhibit mineralogical and geochemical characteristics of an origin connected them to carbonatites. The first deposit is the Kenya fluorspar mine at Kimwarer in western Kenya. Although carbonate is not exposed nearby, both REE and phosphorus are elevated in those fluorspar ores and the deposit is located in one of the segments of the East Africa Rift. The second is the deep fluorspar deposit at Hicks Dome in the Southern Illinois-Kentucky Fluorspar District. That deposit is characterized by abundant apatite, appreciable REE, and nearby carbonatite intrusions.

Table 1. Recent Fluorspar Production from Carbonatite-related Fluorspar Mines in Tons Concentrate

Year	Okorusu, Namibia	Amba Dongar, India	Mato Preto, Brazil
2009	74,000	~8,000	0
2010	95,000	~8,000	0
2011	100,000	~8,000	0
2012	80,000	0	0
2013	50,000	0	0
2014	32,000	0	0
2015	0	0	0

An advance in metallurgical treatment has had an important effect upon the history of production at Okorusu and is an interesting story (Mark Dawe, personal comm., 2004). Mark Dawe, former mine manager at Okorusu and earlier the chief metallurgist, had been working diligently for an extended period of time trying to improve the flotation results through the elimination of additional amounts of apatite so that the final fluorspar concentrates would have diminished amounts of phosphorus. Although he had achieved excellent results in laboratory experimentation, those results were not replicated in actual mill practice. One day his former professor and mentor from the university visited the mine and mill. When they were resting and drinking a cup of coffee between mill visits, he noted that the cream floated to the top of his cup of coffee. He asked about the origin of the water that was used to make the coffee, and when he found out that the water was derived from a nearby water well, he speculated that the presence or absence of CO_2 in the source water was the explanation for the contrast between laboratory and mill flotation results. He then asked for a cup of coffee to be made using mill water, and the cream did not float in that cup of coffee due to lower CO_2 content of the mill water as contrasted to water from the well. This correct speculation by a university professor interestingly led subsequently to the employment in the mill of an especially large CO_2 generator obtained from Coca Cola Company. Later CO_2 was produced chemically in the mill process. The solution of that metallurgical problem has contributed significantly to subsequent fluorspar concentrate production at the Okorusu flotation mill.

Fluorspar production at Okorusu peaked at 132,000 tons concentrate in 2006; production ranged between 80,000 and 100,000 tons concentrate during subsequent years depending upon the vitality of the general economy. Production diminished at Okorusu to below 80,000 ton in 2009 with worldwide recession, but by 2011 production was back to about 100,000 tons of fluorspar concentrate (Table 1). Production declined in from 2011 to 2014, and the mine was subsequently closed (Table 1).

Okorusu fluorspar concentrates were shipped abroad by ocean vessel from the shipping port at Walvis Bay, Namibia to Solvay's chemical plants especially in Hanover, Germany and also in Rosignano, Italy. The fluorite concentrate is used to make hydrofluoric acid that is

used in the manufacture of refrigerants, plastics, chemicals, and pharmaceuticals (Business Excellence Magazine online, 2009).

BY-PRODUCTS FROM OKORUSU

Although the main product from Okorusu has been fluorspar concentrates, other products have resulted from the mining of fluorspar at Okorusu from time to time. The deposition of fluorite by replacement of various rocks commonly was volume for volume resulting in massive fluorite ores mostly without vugs. Locally, however, the replacement clearly was not volume for volume, and there the fluorite ores are characterized by significant numbers of vugs. Where the ores are vuggy, the vugs commonly are lined by coarse-grained, vug-filling fluorite crystals. Such crystals typically are well-formed cubes and rarely do they have octahedral modifications. Purple cubes are the most common (Figure 6).

Figure 6. Hand specimen of vug-filling euhedral cubes of purple fluorite. A open pit, Okorusu Mine.

Figure 7. Hand specimen of vug-filling euhedral cubes of green fluorite. Goethite was subsequently deposited on top of the green fluorite crystals. A band, B open pit, Okorusu Mine.

Slightly later green cubes are less common (Figure 7) and they may be deposited on top of purple fluorite (Figure 8). Yellow cubes are least common (Figure 9), restricted to the topographically high B open pit, and clearly deposited after purple fluorite (Figure 10, 11). Okorusu vug-filling fluorite crystals have been routinely collected by mineral collectors who have contracts with the mining company, and those crystals are sold at premium prices in the mineral dealer's market.

Figure 8. Hand specimen of green fluorite (medium gray, coarsely crystalline) deposited on top of purple fluorite (medium gray, fine grained). Purple fluorite had earlier been deposited upon potash feldspar (light gray). A band, B open pit, Okorusu Mine.

Figure 9. Hand specimen of vug-filling euhedral cubes of late yellow fluorite crystals. B open pit, Okorusu Mine.

Figure 10. Hand specimen of vug-filling yellow fluorite (top crystal coating) deposited on massive purple replacement fluorite (main portion of hand specimen). 1710 level, B open pit, Okorusu Mine.

Figure 11. Massive purple replacement fluorite (dark gray) with subsequent;y deposited vug-lining yellow fluorite (light gray) coated by late calcite (white). 1695 level, B open pit, Okorusu Mine.

The bodies of carbonatite and fluorspar are surrounded by abundant brecciated fenite (Figure 12). Fenite is a hard dense rock suitable for use as road material. For several years, Okorusu fenite was crushed at the mine for use as road material on nearby highway B1 as that road was undergoing significant repairs.

Magnetite is a common mineral in Okorusu carbonatites and it is especially abundant in the outer rims of the fluorspar orebodies where the fluorspar orebodies have replaced magnetite-bearing carbonatite (Figures 13, 14). The magnetite is separated from fluorspar using magnetic separation during the early stages of the milling process. Okorusu magnetite was first utilized in 2010 at a new cement plant in Ohorongo near Otavi about 30 miles north of Okorusu to contribute needed iron to the concrete mix clinker (staff reporter, 2010). The iron combines with calcium and aluminum to form calcium aluminoferrite [$Ca_2(Al,Fe)_2O_5$] in the cement.

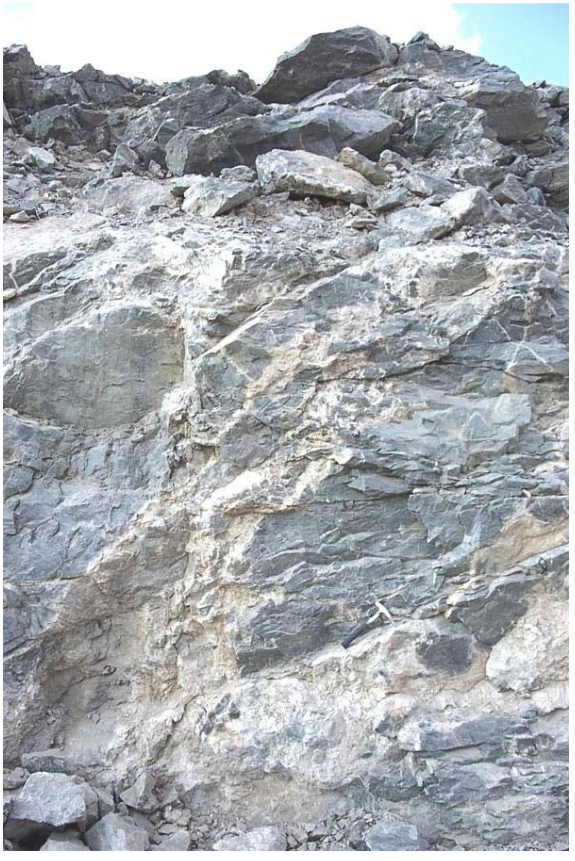


Figure 12. Fenite (upper left corner of photograph) brecciated and cemented by carbonatite (white). A band, B open pit, Okorusu Mine.

Figure 13. Magnetite (black) rim around top of carbonatite-replacement fluorite ore (light gray, beneath geologic pick) with massive fine-grained fenite (medium gray) above magnetite rim. A open pit, Okorusu Mine.

Although rare earth elements (REE) have never been recovered from Okorusu, carbonatites are typically enriched in REE (Hagni, in press-D). It is interesting to note that sufficient concentrations of REE elements occur locally in the Okorusu carbonatites to have encouraged exploration for those elements. Beginning in late 2010, Okorusu Fluorspar Ltd. conducted exploration for rare earth mineralization in Okorusu carbonatites (Weidlich, 2010). The rare earth element mineral, synchysite [$Ca(Ce,La,Y,Nd,Gd)(CO_3)_2F$] (Figure 15), was identified in the Okorusu fluorspar ores (Kogut and Hagni, 1998). Synchysite has been concentrated locally in Okorusu carbonatites by early hydrothermal fluids prior to the introduction of the fluorspar-depositing fluids (Hagni, in press-B). The mineralogical character of the early event is discussed in a section of toward the end of this chapter.

Figure 14. Close-up view of euhedral magnetite crystals (black, center of photograph) deposited on euhedral diopside pyroxene prismatic crystals, both deposited formerly at the edge of a carbonatite body that has been subsequently replaced by fluorspar ore (beneath geologic pick). Massive fine-grained fenite occurs at the top of the image, and it was intruded by the carbonatite. A open pit, Okorusu mine.

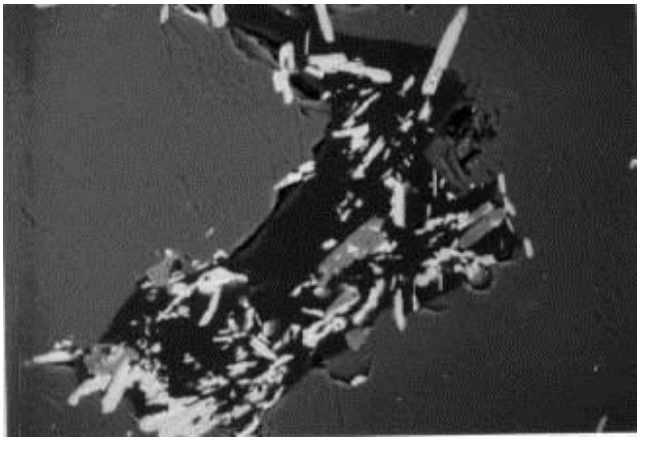


Figure 15 Scanning electron microscope image showing synchysite (white) and apatite (light gray, prismatic) crystals enclosed in quartz (black), in turn, enclosed in fluorite (medium gray). Magnification about 500X.

Figure 16. Hand specimen showing abundant apatite (white, beneath pen) as radial acicular crystals in fluorite (medium gray) ore. Apatite crystallized as a component of carbonatite and remained in the fluorspar as an insoluble constituent upon replacement by fluorspar ore. A open pit, Okorusu mine.

Experimental beneficiation satisfactorily produced phosphate concentrate from Okorusu mine tailings in 2013 (Isaacs, 2013). The phosphate concentrate could be conveniently utilized in Namibia as fertilizer for crops and used as livestock feed. The Okorusu Company has evaluated the economic viability of producing phosphate concentrate from the mine tailings. Apatite was a mineral component of the carbonatites and it remained as an insoluble component when the carbonatites were replaced by the fluorspar ores (Figure 16).

EARLY GEOLOGICAL MAPPING AT OKORUSU

Early mapping of the geology of the Okorusu Alkaline Igneous-Carbonatite Complex was conducted by Van Zijl (1862) in connection with his Ph.D. dissertation at Stellenbosch University in South Africa. His map is the fundamental map of the complex and it has subsequently been published in color by the Namibian Geologic Survey. Van Zijl discovered more than 100 fluorspar bodies of various sizes and fluorspar grades in the Okorusu complex during his mapping, and most of the fluorspar orebodies mined or drilled had been located by Van Zjjl's study. He also outlined areas of fenitization, hydrothermal alteration, carbonatites, magnetite ores, and silicate rocks. The southern rim of the Okorusu complex from Van Zijl's map has been simplified by the present writer and presented as a sketch map in Figure 17. The sketch map shows the distributions of carbonatite, fenite, hydrothermal alteration, some of the fluorspar orebodies, and a portion of the boundary of the complex.

Although Prins (1981) did not conduct mapping, he provided early geochemical information on the rocks and ores at Okorusu as part of a dissertation also conducted at Stellenbosch University.

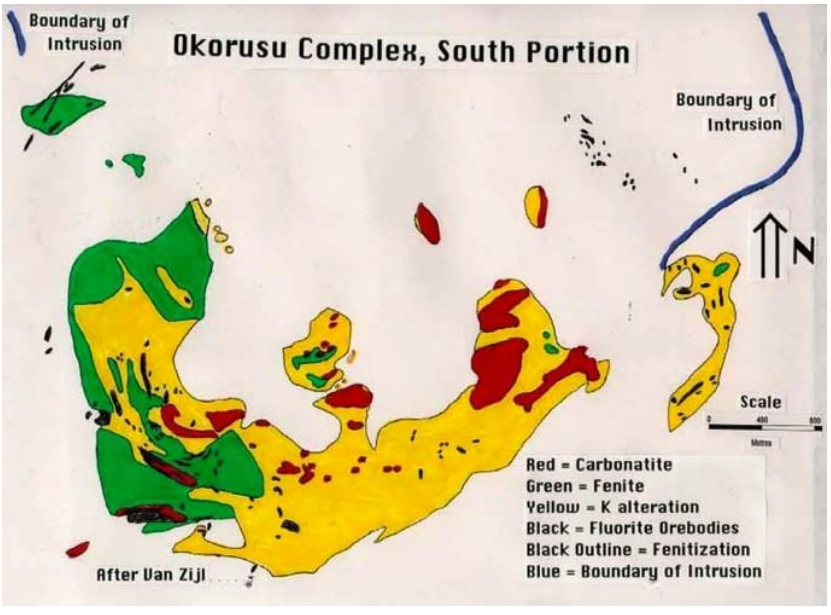


Figure 17. Sketch map of the southern rim portion of Van Zijl's Okorusu complex map showing the distributions of carbonatite (dark gray, center and right side of map), fenite (dark gray, center and right side of map), hydrothermal alteration (light gray), some of the fluorspar orebodies (black), and a portion of the boundary of the complex (black, upper left and right corners of map).

Figure 18. Early exposure in the A pit mine at Okorusu that appears to show fluorspar ore (dark gray, bottom half of photograph) deposited from ore fluids ponding beneath a magnetite dike (light gray, upper portion of photograph). Subsequent mine exposures indicated that magnetite occurred as rims around fluorspar orebodies. A open pit, Okorusu mine.

Figure 19. Pyroxene carbonatite (Px Carb) intruded by later pegmatitic carbonatite (Peg Carb). B open pit, Okorusu mine.

Early exposures of fluorspar ores at the A pit gave the impression that the fluorspar ore fluids were ponded beneath what appeared to be magnetite dikes at that time (Schneider, 1991) (Figure 18). Subsequent exposures in the A pit showed that the magnetite instead formed rims around the fluorspar orebodies (Kogut, 1991; Hagni and Kogut, 1997; Kogut et al., 1997. 1998) (Figures 13, 14), and resulted from the replacement of carbonatite bodies that had primary rims of magnetite (Hagni, 2001; Hagni and Shivdasan, 2001; Shivdasan, 2003; Shivdasan and Hagni, 2004).

GEOLOGY OF OKORUSU ALKALINE IGNEOUS-CARBONATITE COMPLEX

The Okorusu Alkaline Igneous-Carbonatite Complex is nearly circular in plan view, pipe-shaped in vertical section, and about 8 km horizontally across. The complex is late Cretaceous in age (125 +-7 Ma) (Milner et al., 1995), and it intrudes early Precambrian Damara hostrocks that are comprised of regionally metamorphosed quartzites, marbles, and schists. Alkali (sodium and potassium)-rich fluids that streamed up the pipe at an early time produced extensive fenitization of the country rocks in the vicinity of the complex, especially along its southern border. Fenite has been defined by Le Bas (2008), and at Okorusu fenite is a green, dense, fine-grained rock that formed through metasomatism (hydrothermal alteration) of the country rocks (biotite schists, etc.). Several periods of fenitization may well have occurred.

Five generations of carbonatites were recognized to have been derived from the upper mantle and emplaced explosively where they cemented fenite megabreccias (Shivdasan and Hagni, 2005; Shivdasan-Gebhardt and Hagni, 2008). Two types of carbonatite are most common, and both are composed dominantly of calcite ($CaCO_3$) with only small amounts of dolomite [$CaMg(CO_3)_2$]. The earliest carbonatite to be intruded has been termed a pyroxene carbonatite because of its abundant iron-rich diopside [$CaMg(SiO_3)_2$] (formerly called salite

and ferrosalite pyrroxene)[electron microprobe composition: ($Ca_{0.94}$, $Na_{0.06}$, $K_{0.0002}$)($Mg_{0.55}$, $Fe_{0.40}$) ($Si_{1.94}$, $Al_{0.04}$) O_6). The composition of the pyroxene in the carbonatites differs significantly from that of the aegirine-augite pyroxene present in the fenites. A slightly later carbonatite has been termed a pegmatitic carbonatite (Figure 19) because of its very large crystals that are locally as long as one meter (the use of the term pegmatite refers to crystal size and does not have a genetic implication). In addition to diopside, this carbonatite contains large titaniferous magnetite crystals that contain an average of 8.44% titanium and 0.35% V_2O_3 (Shivdasan-Gebhardt and Hagni, 2008). Figure 20 shows a drill core specimen of pegmatitic carbonatite that contains abundant magnetite (Fe_3O_4)(black, Mt), diopside pyroxene (green, Px), and apatite (gray, Ap) in a matrix of calcite (white, Cal). Both carbonatites locally contain abundant platy pyrrhotite (FeS) crystals. Pyrrhotite crystals can be as large as one meter. Apatite [$Ca_5F(PO_4)_3$] is a relatively abundant and characteristic mineral of the two carbonatites. It contains an average of 4.2% fluorine (Shivdasan-Gebhardt and Hagni, 2008).

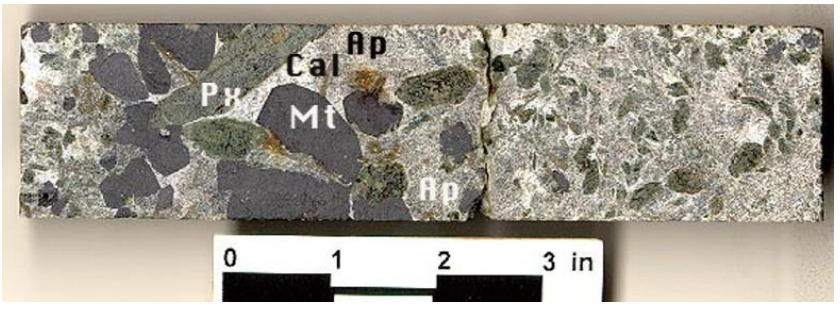


Figure 20. Pegmatitic carbonatite containing abundant magnetite (Mt), diopside pyroxene (Px), and apatite (Ap) in a matrix of calcite (Cal). Drill core, B open pit, Okorusu.

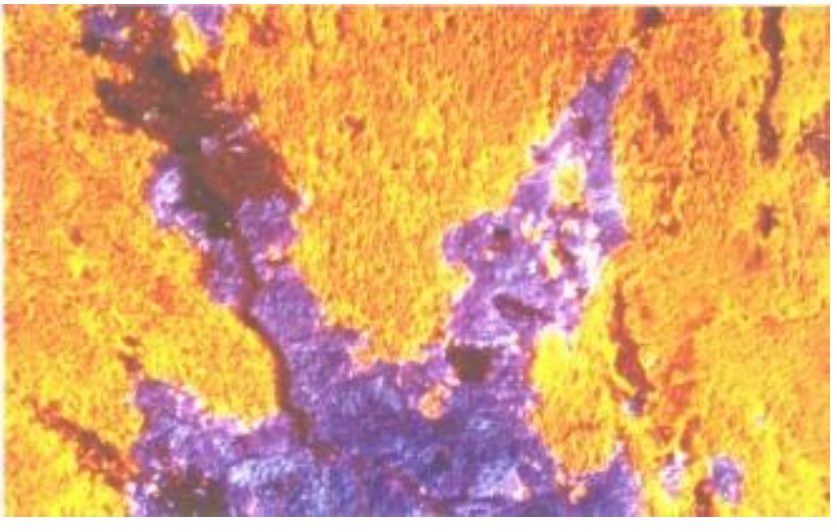


Figure 21. Fluorite (dark gray, veins) veining carbonatite calcite (light gray). Cathodoluminescence microscopic micrograph. 60X.

The temperature of crystallization of the pyroxene carbonatite ranged about 536-475ºC. Based upon electron microprobe analyses of the iron and titanium contents of the titaniferous magnetite was about 475°C (Kogut, Hagni, Schneider, 2001). Electron microprobe analyses of coexisting apatite and magnesian biotite in the pyroxene carbonatite gave a maximum temperature of 536°C (Shivdasan, 2003; Shivdasan and Hagni, 2004).

The carbonatites, as well as fluorspar ores, are very advantageously studied by cathodoluminescence microscopy (CLM)(Hagni, 2006). Calcite, dolomite, apatite, and fluorite exhibit strong cathodoluminescence (CL) that allows even the smallest grains to be detected and studied. Calcite exhibits yellow CL (Figures 21, 22), dolomite shows orange CL (Figure 22), apatite exhibits a variety of yellow, pink, and purple CL (Figure 22), and fluorite shows strong blue to purple CL (Figure 21). The interior zoning and twinning characteristics of those minerals also are prominently displayed (Figures 23, 24) by CLM. In the microscopic study of mill products from Okorusu, the utilization of CLM provides an excellent means to study the character of apatite grains (Figure 25) that form a deleterious constituent in the fluorspar concentrates (Kogut and Hagni, 1995; Hagni and Kogut, 1997).

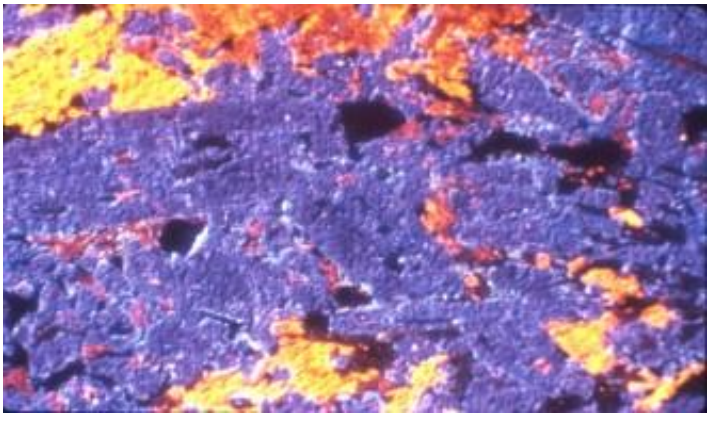


Figure 22. Abundant apatite (dark gray) together with calcite (white) and dolomite (medium gray) in pegmatitic carbonatite. Cathodoluminescence microscopic micrograph. 60X.

Figure 23. Internal zoning in fluorite crystal revealed by cathodoluminescence microscopy. All shades of gray are fluorite. 60X.

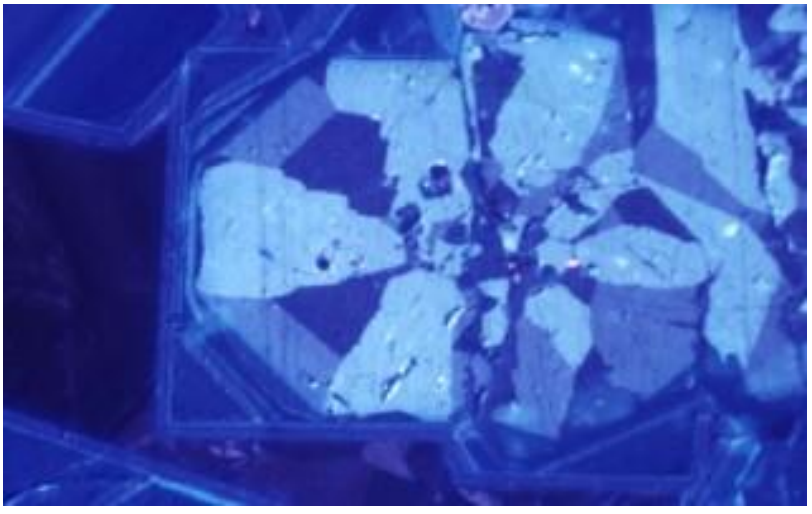


Figure 24. Cyclic twinning revealed by cathodoluminescence microscopy. All shades of gray are fluorite. 60X.

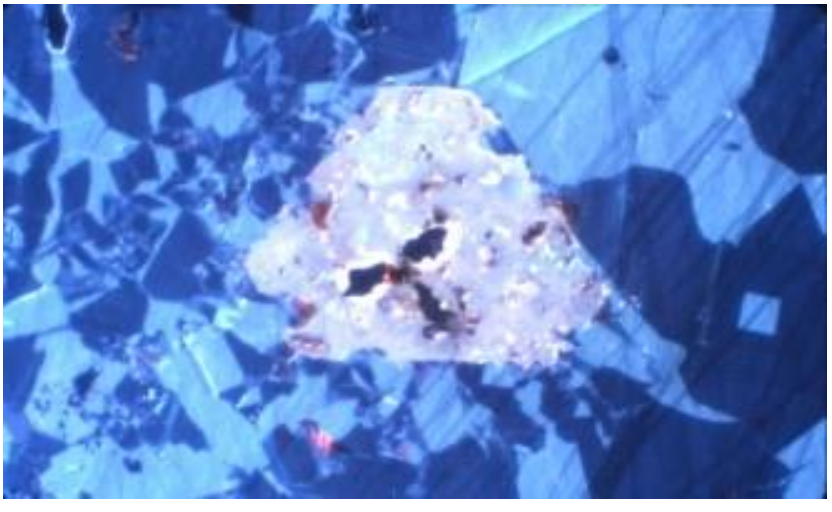


Figure 25. Apatite crystal (light gray and white) retained in fluorite (medium and dark gray) after fluorspar ore had replaced carbonatite. Cathodoluminescence microscopic micrograph. 60X.

Nepheline syenites and foyaite are the most common silicate rocks in the complex, together with smaller amounts of monzonite, nephelinite, and others. Syenite and foyaite form prominent hills in the northern portion of the complex (Figure 26). Their high magnetite content gives those rocks the highest magnetic anomalies in the complex.

Intrusive dikes occur throughout the complex, and they are most commonly tinguaites, but some are syenite, foyaite, and bostonite. Tinguaite dikes were intruded after carbonatite emplacement and they traverse the fenites (Figure 27) and carbonatites.

Figure 26. Hills composed of nepheline syenite at Brandenburg Farm in the northern portion of the Okorusu complex.

Figure 27. Tinguaite dike (dark gray) traversing fenite (medium to light gray) in a mine heading at the B open pit, Okorusu mine.

FLUORSPAR OREBODIES

Fluorspar-depositing fluids replaced easily dissolved calcite in the carbonatite intrusions, and left relatively insoluble titaniferous magnetite at the margins of those intrusions (Figures 13, 14). These fluids converted iron-rich diopside pyroxene (Shivdasan-Gebhardt and Hagni, 2008) and pyrrhotite crystals within the carbonatite intrusions into goethite pseudomorphs

(Hagni, 2007). Apatite crystals in the carbonatites also are partially replaced by the fluorspar-depositing fluids. Cathodoluminescence microscopy provides an especially useful tool to study the mineralogy of the carbonatites, fluorspar ores, and fluorspar mill products (Hagni and Shivdavsan, 2001; Hagni, 2006). Partially replaced apatite crystals form binary locked particles (apatite crystals partly intergrown with fluorite) in the fluorspar concentrates and they produce an important metallurgical problem for carbonate-related fluorspar concentrates (Figure 28). Phosphorus is a detrimental constituent in steelmaking and carbonatite-related fluorspar concentrates therefore usually cannot be used as a steelmaking flux. At Okorusu the carbonatite-replacement fluorspar ores average 2.5% P_2O_5, and flotation reduces that content in the final concentrates to 0.3-0.5% P_2O_5.

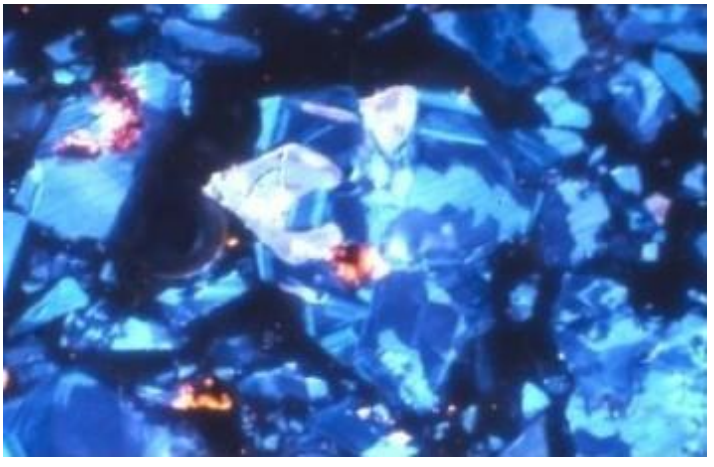


Figure 28. Apatite crystals (white, center of micrograph) partly replaced by fluorite (light to dark blue) in carbonatite-replacement fluorspar ore. During milling this intergrowth produces binary locked apatite-fluorite particles that carry deleterious phosphorus into the fluorspar comcentrates. Note zoning (dark and light gray bands) of central fluorite crystal. Cathodoluminescence microscopic micrograph. 60X.

Figure 29. Fluorspar ore (center of mine face, horizontal banding) replacing marble to the right of the fluorspar orebody. A band, B open pit, Okorusu mine.

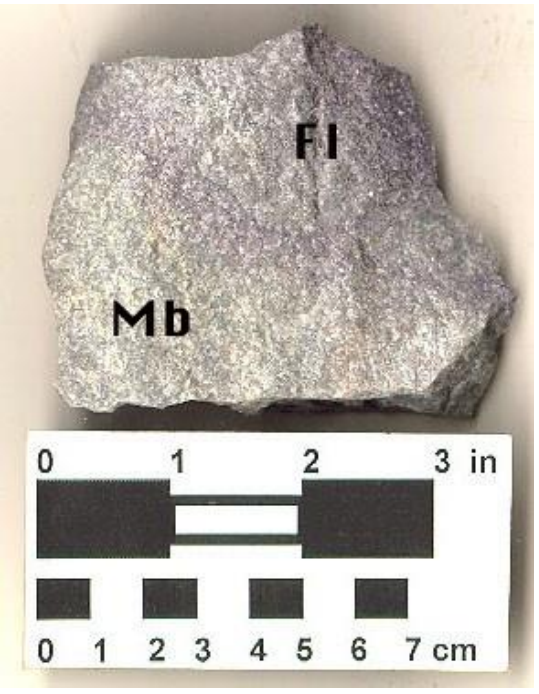


Figure 30. Hand specimen showing fine-grained fluorspar (Fl, medium gray) ore formed as a result of fluorspar replacement of fine-grained marble (Mb, light gray). A band, B open pit, Okorusu mine.

Where the fluorspar-depositing fluids locally encountered Precambrian Damara marbles they produced fine-grained marble-replacement fluorspar ores (Hagni, 2011), and this is especially the case for the A band fluorspar ore of the B open pit at Okorusu (Figure 29). Those ores are not only characterized by a finer grain size (Figure 30) than the carbonatite-replacement fluorspar ores, they also are characterized by negligible phosphorus contents. It has been calculated that 84% of the fluorspar ores at Okorusu have formed by the replacement of carbonatite, 15% by the replacement of marble, and 1% by the veining and replacement of fenite breccias (Hagni, 2011).

Multiple separate fluorspar orebodies have been mined at the Okorusu mine property. The average grade of those ores is about 35% fluorspar, but the grade varies between orebodies and averages as high as 60% for some orebodies (Lanham, 2005). The grade also varies significantly within each orebody. The ore grades at the A and B pits ran 50-60% fluorite. The A orebody was the first one mined at Okorusu, and for many years it was the only orebody mined. It is located about two-thirds of the distance up the east side of Okorusu Mountain. It was characterized by especially high grade fluorspar ore, but also typically contained significant amounts of apatite. The A orebody is tabular in shape, about 300 meters long (east-west), 50 meters wide, and it dips 40 to 60 degrees to the north.

The B orebody is situated at the summit of Okorusu Mountain, and it consists of two separate bands that were joined together by three cross bands during early mining of the B open pit (Figure 31). The runs strike in a northwest direction. The band (B band) on the northeast side is located higher up the mountain, has formed mainly by the replacement of carbonatite, and therefore it contains elevated contents of apatite and phosphorus. The band (A band) on the southwest side is lower on the mountain, has formed by the replacement of

marble, had a little higher grade than B band, and is lower in apatite but higher in quartz and therefore silica content. The cross bands, like the B band, were formed by the replacement of carbonatite as indicated by the presence of carbonatite replacement remnants in the fluorspar cross bands. As the mining progressed deeper those cross bands of fluorspar ore pinched and disappeared.

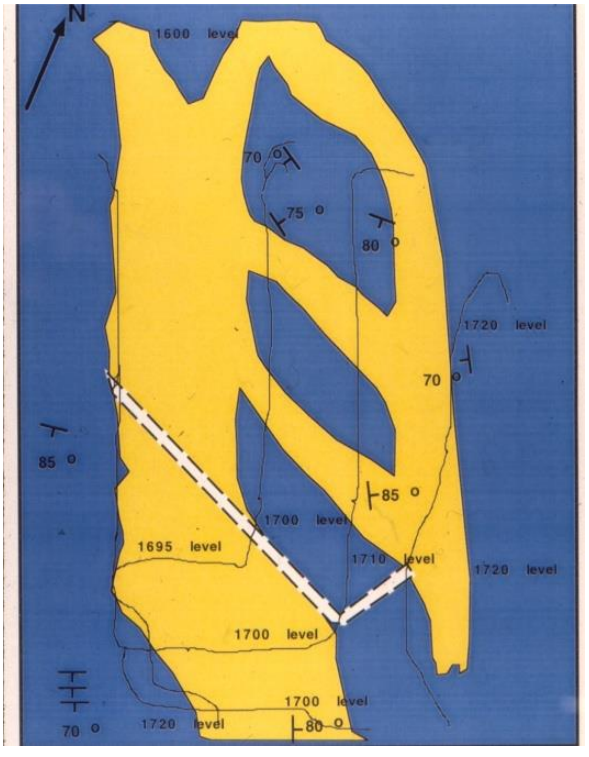


Figure 31. Map of B pit orebodies prepared at a time when mining had reached the 1695 level (1695 meters above sea level) showing the distribution of fluorspar ore (light gray) in Damara fenitized country rocks (dark gray). The narrow band on the right (A band) formed by replacement of marble and the wide band on the left (B band) formed by replacement of carbonatite. Three cross bands of fluorspar (light gray) between the A and B bands have formed by replacement of carbonatite and they locally contained replacement remnants of carbonatite. A single tinguaite dike (dashed outline, white) traversed the B band and fenite.

The C orebody is located west of the A pit, and it has been mined only to a limited extent to date. It is polywag shaped with a tail that extends southward. Mining began in the tail that had replaced marble. Subsequent mining reached the southern edge of the head of the polywag where the fluorspar ore has replaced carbonatite. Drilling and ground magnetics have outlined a carbonatite body at the north edge of the C deposit, and that body is continuous from the carbonatite exposed in the B pit. Portions of the C ores had grades as high as 70 to 90% fluorite. Figure 32 summarizes the distributions of carbonatite-replacement, marble-replacement, and fenite-replacement fluorspar ores in the A, B, and C orebodies.

The D deposit is located north of the A pit and it has been intensively mined. Based upon drilling, the D deposit consists of six or seven north-trending bodies of fluorite ore (Hagni, in press-C). The D deposit appears to have formed entirely by the replacement of carbonatite.

Drilling has outlined two fluorspar orebodies, called the G deposits, located east of the A deposit (Hagni, in press-C). One deposit, G main, has formed by the replacement of carbonatite and it was mined for a short period of time. The other deposit, G extension, has formed by replacement of marble, and it was drilled out by exploratory drilling but never mined.

The Wishbone fluorspar deposit, located far to the north of the other mined deposits, was explored but not mined. Limited outcrops of both carbonatite and marble occur near that fluorite deposit, and the original rock type(s) replaced by this deposit require further investigation.

Most recently, there was mining of fluorspar ore at an orebody (E deposit) about 5 km east of the A pit, but the distance of transport to the mill was an important problem. Exploration was also conducted at another fluorspar orebody (F deposit) about 2 km northwest of the E deposit.

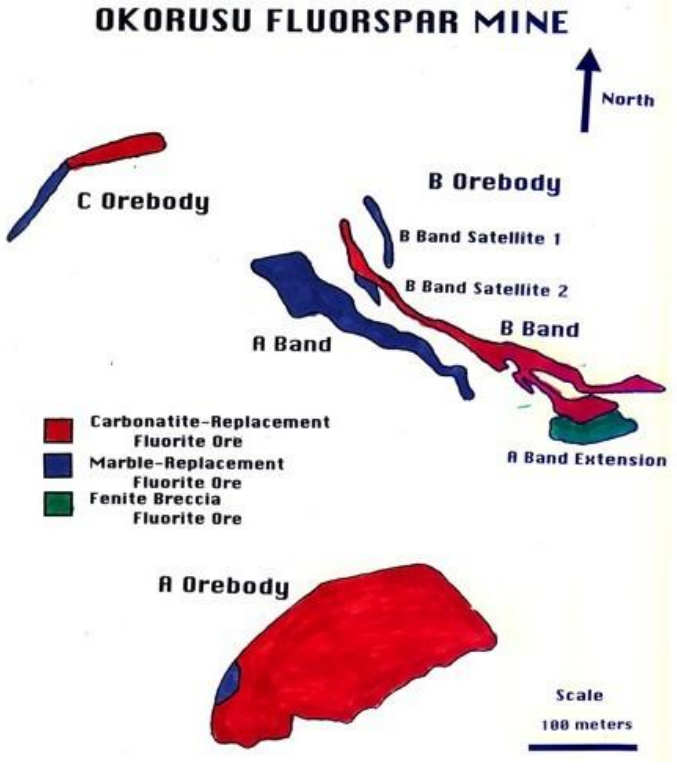


Figure 32. Map showing the distributions of carbonatite-replacement (medium gray, A orebody, B band of B orebody), marble-replacement (dark gray, A band of B orebody, southwest half of C orebody), and fenite-replacement (dark gray, south end of B band, B orebody) fluorspar ores for the A, B, and C orebodies.

RECOGNITION OF CHARACTER OF HOSTROCKS REPLACED BY FLUORSPAR OREBODIES AND ITS IMPORTANCE

The character of host rocks replaced by the fluorspar ores is important because it determines the nature of beneficiation problems that are likely to be associated with the fluorspar ores. Most Okorusu fluorspar ores have formed by the replacement of carbonatites, some ores have formed by replacement of Damara marble, and minor amounts of the ores formed by veining and replacement of fenite. The original rock types replaced by the fluorspar ores can be determined by the observation of a number of geological features of the ores. The fluorite crystals in ores that have replaced carbonatites are more coarsely crystallized than those in ores that replaced marble. Fluorspar ores that replaced marble locally exhibit a banded character that is retained from the bedding of the marble replaced. In contrast, fluorspar ores that replaced carbonatite show little or no banding. In addition, carbonatite-replacement fluorspar ores commonly contain goethite pseudomorphs after minerals originally present in the replaced carbonatite. Goethite pseudomorphs after pyrrhotite, pyroxene, and magnetite crystals are present locally in the fluorspar ores and easily recognized due to their characteristic crystal shapes (Figure 33). In addition, small local replacement remnants of the original carbonatite and marble may be present to attest to the replacement process. Figure 34 shows a large replacement remnant of carbonatite (dull white) that has remained within fluorspar ore (purple) in the B band at the B open pit that attests to the replacement process and arrests to the fact that the fluorspar ore has replaced carbonatite. Especially noteworthy is the fact that carbonatite replacement ores typically have a rim of titaniferous magnetite retained from titaniferous iron oxide present at the rims of the replaced carbonatite intrusions. The important discovery of two dikes of carbonatite in the A pit, one vertical (Figure 35) and a second horizontal carbonatite dike (Figure 36) exposed by a pushback of the fenite to reach additional fluorspar ore, exhibited partial replacement by fluorspar ore and showed clearly that fluorspar had replaced carbonatite (Hagni, 2007). Finally, examination of drill core shows clearly that the two types of fluorspar ores change laterally along strike and dip into carbonatite (Figure 37) on the one hand and to marble on the other hand (Hagni, 2007).

The importance of recognizing the nature of the replaced host rocks is several fold. It is scientifically satisfying to understand the character of the host rocks replaced by the fluorspar ores. More important is that an understanding of the rocks replaced provides a better understanding of where to explore for additional fluorspar ore deposits. That is, areas of carbonatite and marble are favorable for fluorite exploration, and areas of fenite and biotite schist are unfavorable. Most important is the fact that the character of the host rock replaced by the fluorspar ores determines the nature of beneficiation problems to be encountered (Kogut and Hagni, 1995; Hagni and Kogut, 1997; Hagni and Shivdasan, 2000; Hagni, 2004). Fluorspar ores that have formed by the replacement of carbonatite tend to have problems with high deleterious phosphorus contents. The phosphorus in the fluorite concentrate is derived from the presence of apatite in the replaced carbonatite. Apatite is an insoluble constituent in the carbonatite, and whereas the carbonatite calcite is replaced by fluorite much of the apatite remains behind in the fluorspar ores. During flotation most of the apatite is directed to the tailings. However, some of the apatite goes into the fluorite concentrates in the form of binary locked fluorite-apatite particles.

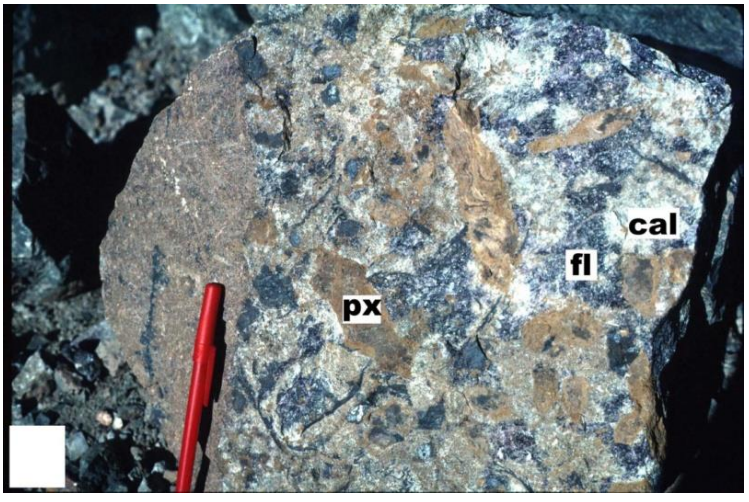


Figure 33. Hand specimen of carbonatite partly replaced and altered by fluorspar ores. Diopside pyroxene (Px) has been altered to goethite, pyrrhotite crystals (long, thin, black) also are altered to goethite, and magnetite crystals (black, equant) are largely unaltered. Small remnants of calcite (white) are only partly replaced by fluorite (medium gray, Fl). Fine-grained fenite (light medium gray) is located at the left side of the photograph (beneath pen).

Figure 34. Large replacement remnant of carbonatite (light gray, left half of photograph) that has remained within fluorspar ore (dark gray, right side of photograph), and it attests to the replacement process and that the replaced rock is carbonatite. B band, B open pit, Okorusu.

Fluorspar ores that have formed by the replacement of marble, by contrast, have low or no content of phosphorus but instead they tend to have high silica contents. The silica is derived from quartz grains in the limestone, late quartz crystallized on top of fluorite crystals, and potash feldspar connected to fenitization of host rocks. Most commonly the silica tends to be present as free quartz particles in the fluorite concentrates.

The relationship between rock type replaced by the fluorspar ores and beneficiation results is so well established at Okorusu that it is possible after examining the beneficiation results to correctly interpret the rock type that had been replaced by a particular fluorspar orebody.

Figure 35. A nearly vertical dike of carbonatite (medium grey with white spots) with magnetite (black) rims, which is partly replaced by fluorspar ore (darker gray) that retains those magnetite rims. A pit, Okorusu.

Figure 36. Horizontal carbonatite (white, Carb) dike intruding fenite (medium gray, Fenite) that is partly replaced by fluorspar (medium gray, Fl ore) ore. A open pit, Okorusu.

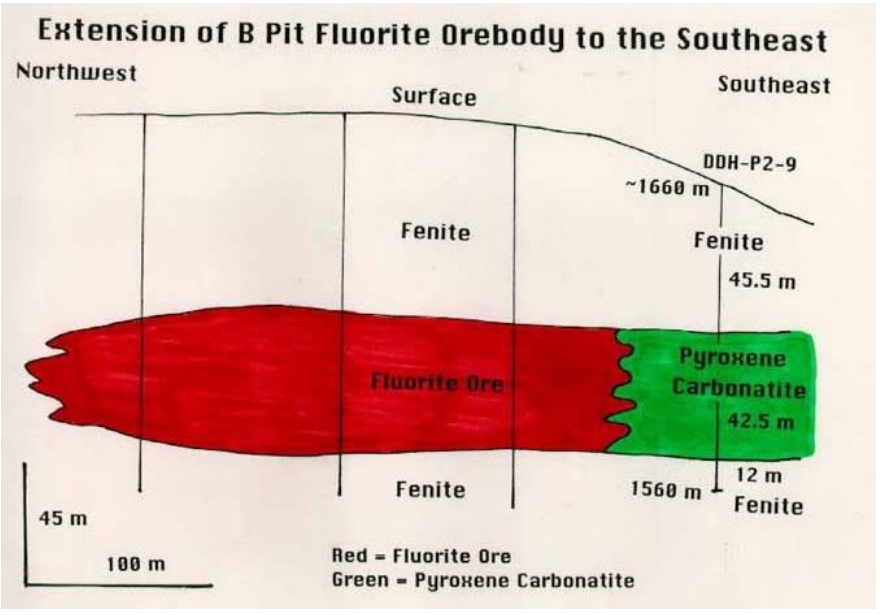


Figure 37. Geological section constructed based upon logging drill core that shows that the B pit fluorspar orebody (dark gray) changes gradually into pyroxene carbonatite (light gray) beyond that orebody to the southeast.

TEMPERATURES AND SALINITY OF FLUORITE-DEPOSITING FLUIDS

The temperatures and salinity of fluorite-depositing fluids can be measured by studying small voids in the fluorite crystals partially filled with water-dominant fluids that are called fluid inclusions. Study of Okorusu fluorite fluid inclusions by Roedder (1973), Shivdasan-Gebhardt and Hagni (2008), and Bühn et al. (2002) and summarized by Hagni (2007) have shown that the main periods of purple and green fluorite deposition occurred from 166-144ºC, and a slightly later period of yellow fluorite deposition took place at 132-128ºC. Yellow fluorite was restricted to the topographically higher open pit B mine where it clearly was later than purple fluorite upon which it was deposited (yellow fluorite was absent from the A open pit mine). The salinity of the fluorite-depositing fluids ranged from 5 to 1.5 wt per cent NaCl equivalent. The salinity is significantly lower than for Mississippi Valley-type fluorspar ores and the temperatures are slightly lower than for most epithermal ore deposits.

Geochemical analyses by Bühn et al. (2003) have provided a large amount of trace element and isotopic data for Okorusu fluorite, calcite, barite, and manganese oxide. Fluorite samples were collected and analyzed from the B pit. The trace element and isotope content of purple (and colorless) fluorite was contrasted with that of yellow fluorite. Chemical trends of the fluorite-depositing fluids through paragenetic time were determined, but they believed yellow fluorite was deposited before purple fluorite. The results also were interpreted in terms of variations in the activities of CO_2 and F^- through paragenetic time.

EVIDENCE FOR EARLY HYDROTHERMAL EVENT

An early hydrothermal event has affected the carbonatites at Okorusu prior to the introduction of fluorite-depositing fluids (Hagni, in press-A). That event is especially characterized by the deposition of quartz and synchysite (Figure 16). The introduction of hydrothermal fluids of this event dissolved rare earth elements from the carbonatite and redeposited those elements in the form of synchysite, a rare earth fluorcarbonate with the composition of $Ca(Ce,La)(CO_3)_2F$. Synchysite was deposited prior to the closely associated quartz and commonly it is enclosed within that quartz. Where synchysite is enclosed in quartz it was partially protected from dissolution by the subsequent fluorite-depositing fluids.

Additional evidence for the early hydrothermal event that affected Okorusu carbonatites has been recognized by mineralogical studies under the reflecting light microscope (Hagni, in press-B). Distinctive alteration of pyrrhotite (FeS) crystals in the carbonatite to a sequence of fine-grained marcasite (FeS_2) and pyrite (FeS_2), together with associated secondary fine-grained magnetite and hematite, coarse-grained pyrite, siderite, and chalcopyrite (Figure 38). The formation of these sulfide and oxide phases indicates that the early hydrothermal event was due to moderately oxidizing fluids. In contrast, the subsequent fluorite-depositing hydrothermal event was characterized by strongly oxidizing fluids that altered all of those minerals further to goethite.

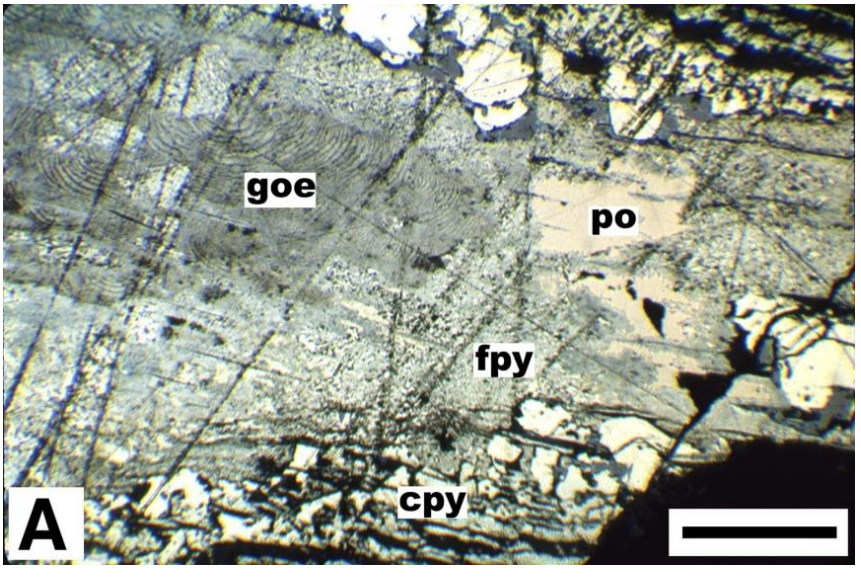


Figure 38. Platy hexagonal pyrrhotite crystals in the carbonatite are altered by an early hydrothermal event to fine-grained pyrite (fpy) and marcasite, then to coarse-grained pyrite (cpy), and then further altered by the introduction of the fluorspar-depositing fluids to goethite. Remnants of the original pyrrhotite (Po) are present in the fine-grained pyrite and goethite. Where goethite has altered from fine-grained pyrite the goethite has a fine-grained texture, but where goethite has altered directly from pyrrhotite it shows a concentric colloform texture (beneath "goe" designation). Reflected light photomicrograph. 60X.

Figure 39. The alteration of rocks at Okorusu by early fenitization, early hydrothermal event, later by hydrothermal fluorite-depositing fluids, and finally by supergene oxidation fluids renders the already challenging geology even more challenging. The mine face in this view is typical of the difficulty in distinguishing areas of fenite (medium gray) from intrusive areas of carbonitite (light gray). A pit, Okorusu mine.

The character of the original pyrrhotite crystals in Okorusu carbonatite is shown in unreplaced carbonatite in the Okorusu fluorspar mines. Black platy pyrrhotite crystals and equant magnetite crystals are disseminated in white pegmatitic carbonatite amd commonly associated with dark pyroxene carbonatite. Pyroxene crystallized before magnetite and may be enclosed in the subsequently crystallized magnetite. The pyrrhotite crystals, even where completely altered to pyrite, show crystal shapes characteristic of hexagonal pyrrhotite.

The early alteration of pyrrhotite is to smythite (Fe_3S_4) but the principal alteration products of the pyrrhotite are fine-grained marcasite and pyrite. Fine-grained marcasite exhibits elongate textures, and fine-grained pyrite usually exhibits anhedral grains but locally it shows a reticular pattern consisting of loosely clustered small pyrite crystals with similar orientations. Fine-grained marcasite and pyrite are subsequently replaced by coarse-grained pyrite formed especially at the margins of the former pyrrhotite crystals. The secondary magnetite and hematite have been formed simultaneously with the fine-grained and especially coarse-grained pyrite. The secondary magnetite and hematite are intimately intergrown with both fine-grained and coarse-grained pyrite.

Chalcopyrite is a minor phase deposited in association with altered pyrrhotite crystals. The chalcopyrite typically is deposited outside the pyrrhotite crystals, but locally it has been deposited by replacement of fine-grained marcasite and pyrite within the altered pyrrhotite crystals. Similarly, siderite was deposited late in the alteration paragenesis. Siderite usually was deposited at the margins of the former pyrrhotite crystals, but locally it was also deposited within those crystals.

When the fluorite-depositing fluids were subsequently introduced into the carbonatite, after cessation of the early hydrothermal pyrrhotite-altering event, all of the minerals formed during the early alteration event were further altered to goethite (Figure 40). Fine-grained

marcasite was altered to goethite with elongate texture pseudomorphic after the elongate texture of the replaced marcasite. Fine-grained pyrite was altered to fine-grained goethite. Where the pyrrhotite had been altered to both fine-grained and coarse-grained pyrite the alteration product for both grain sizes have been pseudomorphically replicated by goethite. Where portions of the original pyrrhotite remained after alteration by the early hydrothermal event, that pyrrhotite was altered directly to goethite with a distinctive colloform texture.

The end result of the alteration processes is that goethite pseudomorphs after the pyrrhotite crystals are present locally in the fluorite ores, and they provide evidence for the alteration process, and they are important in indicating that the fluorspar ores had formed by the replacement of pyrrhotite-bearing carbonatite. The fact that much of the fluorite ores at Okorusu had formed by the replacement of carbonatite is an important factor in the exploration for new fluorite orebodies (Hagni, 2011a; Hagni and Shivdasan, 2000).

FACTORS MAKING STUDY OF GEOLOGY OF CARBONATITE-RELATED FLUORSPAR DEPOSITS DIFFICULT

There are several factors that together render the deciphering of the geology of carbonatite-related fluorspar deposits challenging. It is perhaps useful, somewhat as a sort of final contribution to this chapter, to briefly discuss those factors. The rocks exposed in the open pit mine walls at Okorusu typically have been repeatedly altered (Hagni, in press-C) (Figure 39). Firstly, the host Damara country rocks have been highly altered (metasomatized) by early fenitizing fluids. Secondly, the carbonatites have been altered by an early hydrothermal event as discussed in the previous section. Thirdly, the fenites, carbonatites, and tinguaite dikes have been highly altered by the fluorite-depositing hydrothermal ore fluids. Finally, all rocks and fluorspar ores have been highly altered by supergene oxidizing waters in relatively recent time. Supergene altered rocks and ores have developed copious amounts of goethite that largely masks the original character of those rocks. In summary, the complicated geology is further complicated by the difficulty of distinguishing the original rocks in the mine walls due to the multiple episodes of rock alteration.

CONCLUSION

The Okorusu alkaline igneous carbonatite complex is a vertical ignous intrusion derived from the upper mantle. The complex is circular in plan view with a diameter of about 8 km. It was intruded during early Cretaceous time (125 Ma) into late Precambrian Damara Series regional metasediments. The Precambrian Damara rocks of the complex have been highly metasomatized to green, dense, fine-grained, aegirine-rich fenites especially along its southern margin. Fenitization resulted from the introduction of early sodic and potassic fluids prior to the intrusion of carbonatites and alkaline silicate magmas. Multiple explosively intruded carbonatite magmas resulted in large fenite breccia blocks cemented by carbonatites. Introduced silicate igneous rocks in the Okorusu complex include nepheline syenite, foyaite, tinguaite, and monzonite.

Five varieties of carbonatite occur at Okorusu, and the most abundant types are pyroxene carbonatite and pegmatitic carbonatite. Mineralogically the carbonatites consist of major calcite, minor dolomite, diopside pyroxene, titaniferous magnetite, hexagonal pyrrhotite, and the REE mineral, synchysite. The carbonatites and fluorspar ores are best studied under the cathodoluminescence microscope because calcite, dolomite, apatite, and fluorite exhibit strong and characteristic cathodoluminescence. Electron microprobe analyses of coexisting apatite and magnesian biotite and the titanium contents of the titaniferous magnetite in the carbonatites indicates that the carbonatites crystalized from 536°C to 475°C. The carbonatites were altered by an early hydrothermal event that introduced small amounts of quartz, chalcopyrite and synchysite, altered the pyrrhotite crystals to a sequence of smythite, fine-grained pyrite and marcasite, and coarser grained pyrite.

Fluorspar has been mined from or explored for at nine deposits in the Okorusu complex. Deposits mined include: A, B D, E, and G main open pits. Limited mining was undertaken at the C open pit, and exploratory drilling occurred at the F, and G extension, and Wishbone fluorspar deposits. The principle mining activity occurred at Okorusu from 1988 through 2014, and the mine is on care and maintenance at the current time. During most of its period of operation, Okorusu was the world's largest carbonatite-related fluorspar mine, and at one time together with the non-carbonatite-related Witkop fluorspar mine of South Africa supplied about 20% of the world's fluorspar. By-products from the mine have included crushed fenite for local road material, and magnetite for local cement industry. Before its closure Okorusu Limited had satisfactorily produced an apatite concentrate from fluorspar tailings and was considering the production of a phosphorus by-product for the Namibian agriculture industry. Okorusu carbonatites contain REE in the form of the mineral synchysite, and limited exploration for REE mineralization has occurred at Okorusu.

A variety of geological and mineralogical aspects of the fluorspar ores indicate that most deposits formed by the replacement of carbonatite. These features include: 1) the presence of magnetite rims around orebodies that had previously formed magnetite rims around the replaced carbonatite bodies, 2) goethite pseudomorphs after pyroxene, pyrrhotite, and magnetite within fluorspar orebodies that had formed as crystals in the replaced carbonatites, 3) elevated phosphorus contents resulting from the presence of apatite retained in the fluorspar ores after replacement of apatite-bearing carbonatites, 4) detection of small areas of unreplaced carbonatite within the fluorspar orebodies, 5) the recognition in drill core that the fluorspar ores grade laterally into carbonatites, and 6) the direct observation that fluorspar has partially replaced two distinct carbonatite dikes in the A pit. Less commonly, fluoprspar ores have replaced Damara marble. Those ores are characterized by: 1) local distinct banding, 2) gradation into marble, 3) low phosphorus contents, and 4) elevated silica contents. Consideration of tonnage of fluorspar ores present at mined and explored deposits indicates that 84% of the fluorspar replaced carbonatite, 15% replaced marble, and 1% was present as thin veins and replacements of fenite.

The fluorspar ores at the A and B pits were high grade and ran between 50 and 60% fluorspar. Ore grades were lower at most of the other fluorspar deposits at Okorusu. The ores consisted largely of massive fluorspar, but locally there were vugs that were lined by well-formed cubic crystals that have been prized by mineral collectors.

Analysis of fluid inclusions in fluorite crystals indicate that the main stage fluorspar-depositing fluids had a temperature range of from 166 to 144^{o}C and that late yellow fluorite in

the B pit was deposited at 132-128^{o}C. The salinity of those fluids was low and ranged from 5 to 1.5 wt % NaCl equivalent.

Carbonatite-related fluorspar deposits provide a challenging geologic study due to their complicated geological relationships and the variety of alteration types, including fenitization, early hydrothermal alteration of the carbonatites, subsequent hydrothermal alteration associated with the introduction of the fluorspar ore deposits, and finally supergene alteration connected with the present land surface.

ACKNOWLEDGMENTS

The writer wishes to acknowledge Mark Dawe, former manager of the Okorusu mine, for his generous accommodation of the writer during his 10 study visits to the Okorusu mine over the past 20 some years. Without his support and encouragement of the writer's several graduate students, particularly Ari Kogut and Purnima Shivdasan-Gebhardt, the relationships reported in this chapter would not have been accomplished.

Most of the study visits were financially supported by grants from the NSF. One study visit was sponsored by the University of Missouri-University of the Westerrn Cape, South Africa Faculty Exchange Program.

REFERENCES

Bühn, B, Rankin, A. H., Schneider, J. and Dulski, P. 2002. The nature of orthomagmatic, carbonatitic fluids precipitating REE, Sr-rich fluorite: Fluid inclusion evidence from the Okorusu fluorite deposit, Namibia, *Chemical Geology*, vol. 186, pp 75–98.

Bühn, B., Schneider, J., Dulski, P. and Rankin, A. H. 2003. Fluid-rock interaction during progressive migration of carbonatitic fluids, derived from small-scale trace element and Sr, Pb isotope distribution in hydrothermal fluorite, *Geochem. et Cosmochem. Acta*, vol. 67, pp 4577-4595.

Business Excellence Magazine online. 2009. *Okorusu mine*. http://www.bus-ex.com/article/okorusu-mine. Accessed February 1, 2012.

Hagni, R. D., 2001. Variations in ores, host rocks, and ore controls for the carbonatite-related fluorspar deposits at Okorusu, north-central Namibia. In R. D. Hagni. Ed. *Studies on ore deposits, mineral economics, and applied mineralogy: With emphasis on Mississippi Valley-type base metal and carbonatite-related ore deposits* (pp 143–158). Rolla, MO: University of Missouri-Rolla Press.

Hagni, R. D. 2006. Cathodoluminescence microscopy applied to industrial minerals. In *Proceedings Volume, 42nd Forum on the Geology of Industrial Minerals*, Asheville, NC, Information Circular 34 (CD Rom), North Carolina Geological Survey, Raleigh, NC: 17 pp.

Hagni, R. D. 2007. Petrologic controls for fluorspar deposits at Okorusu, Namibia: Hydrothermal replacement of carbonatite, marble and fenite. In *Proceedings of the 40th Forum on the Geology of Industrial Minerals*, Indiana Geological Survey (pp 51–63). Occasional Paper No. 67.

Hagni, R. D. 2011. The replacement of carbonatite and marble by fluorspar ores and its relationship to beneficiation problems at Okorusu, Namibia. *10th International Congress for Applied Mineralogy* (pp 297-206). Norwegian Geological Survey Trondheim, Norway, CD Rom,

Hagni, R. D. 2015. Possible causes for significant variations in chemical and mineralogical compositions among the major ore districts in the Mississippi Valley: Tri-State Zinc District, Southeast Missouri Lead District, and Southern Illinois-Kentucky Fluorite District. In Z. Lasemi. Ed. *Proceedings of the 47th Forum on the Geology of Industrial Minerals*, Illinois State Geological Survey, Circular 587, 10 pp.

Hagni, R. D., in press-A. The Okorusu carbonatite-related fluorspar deposits in North-Central Namibia: The character of the fluorite ores, their emplacement by the replacement of carbonatite and marble, and evidence for early pre-fluorite hydrothermal activity. In S. Krukowski. Ed. *Proceedings Volume, 44th Forum on the Geology of Industrial Minerals*, Midwest City, Oklahoma: Oklahoma Geological Survey, Norman, Oklahoma.

Hagni, R. D., in press-B. Early hydrothermal event in the fluorite ores at the Okorusu Alkaline Igneous-Carbonatite Complex, Namibia, *48th Forum on the Geology of Industrial Minerals*, Phoenix, Arizona: Arizona Geological Survey.

Hagni, R. D., in press-C. The Character and Field Relations of Fluorspar Deposits, Carbonatite, Titianiferous Magnetite, and Tinguaite in the Okorusu Alkaline Igneous-Carbonatite Complex, North-Central Namibia, *Proceedings Volume, Forum on the Geology of Industrial Minerals*, Kingston, Jamaica.

Hagni, R. D., in press-D. The role of carbonatite deposits in the industrial minerals industry: mineralogical aspects of selected economically important carbonatite-related industrial mineral deposits, British Geological Survey, 9 pp.

Hagni, R. D. and Kogut, A. I. 1997. The character of phosphorus in fluorite ores and concentrates from the Okorusu fluorite deposit, north-central Namibia, *Applied Mineralogy: Proceedings of the 5th International Congress on Applied Mineralogy in the Minerals Industry* (pp 216-220). Warsaw, Poland.

Hagni, R. D. and Shivdasan, P. A. 2000: Megascopic textures in fluorspar ores are valuable indicators of potential beneficiation problems. *Journal of Metals*, vol. 52, pp 17–19.

Hagni, R. D. and Shivdasan, P. A. 2001. The origin of large plates of goethite in fluorite ores at Okorusu, North-Central Namibia: Pseudomorphs after platy pyrrhotite and pyrite in replaced pyroxene and pegmatitic carbonatites. In R. D. Hagni. Ed. *Studies on ore deposits, mineral economics, and applied mineralogy: With emphasis on Mississippi Valley-type base metal and carbonatite-related ore deposits* (pp 159-173). Univ. Missouri-Rolla Press.

Hagni, R. D, and Shivdasan, P. A. 2001. The application of cathodoluminescence microscopy to the study of carbonatite-related fluorspar ores, host rock carbonatites, and beneficiation products at Okorusu, Namibia. In *AIME-SME, Annual Meeting*, Denver, Colorado, CD ROM, SME Paper No. 01-133: 7 pp.

Hagni, R. D. and Shivdasan, P. A. 2001. Application of cathodoluminescence microscopy to the study of carbonatite-related fluorspar ores, host rock carbonatites and beneficiation products at Okorusu, Namibia, *Minerals and Metallurgical Processing, Society for Mining, Metallurgy, and Exploration* (pp 203-208). Littleton, Colorado, vol. 18.

Hagni, R. D. and Viladkar, S. G. 2004. A comparison of the carbonatite-related fluorite deposits at Amba Dongar, India and Okorusu, Nambia. In: *Proceedings of the 38th*

Forum on the Geology of Industrial Minerals, Missouri Department of Natural Resources (pp 89–97). Report of Investigations, vol. 74.

Hagni, R. D., Shivdasan, P. A., Viladkar, S. G. and Domoney, R. N. 2004. The carbonatite-related fluorspar deposits at Okorusu, north-central Namibia: Fluorite replacements of carbonatites and marbles, and the application of mineralogy to beneficiation problems, In M. Peccio, F. R. D. Andrade, L. Z. D. D'Agostino, H. Kahn, L. M. Sant'Agostino, and M. M. M. L. Tassinari. Eds. *ICAM, 2004, Applied Mineralogy: Developments in Science and Technology* (pp 649–652). Proceedings of the 8th International Congress on Applied Mineralogy (ICAM2004), São Paulo, Brazil,

Isaacs, D., 2013, *Mine adds value to fertilizer*. http://www.sun.com.na/content/business/mine-adds-value-fertiliser. Accessed June 1, 2013.

Kogut, A. I. 1995. *Mineralogy, paragenetic sequence, geochemistry and genesis of the Okorusu fluorspar deposit, North-Central Namibi*a. Unpublished M.S. thesis, University of Missouri-Rolla, Rolla, MO, 365 pp.

Kogut, A. I. and Hagni, R. D., 1995, Mineralogical Characterization of Phosphorus in Fluorite Ores and Concentrates from Southern Africa, In R. D. Hagni. Ed. *Process Mineralogy XIII: Applications to Beneficiation Problems, Pyrometallurgical Products, Advanced Mineralogical Techniques, Precious Metals, Environmental Concerns, Ceramic Materials, Hydrometallurgy, and Minerals Explorati*on (pp 15-27). The Minerals, Metals and Materials Society, Warrendale, PA,.

Kogut, A. I., Hagni, R. D, and Schneider, G. I. C 1997. The Okorusu, Namibia carbonatite-related fluorite deposits: Comparison with the Southern Illinois-Kentucky fluorite district. In D. F. Sangster. Ed. *Carbonate-Hosted Lead-Zinc Deposits* (pp 290–297). 75th Anniversary Volume, Society of Economic Geologists.

Kogut., A. I., Hagni, R. D. and Schneider, G. I. C. 1998. Geology, mineralogy, and paragenetic sequence of the Okorusu carbonatite-related fluorite ores, Namibia. In R. D. Hagni. Ed. *Proceedings of the Ninth IAGOD Symposium, International Association on the Genesis of Ore Deposits* (pp 555–573). Beijing, China, E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart, Germany.

Kogut, A. I., Hagni, R. D. and Schneider, G. I. C. 2001. Geology, mineralogy, and geochemistry of the carbonatite-related fluorite ores at Okorusu, north-central Namibia, In R. D. Hagni. Ed. *Studies on Ore Deposits, Mineral Economics, and Applied Mineralogy: With Emphasis on Mississippi Valley-Type Base Metal and Carbonatite-related Ore Deposits* (pp 113-142). Rolla, MO: Univ. of Missouri-Rolla Press.

Lanham, A., Mining Weekly.com. 2005. *South Africa and Namibia joint fluorspar production*. http://www.miningweekly.com/print-version/okorusu-faces-an-optimistic-future-2005-06-03. Accessed Feb. 1, 2012.

Le Bas, M. J. 2008. Fenites associated with carbonatites, *Canadian Mineralogist*, vol. 46, pp 915-932.

Milner, S. C,. Le Roex, A. P. and O'Connor, J. M. 1995. Age of Mesozoic igneous rocks in north-western Namibia, and their relationship to continental breakup, *Journal of Geological Society of London*, vol. 152, pp 97-104.

Prins, P. 1981. *The geochemical evolution of the alkaline and carbonatite complexes of the Damaraland igneous province, South West Africa*. Annale van die Universiteit van Stellenbosch, Serie A1 (Geologiese) vol 3, pp 145–278.

Roedder, E. 1973. Fluid inclusions from the fluorite deposits associated with carbonatite at Amba Dongar, India, and Okorusu, south west Africa. *Institute of Mining and Metallurgical Transactions*, Section B: pp 35–39.

Schneider, G. I. C. 1991. *Okorusu*. In ICAM'91, International Congress on Applied Mineralogy, Excursion Guide, pp 46–54.

Shivdasan, P. A. 2003. *Petrology, geochemistry, and mineralogy of pyroxene and pegmatitic carbonatite and the associated fluorspar deposit at Okorusu alkaline igneous carbonatite complex, Namibia*, unpublished Ph.D. dissertation, Univ. of Missouri-Rolla, Rolla, MO, 213 pp.

Shivdasan, P. A. and Hagni, R. D. 2004. The fluorite deposits at Okorusu, Namibia: Their origin by the replacement of carbonatite host rocks:, *Proceedings of the 38th forum on the Geology of Industrial Minerals* (pp 261-268), St. Louis, Missouri, Missouri Department of Natural Resources, Geological Survey and Resource Assessment Division, Report of Investigations Number 74.

Shivdasan, P. A. and Hagni, R. D. 2005. Carbonatite-related fluorspar deposits at Okorusu, Namibia: Control of ore emplacement by selective carbonatite replacement, electron microprobe analyses of carbonatite minerals, homogenization and freezing temperatures for fluid inclusions in fluorite, *Proceedings 41nd Industrial Minerals Forum*, Istanbul, Turkey, Istanbul Technical University (pp 18-31).

Shivdasan-Gebhardt, P. and Hagni, R. D. 2008. Fluorspar deposits at Okorusu, Namibia with emphasis upon electron microprobe analyses of carbonatite minerals and fluorite fluid inclusion temperatures and salinities. In *Ninth International Congress for Applied Mineralogy, ICAM 2008* (pp 631–641). Brisbane, Australia, the Australasian Institute of Mining and Metallurgy, Publication Series No 8/2008, Carlton Victoria, Australia.

Staff reporter. 2010. *Okorusu to supply iron ore to Ohorongo cement factory*. http://www.namibian.com.na/index.php?id=28&tx_ttnews%5Btt_news%5D=71371&no_cache=1. Accessed February 1, 2012.

Van Zijl, P. (1962) *The geology, structure and petrology of the alkaline intrusions of Kalkfeld and Okorusu and the invaded Damara rocks*, In: Ph.D. dissertation, Universiteit van Stellenbosch, vol. 37, Ser. A, no. 4, pp 241–324.

Weidlich, B. AllAfrica.com. 2010, *Namibia: Rare earths could boost mining sector*. http://allafrica.com/stories/201012220170.html. Accessed Feb. 1, 2012.

In: Handbook on Africa
Editor: Whitney Sherman
ISBN: 978-1-53610-063-1

Chapter 9

RABIES IN NAMIBIA, MORE THAN A HORRENDOUS DISEASE: THE SOCIAL, ENVIRONMENTAL AND ECONOMIC CHALLENGES FACED

T. P. Scott[1,2], A. Coetzer[1,2] and L. H. Nel[1,2]
[1]Global Alliance for Rabies Control (GARC)
[2]Department of Microbiology and Plant Pathology, University of Pretoria, South Africa

ABSTRACT

Rabies remains a common affliction to the African and Asian continents, where more than 59 000 people die of the disease every year. In recent years, the social, economic and environmental impacts of this tragic disease on various developing countries and their populace have become better documented. Concertedly, it needs to be reinforced that this very significant burden is completely unnecessary. Rabies can be prevented and even eliminated by practical and cost effective control measures. Although rabies can be transmitted by a variety of terrestrial mammals, canine-transmitted rabies accounts for 99% of the human deaths every year. In consideration, the FAO, OIE, WHO and GARC, at their global rabies meeting in 2015, called for and initiated a framework and strategy towards the elimination of canine-mediated human rabies by 2030.

In Namibia, canine rabies has been present since the 19th century, with cases reported from as early as 1887. While canine rabies, with predominant cycles in dogs and jackals, remains endemic in Namibia, a further development plagued the country in recent decades: a unique and progressive rabies cycle in the antelope species, the Greater Kudu (*Tragelaphus strepsiceros).*

For Namibia, the estimated financial burden related to canine-mediated rabies is US$5 111 282 per annum. However, the inclusion of kudu rabies and the economic impact as it relates to losses in the game farming, trophy hunting and tourism industries would undoubtedly be a significant addition to the total rabies burden estimate.

In a fresh approach to control rabies, the Namibian government elected to develop a strategic plan aimed at producing a controlled and carefully considered approach. Various international collaborators were encouraged to contribute skills and expertise to facilitate the development of a cost-effective, manageable and sustainable National Strategy.

In support of the National Strategy for human rabies elimination in Namibia, various supporting research initiatives have been undertaken, including oral vaccine trials in kudu

that endeavour to stop the intra-specific transmission of rabies among kudu. Additionally, an in-depth Namibian epidemiological study of rabies is currently underway in order to infer the transmission and epidemiological cycles of rabies within the country. This study will facilitate the targeted and strategic vaccination of local dog populations to curb, and eventually eliminate, the spread of rabies in Namibia.

The National Strategy has provided a clear and defined guide towards controlling and eliminating rabies and Namibia will greatly benefit from the social and economic implications of such an endeavour. If the strategy is executed vigorously, we believe that human rabies elimination can be achieved in Namibia by the year 2030.

INTRODUCTION

Rabies is an acute encephalitic, zoonotic viral disease caused by members of the Lyssavirus genus, of which rabies virus (RABV) is the prototype species. Rabies manifests in a variety of classic symptoms that include hydrophobia and various behavioural changes. Death is inevitable once these clinical symptoms appear and it is no surprise that rabies has the highest case-fatality ratio of all known zoonotic diseases.

In Africa the domestic dog is a classical reservoir and vector for rabies and accounts for the majority of human deaths. Several other African carnivore species, such as the black-backed jackal (*Canis mesomelas)* and the bat-eared fox (*Otocyon megalotis*), are able to maintain sylvatic cycles of rabies [1]. These wildlife vectors are able to contribute to the disease maintenance, spread and cross-species transmission among various mammalian species, including those of spill over hosts such as cattle and other livestock [2–4].

Rabies in domestic dogs accounts for more than 99% of human rabies cases, the majority of which occur in children under the age of 15 years. This is often as a result of their lack of knowledge with regards to animal behaviour, as well as the increased likelihood of receiving a more severe bite wound from a dog due to their smaller stature [5]. One person dies of rabies every 10 minutes, resulting in an estimated 59 000 human deaths every year, the majority of which occur in Africa and Asia [6]. Africa has the highest per capita death rate for rabies globally, and no country on the African continent has been declared rabies free [6]. However, rabies is an entirely preventable disease through the mass vaccination of domestic dogs and the timeous administration of Post-exposure Prophylaxis (PEP) in humans, resulting in the prevention of the unnecessary loss of human lives [7].

Despite the fact that rabies is an entirely preventable disease, it is still considered to be a neglected disease due to the low priority assigned to its prevention and control [8]. Poor surveillance and diagnosis, poor reporting and the low priority of the disease in many countries contributes to the cycle of neglect that ensures the continued, yet entirely preventable, cost to human and animal lives. However, some progress towards the control and elimination of human rabies has been evident. This evidence comes from programmes where the coordinated and targeted vaccination of dogs has resulted in the elimination of human rabies deaths, most notably in North America and some European countries [7]. Isolated successes have been observed in Africa [9], but the majority of these have been observed on a provincial/regional level. Thus, rabies remains endemic throughout Africa and continues to pose a severe public health threat, as well as having harsh financial implications on the affected countries [6]. In order to drive progress towards a world free of the social and financial burden associated with human rabies, the global rabies community has set the target

of the elimination of canine-mediated human rabies deaths by the year 2030, in line with the Sustainable Development Goals [10].

RABIES IN NAMIBIA

Rabies was first documented in Namibia in approximately 1887, where anecdotal records from the Herero tribe named this year "the year of the rabies" [4]. This description however, suggests that rabies was a known disease in Namibia prior to 1887, but there are no reports of the disease to our knowledge. However, the first confirmed case of rabies in Namibia was recorded 1906 from Swakopmund – a town situated in the middle of the western coastline of the country [4]. This suggests that rabies was either present and endemic in the region before this first confirmed case, or it indicates that rabies was imported, as Swakopmund was a main shipping harbour for Namibia. As a result of the influx of slaves from various regions in 1904 [11], it is not unlikely that rabies could have been introduced into Namibia via the harbour at Swakopmund, but with a lack of molecular epidemiological evidence these hypotheses remain speculative. The first reported case of human rabies was noted from a child bitten by a dog in Swakopmund in 1928 [2, 3], suggesting that rabies was still present, and possibly endemic, two decades after the first confirmed case.

Throughout the 1920's and continuing up until World War II, a flurry of reports of dog rabies from southern Angola coincided with several unconfirmed reports of rabies in the northern regions of Namibia [4, 12]. The rabies outbreak in dogs from southern Angola resulted in the widespread infection of dogs, cattle and other livestock in the northern regions of Namibia, with the confirmed clinical diagnosis of a rabies-infected dog occurring in both 1938 and 1947 from Rundu, a border town with Angola [2, 3, 13]. Despite some detailed reports of animal rabies cases in Namibia at this time, evidence of human rabies cases were limited, except for an anecdotal report of an increased incidence of human rabies cases reported by missionary doctors in the same area [4]. The confirmation of a dog case in 1947 was followed by the appearance of rabies in cattle in the Outjou district in 1948 and the subsequent spread of rabies in a southerly direction, with cases being confirmed in Otjiwarongo (1949) and later in Gobabis and Windhoek (1951) (Figure 1). In 1952, a rabies case was confirmed from an African wild cat (*Felis silvestris lybica*) in the southern district of Keetmanshoop, close to the South African border [14]. Although rabies was present in dogs, the rapid southerly spread of rabies from the northern borders of Namibia into the central regions was attributed to transmission among black-backed jackals (*Canis mesomelas*), and subsequent spill over infection of cattle [2–4].

From 1967 onwards, sporadic cases of rabies in bat-eared foxes were also reported each year in the southern regions of Namibia, which subsequently spread further south into the Northern Cape Province of South Africa [15]. By the early 1970's, rabies was considered to be endemic in Namibia with dogs being the primary vectors in the northern regions. Rabies in jackals and subsequent cattle spill over events were most prevalent in the central regions, where the dog population density was not high enough to maintain rabies transmission [16]. Within the more arid southern regions of the country, endemic cycles of rabies are maintained within the mongoose, genet and caracal populations [12, 14, 15]. Since rabies was declared

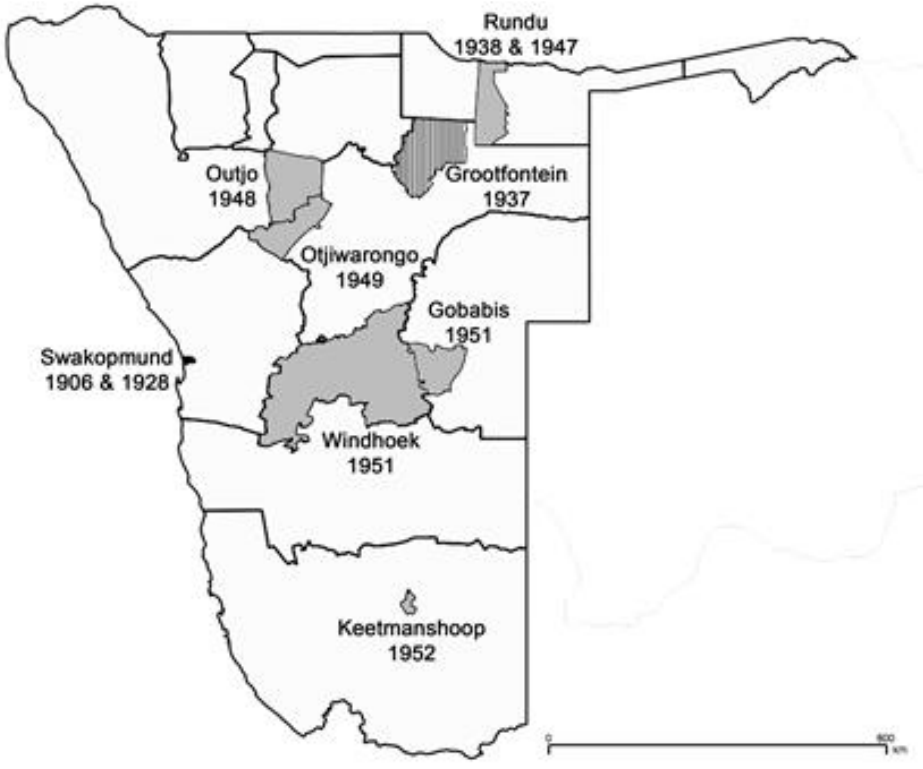
endemic, the situation has remained relatively consistent throughout Namibia and currently still reflects the status quo as described over the last few decades (Figure 2) [13, 17, 18].

Although the historical spread of rabies through southern Africa has been well documented and widely accepted, some evidence suggests that there may have been earlier introductions or possibly endemic cycles within Namibia before the accepted introductions occurred. As discussed earlier, it is accepted that rabies spread from the southern border of Angola into the northern regions of Namibia and progressively spread in a southerly direction. However, an undocumented cycle of rabies may have already existed, as an isolated case of a woman being bitten by a wild cat in Grootfontein – a town situated in a province that does not directly border with Angola or Botswana - was reported in 1937 [2, 3]. This suggests that rabies was likely present in Namibia before the reported introduction of rabies from the epizootic occurring on the southern borders of Angola, correlating with the first reported rabies incidences from the Herero tribe in 1887. The Herero tribe land consisted of areas in the central and eastern parts of the country [19], close to the Grootfontein district where the isolated case was reported in 1937. The Herero people have traditionally been hunter-gatherers and commonly used hunting dogs, providing a possible avenue for the cross-species spread of rabies from the dog rabies outbreak in 1887 to wildlife species such as jackals [20]. In support of the hypothesis of a previous endemic cycle in the eastern region of Namibia, the bite originated from an African wild cat (*Felis silvestris lybica*), a particularly reclusive wildlife species, therefore minimizing the likelihood that this case was associated with human movements. Additionally, at this point in history, rabies had not yet been documented from Botswana, precluding the possibility of trans-border spread of the disease from the east. Thus, we suggest that this isolated case of rabies in 1937 could have been part of an endemic cycle of rabies that had been maintained within the wildlife population since 1887. Despite this evidence, the reports from both 1887 and 1937 were based solely on clinical diagnosis and therefore, although plausible, cannot be confirmed.

Barriers to the Spread of Rabies

Natural barriers are any geographical circumstances such as mountains, rivers, oceans, ravines and deserts that prevent or restrict the movement of humans or terrestrial animals [21]. By restricting the movement of humans and terrestrial animals, natural barriers can also hinder or impede the spread of zoonotic diseases such as rabies. Rivers can prevent two populations from physically interacting, while deserts are difficult to cross and are commonly scarcely populated by vector species, due to limited food and water availability.

The Namib Desert is a 2000 km piece of unbroken desert, stretching along the western coastline from southern Angola, through Namibia and into South Africa [22] and is considered to be a major natural barrier to the spread of rabies within Namibia. The presence of such a natural barrier has historically resulted in the formation of isolated endemic disease cycles within wildlife populations that inhabit the surrounding environments. One such example is the human cases that occurred in the Swakopmund district in 1906 and 1928 [2, 3]. The Namib Desert likely prevented the historical spread of rabies from Swakopmund towards the interior of the country, and ensured that the endemic cycles remained limited to the coastal region (Figure 1).

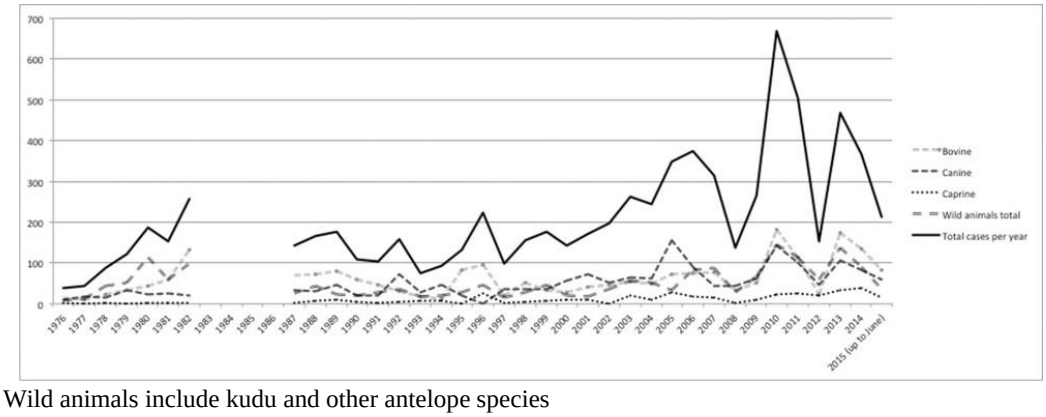


Dark grey, vertical stripes depict the first confirmed case in the Grootfontein district, suspected to have originated from the initial outbreak from 1887.

Light grey depicts the spread of rabies from southern Angola into Namibia, spreading in a systematic southerly direction.

Black depicts the introduction of rabies in Swakopmund, which is suspected to be a separate cycle due to the presence of the Namib Desert as a natural barrier to the spread of rabies.

Figure 1. Map depicting the historical introduction and initial spread of confirmed rabies cases through Namibia.



Wild animals include kudu and other antelope species

Data from 1983-1986 is unavailable.

Figure 2. Number of rabies cases from 1976 – June 2015 in Namibia for Bovine, Canine, Caprine, and wild animals.

As the farming industry developed in Namibia, man-made barriers such as fences were erected to better contain the movement of larger animals, primarily livestock and kudu. Cattle fences were solely erected to prevent the movement of livestock, but did not restrict the movements of small carnivores, such as jackals and dogs. As the cattle fences did not prevent the movement of reservoir species, they did not restrict the spread of rabies, explaining the prevalence of high numbers of cattle rabies cases over time [23]. The larger game fences, erected initially for foot and mouth disease (FMD) control, initially prevented the spread of rabies in kudu during the first epizootic (as discussed in the next section), showing that these barriers to the spread of rabies can be important in control efforts [24]. The southern regions, which are more suitable to goat and sheep farming due to the arid conditions, rely on jackal-proof fences to prevent predation by jackals. These specific fences have been shown to prevent jackal movement, which in turn limits, but does not prevent, the spread of rabies in the region [23].

However, human settlement and development has enabled and facilitated the rapid and widespread dispersion of rabies in dogs through the use of road and other transportation networks. This has resulted in the intermingling of various disease cycles that were historically isolated due to both natural and man-made barriers [25, 26].

KUDU RABIES

Prior to 1977, rabies in kudu had previously been observed as sporadic, presumed spill over infections from the endemic jackal and dog cycles in Namibia. From 1967 – 1976, only 3 kudu had been reported to have died of rabies – corresponding to the expected numbers from spill over infections [27, 28]. However, the first case attributed to the beginning of the epizootic of rabies in kudu was in 1977 from a farm approximately 80km from Windhoek in the central regions of the country [29, 30], with another case in kudu being confirmed later that same year [27, 30]. In 1978, a dramatic increase in the number of reported cases of rabies in kudu occurred, with an increase in cases to levels suggestive of an epizootic. Although the exact number of cases of rabies in kudu reported during this period is not clear due to discrepant reporting [14, 27, 30], the increasing trend of cases of rabies in kudu was alarming. This was especially so, as the number of rabies cases in other animal species did not indicate a concurrent increase [27]. The epizootic had spread approximately 100km within an 8 month period in 1978 [14] and had remained confined to the western side of the north-south game proof fences [14, 30]. A further growth in the reported numbers of rabies in kudu occurred in 1979 with kudu rabies cases accounting for more than 30% of the total number of rabies cases confirmed that year [14, 27, 30]. The same year, cases of rabies in kudu were observed on the eastern side of the game fence, resulting in the spread of the epizootic to encompass the entire Okahandja district. Rabies spread in a northerly and easterly direction early in 1980, and continued to spread at a rate of approximately 40 – 60km per year until the majority of the central region of Namibia was affected by 1982 [30]. In 1978-1979, an estimated 3 000 kudu had died of rabies, further increasing to reach the peak of the outbreak in 1980 with the highest number of cases of rabies in kudu reported that year. This accounted for approximately 30 - 50% of the total reported number of rabies cases [4, 14, 30], and by 1981, an estimated 10 000 kudu had already died due to the rabies epizootic [27]. In 1980, a survey

was performed on 143 farms in the central districts of Namibia, with farmers reporting 16-20% losses of their kudu population due to rabies [30]. A second peak in the number of reported kudu cases was observed in 1982, and the epizootic continued, but declined, until 1985. In the first 8 months of 1986, only 2 cases of rabies in kudu were noted, signifying the end of the epizootic and the return in numbers of rabies cases in kudu to what would be expected from typical spill over events from jackals [4]. By the end of the epizootic, an estimated 30 000 – 50 000 kudu had died from rabies [2, 4]

A second epizootic of rabies in kudu began in 2002 and by 2003, 81 farms had been affected, resulting in the estimated deaths of more than 2500 kudu [31, 32]. The epizootic continued with devastating losses to the game farming industry and in 2011, farmers reported a 30-68% loss of kudu within one year due to rabies on their land [33]. The severity of the epizootic of rabies in kudu was emphasised when the Ministry of Environment and Tourism in Namibia reduced the hunting quota for kudu in 2012, leading to repercussions on the game farming and trophy hunting industries, resulting in an impact on the Namibian economy [33]. The current epizootic seems to be well established and may have reached an endemic status, as reports from the most recent data show that confirmed cases of rabies in kudu account for approximately 20% of the total confirmed number of rabies cases within Namibia (Figure 2). Drastic underreporting of rabies in kudu has remained a challenge as farmers typically only report cases at the beginning of the outbreak and subsequently diagnose the remaining infected animals based on clinical symptoms, without reporting to authorities. Many infected kudu may also have been missed as these animals are shy and live in small herds of 4-6 animals. For this reason, the number of affected kudu remain largely unknown until game censuses are performed [33].

Although two distinct epizootics were documented, it is hypothesised that these 2 rabies epizootics were not separate, individual events, but were a single endemic occurrence with major peaks when the conditions were most suitable to create high population densities [33]. In support of this hypothesis, the first epizootic occurred after a period of heavy rainfall – resulting in a kudu population explosion depicted by a growth rate of 8-10% before the epizootic compared with the 4% growth rate observed in 1988 [4]. The population explosion resulted in a kudu population growth from 80 000 kudu in 1972 to 200 000 kudu in 1978, and was subsequently followed by a severe drought [4]. This resulted in kudu population densities effectively increasing as animals were drawn towards scarce water sources, with abnormally high densities of 1 kudu per 40ha, in comparison to the typical 1 kudu per 100ha of land [27, 30]. The second epizootic was also preceded by a population increase followed by a drought, resulting in high numbers of kudu [34]. In further support of the hypothesis of a single endemic event with two epizootic peaks, molecular evidence has demonstrated a close relationship between RABVs isolated from kudu in 1980 to those in 2003, 2008 and 2009, suggesting that a single, or limited number of, spill over events occurred into the kudu population [31, 35].

It had been debated for many years as to whether the epizootic of rabies in kudu in Namibia was kudu rabies or whether it was simply rabies in kudu, with the difference being that kudu rabies implied that a strain of RABV had adapted specifically to circulate within the kudu population. During the first documented epizootic, the trends of cases of rabies in kudu correlated with those of rabies in jackal, with specific peaks in incidence in kudu reflecting those in jackal. It had already been suggested that kudu may have been maintaining and transmitting rabies horizontally, simply due to the sheer number of reported rabies cases in

kudu [2, 4, 27, 30]. Additionally, the number of rabies cases in kudu was disproportionate to the number of observed cases in jackal and despite an initial increase in reported rabies cases in jackal prior to the 1977 epizootic, jackal rabies cases remained relatively consistent. An experimental infection study was also performed on kudu in 1981 and the results from this study demonstrated an increased susceptibility of kudu to mucosal infection of RABV [36]. Once clinical signs of disease manifested, infected kudu were observed to salivate excessively, with high titres of virus present in the saliva. The high titres of RABV in saliva, coupled with hypotheses of non-bite transmission via mutual grooming or mutual browsing [4, 27, 30, 31, 33], strongly support the hypothesis of non-bite, horizontal transmission of rabies among kudu. Lastly, more recent molecular epidemiological studies have provided strong support to the emergence of a unique strain of kudu rabies. Two molecular epidemiological studies compared RABV sequences from kudu, jackal and domestic dogs and saw separate clustering of the kudu RABV sequences compared with the other animal species [31, 35]. Furthermore, two complete genomes of RABVs from kudu and two from jackal were compared at the nucleotide levels and it was determined that unique variations were evident in those RABVs isolated from kudu, supporting the hypothesis that rabies was being maintained independently within the kudu population [35]. Through the evidence gathered from both the first and second epizootics regarding the disproportionate number of rabies cases in kudu compared with those of typical vectors, coupled with molecular epidemiological evidence, it was determined that a unique strain of RABV had adapted to kudu and was being maintained within the population [35].

RABIES IN BOVINES

The unique situation of kudu rabies in Namibia has resulted in speculation regarding potential spill over events of rabies from kudu into cattle. The potential for spill over into cattle is high as the Central regions of Namibia are both cattle and game farming regions, with farms often having a mix of both types of animals. The severity of the kudu rabies epizootics have resulted in major economic losses to the Namibian economy with an impact on rural communities as well, largely due to game meat being an important protein source for many of these rural communities. If a further host shift were to occur, with rabies being horizontally transmitted among cattle, the implications would be considerable. As an indication of the effects of rabies on the farming community, rabies cases in cattle accounted for 49.8% of all reported rabies cases from 1968 to 1975, whilst dogs and jackals accounted for 17.5% and 15.2% of all cases, respectively [14].

Farms typically consist of large communal grazing grounds that provide little restriction to the movement of animals as game fences are easily jumped by large antelope such as kudu [27]. Thus, the potential for the rapid spread of rabies by kudu across farms, including farms specialising in cattle, is great. Although possible spill over events have thus far only been hypothesised, some evidence supports the notion of kudu rabies potentially spilling over into the cattle population. Several reports have made the observations that spikes in cattle rabies cases often occur either at the same time as kudu rabies cases or approximately 1-3 months after a kudu rabies epizootic on the same, or a neighbouring farm [4, 14]. In further support, during the 1977-1985 epizootic, a severe increase in rabies in cattle was observed, rising from

24% in 1980, to 40% in 1981 and subsequently to 52% of the total confirmed number of rabies cases in 1982. This dramatic increase in cattle cases followed the initial increase and subsequent decrease in cases of rabies in kudu during the first epizootic, reinforcing the hypothesis that spill over from kudu to cattle may have occurred [14].

Some hypotheses have also considered the possibility of bovine-bovine spread due to the numbers of reported cases among bovines compared to canid vectors such as jackal and dogs [4]. However, severe underreporting is most likely the result for the disproportionately high number of rabies cases in cattle, coupled with the fact that one jackal in a herd of cattle could bite or expose several animals. Evidence shows that cattle cases are directly correlated with those observed in wildlife (antelope, jackal and other wildlife species) (Figure 3). However, in more recent years (2012 – 2015), the numbers of rabies cases in kudu accounted for the majority of the wildlife cases, providing further support to the hypothesis that kudu and bovine rabies cases may be linked. In order to comprehensively address the questions associated with rabies in cattle in Namibia and to determine whether rabies in cattle is dependent or has become independent of the rabies situation in jackal, an in-depth molecular investigation into the possibility of bovine-bovine and kudu-bovine transmission of rabies is currently being undertaken.

HISTORICAL CONTROL EFFORTS

Historical efforts towards the control and elimination of rabies have been implemented in Namibia to varying degrees of success, some of which were preventative and others responsive to epizootics. One of the key starting points in rabies control and elimination campaigns is to have good dog population management (DPM) that ensures a restricted and known population of healthy animals. An initial Ordinance was created in 1967 based on governing South African laws, dictating that all dogs should be registered, neutered or spayed unless specifically described with governmental permission (e.g., for breeding purposes) [37]. Each owner was responsible for their own dogs and could be spot-fined if an animal did not have the correct identification and their owner could not provide the correct certificate complying with the regulations. This Ordinance ensured the limitation of dogs in municipal regions and also prevented free-roaming dog populations, which in turn reduced the potential risk of disease transmission, including that of rabies.

With specific reference to direct rabies control efforts in Namibia, rabies vaccination in dogs and cats is mandatory as rabies is considered a notifiable and scheduled disease in Namibia [38]. Rabies vaccinations are provided free of charge by state veterinary officials to any dog or cat. Apart from the vaccination of domestic animals, the surge of rabies in cattle resulted in some farmers vaccinating their livestock in the early 1970's, increasingly so as the numbers of rabies-positive cases rose. Later, in 1982 and 1983, when the cattle rabies epizootic had reached its peak (shortly after the beginning of the decline of the kudu rabies epizootic), the vaccination of cattle against rabies intensified. Up until 1981, farmers were only allowed to vaccinate cattle under direct supervision from a veterinarian, however, in 1982, due to the severity of the rabies outbreak, farmers were allowed to buy vaccine and vaccinate their cattle on prescription from a veterinarian [14]. In 1983, farmers were allowed

to vaccinate kudu and eland due to their susceptibility to rabies infection and state veterinarians provided this service free of charge (Table 1) [14].

Due to the role that jackals have played in the spread of rabies and its subsequent introduction into the kudu population, as well as the costly spill over events into cattle, efforts were also made towards the development of an oral vaccine for jackals. In 1987, experiments were undertaken to determine the feasibility of the oral vaccination of jackals using the "Tübingen bait vaccine" which contained the SAD B19 vaccine strain of RABV [4, 23]. This bait vaccine was the same vaccine that was successfully used for the oral vaccination of foxes in Europe and researchers performed experimental trials to determine the efficacy of this oral vaccine in Namibia. Initial experimental results looked extremely promising, but according to reports, no further research or implementation was done due to financial and other constraints [23]. However, titres obtained from the subject animals were in excess of 1:1000 11 months after the initial vaccination, demonstrating feasibility and success in the initial phases of the trials [23].

The widespread implementation of oral-bait vaccine, targeting the main rabies wildlife vectors such as jackals and kudu, could thus be a feasible approach to the prevention and control of rabies in Namibian wildlife, which will subsequently prevent spill over events into other animal populations. In a recent study, the use of oral rabies vaccine in kudu was demonstrated with good results and further research will be required in order to make this a feasible option for the control of rabies in wildlife and the subsequent prevention of costly bovine and kudu rabies outbreaks [39]. Further studies will also be required to reinvestigate the feasibility of orally vaccinating the jackal population, whilst the continued compulsory vaccination of dogs will remain crucial to rabies elimination efforts.

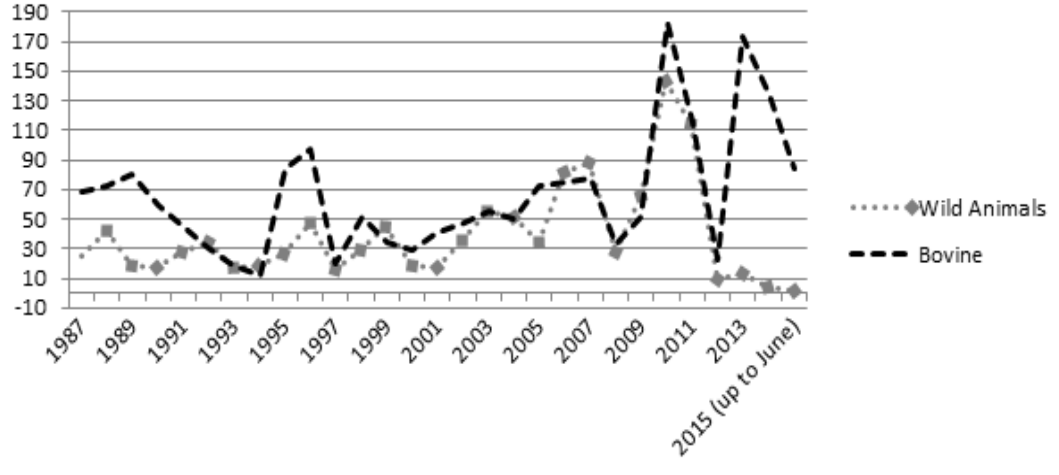


Figure 3. Representation of the direct correlation between wildlife rabies cases and cattle rabies cases from the central cattle farming region of South Africa for the time period of January 1987- June 2015.

Table 1. Number of animals vaccinated against rabies in Namibia, 1972-1982

Year	Dog[1]	Cattle[2]	Total
1972/1973	39 892	-	39 892
1973/1974	34 290	431	34 947
1974/1975	19 308	456	20 086
1975/1976	27 486	536	30 009
1976/1977	21 151	125	22 195
1977/1978	32 578	159	33 626
1978/1979	18 092	8 316	26 911
1980	43 339	6 885	51 029
1981	35 060	23 340	59 298
1982	35 917	48 655	85 373
1983		167 550*	

[1] Vaccination compulsory, done free of charge by the Veterinary Department and only by veterinary officials or veterinarians.

[2] Vaccination at own expense but under State Veterinary supervision until 1981. Since 1982 vaccine became directly available to farmers for use in cattle.

*Vaccine doses supplied to farmers March - August 1983

Table modified from Rabies in South West Africa/Namibia from Rabies in the Tropics [14].

ECONOMIC BURDEN, UNDERREPORTING AND THE SOCIAL IMPACTS OF RABIES ON NAMIBIA

The epidemiology of rabies in Africa remains poorly understood, primarily due to poor surveillance and underreporting. In light of this, it is difficult to assess the true burden of rabies in countries and, as a result, it remains difficult to gain governmental buy-in and support to fund rabies control and elimination programmes.

Whilst domestic dogs are usually considered companion animals with little or no economic value, human and (to a lesser extent) livestock deaths cause considerable economic losses to society. The presence of independently transmitted kudu rabies in Namibia also poses further challenges to the true estimation of the disease burden. As game farming - and all of the associated industries - is a major contributor to the gross-domestic product (GDP) of Namibia, it is realized that the kudu rabies epizootics place significant further financial and social burdens upon the Namibian populace.

In an attempt to provide reliable data and, in turn, raise the neglected status of rabies, a recent study has estimated the burden that rabies imposes on countries globally [6]. This study has provided the most accurate estimate possible with the limited data available, and suggested that the true number of rabies cases, particularly in developing countries, may be 10-100 times more than what is currently reported [40, 41].

Human

The economic burden of human rabies is not solely based on human deaths, but is also attributed to indirect cost factors associated with providing PEP treatment, hospital costs and travel costs, among others [6]. Although the majority of the financial burden of rabies does not come from human morbidity, as rabies typically has a short duration of illness [8], the costs associated with seeking PEP to prevent rabies from developing are high. These costs are not only attributed to reported cases, but the costs and social implications also often involve close family members or community members that were also in contact with either the affected person or animal. These social implications also carry forward into direct and indirect economic burdens upon individuals, their families and their communities. The bulk of the economic burden of rabies falls at the societal level, due to the lost productivity (future income) of people who die of rabies (Table 2).

As part of the recent burden study, the human rabies burden for Namibia – as well as all other countries globally – has already been estimated as accurately as possible with the limited data currently available [6]. Using this information, the economic burden of canine-transmitted rabies in Namibia is estimated to be USD 2 034 703 every year, despite the fact that only 4 people are estimated to die from the disease in the country annually [6]. Because of the high cost of PEP, the challenges faced by rural communities in accessing clinics or hospitals and the chronic global shortage of PEP, the indirect costs of rabies are far greater than the direct costs of the PEP itself (Table 2). In light of this, the focus for human rabies prevention and elimination in Namibia should remain on dog vaccination, but should also include the improved provision of pharmaceuticals for exposed individuals in rural areas. Namibia has already made good strides towards improved human treatment by providing rabies PEP free of charge in any state hospital [42]; however, improving access to this PEP should be the next step.

Livestock

The burden of rabies not only impacts upon the country as a whole but also upon the social and economic wellbeing of the individual. In light of this, the estimates for the burden of rabies upon livestock were assessed and it was determined that, in Namibia alone, an estimated USD 3 064 690 is lost each year due to rabies affecting livestock. In Namibia, agriculture accounts for approximately 5.6% of the GDP of which 90% is attributed to livestock farming [43]. Although the cost associated with livestock losses due to rabies might seem insignificant in a global scheme, the economic wellbeing of the general population changes the perspective. The average Gross National Income (GNI) of a person in Namibia is USD 3 360 with the lower-middle income group being USD 1 887 (Atlas Method). Despite this, 49.1% of the population live below the USD 1.25 per day poverty line [44], and 70% of the total Namibian population derives its income directly from cattle farming, with one third of these individuals depending on subsistence farming as their only source of income.

Table 2. Annual human rabies burden costs for Namibia [6]

Description	Cost (USD)
Direct Costs	391 636
Travel costs	33 557
Lost income	202 952
Productivity loss due to premature death	1 406 559
Total costs of human rabies per annum	**2 034 703**

Data taken from [6]

Table 3. Cost comparison of annual cattle losses due to rabies to that of the annual gross national income of the country average as well as that of low-middle income earners

Earning category	Annual earnings (USD)	Price per head of cattle (USD)	Annual estimated number of cattle losses due to rabies	Annual cost of livestock losses due to rabies (USD)[#]	Number of annual salary equivalents lost per year due to rabies
Low-Middle income[*]	1 887	364	8 419	3 064 690	1 624
Average income	3 360	364	8 419	3 064 690	912

[*] 49.1% of the population live below the poverty line. More than 70% of the population directly derive their income from cattle farming, of which one third are subsistence farmers and would likely fall within this category.

[#][6]

The average price of one head of cattle is approximately USD 364 when sold locally or in the export abattoir market, therefore as few as 5 head of cattle equates to the annual income of an average low-middle income earner in Namibia. On a national level, the total economic costs due to livestock losses from rabies equates to the complete loss of income for 912 individuals on average incomes, or twice that many on low-middle incomes (Table 3).

Kudu

Due to the unique situation of kudu rabies in Namibia, the burden of kudu rabies has never been assessed or quantified. Despite the fact that there have been numerous reports from farmers, veterinarians and the Ministry of Environment and Tourism emphasising the impacts of kudu rabies on the tourism, game farming and professional hunting industries, no scientific data is available to support these notions. However, such data should be generated as an addition to the burden of canine rabies as previously described by Hampson et al. 2015. Government officials rely on data reported through specific channels in both the Ministry of Health and the Ministry of Agriculture, but if the burden of kudu rabies is underestimated and underreported, then the influence upon policy-makers will be insufficient to source enough support to control and eliminate rabies in the country.

In an effort to estimate the impact of kudu rabies outbreaks throughout the country for the first time, we developed a Kudu Rabies Burden Model (KRBM) using extrapolated historical data to reflect - as accurately as possible with the limited data available – the burden of kudu rabies upon the country as a whole. We then related this to individuals and communities involved in game farming and tourism industries. Estimated kudu population numbers from the game farming sector were taken from a 2004 game census and extrapolated to reflect the population growth up to the present time (2016) [45]. A conservative growth rate of 4% per annum was used for the modelled kudu population (based on reports from a period after the initial epizootic when the kudu population was assumed to be growing stably) [4]. As a proof of concept, the KRBM estimates the kudu population for 2009 to be approximately 428 132, which correlates closely with those of another study performed in 2009 that estimated a kudu population of 449 199 based on the same census data [46]. Based on this assumption, the kudu population in the year 2016 would have been an estimated 563 392, inclusive of any losses from other causes. During the second epizootic, it was reported that 2.5% (81/3500 farms), of the kudu population was affected by kudu rabies within a single year with reported losses of 30-68% on some farms [33, 46]. The affected kudu population estimates in the KRBM were based on the assumption of equal population distribution across all of the farms. Therefore, using the extrapolated data, the KRBM provides various scenarios ranging from conservative (15%) to reported (30-68%) estimates of kudu die-off when only 2.5% of the total kudu population (i.e., 2.5% of farms) was affected by rabies within a single year (Table 4).

In order to determine the most accurate representation of the reported data for the KRBM, we took data from 2003 where a reported 2500 kudu died from rabies and adjusted the parameters. The percentage losses for 2.5% of the population were modelled to reflect the estimated losses reported from farmers ranging from a conservative 15% to the upper 60%. Using these modelled estimates, 30% losses most closely correlated between the model (2534 kudu deaths) and those of reported losses in the same year (2500 kudu deaths).

Based on the KRBM, the financial burden imposed by kudu rabies was subsequently estimated. An average price per head of a male trophy kudu is USD 1 900 [47], whilst the average price per female was approximately USD 330 [46]. The male: female sex ratio of kudu in Namibia is 1:1.67 [48] and taking this information, combined with the prices of kudu, we determined the economic impact of kudu rabies in Namibia. If an outbreak of a similar magnitude to that in 2003 were to occur in 2016, the KRBM estimates that 4 225 kudu would die of rabies. This would result in the deaths of 2 643 females and 1 582 males, resulting in the loss of USD 3 877 990 in a single year (Table 5).

Table 4. Estimated kudu losses due to rabies epizootics on a limited number of farms (represented by an estimate of 2.5% of the total kudu population for 2016)

Percentage losses	Estimated number of kudu dead (single year outbreak in 2016)
15%	2 113
30%	4 225
60%	8 451

The estimates depict 15%, 30% and 60% losses of 2.5% of the kudu population from the KRBM model.

Table 5. Modelled cost implications of kudu rabies in 2016 using the parameters from the Kudu Rabies Burden Model

	Female	Male	Total
Losses (number of kudu)	2643	1582	4225
Cost per head (USD)	330	1 900[#]	-
Financial losses (USD)	872 190	3 005 800	3 877 990
Average annual income (USD)*	3 360	3 360	3 360
Number of annual incomes lost	259	895	1 154
Average annual low-middle income (USD)*	1 887	1 887	1 887
Number of low-middle average annual incomes lost	462	1 593	2 055

*[44]
[#][47]

Although these figures seem miniscule when compared with the Namibian GDP (USD 6.7 billion), the direct economic and social impacts of kudu rabies is far greater. Considering that the annual average income per person in Namibia is USD 3 360, the losses of kudu due to rabies accounts for the loss of the annual income of 1154 people, making it more burdensome than the estimated impact of rabies on livestock (912). Taking into account that the more than 49.1% of the population live below the poverty line, the implications are far greater than expressed in these initial estimates.

Further economic implications can be noted when observing the impacts on farms themselves, as opposed to the individuals involved. Considering that the KRBM parameters assume an even distribution, we know that in reality the actual reports vary much more widely as farmers have reported losses as high as 68% on individual farms [33]. We then continued to use the KRBM to determine the effects of kudu population numbers and their recovery on individual farms, with various losses estimated. This would directly correlate to the affects the losses would have on the farm as well as the amount of time required to recover from the outbreak. The average size of a game farm in Namibia is 70 km^2 [46] and the average kudu population density is 1 kudu per 0,4 km^2 [27]. Therefore, an average farm would have approximately 175 kudu and 30% losses would thus result in the deaths of 53 kudu. Using the KRBM, we estimate that each farm would experience a loss of 52 kudu. Working with the average sex ratio, this would mean that each farm would lose 19 males and 33 females resulting in the average loss of USD 46 990 per farm in a single year, not taking into account the potential loss of a stud bull. The KRBM shows that it would take 9 years at a 4% growth rate for the farm to recover the kudu population to levels equal to those observed before the outbreak (assuming that no further major losses occur). Previous reports have described losses of up to 68% on a single farm, resulting in the fact that the economic and social impacts of kudu rabies on farms affected this severely would be far greater, with an even longer time to recovery for the kudu population. Therefore, the implications that kudu rabies has for farmers and all of the people and industries reliant upon kudu are far greater, with grave consequences to their livelihoods. Considering that kudu rabies outbreaks typically last for several years, and move around the country affecting different farms, the financial and social implications will continue year on year.

Summary

Recent global canine rabies burden estimates have provided countries, governments and stakeholders with essential data to promote rabies control and elimination programmes on a National scale. However, these burden estimates were directed solely for the purpose of raising the status of rabies on various stakeholders' agendas and thus failed to reflect the implications of rabies on an individual or personal scale. By providing a more individual context for this burden, our data has shown the social and economic impacts of rabies in Namibian households and communities as opposed to countrywide. Furthermore, by providing the first economic burden estimates for kudu rabies we addressed the gap in the knowledge of the burden of rabies in Namibia as kudu rabies is an additional unique challenge posed to the country. The economic burden of kudu rabies far exceeds that posed by rabies in humans as well as the burden posed by rabies in livestock in Namibia, suggesting that this unaddressed challenge should receive further consideration in their National Strategy. By coupling the financial burden imposed by rabies on the kudu, livestock and human populations, the total burden of rabies in Namibia is estimated to be USD 8 977 383 each year, which equates to losses of USD 4.26 per capita.

NAMIBIA'S NATIONAL STRATEGY TOWARDS RABIES CONTROL AND ELIMINATION

The development of a National Strategy is paramount to the success of any rabies control and elimination plans, as an endorsed National Strategy enables the coordination of inter-sectoral support, as well as coordinating and concerting international efforts towards a common goal – the elimination of canine-mediated human rabies. It has become evident that the only feasible means to eliminate human rabies is to control the problem at the source i.e., within the dog population. This can be achieved through the mass vaccination of animal – primarily dog – populations on an annual basis in order to create a herd immunity. The creation of herd immunity prevents the transmission of rabies among animals and therefore breaks the cycle of rabies transmission [49].

The resources required to implement effective National Strategies towards rabies control and elimination are often limited, as the assigned budget for disease control and intervention efforts is typically spread among several economically and socially important diseases. As a result of these budgetary constraints, National governments in these developing countries are often reliant upon the support of other international stakeholders to successfully initiate National Strategies for rabies control and elimination. Ultimately, the end goal of these initiatives would be that each country takes ownership of their rabies control efforts and distributes national budgets appropriately to address the disease concerns. However, on occasion, support from numerous international organisations or stakeholders can become detrimental to rabies control within the country, as small, disjointed efforts can overlap and also are usually not sustainable. Studies have shown that random and small-scale vaccination campaigns are less effective and can possibly negatively influence rabies control efforts [50, 51]. Therefore, vaccination campaigns need to be carefully considered with vital information such as high incidence areas, dog population and density, molecular epidemiology and the

current vaccination coverage being important aspects to consider. The key to an effective rabies control and elimination strategy is to have a carefully considered, stepwise approach towards rabies elimination that is sustainable. In this regard, Namibia has developed a National Strategy which enables the coordination of a variety of interested international organisations towards a targeted and progressive rabies elimination approach.

Rabies as the Flagship for the One Health Approach

Conflict often arises as to where the responsibility lies for the control and elimination of rabies. Despite being a zoonotic disease, the health sector typically sees the disease as one primarily affecting animals, whereas the veterinary sector considers human deaths that result from rabies infections to be the concern of the medical sector. Additionally, the veterinary sector is not as affected by the loss of economically important animals such as livestock to rabies when compared with the losses associated with diseases such as FMD. The responsibility for the control of rabies is typically shifted among the various governmental sectors, and thus rabies remains neglected. However, the challenges posed by rabies create the perfect platform for the disease to be the flagship disease for the One Health approach, unifying various sectors, each with their own strengths, into a single front against the scourge of rabies.

The One Health approach for rabies control requires primary involvement from the medical and veterinary sectors, ensuring that the disease is controlled from various angles. The human sector is responsible for ensuring the appropriate and timely treatment of potentially exposed individuals by ensuring adequate human vaccine supply, wound care and post-exposure prophylaxis in all of the clinics and hospitals throughout the country. Thus, the role of the medical sector is to prevent human deaths. However, this approach is not a sustainable approach when performed alone, as the costs associated with post-exposure prophylaxis in humans are high [52]. The veterinary sector is directly responsible for controlling rabies in the animal population, thus preventing the spread of rabies among vectors such as dogs and jackals and the subsequent exposures to humans. The control of rabies is focussed on the mass vaccination of dogs, and with sufficient vaccination coverage, the elimination of its spread. The elimination of the disease in reservoir species thus eliminates the possibility of exposures to humans.

Although the medical and veterinary sectors play the primary roles in the control and elimination of rabies, other stakeholders are also involved in the One Health approach. The animal welfare sector plays an important role in ensuring that animals are humanely treated and cared-for in a manner that ensures their comfort, wellbeing and longevity. By ensuring sufficient primary animal healthcare, owned dogs are: vaccinated against diseases, including rabies; sterilised to ensure population control; registered as pets for census and identification purposes and; healthier, ensuring longevity of the animal, which in turn, affects the rabies vaccination coverage.

The educational sector plays a vital role in educating the populace about rabies, the dangers of this disease, prevention measures, animal healthcare and bite prevention. These educational roles are thus crucial to the successes of disease intervention campaigns. Bite prevention campaigns ensure people, especially children under the age of 15 years who have

been identified as the most at-risk demographic, are educated about dog bite prevention by learning to identify basic dog behavioural patterns and how to correctly assess them in order to not provoke animals into aggression. Furthermore, by being educated about the dangers of rabies and the role that basic healthcare plays in preventing the disease, people will understand the necessity for correct basic wound treatment and subsequent medical treatment in order to prevent rabies after a bite case has occurred.

By embracing the One Health approach into all of the aspects of the National Rabies Control Strategy, the Namibian government will ensure a multi-pronged approach to rabies control and elimination. This approach is essential to the success of the disease intervention strategy and also allows multiple stakeholders and government sectors to contribute to the control of rabies. Thus, in situations where stakeholders are overburdened by other responsibilities, the contributions from other stakeholders can continue to progress the National Strategy.

Passive Rabies Surveillance in Namibia

Disease surveillance is defined by the World Organization for Animal Health (OIE) as the "systematic ongoing collection, collation and analysis of information related to animal health, and the timely dissemination of that information to those that need to know, so that action can be taken" [53]. As such, trained professionals such as veterinarians, para-veterinarians and animal health specialists initiate the process of disease surveillance by submitting potentially infected samples for diagnosis and subsequently act upon the diagnostic results by implementing disease intervention incentives. As of 2016, Namibia has an extensive network of 19 state veterinarians that are spread throughout the country, whilst a vast number of privately owned veterinary practices are interspersed in the regions.

The most critical component of any surveillance network is the presence and functionality of diagnostic facilities capable of confirming whether a sample is indeed positive for the suspected disease. Diagnostic confirmation, relying on an accurate and easy to use assay, is important for various reasons, *viz*. management of disease intervention campaigns among animal and human populations; understanding the role of wildlife reservoirs; and the identification of potential host shifts that could complicate disease elimination endeavours. Namibia's rabies surveillance network consists of two diagnostic facilities, the first of which is situated at the central veterinary laboratory (CVL) in Windhoek. The second rabies diagnostic facility is a regional veterinary laboratory (RVL) situated in Ondangwa. Diagnostic confirmation of rabies in Namibia relies on the recommended direct fluorescent antibody (DFA) test, which is routinely applied in Namibia [42]. In order to ensure the highest diagnostic standards within the country, Namibia partook in a diagnostic proficiency and protocol harmonisation workshop at the OIE Rabies Reference Laboratory for southern Africa in 2009 [54].

In an effort to further improve upon the existing diagnostic capabilities, and thus the subsequent epidemiological information and comprehension of disease dynamics, the Namibian government began the routine implementation of a novel diagnostic assay undergoing global validation and large-scale implementation. The direct rapid immunohistochemical test (DRIT) has, since its development in 2006, been applied in various studies involving the testing of small sample cohorts as well as routine implementation on a

national level. All of the studies performed to date have found that the cost effective DRIT had a diagnostic sensitivity and specificity equal to that of the gold standard DFA test, while being quicker to perform and easier to interpret by inexperienced readers [55–61]. The advantages associated with the DRIT clearly make the assay more applicable to resource-limited developing countries on the African continent, especially those like Namibia that have the opportunity to further the enhancement of the countries' surveillance network by implementing decentralised diagnosis.

The routine implementation of an accredited diagnostic assay (DFA) provides one of the key indicators of a successful National strategy, as the diagnostic confirmation enables the monitoring of the intervention campaign maintained within the country. While the DFA is a key indicator of success, the subsequent diagnostic confirmation with an equally effective assay such as the DRIT is an effective manner to ensure that the diagnostic capabilities within the country are maintained at the highest level.

Education and Awareness Programmes

Enhanced public education and awareness of rabies has been identified as one of the key areas that needs to be addressed in order to ensure a successful disease intervention campaign [62]. By ensuring that the general populace is adequately educated and aware of the disease and its prevention, unnecessary bite cases and subsequent financial expenditure can be negated. The applicability of widespread public education in Namibia was showcased in 2008 when the Namibian government undertook a project whereby Constituency Councillors sensitized the communities to rabies within the Kavango region of the country. The community members within this region were educated about both the dangers of rabies and the importance of having their pets and farm animals vaccinated against the disease. For the duration of the campaign (April 2008 to March 2009), the average number of dog bites within the region decreased from 82 to 39, while the annual expenditure on rabies biologics reduced from USD 56,600 to USD 29,600. Further improvement was seen from April 2009 to March 2010, where no human deaths were reported within the region, showcasing the longevity of focussed education campaigns [63].

In lieu of the successful outputs seen with community education programmes in the country, further education initiatives have been promoted and supported by both governmental and private parties. In recognition of this fact, official country-specific data, reported to the Pan-African Rabies Control Network (PARACON) [64], described the use of various awareness campaigns such as: i) rabies awareness campaigns that target both community leaders and school children within the country, ii) awareness campaigns on bite-wound management, and iii) encouraging bite victims to seek medical attention.

Although various educational campaigns are routinely implemented, a recent study assessing the knowledge, attitudes and practices of residents in two towns of the Oshana region was performed to assess whether the community knowledge is adequate enough to support rabies prevention in their community. The study found that the surveyed participants had a good general understanding of rabies, but specific points needed to be clarified amongst the two surveyed populations. Among the 245 surveyed individuals, 53% associated rabies with a virus, while 90.6% identified a dog bite as the main means of transmission. Seventy-five per cent of the surveyed individuals knew that wildlife could also cause the disease and

should thus be avoided. Considering that 63.3% of the surveyed individuals had received their information from the media, it is clear that the educational messages from the various outlets were fairly effective. Despite the clear message with regards to rabies, only 37% had actually vaccinated their own pets after hearing about the importance of preventing the disease, suggesting that there may still be barriers to adequate vaccination coverage, such as costs and accessibility, or alternatively follow-up educational broadcasts are required in order to encourage people to vaccinate their animals regularly [65].

In light of the problems caused by incorrect or partial information being shared with the public, the Partners for Rabies Prevention (PRP), an informal expert group of rabies-focused professionals, recognized the importance of a coordinated approach to rabies education. As very few rabies educational resources provide comprehensive information pertaining to all of the components associated with proper rabies education, the Global Alliance for Rabies Control established an online rabies educational platform as a means to distribute freely available online certificate courses to members of "at-risk" communities. Since its launch in 2015, these educational courses have been promoted in Namibia in order to establish a network of rabies experts that are well informed and able to further educate other people within their communities.

Preventative and Control Measures

Rabies in Namibia is a notifiable disease for both the human and animal sectors [42]. Dog bite cases and potential rabies exposures are to be reported to the nearest state veterinary office in the country. The vaccination certificate of the animal is assessed and the animal is either put under quarantine for a period of 10 days or, in highly suspicious cases, the animal is euthanised and the dog is subjected to rabies diagnosis at the CVL. After laboratory confirmation, a letter signed by the diagnostician is sent to the bite case victim and rabies post-exposure prophylaxis is provided to the individual free of charge [66]. Although this is an effective means to prevent human rabies cases – through effective and timely treatment – the most feasible and cost effective strategy is to achieve a 70% vaccination coverage of all of the dogs in the country, as well as in bordering regions [24, 67, 68]. Rabies outbreak and response teams are also available to specifically target areas for mass vaccination where suspected outbreaks are underway. These teams work on a response basis and despite being effective, are not designed to prevent rabies outbreaks, but rather to control them. Other prevention measures include: Animal registration that helps to ensure that the animals are correctly and timeously vaccinated against notifiable diseases such as rabies; Legislation that includes specific rabies prevention and control measures and; Strict controls on the cross-border transport of animals. If performed rigorously, these preventative measures should contribute to the improved control and the eventual elimination of rabies in Namibia using a multi-sectoral, multi-pronged approach.

Despite being effective in terms of preventing human death, response-driven action is not a feasible approach to the elimination of canine rabies, as it is costly and does not address the problem at its core. Namibia is attempting to directly address the challenge posed by canine rabies by ensuring that rabies vaccination is compulsory in dogs and cats. Both fixed-point and roving mass vaccination campaigns are undertaken in Namibia and the events are

advertised before the time, ensuring that the target communities are aware of the vaccination campaigns [66].

In recent years, Namibia has undertaken various mass vaccination campaigns in an attempt to achieve the required 70% vaccination coverage in certain regions within the country. These campaigns typically place strain on the veterinary professionals and the resources at their disposal as other more economically important diseases often take precedence. For instance, in 2015, a FMD outbreak occurred throughout the central regions of the country, resulting in the shifting of resources and personnel away from rabies vaccination and surveillance programmes [69]. These challenges endanger rabies control and elimination initiatives; however, with the implementation of a National Strategy towards rabies control and elimination, resources can be allocated solely for the purpose of rabies control, ensuring that other disease outbreaks do not directly influence current rabies control initiatives.

A sustainable supply of rabies vaccine can be a major obstacle to the implementation of mass vaccination campaigns and, in light of this, the OIE has developed vaccine banks that facilitate the sale of discounted vaccine to eligible countries [70]. The vaccine banks also aim to ensure that vaccine manufacturing companies are able to adequately supply the demand placed upon them to provide sufficient doses of vaccine to a country and region. Thus, the implementation of vaccine banks will facilitate the cost-effective purchase and timeous delivery of sufficient vaccine for countries to carry out their envisioned mass vaccination campaigns.

Additionally, the Namibian and Chinese governments are collaborating in order to build a vaccine production facility in Namibia [71]. This vaccine production facility will focus on animal vaccines with specific emphasis on FMD; however, rabies vaccine production will also be considered and likely undertaken in this facility. This will ensure that not only Namibia will have adequate animal vaccine supply at a reduced price, but that neighbouring countries may also be able to benefit from a more localised vaccine production facility.

Regional Collaborations

As rabies is a transboundary disease, it is important that regional collaborations and concerted efforts are considered whilst developing a National Strategy towards rabies control and elimination. Because of the ability of vectors to easily cross political boundaries, a National Strategy based solely on controlling rabies within the country – without any considerations for neighbouring countries – is futile. As was seen with the initial introduction of rabies into Namibia, an epizootic of rabies in a neighbouring country has the potential to spread into the country of concern, resulting in possible human exposures and thus preventing the country from obtaining a ‘rabies-free’ status. In order to ensure that a country remains rabies-free, a buffer vaccination zone that carries into neighbouring countries is required [24].

Namibia has historically been involved in various regional collaborative efforts towards rabies control, demonstrating the willingness to address rabies on a regional scale and to work in collaboration with other countries in order to create a concerted front against the spread of rabies. Namibia was one of the founding member countries of the Southern and Eastern Rabies Group (SEARG), which was initially founded in 1992 [72]. The SEARG group was later merged into the Pan-African Rabies Control Network (PARACON) and in 2015 Namibia was represented at the inaugural PARACON meeting [64].

In light of these efforts, Namibia has demonstrated the importance of regional collaborations and has approached the development of their National Strategy with not only a national, but also a regional, rabies control effort in mind.

CONCLUSION

In light of the recent declaration of commitment by the global community to strive for canine-mediated human rabies elimination by the year 2030, there is an increased focus on endemic countries to address the problem of rabies. In efforts to support and achieve this milestone, the global community has endeavoured to raise the status of rabies as a priority disease within the cohort of neglected zoonotic diseases and has further pledged their support by providing essential tools and resources, as well as expert advice, to endemic countries. PARACON was specifically created in order to facilitate global support and regional collaboration within Africa, thus creating an advisory network for African countries. Despite this unified global approach, the challenges faced by rabies remain the responsibility of each country itself and thus, each endemic country is required to take ownership of their own control and elimination efforts.

Namibia has shown commitment to taking ownership of the challenges faced by rabies in their country by developing a National Strategy towards canine-mediated human rabies elimination. With support from international organisations and the global community, Namibia has developed a comprehensive National Strategy in line with the goals set by the global community. The next few years will be crucial for the implementation of the National Strategy in the efforts to see the developed plan come to fruition so that Namibia can reap the rewards of prioritising rabies for elimination. Namibia can use the momentum generated from their National Strategy to showcase their rabies elimination efforts on a continental scale and drive towards being the first canine-mediated human rabies free country in Africa.

REFERENCES

[1] Bingham, J. Canine rabies ecology in southern Africa. Emerg Infect Dis [Internet]., 2005 Sep, 11(9), 1337–42. Available from: http:// www. pubmedcentral.nih.gov/ articlerender.fcgi?artid=3310623&tool=pmcentrez&rendertype=abstract.

[2] Swanepoel, R; Barnard, BJ; Meredith, CD; Bishop, GC; Brückner, GK; Foggin, CM; et al. Rabies in southern Africa. *Onderstepoort J Vet Res [Internet]*., 1993, 60(4), 325–46. Available from: http://eprints.ucl.ac. uk/152981/.

[3] Von Maltitz, L. Rabies in the Northern Districts of South West Africa. *J S Afr Vet Med Assoc*., 1950, 21, 4–12.

[4] Hübschle, O. Rabies in the Kudu Antelope (Tragelpahus strepsiceros). *Rev Infect Dis*., 1988, 10(4), s629–33.

[5] Knobel, DL; Cleaveland, S; Coleman, PG; Fèvre, EM; Meltzer, MI; Miranda, MEG; et al. Re-evaluating the burden of rabies in Africa and Asia. *Bull World Health Organ [Internet]*., 2005 May, 83(5), 360–8. Available from: http://

www.pubmedcentral.nih.gov/ articlerender.fcgi? artid=2626230&tool= pmcentrez&rendertype=abstract.

[6] Hampson, K; Coudeville, L; Lembo, T; Sambo, M; Kieffer, A; Attlan, M; et al. Estimating the Global Burden of Endemic Canine Rabies. *PLoS Negl Trop Dis*., 2015, 9(4), 1–20.

[7] Lankester, F; Hampson, K; Lembo, T; Palmer, G; Taylor, L; Cleaveland, S. Implementing Pasteur's vision for rabies elimination. *Science*, (80-). 2014, 345 (October), 1562–4.

[8] Lembo, T; Hampson, K; Kaare, MT; Ernest, E; Knobel, D; Kazwala, RR; et al. The feasibility of canine rabies elimination in Africa: dispelling doubts with data. PLoS Negl Trop Dis [Internet]., 2010 Jan [cited 2011 May 27], 4(2), e626. Available from: http:// www. pubmedcentral.nih.gov/articlerender.fcgi?artid =2826407&tool= pmcentrez&rendertype=abstract.

[9] International Coordinating Group (ICG). Report of the sixth meeting of the International Coordinating Group of the World Health Organization and the Bill and Melinda Gates Foundation project on eliminating human and dog rabies. *Durban*, 2014.

[10] Fahrion, AS; Mikhailov, A; Abela-Ridder, B; Giacinti, J; Harries, J. Weekly epidemiological record Relevé épidémiologique hebdomadaire. *World Heal Organ*., 2016, 91(2), 13–20.

[11] Sundiata, I. Brothers and Strangers: Black Zion, Black Slavery, 1914–1940. Durham and London: Duke University Press, 2003, 442 p.

[12] Nel, L; Rupprecht, C. Emergence of Lyssaviruses in the Old World: The Case of Africa. In: Childs JE, Mackenzie JS, Richt JA, editors. Wildlife and Emerging Zoonotic Diseases: The Biology, Circumstances and Consequences of Cross-Species Transmission. Springer Berlin Heidelberg, 2007, p. 161–93.

[13] Courtin, F; Carpenter, TE; Paskin, RD; Chomel, BB. Temporal patterns of domestic and wildlife rabies in central Namibia stock-ranching area, 1986-1996. *Prev Vet Med [Internet]*., 2000 Jan 5, 43(1), 13–28. Available from: http://www.ncbi.nlm.nih.gov/ pubmed/10665948.

[14] Schneider, HP. Rabies in South West Africa/Namibia. In: Kuwert E, Mérieux C, Koprowski H, Bögel K, editors. Rabies in the Tropics [Internet]. Berlin, New York: Springer-Verlag, 1985, p. 520–35. Available from: http://dx.doi.org/10.1007/978-3-642-70060-6_67.

[15] Swanepoel, R. Rabies in Southern Africa. In: Southern and Eastern African Rabies Group [Internet]. Pietermaritzburg, 1993. p. 20. Available from: https:// paracon.rabiesalliance.org/ uploads/ media/ SEARG_Pietermaritzburg_South_ Africa_1993.PDF.

[16] Lembo, T; Hampson, K; Haydon, DT; Craft, M; Dobson, A; Dushoff, J; et al. Exploring reservoir dynamics: a case study of rabies in the Serengeti ecosystem. *J Appl Ecol*., 2008, 1–12.

[17] Depner, K. Rabies in Namibia. In: Southern and Eastern African Rabies Group [Internet]. *Lusaka*, 1992. p. 39–42. Available from: https:// paracon.rabiesalliance.org/ uploads/media/SEARG_Lusaka_Zambia_1992.PDF.

[18] Andima, J. 2 500 cases of rabies recorded in five years. The Namibian [Internet]. Windhoek, 2015 Mar 19, Available from: http:// www. namibian.com.na/index.php? id=134869&page=archive-read.

[19] Fourie, L; Hahn, CH; Vedder, V. The Native Tribes of South West Africa. Frank Cass and Company Limited, 2012, 211 p.

[20] Ferraro, G; Andreatta, S. Cultural Anthropology: An Applied Perspective. 10th ed. Cengage learning, 2014, 480 p.

[21] Côté, H; Garant, D; Robert, K; Mainguy, J; Pelletier, F. Genetic structure and rabies spread potential in raccoons: The role of landscape barriers and sex-biased dispersal. *Evol Appl*., 2012, 5(4), 393–404.

[22] Goudie, A. Namib Sand Sea: Large Dunes in an Ancient Desert. In: Migon P, editor. *Geomorphological Landscapes of the World [Internet]*. Dordrecht: Springer Netherlands, 2009, p. 163–9. Available from: http://dx.doi.org/10.1007/978-90-481-3055-9_17.

[23] Hubschle, OJB. Rabies in Namibia. In: Southern and Eastern African Rabies Group [Internet]. Harare, 1995, p. 47–9. Available from: https:// paracon.rabiesalliance.org/ uploads/media/SEARG_Harare_Zimbabwe_1995.PDF.

[24] Russell, CA; Real, LA; Smith, DL. Spatial control of rabies on heterogeneous landscapes. *PLoS One [Internet]*., 2006 Jan, 1(1), e27. Available from: http://www.ncbi.nlm.nih.gov/pubmed/17183654.

[25] Hampson, K; Dushoff, J; Bingham, J; Brückner, G; Ali, YH; Dobson, A. Synchronous cycles of domestic dog rabies in sub-Saharan Africa and the impact of control efforts. *Proc Natl Acad Sci U S A [Internet]*., 2007 May 1, 104(18), 7717–22. Available from: http:// www.pubmedcentral. nih.gov/articlerender.fcgi?artid= 1863501&tool= pmcentrez&rendertype=abstract.

[26] Brunker, K; Hampson, K; Horton, DL; Biek, R. Integrating the landscape epidemiology and genetics of RNA viruses: rabies in domestic dogs as a model. *Parasitology*., 2012, 139, 1899–913.

[27] Barnard, B; Hassel, R. Rabies in kudus (Tragelaphus strepsiceros) in South West Africa/Namibia. *J S Afr Vet Assoc*., 1981, 52(4), 309–14.

[28] Barnard, B. The role played by wildlife in the epizootiology of rabies in South Africa and South-West Africa. *Onderstepoort J Vet Res*., 1979, 46(3), 155–63.

[29] Shaw, J. Hondsdolheid by koedoes. *J S Afr Vet Assoc*., 1980, 51, 209.

[30] Hassel, R. Incidence of rabies in kudu in South West Africa/Namibia. *S Afr J Sci [Internet]*., 1982 [cited 2011 Jul 20], 78, 418–21. Available from: http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Incidence+of+rabies+in+kudu+in+South+West+Africa/Namibia#0.

[31] Mansfield, K; McElhinney, L; Hübschle, O; Mettler, F; Sabeta, C; Nel, LH; et al. A molecular epidemiological study of rabies epizootics in kudu (Tragelaphus strepsiceros) in Namibia. *BMC Vet Res*., 2006 Jan, 2, 2.

[32] OIE. Office Internationale des Epizooties: *HANDISTATUS II Namibia/rabies multiannual animal disease status [Internet]*., 2011 [cited 2012 Feb 15]. Available from: http:// web.oie.int/ hs2/sit_pays_ mald_ pl.asp?c_pays=135&c_mald=26#.

[33] Scott, T; Hassel, R; Nel, L. Rabies in kudu (Tragelaphus strepsiceros). *Berl Munch Tierarztl Wochenschr*., 2012, 125(6), 236–41.

[34] Reid, H; Sahlen, L; Stage, J; MacGregor, J. The Economic Impact of climate change in Namibia. *Environ Econ Program Discuss Pap*, 07-02. 2007, (November), 1–54.

[35] Scott, TP; Fischer, M; Khaiseb, S; Freuling, CM; Hoper, D; Hoffmann, B; et al. Complete genome and molecular epidemiological data infer the maintenance of rabies among kudu (Tragelaphus strepsiceros) in Namibia. *PLoS One*., 2013, 8(3), e58739.

[36] Barnard, BJH; Hassel, R; Geyer, HJ; De Koker, W. Non-bite transmission of rabies in kudu (Tragelaphus strepsiceros). *Onderstepoort J Vet Res*., 1982, 49, 191–2.

[37] Government Gazette. Municipal Dog Tax Ordinance 13 [Internet]. Republic of Namibia, 1967 p. Animals – 2. Available from: http:// www. lac.org.na/namlex/ Animals.pdf.

[38] Government Gazette. Declaration of Notifiable Diseases; Animal Health Act [Internet]. Republic of Namibia; 2013 p. 5. Available from: http://www.lac.org.na/laws/ 2013/5239.pdf.

[39] New Era Staff Reporter. Phase 1 of Kudu Rabies Project shows promising results – Hassel. *New Era [Internet]*. Windhoek, 2016 Feb 23, Available from: https://www.newera.com.na/2016/02/23/phase-1-kudu-rabies-project-shows-promising-results-hassel/.

[40] Cleaveland, S; Fèvre, EM; Kaare, M; Coleman, PG. Estimating human rabies mortality in the United Republic of Tanzania from dog bite injuries. *Bull World Health Organ [Internet]*., 2002 Jan, 80(4), 304–10. Available from: http:// www.pubmedcentral. nih.gov/ articlerender.fcgi? artid=2567765&tool=pmcentrez&rendertype=abstract.

[41] Taylor, LH; Hampson, K; Fahrion, A; Abela-Ridder, B; Nel, LH. Difficulties in estimating the human burden of canine rabies. *Acta Trop*., 2015, (March 2016).

[42] WHO, GARC. *Namibia [Internet]*., 2014. Available from: www.who. int/rabies/epidemiology/Rabies_CP_Namibia_09_2014.pdf.

[43] UNFAO. Fao Global Information and Early Warning System on Food and World Food Programme Fao/Wfp Crop and Food Security Assessment Mission To Ethiopia. *FAO Corporate Document Repository*., 2009.

[44] World Bank. Namibia Country Brief. Washington, DC, 2009.

[45] Barnes, JJ; Lange, GMG; Nhuleipo, O; Muteyauli, P; Katoma, T; Amapolo, H; et al. Preliminary valuation of the wildlife stocks in Namibia: wildlife asset accounts [Internet]. *Ministry of Environment and Tourism Report*., 2004 [cited 2011 Aug 20]. Available from: http://scholar.google.com/scholar?hl=en&btnG =Search&q=intitle: Preliminary+valuation+of+the+wildlife+stocks+in+Namibia+:+wildlife+asset+accounts#0.

[46] Lindsey, P. An analysis of game meat production and wildlife-based land uses on freehold land in Namibia: Links with food security. *TRAFFIC*. Harare, 2011.

[47] Jagd Farm Hunting Ranch. *Jagd Farm Hunting Ranch [Internet]*., 2016 [cited 2016 Mar 22]. Available from: http://www.jagdfarm-namibia.de/ html/e_prices.htm.

[48] Annighöfer, P; Schütz, S. Observations on the population structure and behaviour of two differently managed populations of the greater kudu (Tragelaphus strepsiceros, Pallas 1766) in Namibia. *Eur J Wildl Res*., 2011, 57(4), 895–907.

[49] Conan, A; Akerele, O; Simpson, G; Reininghaus, B; van Rooyen, J; Knobel, D. Population Dynamics of Owned, Free-Roaming Dogs: Implications for Rabies Control. *PLoS Negl Trop Dis [Internet]*., 2015, 9(11), e0004177. Available from: http://dx.doi.org/ 10.1371/ journal. pntd.0004177.

[50] Townsend, SE; Lembo, T; Cleaveland, S; Meslin, FX; Miranda, ME; Putra, AAG; et al. Surveillance guidelines for disease elimination: A case study of canine rabies. *Comp Immunol Microbiol Infect Dis.*, 2013, 36(3), 249–61.

[51] WHO. WHO expert consultation on rabies. 2nd Report. *WHO Tech Rep Ser*., 2013, 982, 1–141.

[52] Sambo, M; Cleaveland, S; Ferguson, H; Lembo, T; Simon, C; Urassa, H; et al. The Burden of Rabies in Tanzania and Its Impact on Local Communities. *PLoS Negl Trop Dis. Public Library of Science*, 2013, 7(11), e2510.

[53] OIE. OIE Terrestrial Guidelines - Glossary. *In: OIE Terrestrial Animal Health Code*., 2015, p. 1–12.

[54] Sabeta, CT; Khaiseb, S; Ngeleja-Mpelumbe, C; Shumba, W. Harmonisation of the fluorescent antibody test (FAT) protocol for use in the SADC countries. *In: Southern and Eastern Africa Rabies Group (SEARG)*., 2011.

[55] Lembo, T; Niezgoda, M; Velasco-Villa, A; Cleaveland, S; Ernest, E; Rupprecht, CE. Evaluation of a direct, Rapid Immunohistochemical Test for rabies diagnosis. *Emerg Infect Dis*., 2006, 12(2), 310–3.

[56] Dürr, S; Naïssengar, S; Mindekem, R; Diguimbye, C; Niezgoda, M; Kuzmin, I; et al. Rabies diagnosis for developing countries. *PLoS Negl Trop Dis [Internet]*., 2008 Jan [cited 2010 Jul 16], 2(3), e206. Available from: http:// www.pubmedcentral.nih.gov/ articlerender.fcgi? artid= 2268742&tool=pmcentrez&rendertype=abstract.

[57] Tao, XY; Niezgoda, M; Du, JL; Li, H; Wang, XG; Huang, Y; et al. The primary application of direct rapid immunohistochemical test to rabies diagnosis in China. Chinese J Exp Clin Virol. Department of Viral Encephalitis, Institute for Viral Disease Control and Prevention, Chinese *Center for Disease Control and Prevention*, Beijing 100052, China., 2008 Jun, 22(3), 168–70.

[58] Madhusudana, SN; Subha, S; Thankappan, U; Ashwin, YB. Evaluation of a direct rapid immunohistochemical test (dRIT) for rapid diagnosis of rabies in animals and humans. *Virol Sin*., 2012 Oct, 27(5), 299–302.

[59] Saturday, GA; King, R; Fuhrmann, L. Validation and operational application of a rapid method for rabies antigen detection. *US Army Med Dep J*., 2010/01/21 ed. 2009, 42–5.

[60] Coetzer, A; Sabeta, CT; Markotter, W; Rupprecht, CE; Nel, LH. Comparison of biotinylated monoclonal and polyclonal antibodies in an evaluation of a direct rapid immunohistochemical test for the routine diagnosis of rabies in southern Africa. *PLoS Negl Trop Dis*., 2014.

[61] Coetzer, A; Markotter, W; Sabeta, CT; Nel, LH. Comparison of biotinylated monoclonal and polyclonal antibodies in an evaluation of a direct rapid immunohistochemical test for the routine diagnosis of rabies in southern Africa. University of Pretoria, 2013.

[62] Banyard, AC; Horton, DL; Freuling, C; Müller, T; Fooks, AR. Control and prevention of canine rabies: The need for building laboratory-based surveillance capacity. *Antiviral Res [Internet]*. Elsevier B.V., 2013, 98(3), 357–64. Available from: http:// dx.doi.org/ 10.1016/ j.antiviral. 2013.04.004.

[63] Katongo, M; Sumbi, V; Pereko, D; Wambugu, M. The Effectiveness of Therapeutics Committees (TCs) in Addressing Key Public Health Problems. In: Third international conference for improving use of medicine [Internet]. *Antalya*, 2011, p. 1. Available from: http:// www. inrud.org/ICIUM/ConferenceMaterials/1009-katongo-_a.pdf.

[64] Scott, TP; Coetzer, A; de Balogh, K; Wright, N; Nel, LH. The Pan-African Rabies Control Network (PARACON): A unified approach to eliminating canine rabies in Africa. *Antiviral Res [Internet]*., Elsevier B.V, 2015, 124, 93–100. Available from: http:// linkinghub.elsevier. com/retrieve/pii/S0166354215300036.

[65] Haimbodi, F; Mavenyengwa, R; Noden, BH. Knowledge and practices of residents in two north Namibian towns with regard to rabies and pet care. *South African J Infect Dis [Internet]*., 2014, 29(4), 141–6. Available from: http:// www.sajei.co.za/ index.php/ SAJEI/article/ view/ 619/845.

[66] PARACON. Namibia Country Report [Internet]. *PARACON Country Reports (available upon request)*., 2015. Available from: https:// paracon.rabiesalliance.org.

[67] Coleman, PG; Dye, C. Immunization coverage required to prevent outbreaks of dog rabies. *Vaccine*., 1996, 14(3), 185–6.

[68] Kaare, M; Lembo, T; Hampson, K; Ernest, E; Estes, A; Mentzel, C; et al. Rabies control in rural Africa: evaluating strategies for effective domestic dog vaccination. *Vaccine [Internet]*., 2009 Jan 1 [cited 2011 Jul 21], 27(1), 152–60. Available from: http:// www.ncbi.nlm.nih.gov/ pubmed/18848595.

[69] NAU-NLU. Livestock Producers' Organisation of Namibia Annual Report. Windhoek, 2015.

[70] OIE. Vaccine bank for rabies [Internet]., 2013 [cited 2016 Mar 30]. Available from: http:// www.rr-asia.oie.int/ activities/ sub-regional-programme/hped/vaccine-bank-fmd-rabies/vaccine-bank-for-rabies/.

[71] Namibian, Sun. Vaccine production plant closer to reality. *Namibian Sun [Internet]*. Windhoek, 2016 Feb 3; Available from: http:// www. namibiansun.com/agriculture/ vaccine-production-plant-closer-reality. 91075.

[72] King, A. SEARG. In: Southern and Eastern Africa Rabies Group (SEARG) [Internet]. Lusaka: Pan-African Rabies Control Network (PARACON), 1992. Available from: https:// paracon.rabiesalliance.org/ uploads/media/SEARG_Lusaka_Zambia_1992.PDF.

In: Handbook on Africa
Editor: Whitney Sherman
ISBN: 978-1-53610-063-1

Chapter 10

MALARIA: AN ENVIRONMENTAL HEALTH ISSUE WITH TREMENDOUS SOCIOECONOMIC IMPACT ON HOUSEHOLDS IN THE DEMOCRATIC REPUBLIC OF CONGO

Di-Mosi Roger Wumba[1], MD PhD,
Nlandu Roger Ngatu[2,3,4,*], MD PhD,
Luzitu Severin Nangana[4], MD MPH,
Sakiko Kanbara[2], RN PhD,
Sifa Marie-Joelle Muchanga[3,5,6], MD MSc,
Madone Mandina[7], MD, MSc, Kei Tanaka[3], RN MSc,
Stanislas Wembonyama[8], MD PhD
and Sayumi Nojima[2], PHN DSN PhD

[1]Department of Tropical Medicine, Unit of Parasitology, Faculty of Medicine, University of Kinshasa, Democratic Republic of Congo (DRC)
[2]Graduate School of Health Sciences and Nursing, University of Kochi, Kochi, Japan
[3]BRIDGE (Non-Governmental Organization), Kochi prefecture, Japan
[4]Congo Heiwa-Mura (Non-Governmental Organization), Kongo central, DRC
[5]Department of Environmental Medicine, Kochi University Medical School, Nankoku-city, Japan
[6]Department of Gynecology and Obstetrics, Faculty of Medicine, University of Kinshasa, DRC
[7]Department of Internal Medicine, Unit of Infectious Diseases, Faculty of Medicine, University of Kinshasa, DRC
[8]Department of Pediatrics, University of Lubumbashi, DRC

[*] Corresponding author: Ngatu Roger Nlandu, MD. PhD. Specially Appointed Associate Professor; University of Kochi. Address: 2751-1 Ike, Ike campus. Kochi-city, Zipcode: 781-8515. Kochi prefecture, Japan. Tel/Fax: +81-888478633. E-mail: ngatu@dngl.u-kochi.ac.jp.

ABSTRACT

Background and objective. Malaria is a mosquito-borne infectious disease with high morbidity and mortality in tropical regions, caused by Plasmodium parasite and transmitted to humans by female Anopheles mosquitoes. WHO estimates that African households lose about 25% of income to malaria. The aim of this pilot study was to determine the prevalence and socioeconomic impact of malaria on households in the Democratic Republic of Congo (DRC).

Methods. An analytical cross-sectional study was conducted from 16 November through December 2015 in which 152 heads of households took part. They were from a rural (n1=81) and an urban county (n2=71). All participating households made up 1,029 members. The French version of 'Malaria Indicator Survey' questionnaire was completed anonymously.

Results. There were 51.3% of male and 48.7% of female heads of households ($p>0.05$). The mean age was 38.97±9.88, and 22% of them were unemployed. Household size varied from 3 to 18, and more than half (61.7%) of rural households had more than five members (vs. 38.3% for urban households). The estimated household monthly income varied from 10 to 700 $US, and only 10.5% of households earned more than 300 US$ a month (vs. 89.5% earning less than 300US$ and 50.6% less than 100 US$; $p<0.05$). Participants from the urban site had higher level of education, with 37.2% having a college or university degree (vs. 21.6% for rural site); 12.5% either had primary education level or were illiterate. Regarding anti-vector measures for malaria prevention, 15.8% of heads of households reported the existence of a public sanitation activity implemented in their residential area ($p<0.001$); 65.8% used insecticide-treated bed nets (ITN), 13.8% used spray, 0.6% combined ITN and spray, 12.5 used ordinary bed nets, whereas 7.2% did not use any preventive measure. For monthly anti-mosquito expenditure, 50% (76/152) of participants reported that they spent nothing due to lack of money, 24.3% spent 10-20 $US, 15.7% spent 21-30 $US; the remaining participants (9.9%) spent more than 30 $US a month. The availability of nets showed a positive association with socioeconomic status of households. Overall malaria prevalence-rate among heads of households was 92.4% (at least one episode), with an average of 2.5 malaria episodes per person (range: 1–7 episodes). It was equally high in participants from both rural and urban sites, 90.1% and 88.7%, respectively ($p>0.05$). In the group of participants who reported using ITN, malaria prevalence-rate was 89%; it was 90.5% in spray users, 100% in ordinary bed net users and 100% in those who did not use any measure. Heads of households who reported earning less than 300 US$ had 2.76 times malaria risk than those from households with a monthly income of 300 US$ or higher (aOR: 2.76±1.87; 95% CI: 1.73-10.41; $p<0.05$); those who had primary education level (or illiterate) had a 33.87 times risk of developing malaria (vs. higher level; aOR: 33.87±34.42; 95% CI: 2.45-89.49; $p<0.05$); whereas those living in areas without public sanitation program had a 3.01 times malaria risk (aOR: 3.01±2.19; 95% CI: 1.37-24.23; $p<0.05$). Regarding individual malaria care expenditure in the previous 12-month period, the estimated cost was 101.56 ± 10.63 $US per person.

Conclusions. Findings from this pilot study showed high malaria rates in both rural and urban households with a relatively high malaria care expenditure, causing a real socioeconomic burden to Congolese households. There is a necessity to enhance malaria prevention programs with the adoption of an integrated anti-malaria approach aiming at increasing malaria awareness and eliminating its vector in the living environment.

Keywords: Congo, household, malaria, prevalence, socioeconomic status

1. INTRODUCTION

1.1. Definition, Etiology and Epidemiologic Profile of Malaria

Malaria is a mosquito-borne infectious disease caused parasites of the genus *Plasmodium*, transmitted to humans by female *Anopheles* mosquitoes. It is a disease that is well established as a major global health problem (WHO 2011; Bhatt et al. 2015; Wumba et al. 2015). There are four species of *Plasmodium* that infect humans to cause malaria: *P. falciparum, P. vivax, P. ovale and P. malariae*; of them, *P. falciparum* is considered the most lethal and widespread malaria parasites infecting humans. Other *Plasmodium* species are known to be responsible of infection in rodents and non-human primates (Cai et al. 2010; Liu et al. 2010). The finding of malaria parasites in human red blood cells in 1880 by the French army doctor in Algeria and winner of the Nobel Prize of Physiology and Medicine in 1907, Charles Louis Alphonse Laveran, inaugurated a new era in the understanding of the pathophysiology of the disease (Haas 1999). It also rendered the finding of anti-malaria remedies possible that could help to manage the disease.

Malaria morbidity tended to decrease in some endemic countries during the first decade of the 21st century. In 2010, the World Health Organization (WHO), estimated that there were 219,000,000 documented cases of malaria worldwide, killing between 660,000 and 1,200,000 people (WHO 2010). A similar trend was reported for the year 2012, with 207,000,000 cases of whom 627 died. It has been estimated that 3.3 billion people are at risk of malaria, of whom 655,000–1,200,000 die annually, and more than one case occurring per 1,000 population in high-risk areas. The disease killed about 482,000 children under five years of age; that is 1,300 children every day, or one child almost every minute (Nayyar et al. 2012; WHO 2013).

1.2. Trends of Malaria Prevalence and Cost in the Sub-Saharan Africa

Malaria is prevalent is tropical and sub-tropical regions because of rainfall, warm temperatures and stagnant water that provide habitat for mosquito larvae. Previous works have established a relationship between Malaria and poverty, hindering economic development of many developing countries, particularly in Africa (Worrall et al. 2005). Of the 627,000 deaths due to malaria in the world in 2012, approximately 90% occurred in sub-Saharan African countries, and DRC and Nigeria accounted for 40% of them (WHO 2013; PNLP 2013). According to WHO, households in Africa lose approximately 25% of income to malaria (WHO 2008), and the disease has a tremendous impact on households and businesses. In one hand, malaria increases health-related expenditures and employee absenteeism; on the other hand, it reduces productivity. In Uganda, a recent study conducted in 100 households found an association between socioeconomic status and malaria, with wealth index as a predictor of malaria risk (Tusting et al. 2016).

1.3. Malaria Status in Democratic Republic of the Congo (DRC)

Several anti-malaria drugs have been discovered, however, their efficacy is often challenged by new resistant species of plasmodium, besides the treatment cost that some families cannot afford. Thus, the use of Insecticide Treated Net (ITN) has recently become the most promoted and reliable preventive measure in the Sub-Saharan Africa. Nonetheless, the persistent high morbidity and mortality of Malaria despite the large distribution of ITN suggests that the measure has some limits, and that the hygiene and sanitation promotion approach might be of great contribution in the fight against Malaria.

The DRC National Malaria Program reported about 9,400,000 malaria cases occurring nationwide within the year 2012, resulting in 24,000 deaths (PNLP 2013). In its recent report, the same program reported that annual malaria incidence varied between 13,591-13,155 cases per 100,000 from the year 2010 to 2014; and that malaria mortality accounted for 39% all-causes mortality nationwide in 2013, whereas it was 36% in 2014 (PNLP strategic plan 2016). Considering the context of extreme poverty, particularly in the central African region (DRC included), the absence of a country level health insurance system and the inaccessibility of a poor populations to malaria treatment, malaria prevention and the universal care coverage initiative will continue to face shortcomings in most countries of the region. This suggests the need for a more integrated approach in the fight against malaria.

1.4. Objectives of the Study

To our knowledge, there have been no research that investigated the real socioeconomic impact of malaria on Congolese households. We conducted a pilot cross-sectional study to evaluate the incidence and the socioeconomic impact of malaria and related risk factors in a sample of 152 Congolese households from a semi-rural and urban sites of DRC from 16th November through December 2015. The objectives of this pilot study were the following:

1. Evaluate the malaria knowledge and awareness of Congolese household representatives;
2. Determine the prevalence of malaria among study participants and household members in the previous 12 months, its socioeconomic impact and determinants on Congolese rural and urban households.

2. MATERIALS AND METHODS

2.1. Study Design, Sites and Participants

A pilot analytical cross-sectional study was conducted, from 16 November through December 2015, at two sites of the western DRC's provinces of Kinshasa, the capital, and Kongo central. Participants were enrolled at the urban county of Limete, in the capital Kinshasa, and at Kasa-Ngulu, a rural county located in the Kongo central province. Both sites share quite similar ecological conditions: populous residential areas and proximity to a river.

This was a collaborative study between the University of Kochi in Japan and the Unit of Parasitology, Faculty of Medicine of the University of Kinshasa in DRC.

Local Congolese research team counterpart has visited the study sites weeks prior to conducting the survey and contacted community and social leaders (church and social leaders, district and county administrative and health authorities) in each study site. After a thorough explanation of the study activities, later on, the leaders had to explain to their community members during weekly gatherings and schedule the survey. Only community members who were heads of households, voluntarily accepted to take part in the study and signed the informed consent form were eligible.

In this first phase of the 'Congo Malaria Study', a sample of 150 household representatives (75 from each of the study sites) was expected. In total, 152 heads of households were enrolled in the study (71 from the rural and 81 from the urban sites). The household size varied from 3 to 18 members, and all participating households made up 1,029 members. Each participant had to answer the survey questionnaire on behalf of his/her household. Those with a low educational level were assisted by trained surveyors using local dialects to explain the content of informed consent form, and the questionnaire as well.

2.2. Survey Questionnaire

The French version of 'Malaria Indicator Survey' (Global Fund and Madagascar National Malaria Program, 2013) questionnaire was completed anonymously by each participant. It comprised 49 items related to the following five categories:

1. Clinical and sociodemographic characteristics;
2. Personal and family history;
3. Personal lifestyle characteristics;
4. Household characteristics;
5. Household malaria preventive measures and malaria care options.

However, in this first report, only outcome information related to participants' characteristics, malaria rates, malaria preventive measures and care is provided. Study outcomes in regard to water provision and management, the general hygiene and sanitation (WASH) in the study sites will be included in another report.

2.3. Ethical Considerations and Statistical Analyses

The present study was approved by the ethics committee of the Graduate School of Health Sciences and Nursing, University of Kochi in Japan and the local Congolese district administration officers of participating counties and community leaders. Each of the study participants provided a signed informed consent form after receiving explanations of the study objectives and activities. Survey data are presented as means for continuous variables and proportions for categorical variables; outcome variables are either dichotomized or stratified into three to five categories. Cross-tabulation and paired T test were performed to

compare study group, whereas logistic regression test was used to determine predictors of malaria in the sample of heads of households. P-value for statistical significance was set at 0.05. All analyzes were performed with the use of Stata software version 10 (Stata corporation, TX, USA).

3. RESULTS

3.1. Characteristics of Study Participants

Table 1 shows the demographic and socioeconomic characteristics of the participating heads of households from both study sites. There were 51.3% of male participants (78/152; 32 from urban and 46 from rural sites) and 48.7% of females (39 from urban and 35 from rural study sites) ($p>0.05$). The mean age was 38.97±9.88. Of the participants, 46.7% (71/152) were 30 years or younger, whereas 53.3% (81/152) were over 30 years of age ($p<0.05$). Regarding marital status, overall 65.1% (99/152) were married (37 from urban and 62 from rural study sites), 3.9% (6/152) were divorced, 5.3% [8/152) were widowed, 7.9% (12/152] were single with children, whereas 11.2% (17/152) of participants were single without children ($p<0.05$).

Education is an important factor that may influence the outcomes of health education programs or interventions in communities exposed to a health threat. Of study participants, those from the urban site had higher level of education, with 37.2% (29/71) having a college or university degree (vs. 21.6% for rural participants); 12.5% (19/152) either had primary education level or were illiterate (8 from urban and 11 from rural site).

The highest family size was 18, and more than half (61.7%; 50/81) of rural household had more than five members (vs. 38.3% (31/71) for urban households). Regarding participants' occupation, 21.7% (33/152) were unemployed (18 from urban and 15 from rural site), 5,9% (9/152) were students, 13.8% (21/152) were civil servants, 7.2% (11/152) were teachers, 3.9% (6/162) were health care workers, 11.2% (17/152) were businessmen and the remaining participants (36.2%; 55/152) had other occupations ($p<0.001$) (Table 1).

Considering the economic status of households, no statistically significant difference was found between urban and rural households, in terms of household monthly income ($p>0.05$). The estimated household monthly income varied from 10 to 700 $US; half of households (50.6%; 77/152) had a monthly income below 100 $US and only 10.5% (16/152) earned more than 300 US$ a month (10.3% for urban and 11.1% for rural households) (Table 1).

3.2. Anti-Malaria Preventive Measures Used in the Previous 12-Month Period

As for malaria prevention, 15.8% (24/152) of household representatives (9.9% of rural and 23.9% of urban participants) reported the existence of a public service or volunteer group that implemented public sanitation activity in their residential area ($p<0.05$) (Figure 1a); 65.8%, (100/152) used insecticide-treated bed nets (ITN), 13.8% (21/152) used spray, 0.6% (1/152) combined ITN and spray, 12.5 (19/152) used an ordinary bed nets, whereas 7.2%

(11/152) did not use any preventive measure (Figure 1b). Regarding monthly anti-mosquito expenditure, 50% (76/152) of participants reported that they spent nothing due to lack of money, 24.3% (37/152) spent 10-20 $US, 15.7% (24/152) spent 21-30 $US; the remaining participants (9.9%; 15/152) spent more than 30 $US; and the availability of nets showed a positive association with socioeconomic status of households ($p<0.05$) (not shown).

Table 1. Characteristics of participating household representatives

Characteristics of household heads	Study site		P-value
	Urban (n, %)	Rural (n, %)	
Gender M	32 (41.0)	46 (59.0)	0.149
F	39 (52.7)	35 (47.3)	
Age ≤ 30 y.	14 (19.7)	57 (80.3)	0.722
> 30	17 (21.0)	64 (79.0)	
Marital status			
Married	37 (37.4)	62 (62.6)	
Divorced	4 (66.7)	2 (33.3)	0.032
Widowed	6 (75)	2 (25)	
Single with children	4 (63.6)	8 (6.4)	
Single without child	10 (58.8)	7 (41.2)	
Education			
None	5 (6.4)	6 (8.1)	
Primary	3 (3.8)	5 (6.8)	
High school	22 (28.2)	41 (55.4)	0.013
Technical school	19 (24.4)	6 (8.1)	
College/university	29 (37.2)	16 (21.6)	
Household size			
2 – 5	29 (40.8)	42 (59.2)	0.996
6 - 18	31 (38.3)	50 (61.7)	
Family type			
Single-parent	18 (27.3)	29 (35.8)	0.466
Single-parent/extended	10 (15.2)	10 (12.4)	
Bi-parental/not extended	19 (28.8)	28 (34.6)	
Bi-parental/extended	16 (24.2)	12 (14.8)	
Polygamic	3 (4.5)	2 (2.4)	
Occupation Unemployed	18 (25.4)	15 (18.5)	< 0.001
Student	4 (5.6)	5 (6.2)	
Civil servant	5 (7.0)	16 (19.8)	
Teacher	2 (2.8)	9 (11.1)	
Health care worker	3 (4.2)	3 (3.7)	
Businessmen	14 (19.7)	3 (3.7)	
Other	25 (35.2)	30 (37.0)	
Household monthly income (US$)			
< 50	21 (30.8)	19 (23.5)	0.887
50 -99	16 (23.5)	21 (25.9)	
100-150	8 (11.8)	12 (14.8)	
151-200	8 (11.8)	10 (12.3)	
201-300	8 (11.8)	10 (12.3)	
‘> 300	7 (10.3)	9 (11.1)	
Total	71 (100)	81 (100)	-

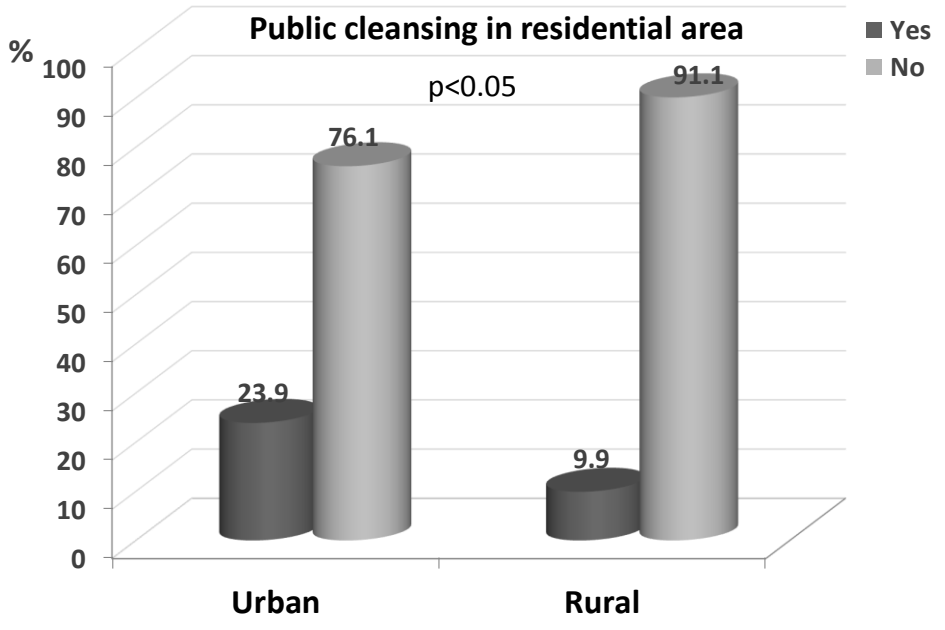


Figure 1a. Periodic public sanitation activity in the residential area.

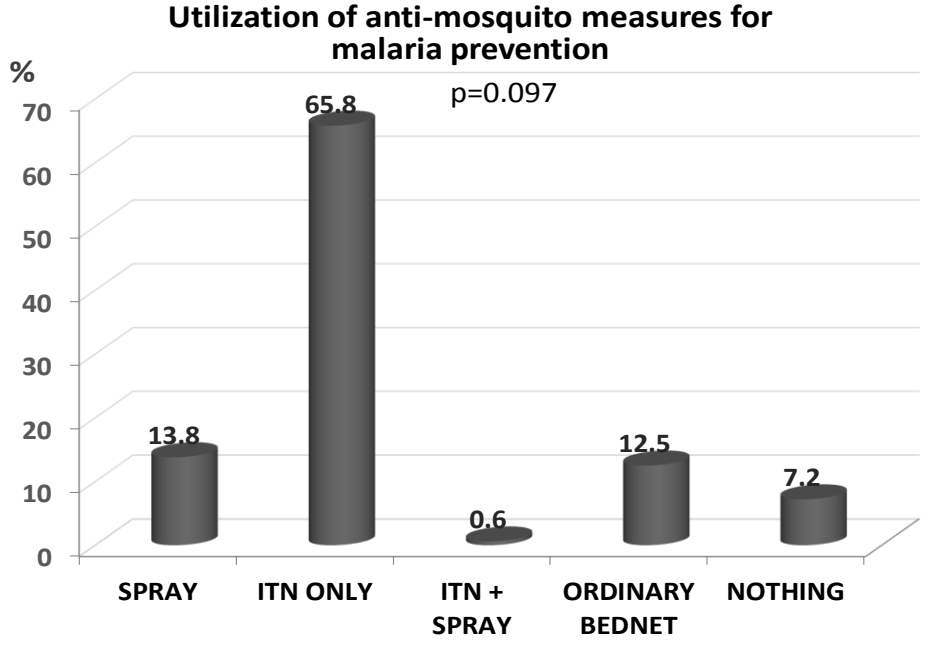


Figure 1b. Anti-mosquito measures used by participants for malaria prevention.

3.3. Malaria Prevalence among Heads of Households According to Socio-Demographic Characteristics and Study Site

Table 3. Malaria prevalence according to study sites and socio- demographics

Sociodemographics	Malaria (1 episode at least) N (%)	P
Gender		
M	68 (89.5)	0.556
F	64 (90.1)	
Age		
20 – 30	27 (93.1)	0.957
> 30	110 (89.4)	
Marital status		
Married	96 (93.2)	0.160
Divorced	3 (75)	
Widowed	6 (75)	
Single with children	13 (85.7)	
Single without child	14 (87.5)	
Occupation		
Unemployed	37 (97.4)	0.332
Student	6 (66.7)	
Civil servant	17 (89.5)	
Teacher	9 (81.8)	
Health care worker	5 (83.3)	
Businessmen	13 (86.7)	
Others	45 (94.3)	
Education		
None – Primary	15 (93.7)	0.549
High school or higher	122 (95.3)	
Family size		
2 – 5	47 (87.0)	0.326
6 - 18	90 (91.8)	
Residential area		
Rural	74 (90.1)	0.548
Urban	63 (88.7)	
All participants	132 (89.8)	-

Overall malaria prevalence-rate (both study sites; at least one episode) was 92.4%, with an average of 2.5 malaria episodes per person in the previous 12 months (range: 1–7 episodes). It was equally high in participants from both rural and urban areas, 90.1% (74/81) and 88.7% (63/71), in participants from household with small and big family size [47 (87%) and 90 (91%)], in males and females [68 (89.5%) and 64 (90.1%)], and in those with low and high education level [15 (93.7) and 122 (95.3)], respectively ($p>0.05$). Similarly, no significant difference was found when comparing groups of participants according to marital status and occupation ($p>0.05$) (Table 3).

3.4. Malaria Prevalence (at Least One Episode) According to Anti-Vector for Malaria Prevention

Figure 2 shows the trend of malaria-rate according to anti-mosquito preventive measures implemented by the study participants. In the group of participants who reported using ITN,

malaria prevalence-rate was 89% (89/100), 100% in those who used ordinary bed-nets, 100% in ITN and spray users, 90.5% in spray users and 100% in those using none of anti-vector measures. No statistically significant difference was found between those subgroups in terms malaria rates ($p>0.05$) (Figure 2). Furthermore, regarding the question on the implementation of public sanitation or environment cleaning in residential area, a relatively high (not significantly) malaria-rate was found in the group of participants who reported the absence of such activities, 91.9% (122/124) [vs. 76.7% (23/30; $p>0.05$) for areas where such program existed] (not shown).

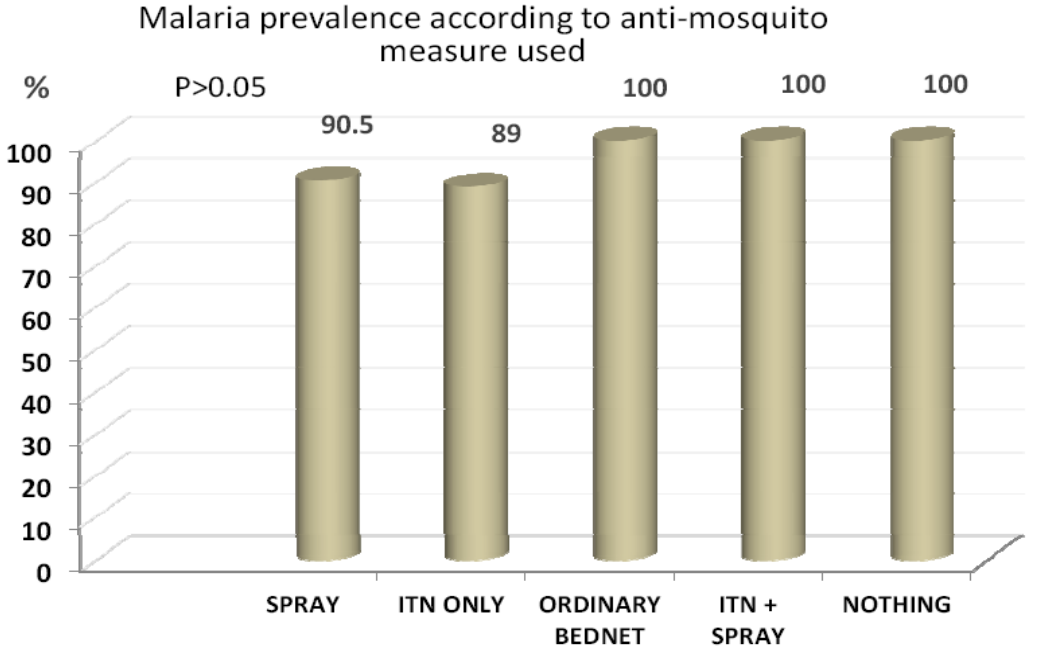


Figure 2. Trend of malaria rate according to anti-mosquito measure.

3.5. Malaria Prevalence According to Household Economic Status and Estimation of Malaria Care Expenditure

Figure 3 shows the trend of malaria-rate according to household monthly income. Relatively high malaria-rate was reported by participants with a monthly household income between 100-150 US$, 97.3%, followed by those with an income between 151-200 US$ (90%), less than 100 US$ and more than 300 US$ (87.5%) and 201-300 US$ (82.4%) ($p>0.05$). Regarding individual malaria care expenditure in the previous 12-month period, the estimated mean cost was 101.56 ± 10.63 $US (range: 0-500$US) per person; it was lower in participants from rural area, 87.75 ± 9.24 $US (range: 10-200 $US) as compared to urban area, 101.58 ± 16.87 $US (range: 25-500 $US; $p<0.05$) (not shown).

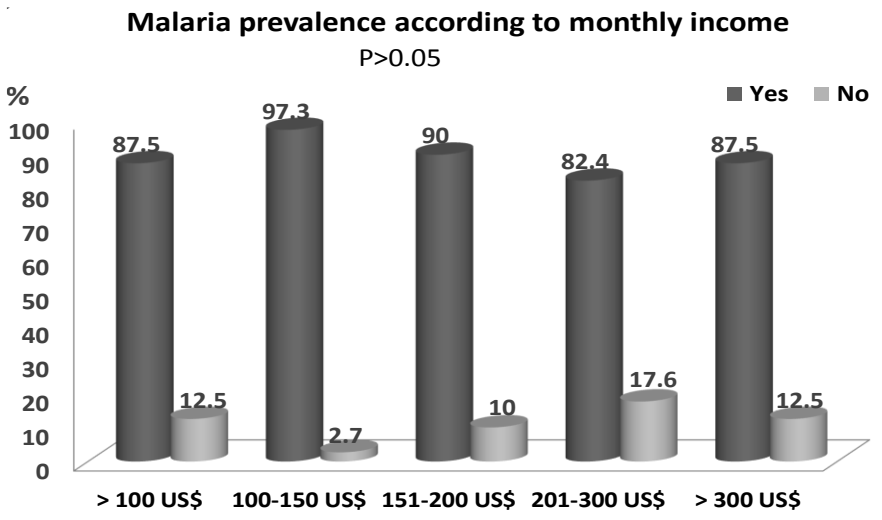


Figure 3. Malaria rate among study participants according to household monthly income.

Table 4. Association between preventive measures, demographics, socioeconomic characteristics and malaria episodes

Variable	OR (SE)	95% CI	P	aOR (SE)	95% CI	P*
Gender (M vs. F)	0.93 (1.32)	0.05-15.21	0.961	1.08 (0.57)	0.06-18.54	0.953
Age (younger vs. older)	1.04 (0.08)	0.89-1.23	0.553	1.05 (0.81)	0.89-1.23	0.552
Marital status (married vs. others)	0.57 (0.25)	0.23 -1.37	0.211	0.59 (0.28)	0.23-1.49	0.267
Occupation	1.08 (0.25)	0.69-1.71	0.711	1.07 (0.24)	0.67-1.68	0.771
Education (Low vs. high)	22.50 (33.17)	1.25-404.81	**0.035**	33.87 (34.42)	2.45-89.49	**0.028**
Household size (< 6 vs. 6-18)	1.71 (0.12)	1.51-1.99	**0.049**	1.58 (1.85)	1.35-1.98	0.052
Residential area (rural vs. urban)	1.81 (1.03)	0.58-5.53	0.305	1.05 (0.14)	0.79-1.39	0.711
Electric power (No vs. yes)	0.48 (0.39)	0.09-2.37	0.373	0.43 (0.37)	0.08-2.33	0.331
Radio/TV (No vs. yes)	0.71 (0.34)	0.27-1.85	0.489	0.72 (0.35)	0.27-1.88	0.500
Telephone (No vs. yes)	0.48 (0.41)	0.25-3.61	0.941	0.96 (0.64)	0.26-3.56	0.960
Anti-vector/environm. (No vs. Yes)	3.98 (1.36)	2.37-2.38	**0.033**	3.01 (2.19)	1.37-24.23	**0.010**
Anti-vector/ household (No vs. Yes)	1.21 (0.22)	0.84-1.75	0.296	1.21 (0.22)	0.83-1.75	0.314
Income (>300$ vs. > 300$)	2.98 (2.08)	1.75-11.72	**0.018**	2.76 (1.87)	1.73-10.41	**0.034**

Notes: p, p-value without adjustment; p*, p-value after adjusting for age and gender; OR, odds ratio; aOR, adjusted odds ratio.

3.6. Association between Malaria, Demographics, Anti-Vector Measures and Socioeconomic Status

Participants who had primary education level or not educated had a 33.87 times risk of developing malaria compared to those with a higher education level (aOR: 33.87+/-34.42; 95% CI: 2.45-89.49; $p<0.05$). Participants living in areas without public sanitation program had a 3.01 times risk of developing malaria than subjects whose households were from areas with such a community health program (aOR: 3.01+/-2.19; 95% CI: 1.37-24.23; $p<0.05$). An association was also found between household monthly income and malaria. Participants who reported earning less than 300 US$ had 2.76 times risk of developing malaria than those from households with a monthly income of 300 US$ or more (OR: 2.76+/-1.87; 95% CI: 1.73-10.41; $p<0.05$). No association was found between malaria and marital status, malaria and occupation, malaria and study site, and between malaria and anti-vector (mosquito) measures used by participants (Table 4).

4. DISCUSSION

4.1. High Malaria Prevalence in Congolese Rural and Urban Households

DRC is known as a malaria hyper endemic country; this infectious disease has a high morbidity and mortality and causes a real socioeconomic burden on Congolese households. In the present study, we searched to determine the prevalence-rate and the socioeconomic impact of malaria on households in two counties located in a rural and urban areas in DRC. Results showed that malaria prevalence-rate was high in both study sites and that effective anti-vector products are not easily affordable for poor households.

This study showed an overall malaria prevalence of 92.4% among heads of household (approximately 90% in those from rural and urban counties); whereas the mean number of malaria episodes per household was 4.35 (3.98 and 4.66 for urban and rural households, respectively) in the previous 12 months, with a minimum of zero and a maximum of 20 episodes (not shown). These household malaria rates are unexpectedly very high.

Of the numerous anti-vector measures aimed at preventing mosquito bites, the majority (65.8%) of heads of households reported using ITN. Similar results have been reported by other authors in the Sub-Saharan Africa. The Ethiopian 'Malaria Indicator Survey 2007' found that 65.6% of ITN coverage; however, ITN utilization was low, varying from 25.3% to 35.9% according to household members' age (Jima et al., 2010). Another household survey conducted in rural Mozambique on long-lasting insecticide treated bed nets showed 62.5% of coverage (Quive et al. 2015). A lower coverage was reported by a Sudanese study, 59.3% (Eyobo et al. 2014). The same study also found that only 2% of households were covered by indoor spraying the previous 12 months; in our study, however, a higher proportion of heads of households (13.8%) used anti-mosquito spray.

Despite the use of the above mentioned preventive measures, malaria rates were high even among ITN and anti-mosquito spray users (89% and 90.5%, respectively), the most commonly used anti-vector measures in the country. Nonetheless, these results are in contrast with findings from studies conducted in DRC's neighbor countries which concluded that ITN

coverage was related to the reduction of malaria rate and associated with malaria risk-protective effect (Alemu et al. 2011; Mulligan et al. 2008; Rulisa et al. 2013). This contrast might suggest the existence of an issue related either to the quality, the efficacy of products used or a negligence in their utilization.

Considering the context of extreme poverty for a large majority of households in DRC, which makes it quite difficult for most households to regularly purchase ITN and/or insecticide, there is a necessity to revisit ITN distribution policy. The fact that some households cannot continuously afford related cost limits the efficiency of such community health interventions. Another obstacle is the huge mosquito population in residential areas. During the post-survey anti-malaria education sessions conducted in both study sites, some of the participants testified about realities they face daily in regard to malaria prevention. For example, some said that "mosquitoes are ubiquitous in their residential area and the mosquitoes can bite outside and inside the houses or apartments prior to going to bed"; thus, without eliminating mosquitoes in the living environment, no sustainable progress can be made.

In our study, we found an inverse association between education and malaria. The group of illiterate and heads of households with primary school level had a 33.8 times risk of malaria than those with higher education. Improving literacy in communities is one of the factors that make health interventions successful. And community and individual knowledge and awareness have an influence on malaria control (Yadav et al. 2014). However, a study conducted in Nigeria showed no association between education and malaria infection in pregnant women (Amogo et al. 2013).

4.2. Environment Cleansing as a Community Health Measure for Malaria Control

A better way to control an endemic or epidemic disease is to fight against its cause and related risk factors or behaviors. Thus, in case of malaria, one of the community health strategies should be targeting mosquitoes, particularly *Anopheles* mosquito, the vector that transmit malaria parasites to humans. And this fight should not only focus on avoiding mosquito bites within the homes or during bedtime, but also reduce mosquito populations in the living environment.

Our study also showed an inverse association between malaria and the implementation of public sanitation or environment cleansing activity in residential areas, with a 3 times high malaria risk for households from area without such activities. Considering the persistent malaria burden in DRC, the Congolese health minister has only recently recommended families and communities to improve sanitation status in their living environment as one of the measures against malaria (Radio Okapi-UN Mission in DRC, 2016).

4.3. Poverty Undermines Malaria Prevention Efforts and Increases Malaria Risk in Congolese Households

Malaria has been reported to be associated with poverty; it affects households through spending on anti-vector products (ITN, mosquito repellent spray and lotion), income losses

by diseased house hold members and malaria treatment cost; thus, poor households are tremendously affected. The disease affects households directly through spending on treatment, income losses by the sick persons and their careers; it imposes significant costs on households and the poor are disproportionately affected (Sonko et al. 2014).

The present study showed an inverse association between malaria and household socioeconomic status. Households with low monthly income (less than 300 USD) had a 2.76 times malaria risk compared to those earning more money. Our findings are in line with some previous studies. For example, a study by Krefis et al. in Ghana and the "Gambia Malaria Indicator Survey (MIS) 2010/11" showed that children form rich households were significantly less likely to have malaria compared to those from poor households. Kazembe and Mathanga also reported an association between high income with reduced malaria risk in households in Malawi (Krefis et al. 2010; Sonko et al. 2014; Kazembe and Mthanda, 2016).

Malaria economic impact on Congolese households is overwhelming. With an average of 4.35 episodes per household and an estimated mean malaria care expenditure of 101.56 ± 10.63 $US per person during the previous 12 months (see results), each household should have spent at least 396 - 488 US$ in malaria care within a year. Given that 90% of households earned less than 300US$ a month (50.6% earned less than 100 US$ per month), these results confirm the fact that malaria imposes a real economic burden to poor families.

4.4. Need of a More Integrated Malaria Prevention Approach in Hyper Endemic Zones

Several countries of the western world (USA, some European nations) and Japan have successfully achieved malaria elimination through implementation of effective anti-malarial interventions adapted to their environment and socioeconomic development. Currently, with the ongoing of outbreak of Zika virus infection in the Americas, huge resources have been mobilized to eliminate its vector (*Aedes* mosquito) in the living environment in the fight against this new epidemic. By the same token, malaria, a disease that threatening millions of lives every year and claiming the lives of hundreds of thousands people annually, should have been considered a global health threat and the fight against this deadly disease must take into account the elimination of its vector in the living environment as one of top priorities.

African countries, with their rich natural resources, have a great economic potential that could help to improve the living conditions of their populations. As a consequence, housing quality and provision of necessary effective anti-malarial preventive tools could be made affordable to most households. On the other hand, with the participation of communities, the elimination of malaria vector in the living environment could be possible by avoiding the presence of mosquito breeding sites in residential areas (stagnant water, used bottles, cans and bins) and a better management of waste water and rain water. These interventions, combined with the improvement of the general sanitation in households' living environment, a good governance that ensures a sound distribution of the country's resources to improve daily living conditions of Congolese people, the promotion of human security through the restoration of peace in the entire DRC territory are likely to reduce disease burden in DRC and improve malaria control in the country.

REFERENCES

Alemu A, Tsegaye W, Golassa L, Abebe G. Urban malaria and associated risk factors in Jimma town, south-west Ethiopia. *Malar J* 2011; 10: 173.

Amogo CO, Oyibo WA. Factors associated with risk of malaria infection among pregnant women in Lagos Nigeria. *Infect Dis Poverty* 2013; 2: 19.

Bhatt S, Weiss DJ, Cameron E, Bisanzio D, Mappin B, Dalrymple U et al. The effect of malaria control on *Plasmodium falciparum* in Africa between 2000 and 2015. *Nature* 2015, 526: 207-211.

Cai H, Gu J, Wang Y. Core genome components and lineage specific expansions in malaria parasites *Plasmodium*. *BMC Genomics* 2010; 11(3): S13.

Eyobo MB, Awur AC, Wani G, Julla AI, Remijo CD, Sebit B, Azairwe R, Thabo O, Bepo E, Lako RL, Riek L, Chanda E. Malaria indicator survey 2009, South Sudan: baseline results at household level. *Malaria Journal* 2014; 13:45.

Global Fund and National Malaria Program (Madagascar). Enquete sur les indicateurs du paludisme (French article). Accessible from: https://dhs program.com/pubs/pdf/MIS17/ MIS17.pdf.

Haas LF. Charles Louis Alphonse Laveran (1845-1922*). J Neurol Neurosurg Psychiatry* 1999; 67: 520.

Jima D, Getachew A, Bilak H, Steketee RW, Emerson PM, Graves PM, gebre T, Reithinger R, Hwang J. Malaria indicator survey 2007, Ethiopia: coverage and use of major malaria prevention and control intervention. *Malaria Journal* 2010; 9: 58.

Kazembe LN, Mathanga DP. Estimating risk factors of urban malaria in Blantyre, Malawi: A spatial regression analysis. *Asian Pacific Journal of Biomedicine* 2016; 6 (5): 376-381.

Krefis AC, Schwarz NG, Nkrumah B, Acquah S, Loag W, Sarpong N, Adu-Sarodie Y, Ranft U, May J. Principal component analysis of socioeconomic factors and their association with malaria in children from the Ashanti Region, *Ghana. Malaria Journal* 2010; 9: 201.

Liu W, Li Y, Learn GH, Rudicell RS, Robertson JD, Keele BF et al. *Nature* 2010; 467: 420-425.

Mulligan JA, Yukich J, Hanson K. Costs and effects of the Tanzanian national voucher scheme for insecticide-treated nets. *Malar J* 2008; 7: 32.

Nayyar GML, Breman JG, Newton PN, Herrington J. poor-quality antimalarial drugs in southeast Asia and sub-Saharan Africa. *Lancet Infectious Diseases* 2012; 12: 488-496.

Quive IM, Candrinho B, Geelhoed D. Household survey of availability of long-lasting insecticide-treated nets and its determinants in rural Mozambique. Malaria Journal 2015; 14: 304.

Radio Okapi-UN Mission in DRC. Bukavu: Kabange calling populations to improve hygiene and sanitation to prevent malaria (French article). Acces- sed 15 May 2016. http://www.radiookapi.net/2016/04/25/ actualite/sante/ bukavu-kabange-numbi-appelle-la-population-la-proprete-pour-combattre-le.

Rulisa S, Kateera F, Bizimana JP, Agaba S, Dukuzumuremyi J, Baas L, Harelimana JD, Mens PF, Boer KR, Vries PJ. Malaria prevalence, spatial clustering and risk factors in a low endemic area of Eastern Rwanda: A cross-sectional study. *PLoS One* 2013; 8 (7): e69443.

Sonko ST, Jaiteh M, Jafali J, Jarju LBS, D'Alessandro U, Camara A, Komma-Bah M, Saho A. Does socio-economic status explain the differentials in malaria parasite prevalence? Evidence from The Gambia. *Malaria Journal* 2014; 13: 449.

The Abuja Declaration and the Plan of Action. Available from: www.rbm. who.int/docs/abuja_declaration_final.htm.

Tusting LS, Arinaitwe E, Staedke SG, Kamya MR, Bottomley C et al. Measuring socioeconomic inequalities in relation to malaria risk: a comparison of metrics in rural Uganda. *AM J Trop Med Hyg* 2016; 94(3): 650-658.

World Health Organization (WHO). Factsheet on the world malaria report 2013. Available from: http://www.who.int/malaria/media/world_malaria_ report_2013/en/.

World Health Organization (WHO). Malaria and HIV interactions and their implications for public health policy. Available from: http://www.who.int/hiv/pub/prev_care/ malariahiv.pdf.2011.

Wumba RD, Zanga J, Aloni MN, Mbanzulu K, Kahindo A, Mandina MN et al. Interactions between malaria and HIV infections in pregnant women: a first report of the magnitude, clinical and laboratory features, and predictive factors in Kinshasa, the Democratic republic of Congo. *Malaria Journal* 2015, 14: 82. DOI 10.1186/s12936-015-0598-2.

In: Handbook on Africa
Editor: Whitney Sherman
ISBN: 978-1-53610-063-1

Chapter 11

SOLID WASTE MANAGEMENT AND ENVIRONMENTAL JUSTICE IN KINSHASA, THE DEMOCRATIC REPUBLIC OF CONGO

Nzalalemba Serge Kubanza[1,*] and Danny Simatele[2,†]
[1]School of Geography, Archaeology and Environmental Studies, Department of Geography and Environmental Studies,
University of the Witwatersrand, Johannesburg, South Africa
[2]School of Geography, Archaeology and Environmental Studies, Department of Geography and Environmental Studies;
Wits Siyakhana Initiative for Ecological health and Food Security
University of the Witwatersrand, Johannesburg, South Africa

ABSTRACT

The argument that "one in every two urban resident is poor" in cities of the developing world can be articulated in the discussions of social and environmental inequalities occurring in the management of solid waste, particularly in sub-Saharan African countries. This paper discusses environmental justice in the context of solid waste management (SWM) in Kinshasa, the capital of the Democratic Republic of Congo. It is argued that the urban poor in most parts of Kinshasa face serious consequences of poor solid waste management and bear a huge proportion of the environmental burden. It is further argued in the paper that the plight of the poor people in Kinshasa has been worsened by the accelerated rate of urbanisation which has occurred in the presence of bad urban governance, increased civil conflict and weak institutional framework. A combination of these challenges have resulted in increased injustices in the management of solid waste with poor suburbs poor being exposed to

* Serge Kubanza is a PhD student in the School of Geography, Archaeology and Environmental Studies at the University of the Witwatersrand, South Africa. Nzalalemba.Kubanza@students.wits.ac.za. sergekubanza1 @yahoo.fr.
† Danny Simatele is a Senior Lecturer in the School of Geography, Archaeology and Environmental Studies at the University of the Witwatersrand. He is also a senior researcher and academic coordinator for the Wits Siyakhana Initiative for Ecological health and Food Security. Danny.Simatele@wits.ac.za.

living conditions that are inhumane and demeaning. Using secondary data and other archival records, this chapter argues that solid waste in Kinshasa is not only a health risk, but it also presents issues of environmental injustice. These issues have been analysed within the context of evolving arguments that focus on the need to develop pro-poor approaches in the management of urban solid waste in order to promote urban sustainability.

Keywords: social justice, environmental justice, solid waste management, Democratic Republic of Congo

1. INTRODUCTION

The argument that "one out of every two urban residents is poor" in cities of the developing world can be articulated in the discussions of social and environmental inequalities occurring in the management of solid waste, particularly in the cities of the sub-Saharan African countries. The environmental inequalities discussions in the context of solid waste management (SWM) initially started in the late 1970s in the United States of America (USA), where the unequal distribution of SWM services and other environmental burdens was highly uneven and driven on racial lines (Pollock and Vittes, 1996, Massey 2004). Most studies of environmental inequality focused on issues of the management of toxic waste, solid waste and pollution in the developed world where civil rights movement, inevitably confronted environmental laws and institutions (Myers 2008, Taylor 2002). Thus, discussions and debates around environmental inequality grew out of the realisation and anger that poor communities, particularly those without overt and covert powers were either purposely or implicitly subjected to routine poisoning in the face of inadequate institutional capabilities to effectively manage solid waste which had been generated through various anthropogenic activities (Byrne et al. 2002, Agyeman et al. 2003). It is within this context that ideas, meanings, aspirations and boundaries of the EJ movement were constructed as a way of finding avenues through which individuals and groups of individuals or communities responsible for generating solid waste, regardless of racial, social or economic orientation, could be held accountable for their actions (Walker 2009).

Dominelli (2013) is of the view that over the past decades, the environmental justice paradigm has shifted the locus of the arguments to include the current unsustainable models of development, the unequal power dynamics within and across communities and national states, as well as the unequal distribution of resources, which are central to the current global socio-economic systems of neo-liberalism (see Dominelli 2013). These attributes combine to exacerbate structural inequalities and marginalities that affect most of the poor people and low-income households thereby, reducing their capacity to mitigate and deter any risk arising from internal or external stressors. Thus, as a way to capture the new locus of debates within the environmental justice discourse, kindred labels of "environmental racism" and "environmental discrimination" have become increasingly popular and are used to reflect the highly socio-economic status and power-based systems manifested in contemporary urban governance and the provision of socio-economic facilities (Godsil 1991, Cole 1992, Gelobter 1992, Lavelle and Coyle 1992, Capek 1993).

Although environmental justice as a discourse is rooted in the USA, the use of the term "environmental justice" has now extended far beyond its original context. Environmental justice discussions have, for example, been taken up to illustrate the lack of or uneven distribution and access as well as use of natural resources of poor households in rural areas of India, Latin America, and to some extent in sub-Saharan Africa (Meyers 2008). Bane´gas et al. (2012) and Binns et al. (2012), for example, observes that under colonial rule, thousands of black Africans were forcibly removed from their ancestral lands to make way for game parks, and a lot of money was spent on preserving wildlife and protecting wild flowers, while native people lived without adequate food, shelter, and clean water. Furthermore, Cheru (2002) argues that while external actors have contributed enormously to the resource marginalisation of the African people, through governance deficits, African governments themselves bear a significant portion of the blame for successfully suppressing the avenues of democratic expression, participation and self-governance of their citizens.

From an urban area perspective, particularly with reference to healthy living conditions, environmental injustice seem to be more exacerbated in urban contexts of the developing world where the majority of the urban dwellers have taken up residence in unplanned settlements with little or no access to basic socio-economic services such as adequate housing, clean water and sanitation facilities (Abuzeid 2009, Binns et al. 2012, Hove et al. 2013). With an inadequate urban infrastructure that was inherited and retained at independence, and which has remained unmodified to suit the new political, economic and social realities in many of these countries, the poor, powerless and voiceless continue to be subjected and to live in deplorable environments and conditions where socio-economic facilities and services such as solid waste management are virtually non-existent (see Myers 2005, Couth and Trois 2012). The poor continue to be denied through inadequate urban and planning policies, appropriate and healthy living environments in which they can articulate redefine themselves and realise their potential and contribute significantly to both urban economic growth and development. The urban development and planning policy, particularly in sub-Saharan African cities, hardly raises and addresses questions of urban environmental justice (see Meyers 2008, Patel 2009, Otang-Ababio et al. 2013).

This situation is rather strange considering the starkly and intertwined social and environmental injustices evident in many sub-Saharan African cities. In the quest to address these challenges, sustainable urban development, focusing on meeting the needs of the poor and ensuring ecological health, has been argued and presented as environmental lens through which to promote environmental justice and address some of the issues that have permeated urban environments, through neo-liberal ecological modernisation, wherein marketisation and technological innovations and developments, are sometimes falsely advanced as the panacea that will rescue African cities from environmental calamity, and magically reduce poverty and institute democracy (Myers 2008, Couth and Trois 2012).

Despite the emphasis on economic and social reforms, with marketisation playing a pivotal role in societal and economic stabilisation, most cities that have implemented sustainable urban development programmes in sub-Saharan Africa seem to do little or nothing to address the ever-increasing inequalities in spatial distributions of negative social and environmental costs (Myers 2008, Din and Cohen 2013). Discourses on urban environmental justice are comparatively rare in African cities, with notable exceptions of South Africa (Myers 2008, Binns et al. 2012). Existing studies on solid waste managements, for example, have used political ecology, sustainable waste management and good governance as

theoretical frameworks to understand urban processes, but environmental justice has received no attention in these approaches (see Schubeller et al. 1996, Binns et al. 2012). In light of these observations, this paper discusses social and environmental injustice in solid waste management in Kinshasa, the Democratic Republic of Congo (DRC). It explores the extent to which environmental injustice manifests itself and the factors accounting for this state of affairs. This paper traces the development of the social justice and environmental justice discourses and how the two aspects manifest themselves at a range of scales in Kinshasa. The discussion ends with a synthetises and critical engagement with issues of social and environmental injustices in solid waste management in Kinshasa before drawing out policy recommendations.

2. APPROACH OF THE PAPER

This paper is based on a study desk study conducted between April 2014 and February 2015 and involved a review of different pieces of the literature obtained from various sources. Data collection was carried out through a rapid evaluation and appraisal of various survey reports on global, regional and national levels. The first stage in the search of the literature involved an internet search using various search engines such as Google. Keywords such as EJ and solid waste management were entered in the search engine and several pieces of the literature on the topics were realised. These were rapidly scanned and only those articles that focused on EJ and solid waste management in a developing context were reviewed.

The second phase involved entering the same keywords in the search engines, but limiting the search to articles on solid waste and EJ in sub-Saharan Africa. This action resulted in 68 different articles and reports and these were rapidly appraised and evaluated. A third phase involved checking for additional and relevant articles to the topic under discussion and this was carried out through reviewing the bibliographies of each article. Once the relevant and appropriate references were identified, a library search was embarked on and this was executed through visiting different libraries at the University of the Witwatersrand, the University of Johannesburg and the University of Pretoria. Other sources of information included libraries at the universities of Sussex, St. Andrews and Manchester.

In total, 26 peer-reviewed articles focusing on environmental issues and waste management in the global North were selected, reviewed and included as the basis for discussion. An additional 18 journal articles focusing on the global south, particularly in the context of sub-Saharan Africa were selected, reviewed and included as the locus of discussion for this paper. Finally, 12 articles focusing on the national level (DRC) were identified, selected and included in the literature review. This brought a total number of 56 articles and reports that were selected, reviewed and informed the discussion and analysis contained in this paper.

As part of the data collection process, these sources were critically examined for information relating to social and environmental injustices. A number of studies were also available that had investigated aspects of the urban environment including sanitation, water and waste disposal. These were reviewed to draw relevant data for this paper. The print media also provided a rich source of information about the state of solid waste management in the

city of Kinshasa. These included reports of workshops and press conferences on issues around the urban environment including sanitation, water pollution and waste disposal.

3. Social and Environmental Inequalities the Management of Solid Waste in an Urban Context of the Developing World

Recent years have seen a re-emergence of interest relating to issues surrounding social justice and environmental justice, with the two increasingly becoming considered closely inter-linked (Coughlin 1996, Kindornay and Ron 2012, Ako et al. 2013). A community that is subjected to different levels of social marginalities is most likely going to experience different levels of environmental injustices, and this situation owes much to the power structures and relationships that exist within a community (Chambers 2003). Couth and Trois (2012), for example, observe that decisions regarding solid waste management in most developing countries are usually driven by a top-down governance system which usually is disguised in the form of promoting community participation. However, in principle and practice, the participation of local people in managing issues that impacts their lives often simply lends credibility to decisions that have already been made by the powerful members of the community and local government officials, who in most cases are out of touch with contemporary challenges faced by the poor people. Thus, the strong embrace of participation as a supposed avenue for community empowerment only tends to serve the interest of the rich and most powerful members of the community (see Taylor 2000, Hove et al. 2013).

It must be noted; however, that social justice as a discourse is a well-developed and long-debated body of knowledge that addresses issues around relative deprivation and fairness (Scott and Oelofse 2005). It addresses issues of inequity through social redistribution of the benefits of society (Dominelli 2013). It challenges the status quo by proposing changes in economic and social relations that may help prevent continued environmental deterioration and social crisis (Scott and Oelofse 2005). This discourse is proposed as an appropriate normative framework for measuring the advance of democratisation. Some theorists and philosophers, such as Coninck et al. 2013, argue that as a concept, social justice can be abstractionist in that it focuses attention on an idealised state of what a society should be. Yet another strand of thought argues that discourses on social justice cannot be delinked from the contextual realities in which people live (Nussbaum and Sen 1993, Mabbett 2005).

Despite the above observations, some principles are common across most discourses on the various conceptions of social or environmental justice. These include principles of equality, distribution and redistribution, solidarity, subsidiarity, inclusion, fairness, equity, equality and nation building (Coninck et al. 2013). However, these principles are rather complex to attain using the current model of urban governance which has developed as a system of management using the top-down approach as noted above. In essence the top-down solid waste management approach adopted by many local authorities in developing countries considers the poor urban residents as having no role to play in the management and development of city processes (see Cheru 2002, Christens and Speer 2006). It is intrinsically assumed that urban residents, particularly the poor, have no knowledge and capacity to identify, define and design systems and processes which can be used to address urban

problems and challenges as well as contribute to the sustainable development and management of urban spaces and processes (Binns et al. 2012, Otang-Ababio et al. 2013). The urban poor who in most cases live in poor environments are often and frequently excluded from actively engaging and participating in urban processes that have a direct influence on their lives (see Hove et al. 2013). Lack of political and economic power, as observed by Simatele et al. (2012a), plays a key role in subjecting the poor to situations where powerful members of society either implicitly or explicitly deny the poor people an appropriate podium with which they can genuinely express their frustrations and aspirations.

In view of the above sentiments, it would not be an exaggeration to argue that both social justice and environmental justice discourses provide useful and valuable analytical and operational frameworks, within which to discuss solid waste management in urban areas of the developing world, particularly in sub-Saharan Africa. This is because a key tenet in both social justice and environmental justice is the need for equality in the distribution of a society's resources or challenges (see Taylor 2000, Dominelli, 2013). Thus, to obtain a fair distribution of resources within a community as observed by Otang-Ababio et al. (2013), there is a need to promote a strong and genuine grassroots grown community participation in solid waste management decision making. They argue that public participation is at the heart of democracy because it facilitates and promotes a sense of ownership in any decision-making and social development issues of a society (Otang-Ababio et al. 2013).

Participation is at the core of promoting a sense of belonging and ownership of any development process and is cardinal to ensuring that issues relating to social and environmental marginalisation are addressed in a more equitable manner. Christen and Speer (2006), for example, observe that public participation in the identification of priorities and in the formulation of policies and programmes is critical to the development of sustainable human settlement. This position is supported by Lowry (2013), who is of the view that public participation and the empowerment of the most vulnerable groups of people in society have been touted as key to redressing social justice and environmental justice issues and can contribute to sustainable development. This perspective is based on the idea that revolves around the notion that considers social justice and environmental justice issues to be highly technical problems that affect traditionally disempowered communities and in which citizens may have different goals and aspirations.

In order to address social justice and environmental justice issues, particularly in sub-Saharan Africa, there is an urgent need for government authorities and other collaborating partners to adopt a rights-based approach to development. A rights-based approach to environmental is based on the belief that individuals and groups are a means to an end, and should be given a certain degree of dignity. They should have, according to Onstad (1997, p. 7), "basic rights to a decent living environment and must be in a position to claim justice when these rights are abused or left unfulfilled". A rights-based approach has advantages of providing a means of mobilisation of the poor and their supporters by offering a podium for lobbying and for insisting that groups, states and companies behave in a certain way (Kindornay and Ron 2012). It also has the advantage of bringing in an unpredictable group of actors into the development equation and it is this transdisciplinary approach that will foster the development of sustainable urban communities (Mabbett 2005).

4. Social and Environmental Inequalities in Solid Waste Management in the Context of the Sub-Saharan Africa

The sub-Saharan African countries face an increase in the demand for urban services due to augmented rates of urbanisation driven largely by rural-urban migration. In most suburbs of African cities, the supply of basic services such as social economic, waste removal and clean piped water supply has largely not kept pace with the increasing demand for urban services (Cheru 2002, Okot-Okumu and Nyenje 2011). This situation has been a result of a number of factors among which include weak institutional frameworks, lack of skilled labour which has impacted on urban governance, and economic deteriorations. The combination of these factors, as argued by Abuzeid (2009), has resulted in municipal solid waste management, constituting one of the most crucial management challenge and environmental problem facing many governments of African cities. Although many of these cities are using between 20% and 50% of their budget on solid waste management, only an estimated 20–40% of the waste is collected (see Binns et al. 2012, Otang- Ababio et al. 2013). The uncollected and usually illegally dumped solid waste is now increasingly becoming a disaster for human health and environmental degradation, especially in poor and marginalised areas of these cities (Okot-Okumu and Nyenje 2011).

Solid waste collection and management in many sub-Saharan African cities is a duty entrusted to public-funded municipal authorities and should, therefore, be extended to all areas of the city (Schubeller et al. 1996). However, this facility in many African cities tends to be restricted to wealthy and rich neighbourhoods where groups of individuals with control of either state or national and economic power reside. Poor and deprived neighbourhoods, which normally house the majority of the urban poor in these cities, usually tend to receive no or little services, and the little is normally provided on a very erratic basis (Simatele et al. 2012b). In order to promote social justice and environmental justice in the context of sustainable solid waste management, it becomes important to ensure that urban services for waste removal are fairly and equitably provided for all residents in a city, irrespective of such variables as socio-economic class, ethnicity or culture (Schubeller et al. 1996, Kindornay and Ron 2012, Ako et al. 2013).

It must also be argued that equality in the distribution of the solid waste burden in African cities requires that urban managers in these cities ensure fairness in the provision of solid waste collection and disposal services. It is only through the use of a rights-based approach that incorporates the voices of the poor people in the development of solid waste management strategies that social justice, in its different facets would be pursued and guaranteed. In other words, municipal authorities responsible for the organisation of solid waste disposal have a social duty to ensure that all residents of a city receive impartial and adequate services for solid waste removal and disposal in order to protect them from the nuisances associated with solid waste.

On the contrary, environmental justice is about the fair treatment and meaningful involvement of all people regardless of race, colour, national origin, or income status in the development, implementation, and enforcement of environmental laws, regulations and policies. It is about social transformation directed towards ensuring that environmental resources contribute in a meaningful way to meeting the basic human needs and enhancing the quality of mankind. Taylor (2000), for example, observes that environmental justice (in

the context of sub-Saharan African solid waste management) can only be achieved when everyone enjoys the same degree of protection from environmental and solid waste-related health hazards, and equal access to the decision-making process to have a healthy environment in which to live, learn and work (see also Patel 2009).

Exposure to solid waste-related disasters remain a major source of health risk throughout the world, though risks are generally higher in developing countries, particularly in sub-Saharan Africa where high levels of poverty, low or lack of investment in modern technology and weak environmental legislation combine to cause high levels of environmental degradation (Potter et al. 2008). Although several African countries, as argued by Patel (2009), have made some significant progress in formulating environmental legislation, the lack of legislative implementation and community participation has impeded the pursuance of an environmentally just sub-Saharan Africa (see also Venot and Floriane 2013). The top-down system in urban governance that is employed by many city authorities in African cities continues to ignore the needs of the poor people and to erode their confidence in urban managers (Binns et al. 2012). It is the lack of community participation in urban processes that continue to subject the poor people in African cities, living in conditions that are not conducive for human habitation, as well as for the none development of an effective environmental management framework, within which environmental justice issues could be pursued.

Existing literature on environmental management and sustainability, for example, suggests that there is no integrated approach to urban environmental management in many African countries (Kotze´ 2007, Faure and Du Plessis 2011, Kihangi 2012). In the absence of an integrated approach to urban environmental management, one would therefore argue that many urban dwellers in African cities are still subjected to high levels of environmental injustices (Mzidzornu 2004, Leonard 2013). In order to address this issue, there is an urgent need to implement a process of enacting the environmental legislation, particularly in relation to solid waste management. This should take the form of consultative engagement and enlisting the participation of communities, NGOs, associations of solid waste pickers, local authorities and the private sector. Once legislation is enacted, local authorities in collaboration with its agencies should have the institutional capacity and budget to enforce the law.

Table 1. Countries in which the term ‘environmental justice’ has been incorporated in planning policies: 1990 – 2012

Region	Countries
Africa	Nigeria, Ghana, South Africa, Tanzania, Cameroon, Zambia, Angola, Mozambique, Uganda
Asia	Taiwan, Israel, India, Singapore, Philippines
Australasia	Australia, New Zealand
Europe	United Kingdom, Germany, Sweden, France, Spain, Belarus, Bulgaria, Hungary, Macedonia, Romania, Slovakia, Czech Republic, Latvia, Ireland; Finland, Holland, Norway, Scotland
North America	United States, Canada
South and Central America	Brazil, Peru, Nicaragua, Ecuador, Columbia, Mexico.

Source: Binns et al. (2012), Walker, 2009; Fan 2006; Hillman, 2006; Pearce et al., 2006; Chaix et al., 2006.

Table 1 shows countries that have adopted and used the term, "EJ" in their policies on a global level. It is suggested in the table that only 9 out of 53 African countries are cognisant of the importance of incorporating environmental justice in their development and planning policies. We can also speculate from the information in Table 1 that the discourse on urban environmental justice is comparatively rare in African cities and is thus, not a priority policy. This situation may be a result of the fact that urban authorities in many sub-Saharan African cities are concerned with more urgent issues such as addressing poverty and are therefore unable to provide adequate waste disposal and other environmental services within their jurisdictions.

Studies by a number of scholars suggest that municipal authorities in African countries tend to concentrate their waste collection efforts in wealthy areas, while the poorer areas receive little or no service even though waste collection operations are usually funded by public resources (Schubeller et al. 1996, Cheru 2002, Lohse 2003, Binns et al. 2012). Okot-Okumu and Nyenje (2011) as well as Bullard (2005) are of the view that waste disposal facilities in sub-Saharan Africa are usually poorly maintained, and are frequently located in the neighbourhoods of the poor and other vulnerable members of society. In practice, this state of affairs implies a situation where the more powerful members of society shift the environmental burden to the poor people. This status quo illustrates the vulnerability of the urban poor in Africa who are increasingly becoming subjected to different vulnerability markers among which social and environmental injustices are cardinal. Until the poor people in sub-Saharan Africa become involved in decision-making on issues that affect their lives, social and environmental injustices will remain part of the urban landscape among the poor in African cities.

5. Social and Environmental Inequalities in Solid Waste Management in the Context of the Democratic Republic of Congo

Despite the civil war that has ravaged the country and many lives in the DRC, there has been a concerted effort by government to include environmental issues and natural resource management in development and planning policies. However, Kihangi (2012) is of the view that environmental provisions within the national development policies and constitution have been incorporated with different motivations and largely revolve around benefiting selected powerful political and economic actors. As a result, a fundamental concern, with regard to environmental management in Kinshasa and DRC as a whole, revolves around the complexity of the implementation and enforcement of environmental legislation, which if appropriately implemented can contribute to unpacking the balance of all interested parties and contribute to promoting an urban environment in which all the needs of all urban residents including the poor are met (Kihangi 2012).

During colonial rule, the management of the environment and natural resources was one of the issues that Belgium had to contend with in the DRC (Kihangi 2012). The Belgian colonial government was interested in the protection of the environment for exploitative reasons, and not out of any great concern for the welfare of the Congolese people, who were treated as subjects without rights (Mzidzornu 2004). For this reason and among others, the

care of the environment was managed through various treaties and royal decrees (Kihangi 2012). The effect of this system of management left significant scars in the sense that the colonial government failed to facilitate a situation where the local people were able to meet their livelihood needs from using and accessing natural resources and environmental services (Dougall and McGahey 2003). Thus, social and environmental injustices in terms of local people's access to environmental resources have a long history in the Congo and have therefore become a common concern, particularly with questions of resource access and distribution as well as power relations in decision-making processes.

The lack of community participation in decision-making and development processes in the DRC has contributed significantly to civic disorder and conflict in the country. The brutal exploitation of the country's resources at the expense of the poor people and staring in the colonial period (since King Leopold II rule) and filtering through the post-independent period have fuelled such violent and devastating conflicts (Pole Institute and International Alert 2014). The Pole Institute and International Alert (2014), for example, are of the view that if a greater proportion of the benefit from the exploitation of the DRC's resources is retained within the country, and there is more equitable distribution of this benefit to communities, there would be significant progress made towards achieving peace and sustainable development of the country.

However, the absence of working institutions and frameworks through which effective and equitable distributions of the country's wealth and resources could be harnessed, has in a large share resulted in discontentment by the general populace. This has in turn given rise to public discussions in the form of "parlement de´bout" (i.e., standing up parliaments on streets) and such gatherings have often generated social tensions and fuelled continued civil unrest in the country (Bane´gas et al. 2012). It is important to note that "parlement de´bout" discussions play a key role in transmitting information and rallying up new partisan paradigms through which the new recruits assert themselves as citizens and claim certain entitlements and rights. Failure to obtain some of these entitlements has often resulted into violent episodes and this is true for the case of resource management in the DRC (Bane´gas et al. 2012).

Thus, the context of resource use and management in the DRC has been a source of conflict and has attracted considerable attention in political debates. Depending on the respective theoretical premises, some scholars have argued that scarcity of renewable natural resources inevitably leads to violence not only in the DRC, but also in other countries of the global south. The abundance of natural resources, for example, in the context of a country with absent sound and effective legislative and governing structures, often tend to create enormous challenges in the distributions of a country's wealth and this often generates injustices at different scales (Krummenacher 2008). This is more so in economies with centralised systems of governance, the case of the DRC (Cheru 2002, Binns et al. 2012, Simatele and Simatele 2014).

The alternative to centralising the state, as was the case in the Mobutu regime, is to move the power of control and to endow local populations with greater decision-making power. Such an approach would remove the burden of resource management to local communities which in the context of the DRC as a whole, exhibit and expend tremendous energy and vitality in changing the course of their future. Shifting the control of resource management to local people and communities would ensure that where national governments and local municipal authorities have failed to articulate new visions or provide necessary services,

citizens' group can organise and reorganise themselves to meet their solid waste management, shelter needs, mobilise funds to build roads and clinics, etc. (Simatele and Simatele 2014). Simatele and Simatele (2015) further observe that a major feature of a centralised state such as the DRC is the preoccupation with bureaucracy and planning systems which tend to emphasise the concentration of governance structures rather than adopting institutions and planning policies that emphasise grassroots empowerment of the people. This situation has often meant that powerful individuals and elite groups of people have taken control of political and economic power and this has encouraged a top down approach to the management of public affairs such as solid waste, even when decentralised structures were created and established. Administrative structures in Kinshasa lack adequate resources and discretionary authority and this state of affairs has hampered the efficient deliverance and provision of socio-economic services in the city. As the city has remained the principal industry for patronage, it has become burdened as more and more resources have been required to maintain city processes. And in the face of political instability, weak institutional frameworks and economic deterioration, solid waste collection and management has become one of the greatest challenges facing local government authorities in Kinshasa (Din and Cohen 2013).

The increasing amount of uncollected solid waste threatens the survival of urban residents, especially the poor, who in most cases are resident in locations that do not or receive little support from government. They are thus, vulnerable to communicable diseases and this situation undermines any of their efforts to contribute to the sustainable development of the metropolitan centres in the Congo (Medina 1997, Rapten 1998, Din and Cohen 2013). The generally poor waste situations in Kinshasa and the perpetuation of social and environmental injustices against the poor remain a critical challenge in a country that has never known peace since its political independence from Belgium in 1960. Social and environmental injustices are increasingly deviating the country's aspiration to achieve the Millennium Development Goals, Agenda 21 and other moves to address the Brown Agenda problems in order to improve the living condition of the poor (Din and Cohen 2013). The city of Kinshasa is grappling with mounting solid waste and associated environmental problems with socio-spatial inequalities in the distribution of the waste with the poor bearing the largest burden (Schubeller et al. 1996, Din and Cohen 2013). This situation has further subjected in the urban poor in Kinshasa to living in locations that are more closely to potential pollution sources, thereby exposing them to different health risks.

In additional to biological and plastic waste, a particular feature of the solid waste challenge in Kinshasa is imported second hand goods: old computers and other technological associated materials from the developed north, and which normally end up being dumped within city spaces, if not used or sold (Lateef et al. 2010). If not collected and managed properly, these materials not only become a health hazard, but end up blocking most of the anaerobic canals and waterways leading to recurrent flood episodes. According to Din and Cohen (2013) and supported by Lateef et al. (2010), Kinshasa's city is increasingly becoming a city that is overcrowded with solid waste and this situation poses a number of risks among which include fire and health hazards, especially for children playing on or near to waste dumps (see Hardoy et al. 1992). Thus, children from poor households in Kinshasa are considered as the most at risk to waste that has not been disposed off in a safe and scientific manner. Other high-risk groups include waste workers, and workers in facilities producing toxic and infectious material, population living close to a waste dump and those, whose water

supply has become contaminated either due to waste dumping or leakage from landfill sites. Uncollected solid waste also increases risk of injury, and infection particularly for poor households who often times burn their waste as a common practice of waste disposal. This is because these households have the least adequate garbage collection services (Hardoy et al. 1992, Nsokimieno 2010).

It is important to note that the solid waste problem in Kinshasa has been made worse by the increase in the urban population. The population has increased from 400,000 in the 1990s to more than 6 million people in 2008 and it is now estimated to have reached 10 million in 2010 (Nsokimieno 2010). The urban growth does not correspond to the provision of socio-economic facilities in the city. The growth in population is rapidly pushing the city's growth in the form of outward expansion but resulting in large-scale uncontrolled urban sprawl and affecting land use changes. Nsokimieno (2010), for example, contends that Kinshasa lost progressively its ecological heritage and identity due to enormous environmental problems and its weak and none existent solid waste management and disposal mechanism and strategy. A coherent broad-based approach to solid waste management does not exist because of insufficient funds and poor management. In the face of these challenges, the municipal government in Kinshasa cannot begin to meet the demands of waste evacuation and sanitation.

Although poor urban communities might understand the need for elementary hygiene, they lack the means to procure basic services either on their own or from failing national or municipal services (Dougall and McGahey 2003). On the contrary, wealthy residential areas are often given preferential treatment over the poor in the delivery of solid waste disposal service. This situation is however, unfair and unjust, and a breach of social justice. The supply of refuse bags and waste bins in poorer neighbourhoods is usually erratic, as the residents of these locations usually have no voice to challenge city managers (Samson 2008). The refuse rounds, although planned for collection, are usually based on a system of loading from the service point directly to the refuse collection vehicle. The worker allocation varies from area to area but in poor neighbourhoods, it is generally between 6 and 8 workers per refuse round, with 2 people loading the vehicle and 4 people bringing the bins or bags to the side of the road for collection. This system in many cases increases spillage of refuse in the loading process, thus adding to the cost of street-cleaning (Samson 2008). In most cases, the service to the informal settlements has usually been rendered on an emergency basis. A 5.5 m3 bulk-refuse container is allocated to every 200 households or shacks. In theory, this system has not worked effectively in these locations as shack dwellers usually tend to deposit their refuse outside the refuse containers and the refuse that ends up in the containers is often set on fire thereby, triggering other health and safety hazards (Onibokun 1999).

Solid waste management in Kinshasa has further been complicated by increased rural–urban migration, and this situation has overwhelmed city authorities, who in most cases are operating under huge budget deficits on one hand, and on the other, are implementing urban development approaches that appear to be out of touch with reality on the ground. In the face of increased civil unrest, coupled with dramatic deterioration in the supply of basic infrastructure and urban services, as well as the declining economic situation, has left the urban authorities in Kinshasa stunned by the demands for solid waste management services (Misilu et al. 2010). With narrow revenue bases, increased civil conflict and limited technical capacities, the municipal authorities in Kinshasa have thus been unwilling or unable to

effectively deliver on their mandate such as provision of refuse collection, road maintenance and water supply to mention but a few.

The solid waste management challenge in Kinshasa is not only a question of the scale of population growth, but also the weaknesses and deficiencies in both national and local government institutions in the face of rapid urban change. Longondjo (2010), for example, observes that at the city level of Kinshasa, a lack of resources and knowledge prevent not only people from solving their solid waste problems, but also institutions from managing change in a much more coordinated manner. Institutions that are mandated with urban management in Kinshasa usually do not coordinate their activities because urban governance has been developed as a system of procedures imposed from above. Din and Cohen (2013) observes that in Kinshasa, there is a multiplicity of agencies that may deliver urban services, but there is no coordination among them. Mbuyi (1989) further argues that the lack of effective management systems and lack of financial resources have led to conditions that are deleterious to the environment and continue to subject the urban poor to meagre living conditions. The current economic turmoil, coupled with the perpetuation of the civil war, as well as high levels of corruption have combined to exacerbate problems of solid waste management and push the poor into living miserable lives. Financial resources are central to the effective and efficient management of solid waste management because they determine the level or quality of services that can be provided. Thus, financial availability and sound management systems are key elements to determining the nature of solid waste management in a city, particularly in low-income cities such as Kinshasa (Musandu-Nyamayaro 1991).

SUMMARY AND CONCLUSION

The discussion in this paper has revealed that social justice and environmental justice is a global challenge. There are, however, differences between environmental problems faced by developed countries and developing countries. In developed countries, the problems are generally related to high growth and economic development, which generates problems such as air pollution, traffic congestion, water contamination and disposal of radioactive waste (Onstad 1997). In developing countries, on the contrary and especially in sub-Saharan Africa, the reverse is true as environmental problems reflect the very lack of economic development and poverty (Binns et al. 2012). Hardoy et al. (1992), further observes that interest to redress in urban environmental problems in developing countries is overwhelmingly based on Northern perceptions and precedents. Efforts to address these urban environmental challenges are usually biased towards employing eurocentric frameworks that are unfit to deal with the reality of environmental problems in a developing country scenario (Onstad 1997). The use of eurocentric urban development and planning approaches which in most cases are outdated have significantly propagated issues of spatial inequality in the distributions of resources and have contributed to worsening justice issues in many cities of the developing countries, particularly in sub-Saharan Africa (Onstad 1997, Bullard 2005, Patel 2009, Kindornay and Ron 2012, Ako et al. 2013).

It has been illustrated in this paper that social justice and environmental justice in the context of solid waste management must be seen as intrinsically connected as both concepts emphasise the need for empirical understandings, grounded in local contexts (see Patel 2009).

They play fundamental roles in the theoretical construction of principles that can contribute to a sustainable community, one that ensures that the rights and needs of individuals in a society are met (Kindornay and Ron 2012). In the context of solid waste, the concepts of social justice and environmental justice are compelling, because of their focus on ensuring equal service delivery in solid waste collection and disposal, while simultaneously redressing previous imbalances. Walker (2009), however, argues that the principles of environmental and social justice as well as sustainable development are more generally in their infancy in sub- Saharan Africa, and few implementing agencies and practitioners have a clear understanding of how to translate these global principles into practice. It is not surprising, therefore, that unresolved issues around sustainable development and environmental justice have emerged in a period during which implementation and the real implications of following a justice pathway have overwhelmed many urban managers in sub-Saharan African cities (Patel 2009).

There is now growing evidence of the links between environmental problems and social injustices and this is because both social justice and environmental justice work are sensitive to power issues (i.e., who causes pollution and who suffers from pollution); and tend to focus on communities or groups, rather than on individuals. Both social justice and environment justice have tended to adopt a holistic approach to analysing and addressing problems and reforms, and as such the two elements cannot be addressed in isolation of each other. Environmental justice, as argued above, attempts to establish linkages between environmental and social injustices, and it would thus be no exaggeration to argue that tackling both social exclusion and environmental problems through integrated policies and development would be the most appropriate and viable option to address issues of inequality that arises from solid waste management in Kinshasa (Stephens et al. 2001). By seeing social justice through an environmental lens, and analysing environmental issues more clearly in terms of social justice, would provide new and more effective ways of dealing with problems associated with solid waste management challenges (Stephens et al. 2001, Venot and Floriane 2013). A key element to note here is that the environmental justice framework if implemented properly would be a valuable tool for addressing different aspects of social justices in a community.

In conclusion, it has been illustrated in this paper that urban social justice and environmental justice issues are comparatively rare in African cities, with notable exceptions in a few selected countries (Meyers 2008). The urban poor in sub-Saharan African cities face many and complex barriers that make it difficult or impossible for their legal, moral and political human rights to be respected (Onstad 1997). Barriers of access to social justice and environmental justice that the poor face can be dealt with under stable political regimes and effective legislation and governance systems that not only engage communities, but encourage public participation in local politics and policy formulation and implementation (Onstad 1997, Binns et al. 2012, Couth and Trois 2012). Therefore, access to social justice and EJ implies a situation where the poor are afforded to live in homes, neighbourhoods and work environments that are clean, healthy and secure. The often implicit denial of the poor people's rights to good living standards is usually a result of lack of political will on the part of government officials who often give a higher priority to service delivery in more rich neighbourhoods.

In order to have a sustainable solid waste management system that ensures that the solid waste burden is equally shared, there is need for local government authorities in Kinshasa and other developing countries to adopt the rights-based approach to urban development. The

right of access to relevant information and participation in decision-making process by all interested and affected parties are key components of the environmental justice discourse at all levels. The rights of every citizen, and each individual in a city and country, must be enshrined in a city's development and planning policies, and must be embedded in various local and national legislative articles. A rights-based approach to urban development places greater emphasis on community participation and systematic empowerment of the poor and disadvantaged groups to enable them gain self-confidence in articulating themselves, gaining information on available resources and determining their future and that of their children.

If the poor and the powerless in society are given an opportunity to challenge decisions made by more powerful actors, they would demand that their rights are respected and when contravened, gain effective redress and increase their bundle of endowments. This is only possible through the creation of pro-poor institutions that will not only focus on promoting pro-market government agendas, but also the welfare and well-being of the more marginalised and disenfranchised groups of people in society. Pro-poor institutions will not only facilitate the participation of the urban poor in decision-making, but will also enable them to get involved in the implementation of strategies and systems that will promote sustainable solid waste management. Thus, developing a civic centred governance approach to development in Kinshasa may present an opportunity for achieving both social justice and environmental justice for the poor.

REFERENCES

Abuzeid, F., 2009. Foreign aid and the 'big push theory': lessons from sub-Saharan Africa. *Standford Journal of International Relations,* 10 (1), 1-9.

Agyeman, J., Bullard, R., and Evans, B., 2003. Joined up thinking: bringing together sustainability, environmental justice, and equity. In: J. Agyeman, R. Bullard, and B. Evans, eds. *Development in an unequal world.* Cambridge: MIT Press, 2–16.

Ako, M., Anyidoho, N., and Crawford, G., 2013. NGO, rights-based approaches and the potential for progressive development in local contexts: constraints and challenges in Ghana. *Journal of Human Rights Practice,* 5 (1), 46–74.

Bane´gas, R., Brisset-Foucault, F., and Cutolo, A., 2012. Parlements de la rue. 1st ed. Paris: Editions Karthala.

Binns, T., Dixon, A., and Nel, E., 2012. *Africa: diversity and development.* 1st ed. London: Routledge.

Bullard, R.D., 2005. *The quest for environmental justice: human rights and the politics of pollution. San* Francisco: Sierra Club Books.

Byrne, J., Martinez, C., and Glover, L., 2002. A brief on environmental justice. In: J. Byrne, C. Martinez and L. Glover, eds. *Environmental justice: discourses in international political economy.* New Brunswick: Transaction Publishers, 3–17.

Capek, S.M., 1993. The 'Environmental Justice' frame: a conceptual discussion and an application. *Social Problems,* 40 (1), 5–24.

Chaix, B., et al., 2006. Children's exposure to nitrogen dioxide in Sweden: investigating environmental justice in an egalitarian country. *Journal of Epidemiology and Community Health,* 60, 234–241.

Chambers, R., 2003. *Who's reality counts? Putting the first last.* London: ITDG.

Cheru, F., 2002. The urban-rural interface: managing fast-growing cities in Africa. In: F. Cheru, ed. *African renaissance: roadmaps to the challenge of globalisation.* London: Zed Books, 153–192.

Christens, B. and Speer, P.W., 2006. Tyranny/transformation: power and paradox in participatory development. *Forum: Qualitative Social Research,* 7 (2), Art. 22, 23–42.

Cole, L.W., 1992. Remedies for environmental racism: a view from the field. *Michigan Law Review,* 90 (2), 1991–1997.

Coninck, D.J., Culp, J., and Taylor, V., 2013. African perspective on social justice [online]. Uganda: Friedrich EbertStiftung. Available from: http://www.fesuganda.org/media/documents/African_Perspectives_on_Social_Justice.09.2013.pdf [Accessed 27 February 2014].

Coughlin, S., 1996. Environmental justice: the Role of epidemiology in protecting unempowered communities from environmental hazards. *Science of the Total Environment,* 184 (1–2), 67–76.

Couth, R. and Trois, C., 2012. Sustainable waste management in Africa through CDM projects. *Journal of Waste Management,* 32 (11), 2115–2125.

Din, G. and Cohen, E., 2013. Modelling municipal solid waste management in Africa: case study of matadi, the Democratic Republic of Congo. Journal of Environmental Protection, 4, 435–445.

Dominelli, L., 2013. Environmental justice at the heart of social work practice: greening the profession. *International Journal of Social Welfare,* 22, 431–439.

Dougall, J.M. and MeGahey, C., 2003. *Urban Environmental Health Strategies, three communitybased environmental sanitation and hygiene projects conducted in the DR-Congo,* USAID, DR-Congo. Arlington, VA: Environmental Health Project.

Fan, M.F., 2006. Environmental justice and nuclear waste conflicts in Taiwan. *Environmental Politics,* 15 (3), 417–434.

Faure, M. and Du Plessis, W., 2011. *The balancing of interests in environmental law in Africa.* Pretoria: University Press Pretoria.

Gelobter, M., 1992. Toward a model of 'Environmental Discrimination'. In: Bunyan Bryant and Paul Mohai, eds. *Race and the incidence of environmental hazards: a time for discourse.* Boulder, CO: Westview Press, 64–81.

Godsil, R.D., 1991. *Remedying environmental racism. Michigan Law Review,* 90 (2), 394 427.

Hardoy, E., Mitlin, D., and Satterwaite, D., 1992. *Environmental problems in third world cities.* London: International Institute for Environment and Development, Earthscan Publication.

Hillman, M., 2006. Situated justice in environmental decision-making: Lessons from river management in Southeastern Australia. *Geoforum,* 37 (5), 695–707.

Hove, M., Ngwerume, E., and Muchemwa, C., 2013. The urban crisis in sub-Saharan Africa: a threat to human security and sustainable development. *International Journal of Security and Development,* 2 (1), 7–18.

Kihangi, B.K., 2012. The environmental law framework of the Democratic Republic of Congo and the balancing of interests. In: M. Faure and J. Plessis, eds. *The balancing of interests in environmental law in Africa.* Pretoria: Pretoria University Law Press, 95–96.

Kindornay, S. and Ron, J., 2012. Rights based approaches to development: implications for NGOs. *Human Rights Quarterly,* 34 (2), 472–506.

Kotze´, L.J., 2007. Towards sustainable environmental governance in South Africa: cooperative environmental governance and integrated environmental management as possible solutions for fragmentation. In: C. Soskolne et al., eds. *Sustaining life on earth: reconnecting environmental and public health through global governance.* Toronto: Rowman and Littlefield, Lexington Books, 155–169.

Krummenacher, H., 2008. *Environmental factors as triggers for violent conflict: empirical evidence from the 'FAST' data base*. Bern: Swisspeace.

Lateef, A.S.A., et al., 2010. Geographical constraints on urban sustainability, Kinshasa City, Democratic Republic of Congo. *Environmental Geosciences,* 17 (1), 17–35.

Lavelle, M. and Coyle, M., 1992. Unequal protection – the racial divide in environmental law: a special edition. *National Law Journal,* September 21, S1–S12.

Leonard, L., 2013. The relationship between the conservation agenda and environmental justice in post-apartheid South Africa: an analysis of Wessa KwaZulu-Natal and environmental justice advocates. *South African Review of Sociology,* 44 (3), 2–21.

Lohse, U., 2003. *Improving municipal finance: a global challenge. Habitat debate. Innovative urban financing.* UN-Habitat, 9 (1). Available from: http://www.unhabitat.org/hd/hdv9n1/default.asp [Accessed 20 February 2014].

Longondjo, E.C., 2010. The challenges of solid waste management facing the city of Kinshasa: the case of Kinshasa local municipality? Unpublished MSc Dissertation, University of Witwatersrand, South Africa.

Lowry, A.L., 2013. Achieving justice through public participation: measuring the effectiveness of New York's enhanced public participation plan for environmental justice communities. Social Science - Dissertations, Maxwell School of Citizenship and Public Affairs, SURFACE, Paper 180, New York, USA.

Mabbett, D., 2005. The development of rights-based social policy in the European Union: the example of disability rights. *Journal Common Market Studies,* 43 (1), 97–120.

Massey, R., 2004. Environmental justice: income, race, and health [online]. Available from: http://www.ase.tufts.edu/gdae/education_materials/ modules/Environmental_Justice.pdf [Accessed 1 December 2014].

Mbuyi, K., 1989. Kinshasa: problems of land management, infrastructure, and food supply. In: R.E. Stren and R.R. White, eds. *African cities in crisis: managing rapid urban growth.* Boulder, CO: Westview Press, 149–176.

Medina, M., 1997. Informal recycling and collection of solid waste in developing countries: issues and opportunities. United Nations Working Paper No. 24, New York. Available from: www.gdrc.org/uem/waste/swm-ias.pdf [Accessed February 2014].

Misilu, E., Shouyu, C., and Li Qin, Z., 2010. Sustainable urbanisation's challenge in Democratic Republic of Congo. *Journal of Sustainable Development,* 3 (2), 246–258.

Musandu-Nyamayaro, O., 1991. Urban management in Zimbabwe: The case of Harare. Paper presented at the RUPSEA conference on urban management in Southern and Eastern Africa, 7–10 October, Lilongwe, Malawi.

Myers, G.A., 2005. *Disposable cities: Garbage, governance, and sustainable development in urban Africa.* Aldershot: Ashgate.

Myers, G.A., 2008. Sustainable development and environmental justice in African cities. *Geography Compass,* 2, 695–708.

Mzidzornu, M., 2004. Environment protection in Africa: Panorama of the law and practice. *Journal of Energy and Resources Law,* 22, 152–153.

Nsokimieno, E., 2010. Sustainable urbanization's challenge in Democratic Republic of Congo. *Journal of Sustainable Development,* 3 (2), 12–27.

Nussbaum, M.C. and Amartya K.S., eds., 1993. The Quality of Life. Oxford: Clarendon Press. Okot-Okumu, J. and Nyenje, R., 2011. Municipal solid waste management under decentralisation in Uganda. *Habitat International,* 35 (4), 537–543.

Onibokun, A., 1999. *Managing the monster*. Ottawa: International Development Research Centre.

Onstad, J.W., 1997. *Access to environmental justice for the urban poor*. University College of London Working Paper No. 81, London: Development Planning Unit.

Otang-Ababio, M., Melara Arguello, J.E., and Cabbay, O., 2013. Solid waste management in African cities: sorting the facts from the Fads in Accra, Ghana. *Habitat International,* 39, 96–104.

Patel, Z., 2009. Environmental justice in South Africa: tools and trade-offs, Social Dynamics. *African Studies,* 35 (1), 94–110.

Pearce, J., Kingham, S., and Zawar-Reza, P., 2006. Every breath you take? *Environmental justice and air pollution in Christchurch,* New Zealand. Environment and Planning A, 38, 919–938.

Pole Institute and International Alert, 2014. Natural resource exploitation and human security in the Democratic Republic of Congo. Seminar Report. Available from: http://tierra.rediris.es/coltan/ POLE%20INSTITUE.pdf [Accessed 10 September 2014].

Pollock, E. and Vittes, P., 1996. Poverty, pollution, and solid and hazardous waste: the linkages for different sources. *Florida Centre for Solid and Hazardous Waste Management,* University of Central Florida, Report No. 96–3.

Potter, R., Binns, T., Elliot, J., and Smith, D., 2008. Geographies of development. 2nd ed. London: Addison Wesley Longman Limited.

Rapten, K., 1998. Community participation in municipal solid waste management in developing countries: the role of the informal sector. New Haven: Yale School of Forestry and Environmental Studies.

Samson, M., 2008. Local government transformation and waste management privatization in postapartheid Johannesburg in rescaling the state, restructuring social relations. *International Feminist Journal of Politics,* 32 (3), 26–57.

Schubeller, P., Wehrle, K., and Christen, J., 1996. Urban management and infrastructure. A conceptual framework for municipal solid waste management in low-income countries. UNDP/UNCHS Working Paper No. 9, St. Gallen, SKAT: Habitat/World Bank/SADC Collaborative Programme on Municipal Solid Waste Management in Low-Income Countries.

Scott, D. and Oelofse, C., 2005. Social and environmental justice in South African cities: including 'Invisible Stakeholders' in environmental assessment procedures. *Journal of Environmental Planning and Management,* 48 (3), 445–467.

Simatele, D. and Simatele, M., 2014. Climate variability and urban food security in sub-Saharan Africa: lessons from Zambia using an asset-based adaptation framework. *South African Geographical Journal*, 1–21. Available from http://www. tandfonline.com/doi/pdf/10.1080/ 03736245. 2014.924873 [Accessed 10 November 2014].

Simatele, D. and Simatele, M., 2015. Migration as an adaptive strategy to climate variability: a study of the Tonga-speaking people of Southern Zambia. Journal of Disasters. doi:10.1111/disa.12124.

Stephens, C., Bullock, S., and Scott, A., 2001. *Environmental justice.* ESRC Global Environmental Change Programme, University of Sussex.

Simatele, D., Binns, T., and Simatele, M., 2012a. Sustaining livelihoods under a changing climate: the case of urban agriculture in Lusaka, Zambia. *Journal of Environmental Planning and Management,* 55 (9), 1175–1191.

Simatele, D., Binns, T., and Simatele, M., 2012b. Urban livelihoods under a changing climate: perspectives on urban agriculture and planning in Lusaka, Zambia. *Journal of Human Development and Capabilities,* 13 (2), 269–293.

Taylor, D., 2000. The rise of the environmental justice paradigm: injustice framing and the social construction of environmental discourse. *American Behavioural Scientist,* 43 (4), 508–580.

Taylor, D.E., 2002. Race, class, gender, and American environmentalism. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, *Gen. Tech. Rep.* PNWGTR-534.

Venot, J.P. and Floriane, C., 2013. Justice in development? An analysis of water interventions in the rural South. *Natural Resources Forum,* 37, 19–30.

Walker, G., 2009. Globalizing environmental justice: the geography and politics of frame contextualization and evolution. *Global Social Policy,* 9 (3), 355–382.

In: Handbook on Africa
Editor: Whitney Sherman
ISBN: 978-1-53610-063-1

Chapter 12

DISASTERS AND RELATED HEALTH ISSUES IN THE DEMOCRATIC REPUBLIC OF CONGO: EPIDEMIOLOGIC PROFILE AND PERSPECTIVES FOR EFFICIENT HEALTH CARE DELIVERY

Nlandu Roger Ngatu[1,*], MD PhD,
Sayumi Nojima[1], PHN DSN PhD,
Jean Boleme-Izankoy[2], MSc,
Francoise Malonga-Kaj[3], MPH PhD,
Di-Mosi Roger Wumba[4,5], MD PhD,
Sakiko Kanbara[1], RN PhD, Mitsunori Ikeda[1], MD PhD
and Ayami Nakano[1], RN PhD

[1]Graduate School of Health and Nursing Sciences,
and Disaster Nursing Global Leading doctoral program (DNGL),
University of Kochi, Kochi, Japan
[2]Department of Industrial Psychology, Division of Social Sciences,
Ajou University, Suwon, South Korea
[3]School of Public Health, Faculty of Medicine, University of Lubumbashi,
Lubumbashi, Democratic Republic of the Congo
[4]Department of Tropical Medicine, Unit of Parasitology, Faculty of Medicine,
University of Kochi, Kinshasa, Democratic Republic of the Congo
[5]Parasitology Unit, Faculty of Medicine, William Booth University, Kinshasa,
Democratic Republic of the Congo

ABSTRACT

The Democratic Republic of Congo (DRC) is experiencing an unprecedented humanitarian crisis that already affected over 15,000,000 people. The "East-Congo war",

* E-mail: ngatu@dngl.u-kochi.ac.jp, Tel/Fax: (+81) 88-847-8633.

a perfect example of 'economic war', is reported to be the deadliest armed conflict since World War II. This paper highlights disasters occurring in DRC, related health issues and the perspectives to ameliorate health care services in affected areas. A review of available literature on disasters and emergency events, enriched by personal experience of authors in humanitarian field within DRC. Recurrent armed conflicts, gender-based violence (sexual violence in particular), climate-related catastrophes, outbreaks of communicable diseases, volcano eruption and, recently, earthquakes are among the most prevalent manmade and natural disasters taking place in DRC. The "Congo war" and the subsequent armed conflicts have already caused over 5,000,000 deaths mainly among civilians, deepened poverty and increased the prevalence of gender-based violence and communicable diseases; it has also rendered the health system dysfunctional in most affected zones. With 200,000–500,000 cases of sexual assault, war and armed conflicts in Congo have been setting scenes of grueling violations of human rights with sexual crime toward women as a weapon war in which foreign and local military forces. Studies on the magnitude of sexual violence in eastern DRC and its impact on mental health of the victims provide alarming results. A population-based survey implemented among 11-23 years old girls from 22 high schools in Bunia, eastern Congo, showed that about one third of adolescent girls were victims of sexual violence, whereas a retrospective study conducted at Panzi hospital in the eastern province of Kivu reported an average of 1,100 rapes per month occurring between 2008 and 2009 and the hospital has treated about 10 cases a day. DRC is facing one of the worse crises in the world. A proportionate response to reduce the human and economic impacts of those multiple disasters can only be possible with the contribution and the involvement of international governmental and non-governmental organizations. Among the strategies to deal with DRC's disasters, a particular focus should be on targeting the real causes of the current DRC crises, mainly the economic interests of countries and companies that sponsor armed conflicts to freely exploit DRC's natural resources, whose main reserves are located in the eastern DRC. More importantly, besides relief services from international organizations and the involvement of competent United Nations' specialized agencies to ensure security, reinforcing the overwhelmed health system through provision of appropriate medical infrastructures and necessary equipment, periodical training of local health care providers and improving their safety and work conditions are among solutions to address health issues arising mainly in conflict zones and ameliorate health care delivery to affected populations.

Keywords: communicable disease, conflict, Democratic Republic of Congo, disaster, violence

1. INTRODUCTION

The Democratic Republic of the Congo (DRC), a country located in central African region, has been experiencing several complex and recurrent humanitarian crises that already affected approximately 15,000,000 people nationwide (UN OCHA 2015). Natural disasters and conflicts occurring mainly in its eastern provinces since 1990's have been threatening human security and rendered the health system dysfunctional in disaster-affected areas. As for many African countries, humanitarian crises in DRC have recently been on eof top news of many international media corporations. According to the International Rescue committee (IRC), a US-based humanitarian organization, the "eastern Congo war", which has destabilized countries of the great lake region of Africa and represents a perfect example of

'economic war' of the 21st century, is the deadliest armed conflict since World War II. These conflicts have already claimed the lives of more than 6,000,000 people since 1998 (Lewis S. 2007; Ngatu et al. 2013).

1.1. Country Profile

DRC's Geographical and Demographic Information

Located at the 'heart' of Africa, DRC shares 9,165 Km of border with nine other African countries: the Republic of Congo in the west, Central Africa Republic and South Sudan in the north, Uganda, Burundi, Rwanda and Tanzania in the east, and Zambia and Angola in the south. The country has a population of 85,026,000 and an area of 2,345,409 Km^2, making DRC the second largest African country after Algeria (DRC Ministry of health report, 2016). DRC (Zaire) has been colonized by Belgium and became independent since 30 June 1960. It used to have 11 provinces; however, the government has recently created new ones (2015), making a total of 26 provinces. Kinshasa is the capital and most populous province of DRC, with a population of over 9,120,710 inhabitants.

DRC's Health and Socioeconomic Indicators

Life expectancy at birth is estimated to be 52 years for both sexes (51 for male and 54 for female), the total expenditure on health per capita is 26 US$ and a GDP of 3.5 US$. The World Health Organization (WHO) estimates that there is 1 doctor and 5 nurses/midwives per 10,000 people in DRC (WHO, 2013; Our Africa, 2015). DRC ranks 144 and 186 (as of 2012) in the world for gender inequality and human development indexes, respectively. Under-five mortality rate is 98.3 per 1,000 live births, whereas maternal mortality rate is reported to be 693 [509 - 1,010] per 100,000 live births (as of 2015) (WHO 2015).

This paper presents an outline of major emergency events and disasters occurring in DRC, their human impacts and the perspectives to ameliorate health care services in affected zones.

2. LITERATURE REVIEW

A documentary study was conducted, consisting in a review of available literature on large scale emergency events and disasters occurring in DRC was conducted, and enriched with personal experiences of authors who have been working in disaster-affected areas within the country. The literature search and collection of experiences were carried out from July through December 2015. Information on disasters and emergency events (both in English and French languages) from publications were gathered using the search engines of the following databases: Medline, EMBASE and Google scholar. Five keywords or terms were used in the search: Congo, conflict, communicable disease, disaster, and violence.

A combination of two to three of the key words was performed during the search as follows: 'Congo and disaster', 'Congo and disaster', 'Congo and conflict', 'Congo and communicable disease', 'Congo, conflict, disaster', etc. Apart from peer-reviewed articles, useful reports related to the study theme from local and international humanitarian agencies

as well as governmental and non-governmental organizations involved in relief operations in DRC were also considered.

They were double-screened and only publications that matched the topic of this paper were finally considered. Figures and illustrations used in this report are from authors and their co-workers who agreed to have them displayed in this manuscript. An outline on prevalent manmade and natural disaster and emergency events occurring in DRC is provided in the following lines (Figure 1).

3. Disasters and their Health Impact on Populations in DRC

3.1. Manmade Disasters

3.1.1. The East-Congo War and Armed Conflicts and their Human Impact

War and armed conflicts are the worst manmade disaster in DRC and atrocities that accompany them are a source of stress and have a negative impact on the mental health of residents.

The most striking characteristic of these armed conflicts are the tremendous consequences they cause in terms of loss of human resource and the huge economic cost and environmental damages as well.

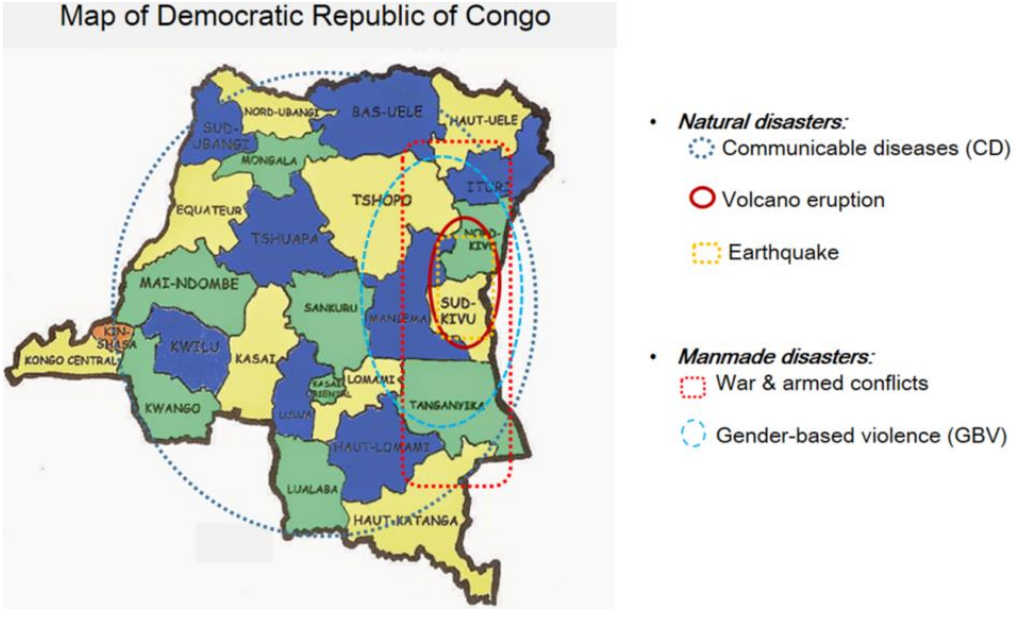


Figure 1. New map of Democratic Republic of Congo with newly created provinces. The figure 1 shows locations of prevalent manmade and natural disasters occurring in the Democratic Republic of Congo (source of original map: one of authors (DRW) and DRC ministry of health malaria report, January 2016).

In July 2010, through its resolution 1925, the United Nations' Security Council decided to reinforce its peacekeeping force in DRC in order to assure appropriate civilian, military and judiciary components and improve the capacity of DRC government to protect the population and consolidate state authority by increasing its personnel to a maximum of 19,815 military personnel, 760 military observers, 391 police personnel and 1,050 members of formed police units (Human Rights Watch 2002; Bartels et al. 2012). This is the biggest UN's peacekeeping force in the world.

3.1.1.1. Historical and Political Background of Armed Conflicts in the Democratic Republic of Congo

East-Congo war and the consecutive armed conflicts in which several African countries have been involved are the worst manmade disaster currently occurring in the world. Knowing the historical background of the armed conflicts in countries of the African Great Lakes region (DRC, Uganda, Rwanda, and Burundi) and their economic and political implications would clarify what is going on in DRC. Except DRC, the other countries of the region have mainly two ethnics, the Hutus and Tutsis, and politicians from each ethnic group seek to control the power. Rwanda has a small territory, and underground natural resources are scarce, but it has a fast growing population. On the other hand, Uganda's main natural resource is petrol whose reserves are mostly located at the border with DRC. Thus, Uganda government seeks to have control over a large portion of this shared rich area, whereas Rwandan leadership exploit DRC's resources thanks to its military presence in the Kivu provinces and expects to gain space within DRC's territory.

Prior to the 1994 Rwandan genocide, which occurred while Hutu leaders had power, the current Rwandan Tutsi leadership was in exile in Uganda where its militia group (now known as the Rwandan Patriotic Army) was being trained in order to attempt a coup d'état in Rwanda. Following the assassination of the Hutu president Habyarimana in 1994, widespread attacks on civilian populations were perpetrated, forcing some millions of Rwandan people to cross the border and settle in East-Congo (Zaire).

The 'Bureau of African Affairs' of the US Department of State has declared that "the conflict in DRC can find its roots in the aftermath of the Rwandan genocide in 1994. When the genocide ended, Rwandan Hutu militias, known as the Interahamwe, fled into Congo when the Tutsis took control of the Rwandan government"; in this statement, the Bureau of African Affairs attempted to explain that the Rwandan army entered DRC to disintegrate the Hutu militia groups that might be using Hutu refugee camps in eastern Congo as bases to perpetrate attacks against Rwanda (US Department 2010). Paul Kagame's army destroyed refugee camps based in East-Congo, forcing a great number of refugees and Congolese people to flee deep into DRC (Guichaoua 2016). Some of the Congolese opposition groups based in Tanzania and other countries that were against president Mobutu's leadership joined Rwandan military group in eastern Congolese provinces and, with the military support from Uganda, they pushed all the way to the capital Kinshasa in Zaire (currently DRC). This was the "first Congo war" which brought down president Mobutu's regime in 1997.

A former Congolese rebel who was ally of Rwandan military, Laurent Desire Kabila, was made the new Congolese president. The newly created Congolese government, however, had its army and security forces mainly controlled by officers from Rwanda. Laurent Kabila will be killed in his office in Kinshasa on 16 January 2001 and replaced by an army general; and one of Laurent Kabila's adopted sons and army officer, Mr Joseph Kabila.

Prior to his death, President Laurent Kabila decided that all Rwandan army officers and soldiers serving in DRC should leave the country and return to Rwanda. This fact caused the Rwandan and Ugandan leaders to be angry with him; they therefore decided to invade the eastern Congo provinces of South Kivu, North Kivu and Orientale province with their military forces. This was the start of the "second Congo war" (1998-2003) that involved armies from ten different African countries.

Both the first and second Congo war and the subsequent armed conflicts that continue until now have caused over 15 million victims, according to reports from international relief agencies working in DRC. These armed conflicts are considered the biggest humanitarian crisis currently occurring in the world, but it has still drawn little response from the international community (Bartels et al. 2012; IRIN, 2003; Coghlan et al. 2006; IRC 2007).

3.1.1.2. A Perfect Example of Economic War

Congo war is primarily motivated by the search for control over rich natural resources in the eastern Congo provinces, such as 'colombo-tantalite' or coltan, one key material used to process smart phones, computers and other electronic devices. The war and armed conflicts in DRC have already made more than 2.7 million internally displaced persons (IDP) within the country's territory, and approximately 430,000 Congolese refugees who have settled in Tanzania, Rwanda, Uganda, Burundi and Zambia. In addition, the death toll is very high, with more than five million people who died as direct or indirect consequence of the war and armed conflicts, according to the UN HCR global report 2015 (WHO 2015).

3.1.2. Sexual Violence and its Impact on the Mental Health of Victims: A War within the Congo War

Sexual violence toward women has become a real epidemic in DRC. Reports from UNICEF and UN News center mentioned about 200,000 - 500,000 cases of sexual violence occurring in East-Congo between 1998–2008 (Turkovich 2008; Plos Medicine Editors 2009; UN News center 2013). A systematic rape has been taking place in the region, which is used as a weapon of war not only to terrorize, displace and demoralize local residents but also to incur severe sexual trauma such as sexual mutilations. The victims include adult women, young female and even male children and babies (Pratt and Werchick 2004; Mukwenge and Niangani 2009; Gettleman 2010; Bartels et al. 2012).

According to reports from researchers, health care providers and humanitarian agencies operating in eastern Congo provinces, women are the principal targets and sexual violence against them are widespread. Victims have been subjected to sexual slavery, mutilation of sexual organs and the killing of rape victims has become commonplace in the eastern Congo region (Wakabi 2008; Casey et al. 2011; Hall et al. 2014). Michael VanRooyen, a researcher and associate professor at Havard School of Public Health who provided humanitarian aid in eastern Congo suggested that what is going on in the region is a "war against women", saying that 'violence against women in Congo is entirely different; not only have women been assaulted by multiple assailants but in many cases, women come to hospital because they have been assaulted by sticks or knives or weapons, causing internal and external injuries. Women are incontinent and suffering tremendous infections and many have died as a result" (Powell 2009). This suggests a severe psychological impact of such violence on Congolese

women who survive sexual assaults and the necessity of mental health support program besides relief medical care.

A registry-based retrospective study conducted in Panzi hospital, a health facility known for treating more than 30,000 victims of sexual violence) in conflict-affected South Kivu province, found 4,311 records of rape cases between 2004 – 2008, of which 53% involved married women (Bartels 2011). Dr Denis Mukwenge, the director of the above mentioned hospital, has reported having cared for about 10 rape victims a day and, between 2008 and 2009, his hospital has registered approximately 1,100 rapes per month (Mukwenge 2009). Another hospital-based study reported 440 pediatric and 54 adult sexual abuse cases occurring between 2006 and 2008 in the same area (Kalisya et al. 2011).

On the other hand, a report by Human Rights Watch (HRW) entitled 'Soldiers who rape, commanders who condone' documents the magnitude of sexual violence perpetrated by the military forces in the North Kivu and South Kivu provinces in DRC, suggesting that the methods and effects of rape by armed forces has created a unique culture of sexual violence in DRC (Human Rights Watch 2009; Brown 2012). Despite the presence of a large United Nations' peace keeping force, local population in East-Congo are still subjects to attacks, violence, mass killing by militia groups and foreign armies from neighbor countries (Gettleman 2010) who serve the interests of those willing to control the East-Congo's rich natural resources.

Armed conflicts in eastern Congo have been setting scenes of grueling violations of human rights with sexual crime as a weapon war. Moreover, this unique feature of Congo war in which military forces have widely been involved is becoming a real phenomenon. Research findings on the impact of sexual violence on mental health of the victims in East-Congo provide alarming results.

A population-based survey implemented in 22 high schools in Bunia, eastern Congo, on the impact of different experiences of sexual violence on 11 to 23 years old adolescent girls' mental health. Of the 1,305 participating girls, more than one third of adolescent girls reported experiences of sexual violence with high levels of daily stressors, stigmatization and stressful war-related events.

A high proportion of girls who experienced either rape or non-consensual sexual experience also reported post-traumatic hyper-arousal and intrusion symptoms (Verelst et al. 2014).

Another study conducted by Mels and colleagues on 1,046 Congolese adolescents and young adults aged 13 - 21 years in eastern Congo showed that, among the 45.6% of girls and 54.4% of boys who participated in the study, 95% reported at least one traumatic event and, on average, adolescents were exposed to an average of 4.7 traumatic events. In addition, 52% of study participants were found to have developed posttraumatic stress disorder (PTSD) (Mels et al. 2009). These findings show a very particular reality of armed conflicts in DRC, which implies the necessity to implement mental care programs in the region.

2. Natural Disasters

2.1. Communicable Diseases

a. HIV/AIDS

According to the DRC's national HIV/AIDS program, permanent HIV surveillance has shown that the national HIV prevalence in pregnant women is 4.6%; on the other hand, DRC's 2006 HIV infection serosurveillance report showed a national prevalence of 5%, setting DRC in the context of countries with generalized HIV epidemic (PNMLS 2006). Moreover, the insecurity caused by armed conflicts in eastern region has made the situation worse. In East-Congo, the presence of soldiers and militia groups that have high prevalence of the disease has caused a rise in the HIV prevalence in the region. According to epidemiological data related to the Great lake region of Africa, armed conflicts have contributed to the rise of HIV prevalence to 1,120 per year or more cases in Uganda and 2,172 cases annually in DRC (Ngatu et al. 2013).

b. Cholera and Other Diarrheal Diseases

Following a disaster or humanitarian crisis, reduced personal hygiene and general sanitation status in IDP and refugee camps (poor water, sanitation and hygiene services), there is an increased risk of outbreak of water-borne and food-borne infections such as salmonellosis, shigellosis, cholera, etc. In April 1997, an epidemic of cholera occurred in refugee camps where 90,000 Rwandan refugees have settled in East-Congo region, affecting 545 persons within a month period and killing 67 of them, according to a report from the Center for Disease prevention and Control (CDC), a US based health institution. The United Nations' High Commissioner for Refugees (UN HCR) reported 50,000 cholera cases occurring in the same year among the refugee population in eastern DRC and some Congolese (Zairians) who were caught up in the turmoil (CDC 1997; UN HCR1997).

In the first decade of the 21st century, the North and South Kivu provinces in East-Congo have been the site of major catastrophic events that caused population displacements, favoring the emergence and spread of epidemics of communicable diseases. An epidemiological survey conducted by Bompangue and colleagues showed a 8-year prevalence of 73,605 cholera cases occurring between the year 2000 and 2007, of which 1,612 died, with a 7-fold increase of risk of cholera in populations from districts bordering the Kivu lake (Bompangue et al. 2009), suggesting the involvement of poor water quality and sanitation status in the area, apart from increased population density in refugee and IDP camps.

The Congolese western provinces are also affected by the consequences of war and armed conflicts that are happening in eastern DRC. The atrocities committed by militia groups cause displacement of Congolese populations that are forced to move to safer areas. For example, during the second Congo war, thousands of Congolese citizens were displaced from the Equateur province to the outskirts of Kinshasa. Three IDP camps were established in Kinkole, a semi-rural county near Kinshasa airport that were managed by the ministry of social and humanitarian affairs, in collaboration with Red cross Switzerland and Biodiversity Emergency Team (BET/EUB). In 2,000, while we were caring for the IDPs at Sicotra camp in Kinkole (Figure 2), an epidemic of shigellosis occurred due to the poor quality of drinking water, which sickened tens of displaced persons and killing one child.

c. Ebolavirus Disease (EVD)

The history of ebolavirus disease dates back to 1970's. The very first EVD epidemic occurred at a hospital in the Congolese Yambuku village, province of Equateur in Zaire (currelty Democratic republic of Congo), in 1976. This epidemic affected 318 villagers and 280 of whom died. A new virus was isolated from blood samples of EVD patients and was called 'ebola'; it was named after Ebola River near Yambuku village (Khan et al. 1999; WHO 1995; WHO 2015).

Figure 2. Sicotra camp for Congolese 'internally displaced persons' (IDP) who fled from the western providence of Equateur to the outskirts of Kinshasa (Kinkole county) during the second Congo war (Source: authors). This photo shows one of the authors (N.R.N.) who cared for women and children in Sicotra IDP camp while working for E.U.B./Redcross Switzerland humanitarian project in Kinkole, Democratic Republic of Congo, in 2000.

Figure 3 shows the epidemic trend of EVD outbreaks in DRC since 1976 in DRC and other countries of the central Africa region. Relatively small and large scale EVD outbreaks have been occurring mostly in countries of the central Africa region, including DRC, Republic of Congo and Gabon. In total, 12 episodes of EVD outbreaks and one isolated case in central African countries, of whom seven occurred in DRC; other six episodes occurred either in the Republic of Congo or Gabon (WHO 2015; CDC 2015). Those EVD episodes have sickened 1,522 people, killing 1,171 (77%) of them.

In August 2014, while the West African EVD outbreak was spreading, a new EVD outbreak occurred in western rural area of Boende in DRC; the epidemic was controlled three months later, thanks to the savoir-faire and clinical experience of Congolese ebola experts in the management of EVD. A specialized ebola disaster response team coordinated by Professor Jean-Jacques Muyembe, the Congolese Ebola expert who recently won the 'Christophe Mérieux Prize 2015' winner (Institut de France 2015) contributed to the control of most EVD outbreaks in the region.

The threat and burden of EVD outbreaks are worrisome in the central Africa, a region that has been the most affected by EVD epidemics in terms of number of episodes of

epidemics. EVD outbreaks in Africa are closely related to humans' eating habits in remote villages. In most EVD epidemics, the first cases involved a human contact with wild animals. Bats and bush meats are part of favorite foods in those countries, and given the weaknesses of the existing public health systems and the quasi absence of occupational safety programs and regulations in the healthcare sector, the diagnosis and reporting of most EVD cases is often delayed, contributing to the spread of EVD epidemics prior to the response from governmental and international relief agencies.

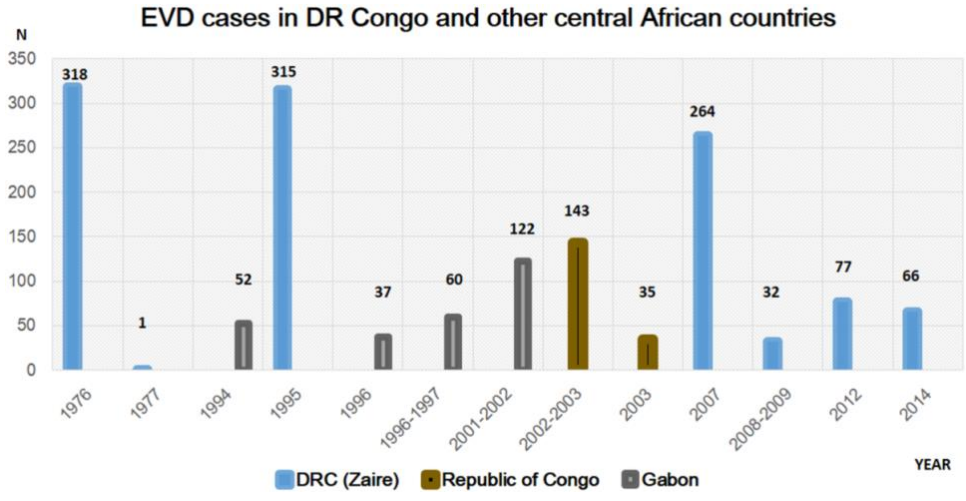


Figure 3. Episodes of Ebolavirus disease outbreaks in Democratic Republic of Congo and other countries of the central Africa region (data are from WHO and CDC's Ebolavirus disease reports 2015).

2.2. Volcanic Eruption and Earthquake

The Eastern region of DRC is well-known for its rich reserves of natural resources and also its mountains such as Mount Nyiragongo (one of most active African volcanoes with 3,470 m of altitude), located near the Kivu lake, Mount Ruwenzori and Mount Nyamulagira (3,058 m of altitude). The volcano Nyiragongo, which is located at 10 Km from the town of Goma in DRC near the border with the Republic of Rwanda, is known as one of Africa's most active volcanoes. It has long active lava lake which causes severe damages whenever an eruption occurs. Historical records have shown that Nyiragongo lava lake activity was first recorded in 1890's (Seach 2002); since, seven eruptions have been registered from1905 to 2002 of which two had a great human impacts. The 1977 Nyiragongo eruption caused 2,000 - 3,000 fatalities and about 800 people left homeless (Wafula et al. 2002).

On the other hand, the Nyiragongo volcanic eruption that occurred on 17 January 2002 was the most devastating, causing a huge disaster in surrounding villages and in the city of Goma. There were approximately 400,000 evacuees and 120,000 people homeless. This volcanic eruption was triggered by tectonic spreading of the Kivu rift which led to ground fracture and the flow of lava from ground fissures, causing inundation of residential areas. The socioeconomic and environmental consequences of this eruption wee huge: over 40 people died within the first 24 hours, about 50 people killed by fire after explosion at a petrol station. A report by Anjani Nayar mentioned that over 100 people killed and 300,000 other displaced (Anjani 2009). Furthermore, 14 nearby villages were destroyed by the lava and ash. In addition, approximately 40% of the city of Goma area were destroyed, including the

international airport and business center, whereas 15% of the city area were covered by lava (Tedesco et al. 2007; BBC news). Regarding Nyamulagira volcano, very few damaging eruptions records exist. And the latest eruptions occurred in 2011 and 2014 (Global Volcanism Program 2014; Earth observatory 2014), causing mainly displacement of populations and environmental damages in the Kivu province, DRC.

Earthquakes are quite rare events in the central Africa region, DRC included. Nonetheless, earthquakes of moderately high intensity have been recently reported in North and South Kivu provinces. However, recently, quakes have been occurring in the mountainous eastern Congo region in a country that has almost never expected such natural catastrophes and has never planned who to deal with. The latest one which occurred on 8 August 2015 at 1:26 GMT, had a magnitude of 5.6; it was followed by two other quakes the same night, killing four people (including two children), and left 28 other people injured; more than 45 houses and buildings collapsed, according to a report from Radio Okapi, a local broadcasting station owned by the UN Mission in DRC (UN Mission in DRC 2015).

DISCUSSION AND CONCLUSION

The present report highlights some of the most prevalent manmade and natural disasters occurring in DRC. It showed that war and armed conflicts in the eastern Congo are currently the most prevalent manmade disasters with huge human impact, claiming millions of lives. This silent genocide has been perpetrated mainly by foreign armies and militia groups from neighbor countries.

Armed conflicts have also been creating a favorable condition for the spread of communicable diseases, due to the violence that accompany the conflicts, the weakening of the health system and their negative impact of the environment. On the other hand, natural disasters such as volcanic eruptions, earthquakes in the eastern Congo region and epidemics of communicable diseases are among natural disasters that have been threatening people's lives.

Though there are similarities with other armed conflicts such as the Syrian and Afghanistan conflicts, the Congo wars present a particular picture of an epidemic of sexual violence against women in particular, with mutilation of sexual organs; this represents one of the dark sides of armed conflicts occurring in DRC; they are quite unique and probably hide the real motivation behind these wars which is beyond the economic interests of foreign countries and companies involved in this long hidden genocide.

This work has some limitations, as it consisted in a narrative review on humanitarian crises and disasters occurring in DRC, which included only relevant articles and reports mainly related to emergency events that are happening in this country, enriched by field experience of some of the authors. Additionally, there are several other emergency events occurring annually in DRC that are not listedin this paper. For example, heavy rains which cause flooding that destroy infrastructures and devastate farms and residences are one of most prevalent climate-related disasters.

In conclusion, considering the human impact of these humanitarian crises, DRC is experiencing an unprecedented crisis that might affect the country's capacity to deal with and weakens its health system. A proportionate and effective response to reduce the human and

economic impacts of those multiple disasters can only be possible with the contribution and involvement of international governmental and non-governmental organizations. Among the strategies to deal with DRC's disasters, a particular focus should be on targeting the real causes of the current DRC crises, mainly the economic interests of countries and companies that sponsor armed conflicts in order to freely exploit DRC's natural resources, whose main reserves are located in the eastern region. Moreover, besides the strengthening of the existing health system on local, district and provincial levels, promoting community health education to improve the personal hygiene and general sanitation status, implementing periodical training for health care providers and emergency drill programs for disaster public health preparedness in regard to communicable diseases and natural disasters as well.

ACKNOWLEDGMENT

The authors thank Ms Yukiko Nakaie of DNGL Kochi, and Ms Itsumi Yamamoto of the faculty of Nursing, University of Kochi, for their wonderful support. We also thank Dr Daniel Tonduangu Kuezina and Dr John Nsiala Makunza, both staff of the Non-governmental Organization "AFMED-Unikin International" for their advices and support. A posthumous acknowledgment to Dr Alpha Bokolombe Apanda, former coordinator of Congolese National Army Emergency Response Team and member of AFMED-Unikin, DRC chapter, who supported our Congo Disaster Study project and agreed to collaborate with us. This work was supported by an internal annual research fund 2015-2016 of University of Kochi Graduate School of Health and Nursing Sciences, Japan, and did not benefit from external fund.

CONFLICT OF INTEREST

The authors declare they have no conflict of interest.

REFERENCES

[1] DRC Ministry of Health. National strategic plan against malaria 2016-2020 (French report); National Antimalarial Program.

[2] UN OCHA. Republique Democratique du Congo: Apercu des besoins humanitaires 2015 (French report). Available from: https:// www.humanitarianresponse.info/en/ system/files/documents/files/HNO%20DRC%202015.%20Final_0.pdf.

[3] Lewis S. Calls for a new UN initiative to end sexual violence in the eastern region of region of the Democratic Republic of the Congo (DRC). Available from: http://www.wunrn.com/news/2007/10_07/ 10_01_07/100707_congo.htm.

[4] Ngatu N. R., Kanbara S., Takezaki K., Yamada S., Fujita S., Nojima S. Value of disaster-oriented educational program for health care professionals. Proceedings of Kochi Women University Academy of Nursing 2013; 38(2): 156-160.

[5] World Health Organization. WHO health report 2013: DR Congo. Available from: http://www.who.int/countries/cod/en/.

[6] Our Africa. Poverty and Health care: DR Congo. Available from: http://www.our-africa.org/democratic-republic-of-congo/poverty-healthcare.

[7] World Health Organization (WHO). Democratic Republic of the Congo: Key indicators. Available from:http://apps.who.int/gho/data/node.cco.ki-COD?lang=en.

[8] Bartels S. A., Kelly J., Scott J., Leaning J., Mukwenge D., Joyce N., VanRooyen M. Militarized sexual violence in south Kivu, Democratic Republic of Congo. *J. Interpers. Violence*, 2012; 28(2): 342.

[9] Human Rights Watch. The war within the war: sexual violence against women and girls in Eastern Congo. Human Rights Watch report, 2002. Available from: https://www.hrw.org/reports/2002/drc/Congo0602.pdf.

[10] US Department of State. Background note: Democratic Republic of the Congo – history. Bureau of African Affairs, 2010. Available from: www.state.gov/r/pa/ei/bgn/ 2823.htm#history.

[11] Guichaoua A. Sexual violence: a weapon of war in eastern Congo for more than 20 years (French article, 17 February 2016). Available from: http://theconversation.com/ les-violences-sexuelles-arme-de-guerre-depuis-plus-de-20-ans-dans-lest-du-congo-54781.

[12] IRIN Africa. Congo: conflict deadliest since World War II-aid agency. Nairobi, 8 April 2003. Available from: http://www.irinnews.org/report/ 42969/drc-conflict-deadliest-since-world-war-ii-aid-agency.

[13] Coghlan B., Brennan R. J., Ngoy P., Dofara D., Otto B., Clements M., Stewart T. Mortality in the Democratic Republic of Congo: a nationwide survey. *The Lancet*, 2006; 367: p44–51.

[14] International Rescue Committee (IRC). Congo crisis; Report 2007. Available from: http://www.rescue.org/special-reports/congo-forgotten-crisis.

[15] World Health Organization (WHO). UNHCR Global Appeal 2015 Update - Democratic Republic of Congo. Available from: http:// reliefweb.int/report/democratic-republic-congo/unhcr-global-appeal-2015-update-democratic-republic-congo.

[16] Turkovich T. As DR Congo crisis persists, UN classifies rape as weapon of war; UNICEF Report, June 2008. Available from:http:// www.unicef.org/infobycountry/ drcongo_44598.html.

[17] The PLoS Medicine Editors. Rape in war is common, devastating and too often ignored. *PLoS Med.*, 2009; 6(1): e1000021.

[18] UN News Center (2013). Senior UN officials condemn recent rapes of young girls in eastern DR Congo. Available from: http://www.un.org/ apps/news/ story.asp?NewsID=45290#.Vtk26nlxl9A.

[19] Pratt M., Werchick L. Sexual terrorism: rape as a weapon of war in eastern Democratic Republic of Congo. USAID/DCHA Assessment Report, 2004. Available from: http://pdf.usaid.gov/pdf_docs/ Pnadk346.pdf.

[20] Mukwenge D., Nangini C. Rape with extreme violence: The new pathology in South Kivu, Democratic Republic of Congo. *Plos Med.*, 2009; 6(12): 1371-1372.

[21] Kalisya L. M., Justin L. P., Kimona C., Nyavandu K., Eugenie M. K., Jonathan K. M., Claude K. M., Hawkes M. Sexual violence toward children and youth in war-torn eastern Democratic republic of Congo. *Plosone,* 2011; 6(1): e15911.

[22] Human Rights Watch. Soldiers who rape, commanders who condone: sexual violence and military reform in the Democratic Republic of Congo. New York: Human Rights Watch report 2009. Available from: https://www.hrw.org/. report/2009/07/16/soldiers-who-rape-commanders-who-condone/sexual-violence-and-military-reform.

[23] Brown C. Rape as a weapon of war in the Democratic Republic of the Congo. *Torture,* 2012; 22(1): 24-37.

[24] Gettleman J. Mass rapes in Congo reveal U.N. weakness. Available from: http://www.nytimes.com/2010/10/04/world/africa/ 04congo.html?_r=0.

[25] Wakabi W. Sexual violence increasing in Democratic Republic of Congo. *The Lancet,* 2008; 371: 15-16.

[26] Casey S. E., Gallagher M. C., Makanda R. B., Meyers J. L., Vinas M. C., Austin J. Care-seeking behavior of by survivors of sexual assault in the Democratic Republic of the Congo. *Am. J. Public Health,* 2011; 101 (6): 1054-1055.

[27] Hall B. J., Bolton P. A., Annan J., Kaysen D., Robinette K., Cetinoglu T., Wachter K., Bass J. K. The effect of cognitive therapy on structural social capital: results from a randomized controlled trial among sexual violence survivors in the Democratic Republic of the Congo. *Am. J. Public health,* 2014; 104(9): 1680-1686.

[28] Powell A. Rebuilding places that peace abandoned. Harvard News Office, 2009. Available from: http://news.harvard.edu/hwn/congo/ stories/vanrooyen.html.

[29] Bartels S. A., Scott J. A., Leaning J., Kelly J. T., Mukwenge D., Joyce N. R., Van-Rooyen M. J. Sexual violence trends between 2004 and 2008 in south Kivu, Democratic Republic of Congo. *Prehosp. disaster Med.,* 2011; 26(6): 408-13.

[30] Verelst A., De Schryver M., Broekaert E., Derluyn I. Mental health of victims of sexual violence in eastern Congo: associations with daily stressors, stigma, and labeling. *BMC Women's Health,* 2014; 14: 106.

[31] Mels C., Derluyn I., Broekaert E., Rosseel Y. Screening for traumatic exposure and posttraumatic stress symptoms in adolescents in the war-affected eastern Democratic Republic of Congo. *Arch. Pediatr. Adolesc. Med.,* 2009; 163(6): 525-30.

[32] Programme National Multisectoriel de Lutte contre le Sida (PNMLS). DRC National report on HIV epidemic 2006 (Report brochure written in French).

[33] Center for Disease Prevention and Control (CDC). Cholera outbreak among Rwandan refugees-Democratic Republic of Congo, 1997. Available from:http://www.cdc.gov/ mmwr/preview/mmwrhtml/ 00052860.htm.

[34] United Nations' High Commissioner for Refugees (UN HCR). Crisis in the Great Lakes-Cover story, Heart of darkness. Available from: http:// www.unhcr.org/ 3b6925384.html.

[35] Bompangue D., Giraudoux P., Piarroux M., Mutombo G., Shamavu R., Sudre B. et al. Cholera epidemics, war, and disasters around Goma and lake Kivu: an eight-year survey. *Plos Neglected Tropical Diseases,* 2009; 3(5): e436.

[36] Khan A. S., Tshioko F. K., Heymann D. L., Le Guenno B., Nabeth P., Fleerackers Y. et al. The reemergence of Ebola emorrhagic fever, Democratic Republic of the Congo, 1995. *Journal of Infectious Diseases*, 1999; 179 (1): S76-86. doi: 10.1086/514306.

[37] World Health Organization (WHO). Ebola viral haemorrhagic fever epidemic (VHF), Final report 1995. WHO, Brazzaville, 1996.

[38] World Health Organization (WHO). Ebola data and statistics (updated, September 7, 2015). Available from:http://apps.who.int/gho/data/ view.ebola-sitrep.ebola-summary-latest?lang=en.

[39] World Health Organization (WHO). Ebola data and statistics (updated, September 7, 2015). Available from: http://apps.who.int/gho/data/ view.ebola-sitrep.ebola-summary-latest?lang=en.

[40] Center for Disease Control (CDC). Outbreaks chronology: ebolavirus disease (as of July 2015). Accessible at: http://www.cdc.gov/vhf/ebola/ outbreaks/history/ chronology.html.

[41] Institut de France. Le prix Christophe Merieux. Available from: http://grands-prix.institut-de-france.fr/fondation-christophe-et-rodolphe-merieux.

[42] Seach J. Nyiragongo volcano eruption. Available from: http:// www.nyiragongo.com/ 1977.html.

[43] Wafula M. D., Zana N., Kasereka M., Hamaguchi H. The Nyiragongo Volcano: A Case Study for the Mitigation of Hazards on an African Rift Volcano, Virunga Region, Western Rift Valley. Available from: http:// iugg-georisk.org/presentations/pdf/ Wafula_volcano_Africa.pdf.

[44] Anjani N. Earth science: A lakeful of trouble. *Nature*, 2009; 460: 321-323. Doi:10.1038/460321a.

[45] Tedesco D., Vaselli O., Papale P., Carn S. A., Volataggio M., Sawyer G. M., Durieux J., Kasereka M., Tassi F. January, 2002, volcano-tectonic eruption of Nyiragongo volcano, Democratic Republic of Congo. *Journal of Geophysical Research*, 2007; DOI: 10.1029/2006JB004762.

[46] Global Volcanism Program (National Museum of Natural History). Nyamulagira. Accessible at: http://volcano.si.edu/ volcano.cfm?vn=223020.

[47] Earth Observatory (NASA). Nyiragongo and Nyamulagira. Available from: http://earthobservatory.nasa.gov/IOTD/view.php?id=8291.

[48] Un Mission in DRC. RDC: au moins 2 morts dans un important seisme dans l'Est (news in French). Available from: http://www.radiookapi.net/ actualite/2015/08/07/ rdc-au-moins-deux-enfants-tues-important-seisme-dans.

In: Handbook on Africa
Editor: Whitney Sherman
ISBN: 978-1-53610-063-1

Chapter 13

EDUCATION AND INCOME INEQUALITY IN THE DEMOCRATIC REPUBLIC OF CONGO

Christian S. Otchia*, PhD
Postdoctoral Research Economist, Nagoya University,
Furo-cho, Chikusa-ku, Nagoya, Japan

ABSTRACT

Education is certainly one of the key determinants of income. To understand how education expansion affects income inequality, this paper started out with the observation that the recent economic growth in DRC increased the average income of the population but has left the poor behind due to the lack of industrialisation and redistribution policies. I then constructed a district-level panel dataset to assess the extent to which education expansion reduces income inequality. I first estimated the impact of educational inequality on income inequality. I found a positive and significant relationship between educational inequality and income inequality. The results are robust across different inequality measures. Then, I went a step further to understand how changes in the average year of schooling affect income inequality. The findings revealed that the increase in the average year of schooling leads to a reduction in income inequality.

1. INTRODUCTION

Over the last decades, many economies—including those in the developing countries—have witnessed a significant expansion of the average level of education (Barro and Lee, 2010). While it is widely acknowledged that education plays an important role in reducing inequalities (Card, 1999; Hanushek, Schwerdt, Wiederhold, and Woessmann, 2015; Heckman, Humphries, Veramendi, and Urzua, 2014; Heckman and Mosso, 2014), there is a little compelling evidence that they play a positive role and even less about the mechanisms by which education affects inequality in developing countries. To date, most of the researches

* E-mail: cotchia@gmail.com.

on education and income inequality have focused on cross-country analysis for developed countries. Hence, the evidence for the relationship concerning education and inequality is arguably absent in the literature for Sub-Saharan Africa, especially at country level. There is particularly limited empirical work because of data issues, among which, in particular, the lack of longitudinal dataset.

In this paper, I provide a detailed picture of the relationship between educational inequality and income inequality in the Democratic Republic of Congo (DRC) between 2005 and 2012, using a district-level panel data. Put differently, I construct a panel dataset by compiling two waves of the DRC household survey data at district level, measure inequality in income and education, and estimate an econometric model in which education expansion predicts income inequality.

Despite its endowment in natural resources, DRC remains one of the poorest countries in the world, as the impressive GDP growth performance in recent years has not contributed to significantly reduce the high levels of initial poverty that were inherited from long years of war and mismanagement. The growth rate has been maintained at an average of 6 percent for more than 10 years while the stock of inwards FDI increased 3 times compared to its 2000 level. However, poverty and employment outcome was relatively poor. The elasticity of growth to employment was 0.71 in 2000-2004 and 0.53 in 2004-2008. Poverty incidence fell from 71.3 percent to 63.4 percent between 2005 and 2012, with an annual rate of 1.66 percent. Subjective poverty figures show that almost half of the households perceive themselves as in worse economic conditions compared to the previous year. Subjective poverty, which is estimated at 73 percent, is very alarming as 55.62 percent of households believe that their living standards have decreased. 42.98 percent of households have seen their purchasing power decreased, 48.83 percent cannot feed themselves and 74.14 percent are unable to save. The weak translation of growth into poverty reduction and better living standard raises the level of urgency with which social policy should be envisaged, as the boom in the commodity cannot last longer.

The purpose of this paper is to analyse the evolution of inequality in DRC and estimate the extent to which educational inequality affects income inequality. Empirical studies on the relationship between income and inequality in DRC are predominantly about the pattern of growth and rely on simulation models (Otchia, 2014, 2015). For example, Otchia (2015) assessed the distributional effect of mining based growth in DRC using a CGE-microsimulation model. The author found that the pattern of growth affects significantly the aggregate performance in terms of poverty reduction. This is because mining-based growth had anti-poor effects in urban areas and almost neutral effects in rural areas. The paper argued also that the initial income distribution had a clear influence on the way this growth has not translated to a proportional poverty reduction. In another study on the effect of agricultural modernization on poverty in DRC, Otchia (2014) found that poverty reduction due to growth led by large-scale investment in agriculture depends on the initial level of inequality in income or distribution of assets.

This research extends the empirical literature on inequality in DRC by examining the effect of educational inequality on income inequality. In fact, income disparity is extremely prevalent among household groups and across regions in DRC. In urban areas, the average income per capita of the richest 10 percent of households is about 20 times the average of the poorest 10 percent, while, in rural area, the income disparity between the richest and the

poorest is about 16 times (Otchia, 2015). This paper is the first of its kind in DRC because I use the most comprehensive data in terms of coverage and time.

The paper is organized as follows. The next section discusses the patterns of the recent economic growth in DRC. Section 3 presents the data and provides a detailed definition of the variables used in this study. In section 4, I introduce the methodology and describe the computation of district measures of income and educational inequalities. Section 5 provides the descriptive analysis of the data and section 6 presents and discusses the results of the econometric regressions. The last section concludes.

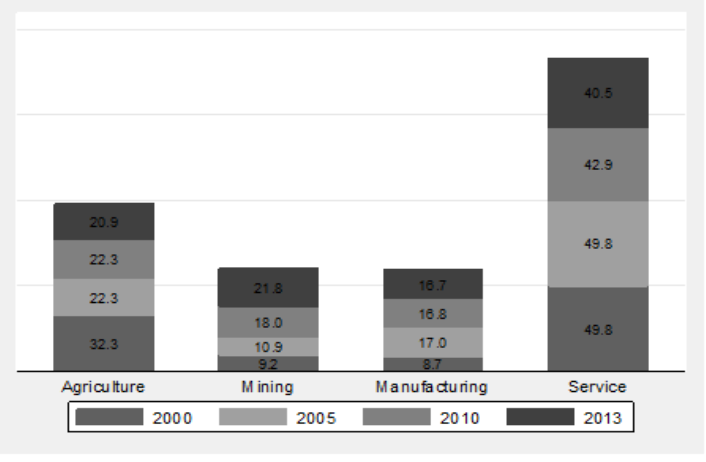
2. BACKGROUND

The economic growth records show that DRC experienced an economic disaster some years after its independence from Belgium in 1960. GDP per capita collapsed from US$350 to US$82 between 1973 and 2001, due to mismanagement, rent-seeking activities, and conflicts. The end of conflicts in 2001 and the establishment of a transitional government composed of representatives of former belligerents gave rise to the implementation of structural reforms that sought to stabilize the economy and create conditions for growth and poverty alleviation. The period of 2002-2012 saw a resurgence of growth, accelerated by the external demand for natural resources by China. GDP recorded a growth of 5.36 percent per year between 2001 and 2005 and of 5.38 percent between 2006 and 2010. More recently, economic growth averaged 6.92 percent, which is high compared to the Sub-Saharan African average of 5.41 percent during the same period. The primary sectors (agriculture and mining) and services remain as the backbone of the DRC economy, contributing 82.3 percent of the GDP in 2013 (Figure 1a).

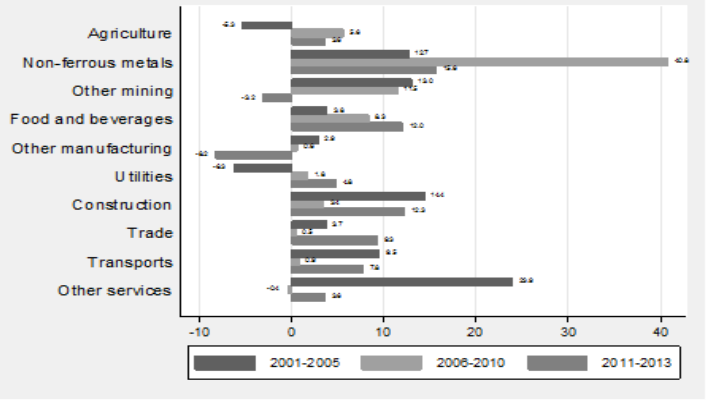
Despite these notable developments, certain important features of the growth pattern, especially in relation to structural change and poverty, are worth noting. The first is the contraction of the other-manufacturing sub-sector (Figure 1b). The real growth of other manufacturing fell at a rate of 8.16 percent between 2011 and 2013. In constant US$, the other-manufacturing sub-sectors grew the least since 2001, specifically by 0.60 percent in 2006-2010 and by 2.86 percent in 2001-2005. One important explanation for this is the lack of growth of labor productivity. In 2001, labor productivity in manufacturing ranked 3rd, after the transportation and communication and mining sectors. However, it decreased by 9 percent in 2000-2005 and by 12 percent between 2005 and 2012. It is only recently that labor productivity in manufacturing has increased, by about 1.3 percent. Another reason for the contraction of the other-manufacturing sub-sector is the obsolete manufacturing base and the high competitiveness of imports. Other manufacturing represents about 15 percent of the manufacturing sector, which in turn is dominated by the production of food, beverages, and tobacco. The output of the food, beverages, and tobacco sub-sector grew by 12 percent in 2011-2013 and by a lesser extent in the previous years. Part of the reason is the low substitutability with imported goods and the improvement in trade, transportation, and communication services, which helped the domestic food and beverages sub-sector to take advantage of the high domestic demand. It is also interesting to observe that the non-ferrous metals sub-sector is the highest growing sub-sector and it is driven by the demand from China. However, other mining is the one affected by the recent slowdown of the Chinese

economy, as it grew by more than 10 percent in 2001-2005 and 2006-2010. Note that this branch, together with non-ferrous metals, accounted for almost 22 percent of the GDP in 2013.

The second salient feature is the small growth in manufacturing employment, probably associated with the contraction of the other-manufacturing sub-sector and the decreasing labor productivity. Figure 1c shows the sectoral division of labor in 2005 and 2012 based on household survey data. The share of manufacturing in total employment rose marginally from 7.5 percent in 2005 to 8.3 percent in 2012, while during the same period, the sector's share in GDP increased annually by about 5.42 percent. The service sector registered the highest employment gains of about 2.2 percent points. Although employment in service has grown more rapidly than in manufacturing, a majority of service employment is provided in lower productive services such as hotels and personal services. In fact, DRC has not succeeded yet to shift labor from the primary sector into more highly productive jobs. The share of employment in the primary sector has decreased only slightly, while trade contracted by 2.7 percent points.

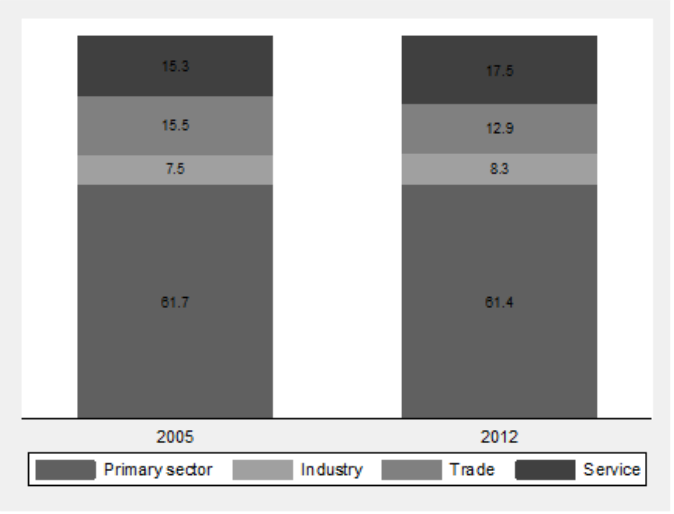


a. Sectoral contribution to GDP

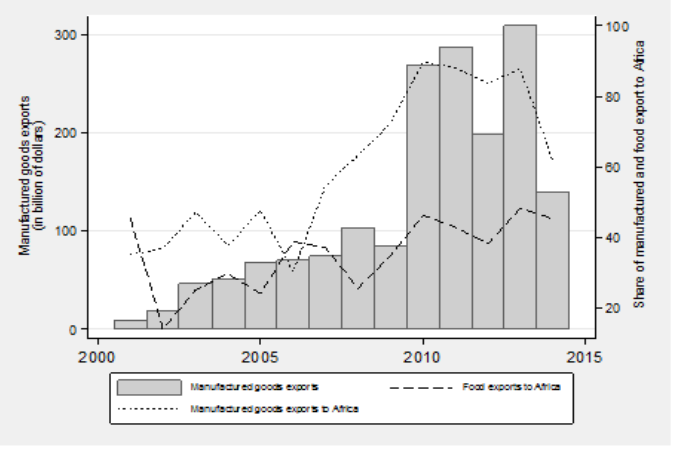


b. Real GDP growth

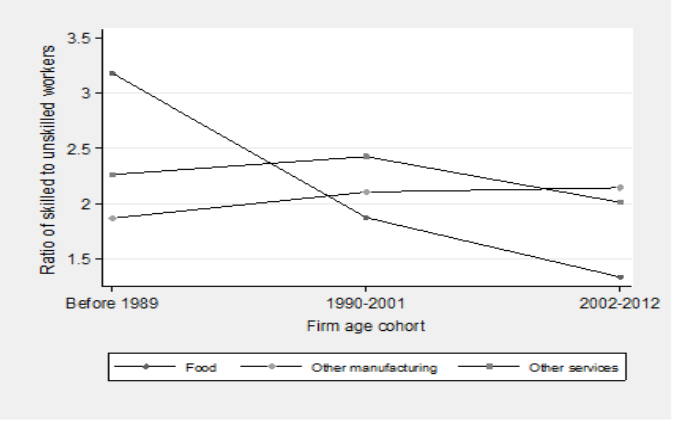
Figure 1. (Continued)



c. Employment share

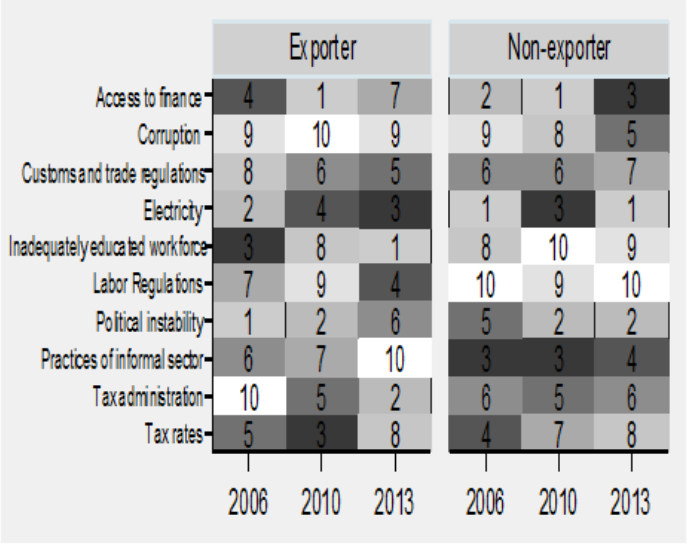


d. Manufacturing goods exports



e. Ratio of skilled to unskilled workers

Figure 1. (Continued)



f. Major obstacles faced by DRC firms (Ranks)

Source: the author.

Figure 1. DRC's economy activity.

The third notable feature of the economic development over the last ten years is associated with manufacturing growth and is related to exports. There are considerable variations of manufacturing exports between different years (Figure 1d). DRC's total manufactured goods exports to Africa as the share of total manufacture export shows the greatest variation, ranging from 35.1 percent in 2001 to 61.6 percent. However, the share of food exports to Africa as the total share of food exports has remained stable. In 2001, food exports to Africa represented almost 45.4 percent, but it dropped to 14 percent in 2002 before picking up again. From a policy perspective, this indicates that food has not been competitive. There are several possible reasons for this, the most plausible being that the food, beverage, and tobacco industry faces the highest transaction costs within the manufacturing sector. According to Otchia (2013), transaction costs in this sub-sector reaches 34.9 percent of the total value of the supply of marketed output, while transaction costs in textiles, chemicals, and wood products are 27.2, 15.9, and 13.3 percent, respectively.

The fourth economic feature worth noting to understand structural change in DRC is the change in the skill mix among newer firms, especially in the food sector, where the ratio of skilled to unskilled workers has been dramatically decreasing. Figure 1e presents the ratio of skilled to unskilled workers in three sectors and across three firm age cohorts, based on the World Bank Enterprise Survey data. Firms created in 1980s use a relatively higher ratio of skilled to unskilled workers, except for other manufacturing, in which the demand of skilled workers relative to unskilled workers has been increasing. Other manufacturing provides better job opportunities for skilled workers due to technological upgrades. Newer firms in the food and service sectors demand more unskilled workers relative to skilled workers, but the changes in the skill composition happen at various speeds. The ratio of skilled to unskilled workers in the service industry increased slightly from 2.3 to 2.4 among firms founded earlier than the 1990s and those entered in 1990-2001, but then decreased to 2 for firms founded after 2002. Part of the reason is that growth in service was driven by ICT and absorbed most

of the workers who moved from manufacturing after the looting of 1991 and 1993. The skilled-unskilled relative demand within the food sub-sector, which started at 3.2 and fell to 1.9 in 1990-2001, and from then onward, the ratio continued downward to an all-time low of 1.4. The steep decline in the ratio of skilled to unskilled workers in the food sector means that newer firms specialized in low-skilled jobs, which reduce their competitiveness against imports. In general, the change in the skilled to unskilled wage ratio equals the change in the ratio of unskilled to skilled labor. In countries like DRC, with ineffective minimum wages and a weak union, these dramatic changes may contribute to national inequality changes, as wage income represents 40 percent of the source of income.

The fifth and final notable feature of growth is the lack of adequate educated workforce, which remains the major obstacle to improving the productivity and competitiveness of export-oriented firms. Figure 1f shows that the inadequately educated workforce was ranked 3rd in 2006 as the major obstacle faced by exporting firms. In 2013, it ranked 1st, indicating a worsening situation for firms who need to recruit workers with appropriate skills to remain competitive in the export market. The recent experience of some African countries like Ethiopia shows the existence of a strong and positive correlation between firm productivity and workers' education and training. In addition, the number of vocational workers is increasing at a slow pace of 16 percent between 2006 and 2013.

3. DATA

This section provides summary information on the data construction and measurement. I present first the data sources, before discussing the variable definition and construction.

3.1. Data Sources

I use the *Enquête 1-2-3* data, which is a mixed households-informal producer's survey on employment, informal sector, and consumption. This survey is carried out in three phases, with nationally representative sample of the population in each stages. The first phase collects information regarding employment and households' economic condition activities. The data collected through the first phase are used to identify household unincorporated enterprises (household whose production unit is not incorporated as a legal entity separate from the owner), which will serve as statistical units for the next stage. The goal of the second phase is to provide information on business conditions, economic performance, and production linkages of the household unincorporated enterprises. Finally, the third phase uses the typical household budget survey to collect information on household consumption.

The analysis uses the 2005 and 2012 waves of the Enquête 1-2-3. The 2005 wave includes a randomly chosen sample of 72,685 individuals, grouped in 12,098 households ("Enquête 1-2-3: Résultats de l'enquête sur l'emploi, le secteur informel et sur la consommation des ménages-2004-2005," 2008). In 2012, the sample is collected from 111,689 individuals in 21,464 households ("Rapport global Enquete 1-2-3: Résultats de l'enquête sur l'emploi, le secteur informel et sur la consommation des ménage-2012," 2014). The First wave was conducted in 12 existing provinces. The provinces were divided into 26

districts, including The Capital Kinshasa. However, the second wave was collected in 36 provinces according to the newly created provinces. The number of districts is 50. This paper aggregates districts in 2012 to match those in 2005 as it is the first year with the most comparable and consistent data over time.

3.2. Key Variables

There are two key variables in this study. The first measures income and the second education. As a measure of income inequality, I use the variable household consumption per adult equivalent. The household consumption expenditures are the annual spending on all goods and services for current consumption, but excluding transfers, construction expenditure, and taxes. It also excludes exceptional expenditures for parties and other ceremonies. Unlike other research on consumption, I include the home-produced consumption as it represents more than 30 percent of total consumption. Concerning educational inequality, I use the years of schooling to measure educational attainment.

3.3. Control Variables

The variables used to control for observed characteristics include a set of variables summarized at district level. I consider the average household size, the share of households that have migrated into the district, the share of workers employed in the informal sector, and the share of workers in agriculture and manufacturing sectors. Descriptive statistics on these variables are reported in Table 1.

Table 1. Descriptive statistics

	2005				2012				Total			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
Household size	5.34	0.55	4.13	6.47	5.10	0.48	3.92	5.88	5.22	0.53	3.92	6.47
Price increase	0.13	0.06	0.03	0.36	0.87	0.06	0.64	0.97	0.50	0.38	0.03	0.97
Migration	0.35	0.14	0.09	0.69	0.30	0.09	0.13	0.50	0.33	0.12	0.09	0.69
Informal sector	0.92	0.03	0.85	0.97	0.87	0.07	0.62	0.96	0.90	0.06	0.62	0.97
Agriculture	0.68	0.16	0.09	0.91	0.62	0.18	0.03	0.84	0.65	0.17	0.03	0.91
Industry	0.07	0.05	0.03	0.20	0.09	0.08	0.03	0.41	0.08	0.06	0.03	0.41
Service	0.24	0.14	0.06	0.79	0.29	0.13	0.08	0.82	0.27	0.14	0.06	0.82

Source: the author.

4. METHODOLOGY

Given the different definitions of educational inequality and income inequality, it is important to use a consistent theoretical framework to define these measures. This section defines and describes the measurements of education and income inequalities.

4.1. Income Inequality

Income distribution is measured by the Gini coefficient, the General Entropy index, the Atkinson index, and the concentration curve.

Gini Index

The Gini index is derived from the Lorenz curve, which plots the cumulative share of total income earned by households ranked from bottom to top. It is measured as the ratio of the area between the 45-degree line and the Lorenz curve, over the total area under the 45-degree line. Gini coefficient takes a value ranged from 0 to 1. A Gini index of zero implies all households have exactly the same income per equivalent adult. A Gini index of one implies one household has all the income, and the others have no income at all. The Gini index is estimated as:

$$\hat{I} = 1 - \frac{\hat{\xi}}{\hat{\mu}} \tag{1}$$

$$\hat{\xi} = \sum_{i=1}^{n} \left[\frac{(v_i)^2 - (v_{i+1})^2}{[v_1]^2}\right] y_i \tag{2}$$

$$V_i = \sum_{h=i}^{n} w_h \tag{3}$$

$$\hat{\mu} = \frac{\sum_{i=1}^{n} w_i y_i}{\sum_{i=1}^{n} w_i} \tag{4}$$

$$w_i = wh_i * ws_i \tag{5}$$

where

wh_i: sampling weight for observation i

ws_i : size of household i

General Entropy (GE) Index

The General Entropy index is estimated by

$$\hat{I}(\theta) = \begin{cases} \frac{1}{\theta(\theta-1)\sum_{i=1}^{n} w_i} \sum_i w_i \left[\left(\frac{y_i}{\hat{\mu}}\right)^{\theta} - 1\right] \; if \; \theta \neq 0,1 \\ \frac{1}{\sum_{i=1}^{n} w_i} \sum_i w_i \log\left(\frac{\hat{\mu}}{y_i}\right) \; if \; \theta = 0 \\ \frac{1}{\sum_{i=1}^{n} w_i} \sum_i \frac{w_i y_i}{\hat{\mu}} \log\left(\frac{y_i}{\hat{\mu}}\right) \; if \; \theta = 1 \end{cases} \tag{6}$$

where

θ: weight given to distances between incomes at different parts of the income distribution

The General Entropy index depends on the value of θ. For θ close to zero, GE is sensitive to changes in the lower tail of the of the income distribution. The GE is equally sensitive to

change across the income distribution if θ equal to one, and sensitive to changes at the higher tail of the income distribution for higher values of θ.

The general entropy index has the following particularities:

- When θ = 1, the General Entropy index is the Theil index,
- When θ = 0, the General Entropy index is equal to the mean log deviation
- When θ = 2, the General Entropy index is half the square of the coefficient of variation

Atkinson Index

Similarly to General Entropy index, Atkinson index places weight in a certain portion of the income distribution in order to determine which part contributes most to the income inequality. Thus, the weight parameter measures the aversion to inequality. The Atkinson index for inequality can be expressed as follow:

$$\hat{I}(\varepsilon) = \frac{\hat{\mu} - \hat{\xi}(\varepsilon)}{\hat{\mu}} \tag{7}$$

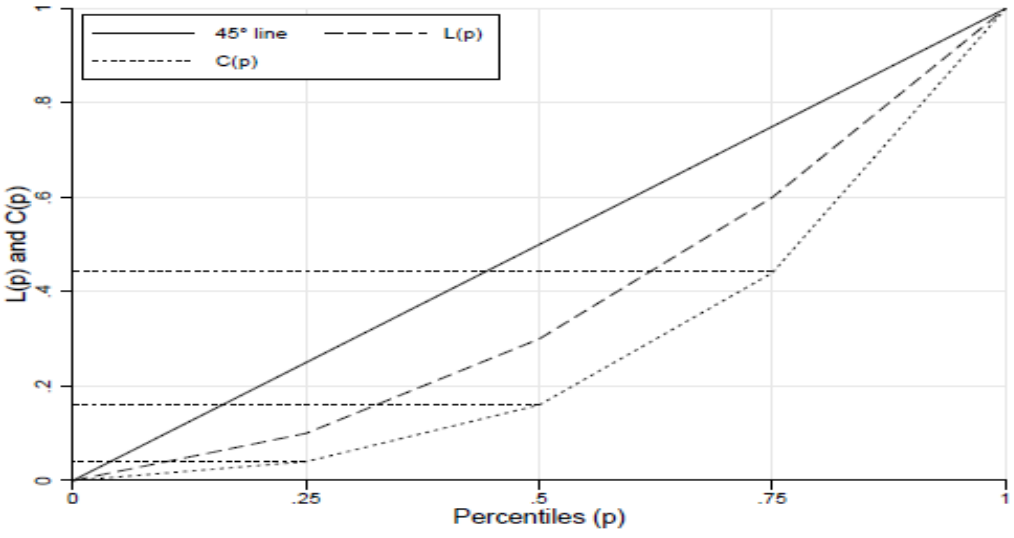
$$\hat{\xi}(\varepsilon) = \begin{cases} \left[\frac{1}{\sum_{i=1}^{n} w_i} \sum_{i=1}^{n} w_i (y_i)^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}} \rightarrow if\ \varepsilon \neq 1\ and\ \varepsilon \geq 0 \\ Exp\left[\frac{1}{\sum_{i=1}^{n} w_i} \sum_{i=1}^{n} w_i ln(y_i)\right] \rightarrow if\ \varepsilon = 1 \end{cases} \tag{8}$$

The Atkinson index for inequality becomes more sensitive to changes in the lower tail of the income distribution as the level of aversion approaches 1 $(\varepsilon \rightarrow 1)$. On the other hand, it becomes more sensitive to changes in the upper tail of the income distribution as the level of inequality aversion falls $(\varepsilon \rightarrow 0)$.

Lorenz and Concentration Curve

The Lorenz and concentration curves are used in this study for capturing the impact of transfer policies on income distribution. The Lorenz curve $L(p)$ is defined as the relationship between the cumulative distribution of income and the cumulative population ranked from the lowest to the highest income. The concentration curve $C(p)$ shows the proportion of total transfer received by the bottom p proportion of the population. This implies that the concentration curve for pre-transfer is similar to the Lorenz curve. However, unlike the Lorenz curve, concentration curves are plotted against some external variables. By plotting concentration curve against the population ranked by income for instance, we are able to display the concentration curves in the same diagram as the Lorenz curve.

- When the concentration curve lies above the Lorenz curve, the poor receive more transfer than the non-poor, relative to their income. This means that the transfer is progressive
- When the concentration curve lies above the 45-degree line, the poor gain more than proportionately to their number.



Source: Abdelkrim and Duclos (2007).

Figure 2. Lorenz and Concentration curves.

4.2. Educational Inequality

I use the years of schooling as an indicator of educational inequality. Unlike other indicators such as the educational attainment which are based in discrete variables, the traditional measures of inequalities (Gini coefficient, the General Entropy index, the Atkinson index, the concentration curve) fit well on the years of schooling (Amidžić, A. Massara, and Mialou, 2014). For example, the Gini coefficient of years of schooling is given by:

$$Gini_{educ} = \frac{n}{n-1}\frac{\sum_{t=1}^{n}\sum_{j=1}^{n}|highest\ grade\ attained_t - highest\ grade\ attained_j|}{2n\sum_{t}^{n} higest\ grade\ attained_t} \quad (9)$$

where

The Theil index can also be written as follows:

$$Theil_{educ} = \frac{\sum_{t=1}^{n} ln\left(\frac{\sum_{j=1}^{n} highest\ grade\ attained_j}{n\times higest\ grade\ attained_t}\right)}{n} \quad (10)$$

4.3. Estimation Strategy

The empirical specification of the effect of education inequality x on income inequality y is as follows:

$$\mathrm{y}_d = \alpha + \beta x_d + \delta Z_d + u_d \quad (11)$$

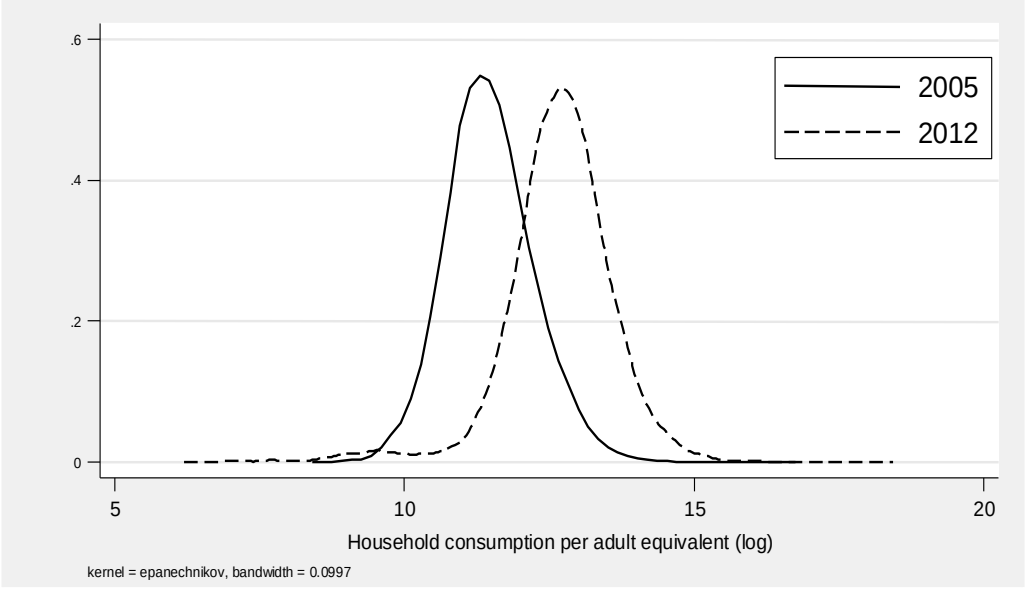
Where β represents our primary predictor of interest and is measured either as a Gini index of years of schooling, or as the average of years of schooling; Z includes controls for household size, price level, migration, and labor composition.

5. Pattern of Income and Educational Inequalities

In this section, the objective is to examine to extent to which the recent economic growth has affected income and education. This section asks a specific question to whether growth has benefited to the poor.

5.1. Growth Has Led to Increase in Income

The history of economic development suggests that economic growth is the key engine of income growth and poverty reduction. However, the extent to which growth reduces poverty depends largely on the source of growth and the factor endowment of those who participate in the growth process. Figure 3 presents the distribution of income in DRC between 2005 and 2012. The graph represents the kernel density estimates of the income for the two years. One of the most striking features is that the 2012 distribution has moved to the right. This implies that growth has led to an increase in the average income of the Congolese. The two shapes are almost similar but small differences appear in the tails of the distributions. It can be clearly seen that the tails of the income distribution in 2012 are very large that those of 2005. This implies that inequality has increased largely between the poorer and the richer.



Source: The author.

Figure 3. Lorenz and Concentration curves.

Table 2 extends the income analysis by estimating a set of inequality measures for the two waves of the dataset. The column "changes" depicts the difference in the inequality measures between 2012 and 2005. A positive sign means that inequality has increased whereas a negative sign implies a reduction of inequality in the district. This table is quite revealing in several ways. First, it shows that all the inequality measures provide consistent estimates across districts, and the difference in magnitude of the changes highlight the fact that the changes in inequality are very sensitive in different parts of the income distribution. Second, it can be seen that income inequality grew in many districts (20 out of 26) and fell in only 6.

Table 2. Income inequality

	Gini		Atkinson (0.5)		Atkinson (1)		GE(0)		GE(1)	
	2005	Changes	2005	Changes	2005	Changes	2005	Changes	2005	Changes
Kinshasa	0.41	0.02	0.14	0.09	0.25	0.25	0.29	0.30	0.34	0.00
Bandundu	0.33	0.08	0.09	0.27	0.16	0.38	0.17	0.43	0.19	0.24
Kikwit	0.37	0.14	0.11	0.60	0.21	0.55	0.23	0.66	0.23	0.28
Kenge	0.35	0.03	0.10	0.01	0.18	0.12	0.19	0.13	0.23	-0.11
Tembo	0.32	0.61	0.08	1.85	0.15	1.39	0.16	1.74	0.17	2.61
Mbanza-ngungu	0.28	1.24	0.07	5.09	0.12	3.30	0.13	4.71	0.15	8.92
Matadi	0.41	-0.01	0.14	0.05	0.25	0.25	0.28	0.31	0.32	-0.09
Mbandaka	0.41	0.02	0.13	0.09	0.24	0.10	0.27	0.12	0.30	0.09
Boende	0.33	0.22	0.09	0.51	0.17	0.51	0.18	0.59	0.18	0.56
Lisala	0.32	0.19	0.09	0.38	0.16	0.37	0.18	0.42	0.21	0.41
Gbadolite	0.42	-0.10	0.14	-0.17	0.27	-0.18	0.32	-0.21	0.31	-0.13
Kisangani	0.34	0.04	0.10	0.14	0.18	0.24	0.19	0.28	0.21	0.09
Isiro	0.32	0.28	0.09	0.76	0.16	0.58	0.18	0.68	0.19	1.07
Bunia	0.40	0.47	0.13	1.83	0.23	1.18	0.26	1.66	0.27	3.96
Goma	0.41	0.32	0.14	0.88	0.25	0.82	0.29	1.10	0.31	1.19
Bukavu	0.35	0.13	0.10	0.29	0.18	0.33	0.20	0.38	0.22	0.26
Kindu	0.35	0.34	0.10	1.17	0.18	1.57	0.20	2.15	0.21	0.91
Lubumbashi	0.43	-0.09	0.15	-0.14	0.26	-0.14	0.31	-0.16	0.33	-0.12
Kamina	0.38	-0.10	0.11	-0.16	0.21	-0.14	0.23	-0.15	0.25	-0.17
Manono	0.30	1.85	0.07	8.81	0.14	5.14	0.15	12.43	0.16	7.14
Kolwezi	0.33	0.82	0.09	3.01	0.16	2.92	0.18	4.74	0.19	2.37
Dilolo	0.33	0.55	0.08	1.64	0.16	1.24	0.18	1.55	0.17	2.22
Mwene-ditu	0.38	0.04	0.11	0.09	0.21	0.08	0.24	0.09	0.25	0.11
Mbuji-mayi	0.45	-0.16	0.16	-0.20	0.29	-0.20	0.35	-0.23	0.36	-0.12
Kananga	0.34	0.12	0.10	0.26	0.18	0.28	0.19	0.32	0.22	0.24
Luebo	0.49	-0.42	0.23	-0.73	0.35	-0.64	0.42	-0.69	0.76	-0.83

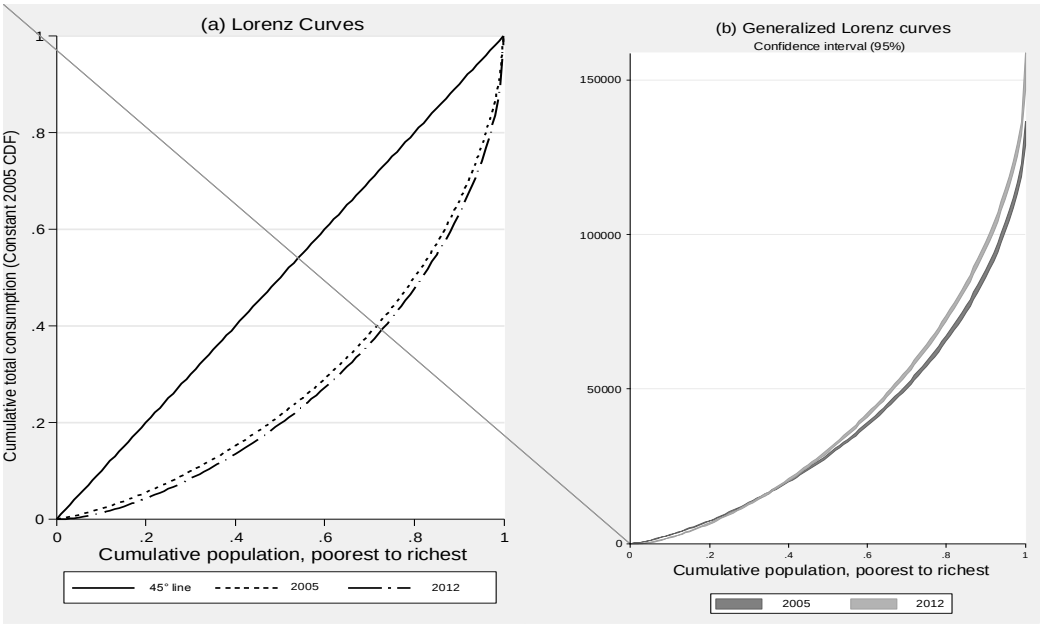
Source: the author.

5.2. The Poor Has Been Left Behind

In addition, it is important to understanding whether the economic growth described above has been pro-poor. Pro-poor here which refers to a growth that reduces inequality and in which the consumption of the poor increases more than the population average. I conduct the distribution analysis in two parts. In the first part, I examine the 2005 and 2012 consumption data from the household surveys to compute the distribution of household expenditure based on the Lorenz curves and the Gini coefficient for the two periods. This is an important step, since inequality influences how economic growth translates into poverty reduction. Next, I use the growth decomposition framework, which has been popularized by

Kakwani (2010), to estimate the pro-poorness of the 2005-2012 growth and measure its contribution to poverty reduction.

The income distribution in Figure 4 clearly shows that, during the period of 2005-2012, DRC experienced a sharp increase in inequality. The degree of inequality, measured by the Gini coefficient, increased from 0.43 in 2005 to 0.47 in 2012. The difference between the Gini coefficients is statistically significant, meaning that DRC is becoming a more unequal country. For instance, the poorest 40 percent of the population in 2005 consumed 15.1 percent of total consumption while in 2012, the poorest 40 percent consumed 13.9 of total consumption. However, comparing these estimates with countries in the region, one finds that DRC inequality is quite high but just below the top 15 unequal countries. According to IMF (2007), the initialy high inequality in DRC is due to the existence of distributive injustice, discrimination, and virtually endemic exclusion in the country.



Source: the author.

Figure 4. Changes in income inequality (national level).

On the other hand, the increase in inequality is somehow related to the changes in the composition of income source, due to structural change. In 2005, wage income represented 42.54 percent of household income. Self-employed in agriculture and non-agriculture accounted respectively for 26.85 and 28.24 percent, and transfers for 2.38 percent. Recently, self-employed non-agriculture has become the main source of income accounting for 39.40 percent, followed by wage income (37.44%), self-employed agriculture (21.49%), and transfers (1.67%). The wage income gap between 10th decile and 1st decile has also increased. Looking to the changes in total consumption across the distribution, Figure 4 panel (b) shows that growth has led to a significant increase in the income of the richest 50 percent, as the real consumption is higher from the top 50 percent of the population in 2012 than it was in 2005.

However, growth has also left the poor behind and the consumption of the poorest has partially deteriorated: the real consumption of the population between the 20th and 50th

percentile has not statistically changed whereas that of the poorest 20 percent is slightly decreased. Despite the fact that the higher income part of the population received higher income, the 2005-2012 growth has led to poverty reduction. In 2005, 71.3 percent of the DRC population lived in households with incomes below the poverty line. From 2005 to 2012, poverty fell annually by 1.66 percent for an overall annual growth of 6 percent. To understand the source of the poverty reduction, I decompose the annual poverty change into the pure growth effect and the redistribution effect, and present the estimates in Table 3. The growth-redistribution decomposition indicates that the growth effects contributed to alleviate poverty whereas the redistribution effects contributed to increase poverty. If inequality did not increase, the 2005-2012 growth would have reduced poverty by 1.70 percent. Thus, the recent increase in inequality was responsible of 0.04 percentage points of poverty.

Table 3. Growth-redistribution decomposition

	P_0	P_1	P_2
Growth-redistribution decomposition			
Annual poverty change	-1.66	-2.76	-3.06
Growth	-1.80	-3.21	-3.73
Redistribution	0.14	0.45	0.67

Source: the author.

Table 4. Educational inequality

	Educational inequality		Mean of years of schooling	
	2005	Changes	2005	Changes
Kinshasa	0.20	0.04	9.76	0.50
Bandundu	0.25	0.12	8.08	-0.65
Kikwit	0.23	0.15	8.03	-1.09
Kenge	0.28	0.19	7.63	-1.81
Tembo	0.30	0.12	7.29	-0.79
Mbanza-ngungu	0.26	0.12	7.58	-0.96
Matadi	0.27	0.11	7.84	-0.47
Mbandaka	0.28	0.08	7.17	-0.01
Boende	0.26	0.21	6.38	-0.80
Lisala	0.28	0.12	6.83	-0.75
Gbadolite	0.28	0.27	6.43	-1.77
Kisangani	0.31	0.13	6.04	-0.19
Isiro	0.28	0.18	5.89	-0.89
Bunia	0.29	0.27	6.22	-1.23
Goma	0.30	0.18	6.84	-0.71
Bukavu	0.28	0.20	7.16	-1.58
Kindu	0.28	0.15	6.69	-0.41
Lubumbashi	0.27	0.08	8.08	0.01
Kamina	0.29	0.18	6.25	-0.68
Manono	0.31	0.31	6.02	-2.36
Kolwezi	0.31	-0.04	6.55	2.09
Dilolo	0.30	0.27	6.21	-2.12
Mwene-ditu	0.26	0.10	7.39	-0.48
Mbuji-mayi	0.30	0.11	6.48	-0.48
Kananga	0.27	0.10	7.39	-0.72
Luebo	0.26	0.14	7.30	-0.50

Source: Author's.

5.3. Education Inequality

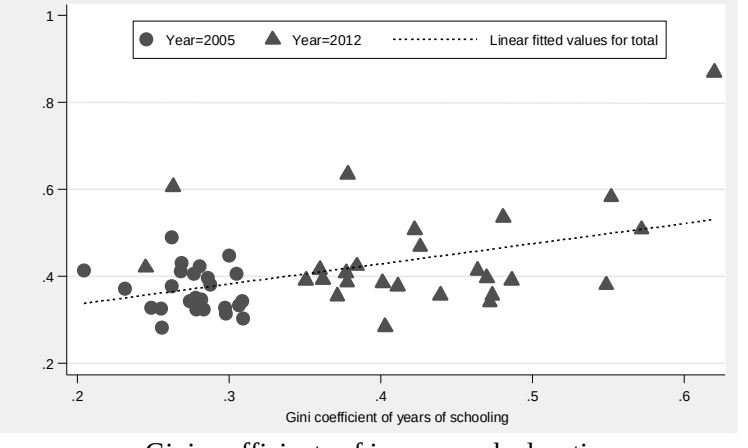
Turning now to the educational inequality, Table 4 indicates that the district-level disparities grew in all districts except in Kolwezi. At the same time, the average years of schooling increased in only two districts, namely Kolwezi and Kinshasa. It is surprising to find that the increase in the average of the years of schooling is related to higher educational inequality in Kinshasa and lower educational inequality in Kolwezi.

6. RESULTS

This section presents the results of the impact of educational inequality on income inequality. First, the correlation analysis between income and educational inequalities is presented. Then, the causal relationship on how educational inequality affects income inequality is estimated and discussed.

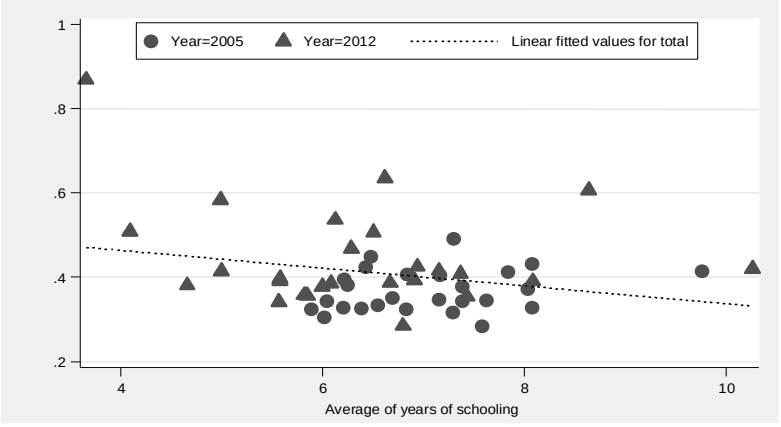
6.1. Correlation Analysis

Figure 5 presents the correlations across the measurements of inequalities. The panel (a) of the figure display the correlation between the Gini coefficients of income and education. While there are many disparities, particularly in 2012, the income inequality is positively related to income inequality. This is consistent with the intuition and historical evidence that high educational inequality reduces the opportunities for jobs and positive resource allocation, which in turn leads to higher income inequality. The correlations between income inequality and the average year of schooling, which are plotted in Figure 5 panel (b), provide similar qualitative results. The graph shows a decreasing relationship between income inequality and the average year of schooling. This means that an increase in the average year of schooling is related to lower income inequality.



a. Gini coefficients of income and education

Figure 5. (Continued)



b. Income inequality and average years of schooling

Source: Author's.

Figure 5. Correlation between income and educational inequalities.

6.2. Regression Results

Table 5 presents the results from the panel estimations with the Gini of educational inequality as the main outcome variable and incorporates both measures of educational inequalities: Gini of the years of schooling and the average year of schooling. Columns 1 and 2 depict the model with the Gini of years of schooling. I find that the Gini of years of schooling is positively correlated with the Gini of income inequality. The result in column 1 shows that a one percent increase in the Gini of years of schooling lead to an increase of 0.513 percent of the Gini of income distribution. When adding the control variables in column 2, I find that the Gini of educational inequality remains significantly related to the Gini of income inequality. The size effect doesn't change significantly, as an increase in the Gini of years of schooling generates 0.514 percent increase in the Gini of income distribution.

Table 5. Estimation results

	Model 1	Model 2	Model 3	Model 4
Gini of years of schooling	0.513***	0.514***		
	(0.170)	(0.187)		
Average year of schooling			-0.0653**	-0.0732***
			(0.0268)	(0.0238)
Controls		Yes		Yes
Fixed effects	Yes	Yes	Yes	Yes
Constant	0.296***	-0.689	0.923***	0.309
	(0.0907)	(0.545)	(0.205)	(0.459)
Observations	52	52	52	52
Number of years	2	2	2	2
R-squared	0.2104	0.5466	0.3977	0.6146

Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1.
Source: the author.

It is worth mentioning that the estimates proved to be robust throughout all the other specifications. For example, the specification in column 3 uses the average year of schooling as the main predictor and confirms the benefit in educational attainment in reducing income inequality. The findings show that one percent increase in the years of education lowers the educational inequality by 0.0653 percent. The column 4 incorporates the control variables. The effects of years of schooling on income inequality are larger and statistically significant.

6.3. Alternative Measures of Educational and Income Inequality

In Table 6, I test whether the results are robust to alternative measures of income and educational inequality. The inequalities variables associated with income and years of schooling are measured using the Atkinson index (column 1), the Theil index (column 2), and the General entropy index (column 3). The control variables in each specification are associated with the average household size, the share of households that have migrated into the district, the share of workers employed in the informal sector, and the share of workers in agriculture and manufacturing sectors. The results of these robustness regressions provide two main insights. First, inequality in years of schooling is positively related to income inequality. Second, regressions suggest the impact varies according to the indicators used to measure educational and income inequality.

Table 6. Robustness analysis

	Model 1	Model 2	Model 3
Atkinson (0.5)	0.883**		
	(0.364)		
Theil		3.039*	
		(1.547)	
General entropy (2)			30.46*
			(17.78)
Controls	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes
Constant	-0.958*	-2.594*	-6.654
	(0.495)	(1.553)	(14.47)
Observations	52	52	52
Number of years	2	2	2
R-squared	0.3412	0.4284	0.2396

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: the author.

CONCLUSION

In this paper, I used a rich and recent dataset from DRC to construct a district-level panel data and study the relationship between income inequality and educational inequality. The dataset is derived from the two waves of the Enquête 1-2-3 conducted in 2005 and 2012. I

proceeded as follows. Since the configuration of the two waves differs in terms of the districts, I matched the 2012 districts with those in 2005. Then, I constructed inequality measures by applying the traditional measures of inequality—Gini, Atkinson, Theil, and General Entropy—on income and years of schooling. After an extensive descriptive analysis to understand the pattern of inequality changes and the extent to which the economic progress between 2005 and 2012 has affected inequality, I used econometric models to explain how income inequality is related to educational inequality.

I found that the recent growth has led to an increase of income. However, growth has left the poor behind because the income of the very poor remained almost constant. In addition, the lack of redistribution policy has contributed to increasing income inequality. The findings on the educational inequality suggest that the average year of schooling has decreased while educational inequality increased in almost all the districts.

The empirical findings provide support to the role of education in reducing income inequality. The econometric results that an increase in the average year of schooling is inversely related to changes in income inequality highlight the importance of designing policies to increase access to education and reduce dropouts in DRC. The main policy implication of this study is that reducing the gap in years of schooling between the least and the most education should be a key priority. Government should invest more in the increasing the access to school in the remote and post-conflict regions. The government should also implement policies to increase retention and promote higher education as well as vocational training.

REFERENCES

Amidžić, G., A. Massara, and Mialou, A. (2014). Assessing Countries' Financial Inclusion Standing: A New Composite Index *International Monetary Fund Working Paper No. 14/36*. Washington, DC.

Barro, R. J. and Lee, J.-W. (2010). A New Data Set of Educational Attainment in the World, 1950-2010. *National Bureau of Economic Research Working Paper Series, No. 15902*. doi: 10.3386/w15902.

Card, D. (1999). Chapter 30 - The Causal Effect of Education on Earnings. In C. A. Orley and C. David (Eds.), *Handbook of Labor Economics* (Vol. Volume 3, Part A, pp. 1801-1863): Elsevier.

INS.(2008). Résultats de l'enquête sur l'emploi, le secteur informel et sur la consommation des ménages:2004-2005. Kinshasa.

_____.(2014). Résultats de l'enquête sur l'emploi, le secteur informel et sur la consommation des ménages:2012. Kinshasa.

Hanushek, E. A., Schwerdt, G., Wiederhold, S. and Woessmann, L. (2015). Returns to skills around the world: Evidence from PIAAC. *European Economic Review, 73*, 103-130. doi: http://dx.doi.org/10.1016/ j.euroecorev.2014.10.006.

Heckman, J. J., Humphries, J. E., Veramendi, G. and Urzua, S. S. (2014). Education, Health and Wages. *National Bureau of Economic Research Working Paper Series, No. 19971*. doi: 10.3386/w19971.

Heckman, J. J. and Mosso, S. (2014). The Economics of Human Development and Social Mobility. *National Bureau of Economic Research Working Paper Series, No. 19925*. doi: 10.3386/w19925.

IMF. (2007). Democratic Republic of the Congo: Poverty Reduction Strategy Paper *IMF Country Report No. 07/330*. Washington, D.C.: International Monetary Fund.

Kakwani, N. (2010). On measuring growth and inequality components of poverty with application to Thailand. *Journal of Quantitative Economics*, *16*(1), 67–79.

Otchia, C. S. (2013). How could industrial structure guide the choice of development strategy? A field of influence analysis for the Democratic Republic of Congo. *The International Journal of Economic Policy Studies*, *8*(1), 89–112.

Otchia, C. S. (2014). Agricultural Modernization, Structural Change and Pro-poor Growth: Policy Options for the Democratic Republic of Congo. *Journal of Economic Structures*, *3*(1), 1-43. doi: 10.1186/s40008-014-0008-x.

Otchia, C. S. (2015). Mining-based growth and productive transformation in the Democratic Republic of Congo: What can an African lion learn from an Asian tiger? *Resources Policy*, *45*, 227-238. doi: http://dx.doi.org/ 10.1016/j.resourpol.2015.06.003.

In: Handbook on Africa
Editor: Whitney Sherman
ISBN: 978-1-53610-063-1

Chapter 14

WHICH DEMOGRAPHIC QUINTILE BENEFITS FROM PUBLIC HEALTH EXPENDITURE IN NIGERIA: A MARGINAL BENEFIT ANALYSIS*

Kanayo Ogujiuba,† PhD and Nancy Stiegler, PhD
Statistics and Population Studies Department,
University of the Western Cape, South Africa

ABSTRACT

In the last twenty years, policy makers have come to an understanding that for poverty reduction to be sustainable and welfare benefits distributed evenly, social investments must act as a catalyst. Thus, no meaningful progress in sustainable development can be made when the level of inequality level is continuously rising and benefits of government expenditure unevenly shared. At the moment, Nigeria is one of the twenty poorest, most unequal societies in the world, with just half of the population controlling 5 percent of national resources. Productive sectors in Nigeria have considerably shrunk in size since the 1980s, to the extent that about 70 per cent of the population lives below the poverty line, which is deep, severe and pervasive. This raises concerns and questions on demographic dividends from investments in the social sector. Data for research was obtained from ministries of health as well as private service-providers in the SE region of Nigeria. Marginal Benefit Incidence Analysis was used in estimating the benefits of various quintiles by combining information about unit costs of providing services with information on the use of these services. Thus, this chapter focused on the distribution of beneficiaries across different demographic groups from services rather than measuring the exact value to recipients of government-sponsored services. Results indicate that the states in the South East (SE) Nigeria subsidized the rich in the society. The chapter recommends effective discretionary targeting of expenditure, and the less privileged in government expenditure programmes. This is a potent strategy for curtailing poverty and inequality in the system and would serve as a means of sustaining societal growth and economic progress.

* An Excerpt from a PhD Thesis (2014) in the Statistics and Population Studies Department, Faculty of Natural Sciences, University of the Western Cape, Cape-Town, South Africa

† Address correspondence to: kannyog@gmail.com

Keywords: expenditure, poverty

JEL Classification Numbers: A11, A13, G31, G32, G38

1. SOCIAL INVESTMENTS AND POVERTY REDUCTION

In most developing countries, Nigeria inclusive, government forms a large bulk of economic activity (Agu and Aldo, 2013) and one major challenge to government at all levels is the decision they make in organizing and distributing resources. However, the nexus between government expenditure and economic growth has been debated constantly among scholars. This includes protection and security of lives and properties and the provision of public and social goods such as defense, good roads, education, and health. Thus, government allocates resources to perform these basic functions, while some scholars argue that an increase in government expenditure promote growth (Al-Yousif, 2000; Ranjan and Sharma, 2008; Cooray, 2009), others argue that government expenditure undermines economic growth (Laudua, 1986; Engen and Skinner, 1992; Folster and Henrekson, 2001). For the last two decades, poverty reduction and public expenditure nexus have taken the center stage (Aigbokhan, 2000), with no agreeable framework on the dynamics.

Over time, economists and demographers have come in agreement that for even benefits across population groups, poverty reduction to be sustainable, social investments in education and health sector should be given high priority. Furthermore, Addison and Cornia (2001) suggest that no meaningful progress in sustainable development can be made when the level of inequality level is continuously rising, which is in contradiction with earlier development theories that inequality is good for growth and poverty reduction. This dichotomy is calling attention to the actual role of health infrastructure in economic growth vis-à-vis poverty reduction. However, much of contemporary debate on the nexus between public expenditure and demographic dynamics has been on what is the right size for a population and implications for standards of living and no emphasis on who gets what, when and how. No doubt, that the efforts by most populous countries to provide an acceptable living condition in terms of social services are constantly frustrated with rapid population growth, without a commensurate increase in economic growth. Therefore, the benefit incidence amongst the different quintiles becomes very pertinent.

The relationship between inequality, poverty and demographic dividends from public health expenditure is part of a larger cycle, where inequality and poverty leads to ill health and ill health due to lack of any substantial benefits sustains the twin evils. Available statistics suggest that people in emerging and transition countries tend to have less access to health services than those in better-off countries, and within countries, the poor have less access to health services. Although a lack of financial resources or information can create barriers to accessing services in developing countries, the causal relationship between benefits to health services and poverty also runs in the other direction. When health care is needed, but is delayed or not obtained, people's health worsens, which in turn leads to lost income and

higher health care costs, both of which contribute to negative outcomes. Lack of health care dividends by the vulnerable could lead to ill health, and worsened poverty levels[1].

Nonetheless, Nigeria has become a reference point for high inequality, economic growth and poverty levels. This has become so, more especially since the oil boom of the 1970s and the current rebasing (2014) of the Nigerian Economy, making it the biggest in Africa. This development paradox stands out when compared with similar comparable countries in Africa and Asia based on their collective history. The current per capita income in Nigeria is still very minimal in real terms and less than the 1975 estimate, despite the receipt of about two hundred and eighty-eight million dollars (USD288) in total oil revenue from 1975 to 2010[2]. Adejuwon and Adekunle (2012)[3] sums it up that about 70 per cent of the population lives below the poverty line and poverty is deep, severe and pervasive in the country. At the moment, Nigeria is one of the twenty poorest, most unequal societies in the world, with just half of the population controlling 5percent of national resources (Temitope, 2008). This raises the question of what has happened to all the investments in the social sector and who is benefiting from government expenditure.

Bridging the income margin between the rich and the poor as well as the efficient allocation of resources is necessary as part of a larger strategy to design and implement a sustainable developmental framework. Ogundipe and Lawal (2013) maintain that such a design would reduce poverty to some extent, especially if funds are well targeted towards health and education. Nonetheless, households in Nigeria are divergent in their ability to access and utilize services provided by the government (Diejomaoh and Eboh 2010). Most often, it is households in the upper income group which may reap larger benefits from public spending (health and education) programs (Suberu 2001). As a palliative to expenditure cutback, Ravallion (2002) argues positively for safety net measures, which would reduce the negative effects on expenditure, more especially on the vulnerable. One of such could be an effective targeting of health expenditure across different population groups.

According to Obansa et al. (2013) and retrieved from www.mcer.org, basic life-saving commodities are in short supply in lower income health systems. In these countries, provision of health related services depends on the availability of relevant equipment, drugs and infrastructure. Therefore, in the light of this, a constant and fundamental component of health management is an effective and accountable framework for procurement. In most states of Nigeria, several health facilities are without portable drinking water, electricity, dysfunctional equipment, etc. Health system is grossly inadequate, most especially at the Primary Health-care level (Obansa and Orimisan, 2013). Furthermore, poor state of infrastructure such as buildings, materials, equipment, and supplies and inequitable distribution of available facilities is the norm in many places in Nigeria.

Furthermore, uncertainty of drug supplies, which is common across the country and lack of basic amenities, has been traced to importation dependency of the health system in the country. The lack of updating of the pharmaceutical regulations could also be responsible for this ambivalence which has resulted in a complete chaotic drug distribution framework in the country. A clear negative fall-out of this scenario is the observed resistance to some drugs by the disease pathogens in some patients (HERFON, 2006, FMoH, 2004, Travis et al., 2004).

[1] The vulnerable in most of sub-Saharan Africa is particularly at risk.
[2] Furthermore, the productive sectors of the economy have considerably shrunk in size since the 1980s.
[3] Poverty is also becoming *dynastic* in Nigeria—with the threat that the children of the poor are also likely to end up poor (Ehigiene 2007).

Nonetheless, without functional health facilities and qualified personnel, the availability of drugs alone would not improve the quality of health service. Vital to the provision of a functional health system is the former. However, it is common knowledge that in most communities in Nigeria, people travel several kilometers for basic health care services and in some case if not most, some these facilities are based on political expediency rather than economic rationality because they lack adequate professionals. Poor services at public health institutions in Nigeria have prompted the use of unorthodox medicines by most people, and for the privileged rich, the use of private health facilities (Ravi Rannan-Eliya, 2008), in addition to government hospitals.

The Nigerian government has been resorting to social spending discretions to alleviate poverty, thus it has become imperative for the government to understand the distributional outcomes from such expenditure. Marginal Benefit Incidence Analysis has assumed a center stage in most policy evaluations. The technique is normally used in assessing the distributional impact of government expenditure in addition to determining which demographic group benefits from the government (cash or in-kind). The underlying framework is that benefits derived from government expenditure should be shared disproportionately so that the lowest strata benefits more than those on a higher quintile. This implies that government spending according to the Keynesian model, should correct failures in the system, while promoting efficiency and equitable distribution of resources.

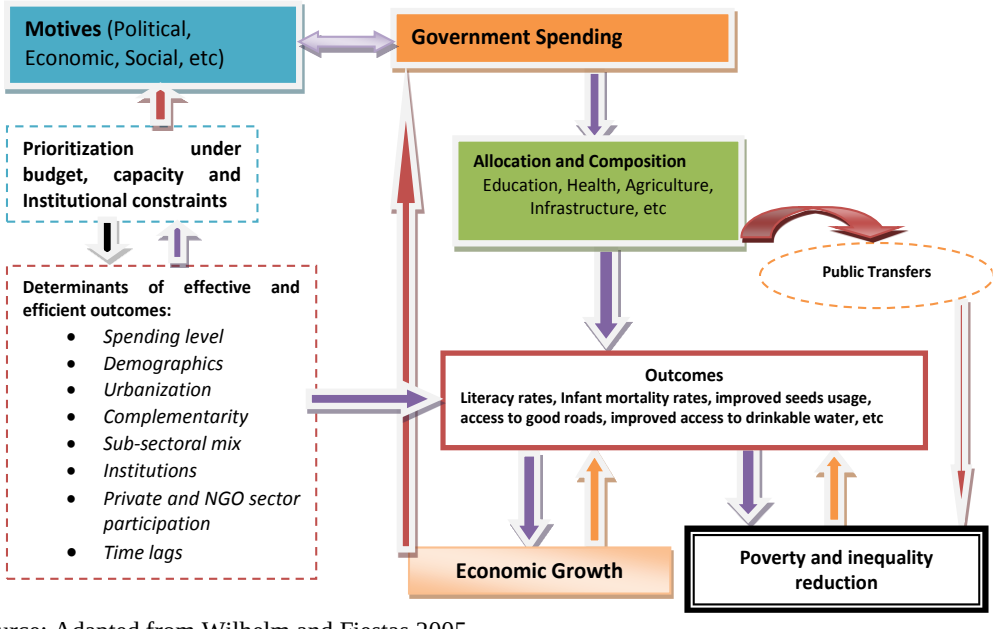
2. CONCEPTUAL FRAMEWORK

Fan, Zhang, and Zhang (2002) report that social expenditure reduced the rural poverty rate effectively. Jung and Thorbecke (2003) study also confirms that government social sector spending contributes to economic growth and supports poverty reduction. According to Lipton and Ravallion (1995), the poor that had less access to the infrastructure in the past can have larger benefits from new investment in health infrastructure. They came to this conclusion from their study on the effects of government expenditure on poverty. Also, in a study by Jung, et al. (2009) the marginal effects of government expenditures on poverty alleviation has generally weakened over time. Their analysis stands out in two ways: (1) contributes to the expanding literature on effects of government expenditure on poverty reduction by determining how the effects on poverty of four categories government expenditures have changed over time and compared these changes among categories; and (2) the study analyzed spatial variation in the effects of government expenditure on poverty across counties using GWR and LISA clustering. Their analysis further examined marginal effects of government expenditure on poverty reduction in each of the identified poverty clusters including the identification of poverty ‘hot-spots’.

There are divided opinions and findings on the relationship between public sector spending and economic performance though most scholars are in agreement that there are circumstances in which decreased government spending would enhance economic growth and other circumstances in which increased government spending would be sought-after. Therefore, the connection between economic growth and government spending is bi-directional, particularly with growth and sectoral outcomes, in that higher growth leads to improved sectoral outcomes (better schools, health indicators, road access, etc.) while

enhanced sectoral outcomes will correspondingly lead to superior growth (in particular investment in health education and infrastructure is associated with higher growth rates). Looking at the theoretical underpinnings of public spending effects, it becomes imperative to look at the motive and its linkages with economic growth, poverty and inequality reduction for it to have the desired effect on distributional outcome.

Available literature suggests that exceptional variables which could hamper or effect positively public spending outcome are the roles of regulatory framework and private sector interventions because of their multiplier effect on service provision to the poor. According to Wilhelm and Fiestas (2005) government spending is driven by the objective to positively affect growth and poverty reduction through improved provision of social services. However, achieving this objective depends to a great extent on specific issues and initial conditions within a country.



Source: Adapted from Wilhelm and Fiestas 2005.

Figure 1. Public Spending Motives, Determinants and Linkage with Growth and Poverty Reduction

Figure 1 above shows the linkage which indicates that motives (political, economic, social, etc.) have effects on public spending while capacity and institutional constraints do affect motives behind public spending. The diagram also shows that effective and efficient outcomes could be determined by spending level; demographics; level of urbanization; complementarity; sub-sectoral mix; strength of institutions; the level of participation for private and NGO sector as well as time lags.

The relationship between public spending and poverty has gained sufficient attention in the literature and Economists are in agreement that expenditure on growth drivers has the capacity to reduce poverty and increase human capabilities. Asghar, et al. (2012) posits that economic growth and poverty reduction could occur with government spending on the social sector which would positively affect economic development. Nonetheless, investments in health, education and generally on the social sector were the mantra in the 1990s for the

World Bank in its poverty Reduction Strategies Programmes. They argued that boosting human capital formation reduces the level of poverty. Human resources according to the World Bank enrich human capabilities and productivity level of the people, which has the capacity to reduce poverty and increase income level through improved opportunities. Their results imply a positive reduction of poverty as expenditure is focused on social issues and the opposite when expenditure is focused on deficit financing, economic and community services in Pakistan.

Nonetheless, the relationship between public spending and poverty has gained sufficient attention in the literature. Demographers are in agreement that expenditure on growth drivers has the capacity to reduce poverty and increase human capabilities which is depicted in Figure 1. Asghar, et al. (2012) posits that economic growth and poverty reduction could occur with government spending on the social sector which would positively affect economic development. Also, according to Fan, Hazell, and Thorat (2000) expenditures on roads, research, and development have the largest impacts on poverty reduction in their study using India. Howbeit results from Gomanee et al. (2005) show the need for new strategies in combating poverty rates, because spending on social services is not as effective as it should be in poverty reduction. This has generated a lot of debate on how effective, the targeting mechanism of government of Nigeria is.

2.1. Federal Government Expenditure on Health in Nigeria

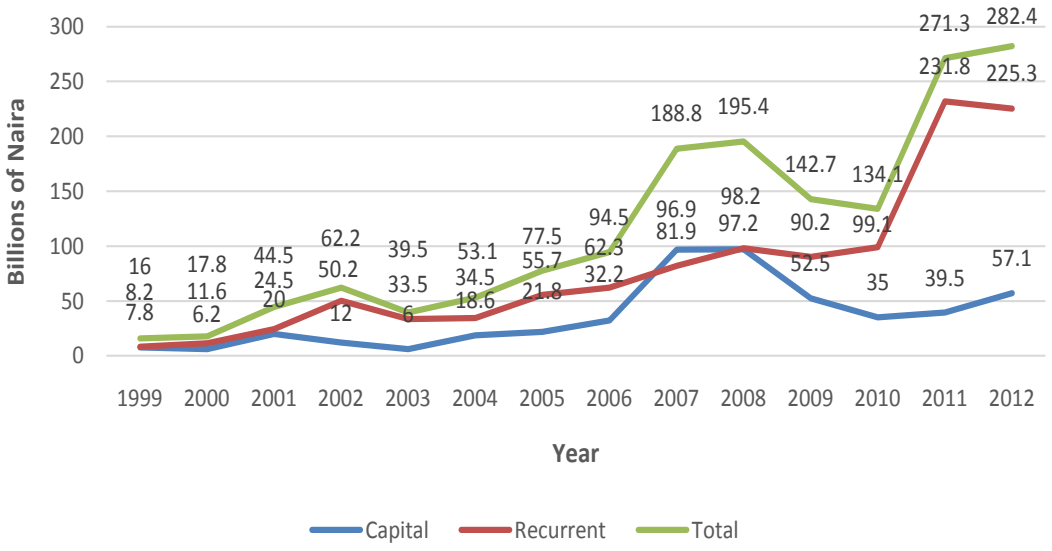
Public expenditure on health has not followed a definitive pattern between 1999 and 2012. The percentage increased from 1.7 in 1999 to 2.7 per cent in 2000, 4.4 per cent in 2001 and 6.2 per cent in 2002 respectively. In 2003, the share reduced to 3.2 percent. Though, health expenditure was 4.2 percent in 2004 and declined slightly to 4.1 percent in 2005. In 2006, the percentage increased to 5.7 percent. Between 2008 and 2010, it declined consistently with 3.7 percent in 2008, and 3.1 percent in 2009 and 2010, respectively. The percentage, however, climbed to 5.8 percent in 2011 and decreased slightly to 5.6 per cent in 2012.

Comparatively, data from selected countries in 2009, shows Haiti as 29.8 percent, Rwanda 27.3 percent, Nauru 25.0 percent, Norway 17.9 percent, Australia 17.2 percent, United Kingdom 16.5 percent, Gabon 13.9 percent, Cameroon 8.6 percent, Niger 10.6 percent and Ghana 6.8 percent (WHO, 2009). The statistics of other countries implies that Nigeria's health spending is weak and needs to be strengthened. Health care indicators also show that public spending on health is a source of concern in Nigeria. The WHO recommends the population to doctor ratio standard at 600: 1. In Nigeria, ratio of population to doctor which stood at 4,529:1 in 2000 further decreased to 5,075:1 in 2007. Between 2009 and 2010 it increased paltry to 3,967:1 and the negative trend is still unbaiting. Available data suggests an annual increase in the number of persons per physicians implying declined access of citizens to the services of physicians. Furthermore, the annual increase in the population to nurse ratio is also worrisome. This indicates reduced access of the citizens to the services of nurses. For example, the ratio stood at 920:1 in 2000 and increased negatively to 1,405:1 in 2007 and has remained high since then. The analysis suggests a higher growth rate of population than the number of nurses. In-addition, most citizens are not aware of the available services and their constitutional rights in relation to the health care.

Table 1. Federal Government Expenditure on Health (N' billion)

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Recurrent	8.2	11.6	24.5	50.2	33.5	34.5	55.7	62.3	81.9	98.2	90.2	99.1	231.8	225.3
Capital	7.8	6.2	20.0	12.0	6.0	18.6	21.8	32.2	96.9	97.2	52.5	35.0	39.5	57.1
Total	16.0	17.8	44.5	62.2	39.5	53.1	77.5	94.5	188.8	195.4	142.7	134.1	271.3	282.4
FGN Total Exp	947.0	701.1	1,018.0	1,018.2	1,226.0	1,384.0.	1,743.2	1,842.6	2,450.9	3,240.8	3,453.0	4,194.6	4,712.1	4,987.0
% of FGN Total Exp.	1.7	2.7	4.4	6.2	3.2	4.2	4.1	5.7	5.2	3.7	3.1	3.1	5.8	5.6

Sources: NBS, CBN (Statistical Bulletin) and Federal Ministry of Finance, 2004, 2008, 2011.



Source: Authors'

Figure 2. Federal Government Expenditure on Health (N' billion) 1999 – 2012.

3. Data and Methods

Most analysis of benefit incidence are derived from the pioneered works of Meerman (1979) and Selowsky (1979) which provides estimates of the distribution of public expenditures. Benefit Incidence Analysis (BIA) normally reveals who is benefiting from public services, and describes the welfare impact on different groups or individual households of government spending. This is achieved by combining information about unit costs of providing those services. In this case, this was obtained from ministries of health as well as private service-providers with information on the use of these services, which was obtained from the households - the 2010 Nigerian Living Standard Survey report (NLSS). Thus, the method could be said to be a measure of how pro-poor government fiscal programme is.

For example, spending on (health), can be formally written as:

$$X_j \equiv \sum_{i=1}^{3} E_{ij} \frac{S_i}{E_i} \equiv \sum_{i=1}^{3} \frac{E_{ij}}{E_i} S_i . \quad (1)$$

As cited in Amakom (2012) where Xj is the amount of the social service (health) subsidy that benefits group j1 (j is the economic group and for the purpose of this paper, all households have been grouped into 5 quintiles representing their economic status - from the lowest income to the highest income group). S and E refer respectively to the government social sector (health) subsidy and the number that is expected to benefit from the (the number of people that uses the health facility for the health sector), and the subscript i denotes the level of social service (health in Nigeria - healthcare in both private and public are categorized into primary, secondary and tertiary hence i = 1 to 3). The benefit incidence of total health imputed to group j is given by the number of primary access from the group (Epj)

multiplied by the unit cost of a primary health facility added to the number of secondary access multiplied by the secondary unit cost of secondary health, plus the number of tertiary access multiplied by the unit cost of tertiary health.

The benefit incidence of total health imputed according to Amakom (2012) to group j is given by `the number of users of primary healthcare from the group (Epj) multiplied by the unit cost of providing primary health care and added to the number of users of secondary healthcare which is multiplied by the unit cost of providing secondary healthcare, plus the number of users of tertiary healthcare multiplied by the unit cost of providing tertiary healthcare.

The share of total health spending imputed to group (Xj) is then given by:

$$x_j \equiv \sum_{i=1}^{3} \frac{E_{ij}}{E_i}\left(\frac{S_i}{S}\right) \equiv \sum_{i=1}^{3} e_{ij} s_i \qquad (2)$$

Equation (2) above depends on two major determinants:

1. The **e**ij's which are the shares of the group in total service use (number that uses a health facility for health sector) reflect household behaviour.
2. The **s**i which is the shares of public spending across the different types of service, reflect government behaviour.

This paper followed a variant procedure, where behavioural information does not determine the monetary valuation of the benefits an individual receives from using public services, rather same monetary value of benefits are assigned to all those who used the services, which is the value of the unit cost of providing the service. The paper is focused on the distribution of beneficiaries from services rather than measuring the exact value to recipients of government-sponsored services (Heltberg, Simler and Tarp 2003). This is the marginal odds of benefits that would accrue to a group for every subsidy or expenditure by government. Given the poor quality of data on public expenditure as well as budget estimates at highly aggregated level, the binary approach proposed by Sahn and Younger (1998) is introduced in our analysis. This bypasses the need for estimating the unit subsidy(S/Si), which then disappears in equations (1) and (2). Focus is made on only whether a service is used or not with users of public services counted and given the benefit of one, while non-users get zero. Secondly, the above assessment of how the health budget is distributed across the population is based on the observed use of government funded health facilities. This is called current accounting. Thus, it may not give an accurate notion of how changes in the health budget will be distributed across the quintiles.

However, Ajwad and Wodon (2001) and Lanjouw and Ravallion (1999) proposed methodologies that use a single cross-section of data to identify the distribution of increases, at the margin, in access rates to public services. Both studies assumed that the distribution of new access in lagging regions will follow the pattern observed in regions where access rates are higher and used the variation in access rates across regions in a country to capture the expected evolution of access over time. However, the techniques by Ajwad and Wodon (2001) and Lanjouw and Ravallion (1999) differ in the method used for ranking individuals.

Furthermore, Lanjouw and Ravallion classify individuals as poor or rich according to their rank in the national distribution of income while Ajwad and Wodon classify individuals according to their rank in the local distribution of income. This presupposes two differences between the works of Ajwad and Wodon (2000) and Lanjouw and Ravallion (1999). They are as follows:

1. The first concerns the manner in which the endogeneity bias in the estimation of the marginal benefit incidence analysis is handled. Both papers regressed access rate in a given quintile against the mean access rate. The mean access rate, however, includes information from the access rates in each quintile. To purge the mean from this endogeneity, Ajwad and Wodon use the leave-out mean as their right-hand side variable. That is, the access rate in any given quintile is regressed against the average of the access rates across all quintiles, except for the quintile for which the regression is performed. Lanjouw and Ravallion, on the other hand, use an instrumental technique, whereby the actual mean is instrumented by the leave-out mean.
2. The second is that Ajwad and Wodon constrain the estimates of the marginal benefit incidence analysis to sum to one, and show that without such a constraint, the estimates will be biased downward, while Lanjouw and Ravallion does not.

Furthermore, Lanjouw and Ravallion provide the following econometric method which has been used in a few studies (Ajwad and Wodon, 2001; Kamgnia et al., 2008; Demery and Gaddis, 2009), given as:

$$\rho_{i,j,q} = \alpha_q + \beta\rho_k + \mu_q \tag{3}$$

Where i index a small geographical unit, k indexes a larger one, and q indexes the welfare quantile. The left-hand variable is the program participation rate for the division and quantile. The regressor is the program participation rate for the region in which the division is located. *q*, then is the marginal effect of an increase in the program participation rates of people in a given region and quantile. According to Lanjouw and Ravallion (1999), the average participation rate is defined as the proportion of the population of a particular quintile that participates in a government sponsored program. The regressor is run separately for each quantile. In addition, because *ijk* is included in *k*, there is an upward bias in the estimation. As mentioned earlier, Lanjouw and Ravallion resolved this problem by instrumenting *k* with the left-out mean. The intuition behind the regression is that by observing variations in participation, it is possible to understand how increased coverage affects the participation of different population groups. If *q* is greater than one, it indicates that a general expansion in coverage is correlated with a disproportionately large increase in participation for that division and quantile. An important assumption in our model is that across locations the same political process determines the correlation between program discretion and incidence. Also, the margin that this model estimates is the incidence of an increase in program participation.

3.1. Justification of Method (Previous Studies)

According to Demery et al. (1995); Castro-Leal et al. (1996); Sahn and Younger (2000); Van de Walle (2003), the World Bank have conducted studies in low and middle income countries using the method. O'Donnell et al. (2007) in their analysis used the technique and justified it because of its application in recent years. Also, Reinikka (2002) posits that employing BIA is most deserving because of evidence of limited impact of public spending on growth and human development outcomes which is the case in Nigeria. Nonetheless, who benefits from government spending is same as judging public policy efficiency in addressing issues on poverty and inequality. Younger (2002) considered a variety of options for analyzing the marginal benefit incidence of policy change and argued that despite the reality that each approach measures, marginal incidence, they neither in reality measure the same thing nor propose to do. Empirically, the accuracy of the approaches varies considerably with those relying on the dissimilarity data or aggregations of household into groups yielding normal errors that are fairly large relative to the expected shares.

Demery (1995) and the World Bank (1995a) used the Benefit Incidence Analysis (BIA) methodology for Ghana, Bulgaria and Vietnam and their results showed that women gained more in terms of an in-kind transfer of about 4,321 cedis per-capita as against 3,576 cedis per-capita in Ghana. Also, their results showed that the Bulgarian Turks[1] were the most disadvantaged when compared to the Gypsies. On the average, the Turks and Gypsies represent Thirteen percent of the population, but they received only six per cent of health subsidy. In Vietnam, the results showed that the mean subsidy for hospital inpatient and outpatient care was used for the benefit incidence estimates. Furthermore, Ghana results showed that a major source of inequality in the benefit incidence of health spending in Ghana was the gender dimension. Females benefited more than males in terms of health subsidy and there was a wide disparity in racial access to health. However, targeting health services to the poor have an ethnic undertone in Bulgaria, but there was no conclusion for Vietnam in the study.

Castro-Leal et al. (1999) examined health and education spending using comparative benefit incidence analysis. He finds that on average, the amount of overall government health spending going to the top twenty 20 per cent of the population was about two and a half times the amount benefiting the bottom 20 per cent. The highest 20 per cent of the population received more financial gains than the lowest 20 per cent in five of the seven countries; overall, the richest 20 per cent gained about one and a half times from primary care expenditure as much as the poorest 20 per cent. The study concluded that public spending in all the countries was found to be reverting.

Ajay et al. (2000) in their study employs BIA in appraising the distributional impacts of health spending in India and its principal states and uncovers that public health spending benefited the richer than the deprived. The financial gains from primary and outpatient service were less unequally allocated than those from hospital care. Overall, the pro-rich favoritism was larger in rural than in urban areas and greatly in poor than in richer states.

[1] The Turks and Gypsy are the two minority groups in Bulgaria comprising 13% of the total population, 25% of the poorest quintile and very few are found among the better off (only about 3% in the richest quintile).

Also, the gains connected with hospital services were less improving than other health facilities according to findings. Generally, the survey concluded that social services were poorly targeted while concentration curves are helpful method to sum up details on the gains of public spending, statistical examination of disparities in curves is imperative.

Heltberg et al. (2001) and (2003) estimated the spread of government expenditure by socio-economic status in Mozambique. They used the non-behavioral method and found that outcomes from the method is that post-primary education crosses the Lorenz curve at 0.1 on the horizontal axis, and lies below the Lorenz curve for the rest of the allocation. Results indicate that the poorest 50 per cent of school children constitute about 50 per cent of students enrolled in lower primary and 32 per cent of students in upper primary. The poorest half of the sample accounted for about 19 per cent and 11 percent of students in post-primary education and intermediate post-primary education respectively. Their results confirmed earlier positions that services in Mozambique[2] were more equal than most African countries and a progressive distribution for services in health and public infrastructure is in place. Amakom (2012 and 2011) in separate studies for Nigeria using the Nigerian Living Standard Survey of 2004 evaluates public spending efforts in reducing inequality and poverty at all levels of both education and health sectors using the benefit incidence analysis (BIA). Results suggest that primary education and primary healthcare were more pro-poor than tertiary education and tertiary healthcare in absolute terms. Furthermore, secondary education and secondary healthcare showed varied results while findings suggest state, region, location and gender partiality influence benefits from government expenditure for education and health services. In conclusion, the study posits that income redistribution may be achieved through subsidies, and not through direct consumption transfers.

However, Soares et al. (2006) developed an approach that separated out the income of different cash transfers. Evaluating the incidence of the programmes using concentration curves indexes and decomposing the Gini indexes. Soares et al. (2006) found that the old age pension and disability grant programmes were targeted properly. Study indicates that the analysis of distributive effects of these programmes contributes to the correction of existing deficiencies; thus implying that the planning of future expansion of the programmes in eradicating poverty and inequality could be achieved within a reasonable time frame. Furthermore, Soares (2006) in his health and the evolution of welfare across Brazilian municipalities study compensates differentials method in estimating the value of the observed reductions in mortality. The results suggest that benefits in life expectancy are responsible for about 28 per cent of the improvement in welfare with a welfare value equivalent to 39 per cent of the growth in income per capita. The study concluded that initial income disparity across Brazilian municipalities was very high and life expectancy benefits were more or less uniform.

[2] Except for Upper Secondary and University Education

4. RESULTS

Beneficiaries' of Health Expenditure across Quintiles in South East Nigeria

Table 2. Primary Health Care (Benefit Spread using 2010 HNLSS)

States	Abia	Anambra	Ebonyi	Enugu	Imo
Quintile 1	0.964	1.385	1.113	1.453	0.988
T - Stat	2.515	2.335	2.449	2.262	1.558
Quintile 2	0.997	1.520	1.063	1.480	1.088
T - Stat	1.644	2.521	2.277	1.734	1.785
Quintile 3	1.112	1.393	1.067	1.327	1.063
T - Stat	2.559	3.060	2.446	1.555	2.466
States	Abia	Anambra	Ebonyi	Enugu	Imo
Quintile 4	1.014	0.514	0.957	0.449	1.039
T - Stat	1.875	1.768	1.788	2.150	1.908
Quintile 5	0.923	0.200	0.822	0.300	0.837
T - Stat	6.619	1.997	5.992	3.908	8.282
Total	5.010	5.012	5.021	5.008	5.015

Source: Author's Computations.

Table 3. Secondary Health Care (Benefit Spread using 2010 HNLSS)

States	Abia	Anambra	Ebonyi	Enugu	Imo
Quintile 1	1.015	1.068	0.964	1.074	0.995
T - Stat	3.747	3.156	2.246	3.622	3.889
Quintile 2	0.927	1.117	1.016	1.076	1.015
T - Stat	6.721	2.458	7.400	2.142	3.556
Quintile 3	1.115	0.979	1.015	1.065	1.023
T - Stat	4.832	2.152	2.720	2.663	5.956
Quintile 4	0.879	0.973	0.891	0.993	1.057
T - Stat	1.445	1.591	1.958	1.163	1.727
Quintile 5	1.066	0.863	1.117	0.793	0.913
T - Stat	3.887	3.519	2.847	2.649	3.483
Total	5.002	5.000	5.003	5.001	5.002

Source: Author's Computations.

Table 4. Tertiary Health Care (Benefit Spread using 2010 HNLSS)

States	Abia	Anambra	Ebonyi	Enugu	Imo
Quintile 1	0.633	0.700	0.670	0.760	0.803
T – Stat	2.246	2.934	1.705	2.450	3.177
Quintile 2	0.814	0.850	0.788	0.882	0.699
T – Stat	3.208	1.776	2.012	1.499	2.803
Quintile 3	1.082	0.974	1.019	1.070	0.975
T – Stat	4.525	2.167	2.456	2.886	3.850
Quintile 4	1.207	1.132	1.113	1.067	1.186
T – Stat	4.648	2.360	2.829	1.996	4.485
Quintile 5	1.264	1.344	1.411	1.223	1.338
T – Stat	4.613	3.926	3.258	4.165	3.615
Total	5.001	5.001	5.002	5.001	5.001

Source: Author's Computations.

N/b:

1. Tables 2 – 4 gives the instrumental variables estimate of the regression coefficient of the quintile specific service rates on the average rate for the South-East Region, based on the 2010 HNLSS.
2. The leave-out mean region service rate is the instrument for the actual mean.
3. The numbers in parentheses are the t-ratios.
4. Quintile 1(Very Poor); Quintile 2(Poor); Quintile 3(Moderate); Quintile 4(Rich); Quintile 5(Very Rich)

4.1. Discussion

A major measurement of success, progress of poverty reduction has been the trend and allocation of resources. This propelled structural adjustment programmes across many countries and according to Geoff et al. (2009), many recorded positive growth rates. It should be noted that in the 1970s, 1980s and 1990s the focus was on growing economies and incomes. This strategy took a new dimension in the 2000s. Thus, financing of social sectors was seen as a strategy to propel growth. In addition, during 1990s, a dominant view in development literature was that growth is the end game for every poverty reduction strategy. Several studies indicated that countries with fast and high growths made progress on poverty reduction via health and education (World Bank, 2000; Dollar and Kraay 2000). Ravallion and Datt (1996) and Mellor (1999) modified this view and argued that it is not growth per se, but the structure of benefits across population groups is fundamental in poverty reduction.

Table 2 above gives the estimated benefits and marginal odds of using public primary health services obtained by regressing participation rates of each quintile across average participation rate. The estimated numbers in the table can be interpreted as the gain in subsidy incidence per capita for each quintile from a one Naira increase in aggregate spending on primary healthcare. A cursory look at the table 2 indicates a pro-poor target for only three states (Anambra, Ebonyi and Enugu) out of five SE States regarding primary healthcare. Quintiles (1, 2 and 3) for the states showed that more benefits from the allocations were received by the vulnerable group. They received a benefit of more than N1 expenditure from government. This is in-tune with MDG Goal 4: Reducing Child Mortality and MDG Goal 5: Improving Maternal Health. However, this supposed improvement would not show an improved average because the other states are still far off from the expected mark. The other three states to a great extent subsidized the rich in the society, which obviously would lead to further poverty and weakness in overall health structure. In- as much as Ebonyi State showed some targeting, resources devoted to the rich was on the high side. These resources could have been re-channeled towards the weak and vulnerable in the society. Out of a 100 per cent scale, Anambra and Enugu states subsidized Quintile 5 with 3.9 per cent and 5.9 percent respectively while Ebonyi, Imo and Abia states gave 16.4 per cent, 16.7 per cent and 18.4 per cent respectively to the same group. The scenario suggests that the scourge of poverty at the minimum would still be felt by the people who do not have access to primary health care.

Health data from developing countries invariably indicates higher-than-average instances of disease, premature mortality, maternal mortality, or HIV/AIDS infection rates. A preliminary conclusion would be that poverty is increasing the vulnerability of the poor to health-related problems in these countries, as well as exacerbating ill-health and whether poverty in itself is proving an impediment to the capacity of the poor to seek adequate health care when sick. A comparative study of Demographic and Health Surveys in over 25 countries suggests that the health status of children is closely linked to poverty, thus suggesting the need for a proper targeting of resources to the vulnerable to abate this scenario.

Table 3 and 4 above gives the estimated benefits and marginal odds of using public secondary health services obtained by regressing participation rates of each quintile across average participation rate. The estimated numbers in the table can be interpreted as the gain in subsidy incidence per capita for each quintile from a one Naira increase in aggregate spending on secondary and tertiary healthcare. At the secondary healthcare level, three states from the South East showed an incidence of more than 1 which is good for population group in

quintile 1. However, population group under quintile 4 and quintile 5 still had the largest benefits from the discretionary spending by the respective state governments. Results from Table 3 shows that targeting for quintiles 1, 2 and 3 were better than quintiles 4 and 5. They collected over 60%. Nonetheless, quintile 5 collected about 20% of the resources which is not pro-poor. The same trajectory was observed at the tertiary level. Table 4 indicates high significant values for quintile 4 and 5 across the five (5) states. These group, benefited about 50% of the public resources. Howbeit, this pattern is believed to occurring across all the states in Nigeria. The structure suggests a total exclusion of the poor from development decisions. There was poor targeting for quintile 1 and quintile 2. The vulnerable group (quintile 1 and 2) in this case, did not benefit at this level. They only had about 155 of total resources. This situation is an aberration of development. Furthermore, tertiary health care is designed to benefit the poor who cannot afford the cost of oversea specialist treatment, but the reverse is the case here. The very rich and the rich across the five eastern states of Nigeria benefited more than the poor. This situation can only support the widening inequality in the system. Our results are supported by Foster et al. (2002). Key findings from other work in five Sub-Saharan African countries, specifically Ghana, Malawi, Mozambique, Tanzania and Uganda, indicated the existing relationships between poverty reduction approach and public social spending management in each country. They established that the efficiency and effectiveness of public spending were very low and benefited largely the wealthy.

Furthermore, the work of Sahn and Younger (1999) using a benefit incidence approach focused on Ghana, Cote d' IVoire, Guinea, Madagascar, South Africa, Uganda, Tanzania, and Mauritania, concluded that social services were poorly targeted in these countries. This confirms the ambivalence observed in Nigeria. Evidence in Nigeria from different studies (Ichoku 2008) indicates that in the health sector, the nature of the tertiary health-care which includes tertiary facilities like teaching hospitals, medical colleges and specialist hospitals are in shambles and hence has been a boost for health tourism in favour of other countries with better health facilities. Despite this trend, the upper class are still being subsidized by government going by our results. In the health sector, for example, poorer households across some states are already incurring catastrophic expenditure as they spend 40% or more of their discretionary (non-food) on health-care. Amakom and Ezenekwe (2012) analyzed whether there is a positive association between a household's poverty shortfall and its health out-of-pocket budget share from two standpoints. Their study found that high out of pocket (OOP) in healthcare has succeeded in changing the poverty situation (pushing households below poverty line) even households who were originally on or above the poverty line including some of the households that were originally in the 4^{th} and 5^{th} quintiles. Statistical data from WDI seem to concur with the above findings, as it suggests that out-of-pocket health expenditure (per cent of private expenditure on health) was 95.34 per cent in 2010 while the Nigerian Medical Association (NMA) in 2012 opined that over 5,000 Nigerians travel to India and other countries monthly for medical treatment implying that the country spends between $1bn and $2bn in medical tourism annually. A total mis-alignment is observed with the health expenditure in the SE region of Nigeria. Households that need the services don't get it, whereas richer individuals are greatly subsidized.

CONCLUSION AND RECOMMENDATIONS

Two recent surveys in Nigeria have shown a low index for health. Firstly, the Nigerian Living Standard Survey (NLSS) of 2004 estimated on the average, an annual per capita for health (out of pocket expenditure) to be equivalent to twenty-two dollars (US$ 22). The 2004 Survey collected data on household health expenditures from a representative sample of 19,159 households. The estimate from these data of average annual per capita out-of-pocket spending on health is Naira 2,999, equivalent to around US$ 22. Out-of-pocket health expenditure by households constituted over 8 percent and was mostly on out-patient care, transportation to facilities and medication, showing that government expenditure on health sector is not effective. This represents one of the largest shares of health expenditure out of total family spending for developing countries. Secondly, the 2009/2010[3] survey which is the follow-up to the 2004 survey showed similar trends. The total health expenditure share of Household for 2009/10 decreased to 7.51 from 7.78 in 2004. Statistics suggests that fewer households visited a health provider in comparism with the 2004 survey results, indicating a lack of confidence on the services provided by the government. Also, the 2009/2010 survey results show that poverty and inequality have been on the increase since the last survey of 2004. Unfortunately, available records suggest, that this trend is still unabated at the moment and indicative that health services payment in Nigeria is still from out-of-pocket expenses. This scenario equally shows that the middle and upper class that benefit from local health facilities are still not satisfied with the health system. This has inadvertently, skewed health benefits to urban areas and for the middle and upper class mostly.

Lack of access and uneven benefits to healthcare services makes the poor vulnerable. Furthermore, the lack of healthcare access contributes to marginalization of the poor and widening inequality. Focusing on re-balancing of expenditure benefits as well as raising health standards by the authorities in Nigeria could enhance empowerment, which represents the expansion of assets and capabilities which will allow households in Quintiles 1 and 2 participate fully; negotiate and hold accountable institutions that affect their lives. Access and benefits to healthcare services not only imparts specific knowledge and develops general reasoning skills, but leads to changes in beliefs and values, as well as attitudes toward work and society. For the Government of Nigeria to meet the challenge of initiating an inclusive rapid growth and social transformation, spending options must be derived from evidence based analysis and evaluation of "who gets what, when and how".

Summarily, poverty and inequality reduction strategies in Nigeria, therefore, have to incorporate effective benefit distributive features and high level of inclusiveness. There are glaring indications that in the SE region of Nigeria, those living in poverty do not enjoy the same levels of care and treatment as other people on a higher income level. Some may not access any health care at all because of poor targeting of resources by the government as a result of absence of a counter-factual framework by the government. This means that poor people are less able to enjoy protection against ill-health that is beneficial for higher income

[3] The 2009/2010 Survey is an enlarged survey compared to that of 2004. The questionnaire included Demographics; Health; and Fertility behaviour, Education and Skills/Training; Employment and Time-use; Housing and Housing Condition; Social Capital, Agriculture; Social Capital, Agriculture; Household Income, consumption and Expenditure.

groups and consequently, most children of poor households may not benefit from immunization programmes by the government.

In this chapter, we analyzed which demographic quintile benefits from discretionary government spending. However, the methodological and framework in this chapter, does not address the policies that might bring about program expansion for health. Rather, it makes a more general appeal to the political economy behind the policies to argue that, whatever policies are used, the outcome must respect the political constraints implied by each group's cost, benefits, and political power.

From the foregoing, a maximum impact in targeting poverty in Nigeria would be achieved if all the states in Nigeria focus on social sector resources exclusively on the households within Quintiles 1(very poor) and 2 (poor) across the country. This would support poverty reduction via productivity increase of able-bodied men and women. Furthermore, households and communities should be enlightened and their consciousness increased in understanding how best to access health care in their various jurisdictions for maximum positive impact on their socioeconomic status. We, therefore, recommend the subsidization of health series for the poor by the use of local government financing, and similar tools in the engagement of communities in their health care programmes. Effective inclusion and targeting of the poor and less privileged in sustaining societal growth and economic progress may be a potent strategy for curtailing poverty and inequality. Health care services are a prominent social good that is very much needed by the citizenry; hence efforts at providing these services should be a national priority. Government should invest more on social services and enhance access to primary health care with a focus on outcomes and not outputs.

REFERENCES

Abdullah, H.A. (2000). The Relationship between Government Expenditure and Economic Growth in Saudi Arabia, *Journal of Administrative Science*, 12(2): 173-191.

Ajwad, M. and Quentin, W. (2001). Do Governments Maximize Access Rates to Public Services Across Areas? World Bank, Latin America Poverty Group, Washington, D.C.

Ajay, M; Singh, J.and Afridi. F. (2000*) Who Benefits from Public Health Spending in India? Results of a Benefit-Incidence Analysis for India* Washington, DC: World Bank.

Amakom, U. (2011). Public Spending and Poverty Reduction in Nigeria: A Benefit Incidence Analysis in Education and Health, Final Report for Publication Submitted to the African Economic Research Consortium (AERC), Nairobi, Kenya, February.

Amakom, U. (2012). Public Spending on Education and Healthcare in Nigeria: Who Benefits and Why, *International Journal of Business and Management.*

Asghar, N., Hussain, Z. and Rehman, H. (2012). The Impact of Government Spending on Poverty Reduction: Evidence from Pakistan 1972-2008. *African Journal of Business Management* Vol. 6(3), January, PP. 845-853.

Al-Yousif Y, (2000). Does Government Expenditure Inhibit or Promote Economic Growth: Some Empirical Evidence from Saudi Arabia, *Indian Economic Journal,* 48(2).

Ashford, L.S. (2001). New Population Policies: Advancing Women's Health and Rights, in Population Bulletin 56 (1): Washington, Population Reference Bureau.

Aigbokhan Ben (2008). Growth, Inequality and Poverty in Nigeria, United Nations Economic Commission for Africa – UNECA Economic Commission for Africa, ACGS/MPAMS Discussion Paper No.3

Retrieved from www.uneca.org/sites/default/files/.../growth inequality poverty.pdf *on January 2013.*

Brian, A; Ward B; Shanta D. and Alejandro I. (2001), *Macroeconomic Policy and Poverty.* Reduction, the IMF's Poverty Reduction and Growth Facility: A Factsheet. http://www.imf. org/external/pubs/ft/exrp/macropol/eng/

Agu, C. and Aldo C. (2013). *Economic Diversification and Macroeconomic Policies: Is Africa's Growth Enough?* Paper for Consideration in the CSAE Conference 2014.

Cooray, A. (2009) Government Expenditure, Governance and Economic Growth Comparative Economic Studies, 51(3): 401-418 [http://www. ingentaconnect.com/ content/pal/ces;jsessionid=q1g8lgkzfvms.alice]

Castro-Leal, F. (1996). The Impact of Public Health Spending on Poverty and Inequality in South Africa. PSP Discussion Paper Series 102. Washington, DC: World Bank, Poverty and Social Policy Department.

Castro-Leal F, Dayton J, Demery L, Mehra K. (1999). *Public Social Spending in Africa: Do the Poor Benefit?* World Bank Research Observer 14: 49–72.

Demery, L., Dayton, J. and K. Mehra, (1996). *The Incidence of Social Spending in Ivory Coast, 1986-95* Poverty and Social Policy Department; The World Bank, Washington D.C.

Demery, L. Chao S, Bernier R, Mehra K. (1995). *The incidence of social spending in Ghana*, PSP Discussion Paper Series 82; Washington, DC: World Bank, Poverty and Social Policy Department.

Engen, E.M. and Skinner, J. (1992). Fiscal Policy and Economic Growth. NBER Working Paper 4223.

Fan, S., Hazell, P. and Thorat, S. (2000). Government Spending, Growth and Poverty in Rural India. *American Journal of Agricultural Economics* 82 (4): PP 1038–51.

Folster, S. and Henrekson, M. (2001). Growth Effects of Government Expenditure and Taxation in Rich Countries, European Economic Review, 45(8): 1501-1520. [http://ssrn.com/abstract=998262], Volume 2010: BEJ-4 1.

Foster, M., Adrian, F; Naschold, F. and Conway, T. (2002) *How*, When and Why does Poverty Get Budget Priority: Poverty Reduction Strategy and Public Expenditure in Five African Countries, Overseas Development Institute, Working Paper 168.

FMoH (2004). Achieving Health-Related Millennium Development Goals in Nigeria – A Report of the Presidential Committee on Achieving Millennium Development Goals in Nigeria, (August 9) – Executive Summary.

Glick, P., Rumki S; and. Younger S.D (2004), Integrating Gender into Benefit incidence and Demand Analysis. CFNPP Working paper No. 167, Cornell University.

HERFON, (2006*) Nigeria Health Review*, Health Reform Foundation of Nigeria, Kenbim Press Ltd, Ibadan. Pg10-12,130,191.

Heltberg, R., Simler K. and Tarp, F. (2003). Public Spending and Poverty in Mozambique FCND Discussion Paper No.167.

Jalan, J. and Ravallion, M. (1998). Determinants of Transient and Chronic Poverty: Evidence from Rural China, World Bank Policy Research Working Paper No.1936, Washington DC.

Jung, S., Seong-Hoon, C. and Roberts R. (2009). Public Expenditure and Poverty Reduction in the Southern United States: Selected Paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting, Atlanta, Georgia, January 31-February 3.

Kamgnia, B; Wangun, S.L; Tatsinkou, C. and Afor, J. (2008). Bénéfices acquis et ciblage des pauvres dans les dépenses publiques de santé et d'éducation au Cameroun, PEP-PMMA Working paper May : Universite laval.

Lanjouw, Peter, and Martin Ravallion. (1999). Benefit Incidence, Public Spending Reforms, and the Timing of Program Capture. The World Bank Economic Review 13:257-73.

Lanjouw, P. and Ravallion, M. (1994), Poverty and Household Size, Policy Research Working Paper 1332, World Bank, Washington, D. C.

Liberati, P. (2003). Poverty Reducing Reforms and Sub-Group Consumption Dominance Curves, Review of Income and Wealth, Series 49, Number 4, pp 589-601.

Mellor, J.B. (1999). The Structure of Growth and Poverty Reduction, (Mimeo) World Bank, Washington D.C.

Meerman, J. (1979). Public Expenditure in Malaysia: Who Benefits and Why, New York: Oxford University Press.

Nigerian Bureau of Statistics (NBS) (2010). Nigerian Poverty Profile (www. nigerianstat.gov.ng) NBS (2010).

Ogundipe, M. and Nurudeen, A. (2013). Health, Poverty Reduction and Human Capital Development in Nigeria (1980–2011). *International Journal of Management Sciences and Business Research*, 2013 ISSN (2226-8235) Vol- 2, Issue 12.

Obansa, S. and Orimisan, A. (2013). Health Care Financing in Nigeria: Prospects and Challenges, Mediterranean Journal of Social Sciences Vol. 4 (1) January 2013. Retrieved from www.mcer.org July 2013; Doi:10.5901/mjss.*2013*.v4n1p221.

O'Donnell O, van Doorslaer E, Wagstaff A, Lindelow M. (2008). Analyzing Health Equity Using Household Survey Data: A Guide to Techniques and their Implementation, Washington, DC: World Bank.

Ogunbekun, et al. (1999). Private Health care in Nigeria, Walking a Tightrope. Health Policy Planning, pp. 174-181.

Rannan-Eliya, R., Badri, P; Killingworth, J; and Somanathan, A. (2001). Equity in Financing and Delivery of Health Services in Bangladesh, Nepal and Sri Lanka, Washington, DC: World Bank.

Rannan-Eliya, R. (2008). National Health Accounts Estimation Methods: Household Out-of-pocket Spending in Private Expenditure. Monograph prepared for WHO/NHA Unit, Geneva, Switzerland.

Ravallion, M. and G. Datt (1996). How Important to India's Poor is the Sectoral.

Reinikka, R. (2002). Public Expenditure Tracking and Service Delivery Surveys: A Review of Design and Implementation Issues, PEAM Course, May 23, DECRG, The World Bank.

Sahn, D and S.D. Younger (1998). Fiscal Incidence in Africa: Microeconomic Evidence, AERC Working papers CR-2-5, Nairobi.

Sahn, D. E. and S. Younger (1999). Dominance Testing of Social Expenditures and Taxes in Africa, IMF Working Paper WP/99/172.

Soares, R. R. (2006). Health and the Evolution of Welfare across Brazilian Municipalities, Journal of Development Economics 84 (2007) 590–608

Soares, F.V., Soares, S; Medeiros M. and Osorio, R.G. (2006). Cash Transfer Programmes in Brazil: Impacts on Inequality and Poverty, Brasilla, International Poverty Centre, UNDP.

Selowsky, M. (1979). Who Benefits from Government Expenditure? A Case Study of Colombia. New York: Oxford University Press.

Sekhri, N. (2006). Forecasting for Global Health: New Money, New Products and New Markets, Background Paper for the Forecasting Working Group, Centre for Global Development. Available: http://www.cgdev. org/doc/ghprn/ForecastingBackground.pdf.

Nigerian Bureau of Statistics (NBS) (2004). Nigerian Poverty Profile Report.

United Nations (2001a). Population, Environment and Development: The Concise Report, New York, United Nations.

Van de Walle, DP. (1995). Public Spending and the Poor: What we Know, What we need to know. Policy, Research Working Paper No. 1476. Washington, DC: World Bank.

Wilhelm, V. and Fiestas, I. (2005). Exploring the Link between Public Spending and Poverty Reduction: Lessons from the 90s, Washington, D.C., The International Bank for Reconstruction and Development/The World Bank.

World Health Organization (2006). World Health Account.

Ye, X. and Canagarajah, S. (2002). Efficiency of Public Expenditure Distribution and Beyond: A Report on Ghana's 2000 Public Expenditure Tracking Survey in the Sectors of Primary Health and Education" The World Bank/

Younger, S. (2002). Benefits on the Margin: Observations on Marginal Benefit Incidence" USAID cooperative Agreement AOT-0546-A-00-3178-00/

Yaqub, J; Ojapinwa, T; and Yussuff, R. (2012) Public Health Expenditure and Health Outcome in Nigeria: The Impact of Governance, European Scientific Journal June edition vol. 8, No.13/

Yuki, T. (2003). Distribution of Public Education Spending for the Poor: The Case of Yemen, Asia Pacific Education Review, Vol. 4, No. 2, 129-139/

BIOGRAPHICAL SKETCHES

Kanayo Ogujiuba

Affiliation: Statistics and Population Studies, University of the Western Cape

Education: PhD Statistics; PhD Economics

Research and Professional Experience: *Ogujiuba Kanayo* is affiliated with the Statistics and Population Studies Department, University of the Western Cape. His research interests include technical demography, development and public policy. He has published several articles in accredited Journals and is a member of numerous research and management development networks.

Nancy Stiegler

Affiliation: Statistics and Population Studies, University of the Western Cape
Education: PhD Demography

Research and Professional Experience: *Nancy Stiegler* is the Chairperson of the Statistics and Population Studies Department. She teaches demographic analysis to postgraduate and undergraduate students, and conducts research in the fields of reproductive health, female rights and census issues.

In: Handbook on Africa
Editor: Whitney Sherman
ISBN: 978-1-53610-063-1

Chapter 15

FIGHTING FEMALE VULNERABILITY WITH FOOTBALL: CHALLENGING THE GENDER EFFECTS OF POVERTY IN THE SOUTH AFRICAN CONTEXT

Cassandra Ogunniyi*
University of Johannesburg, Johannesburg, South Africa

ABSTRACT

The majority of women who participate in South African football (soccer) face a triad of challenges due to their gender, race, and class. Women in general in South Africa continue to fall into the lowest social strata and are considered vulnerable due to poor living conditions, absent fathers, lack of economic opportunities, and poor government infrastructure in terms of education, housing, and health care. Sport participation provides opportunities for women to confront the challenges of poverty, such as traditional gender roles and expectations, avoid deviant behaviours, and become more confident to manage inter-gender power relations. This paper uses comprehensive case studies focused on 21 South African female football players, their significant others, schools and communities. Centered in critical feminism, the case studies in this research reveal how girls can increase their self-confidence and create healthier relationships with boys, leading to better future relationships that reduce the risk of teenage pregnancy, contracting HIV/AIDS, being raped or sexually abused. More research is needed to examine the longer term effects of football participation on gender relations and poverty in South Africa.

Keywords: gender relations, football/soccer, poverty, sport and developmrent, HIV/AIDS

* cogunniyi@ymail.com.

INTRODUCTION

South Africa has changed significantly in the two decades since the end of apartheid; however the scars of discrimination, racism, sexism and segregation are still healing. Despite government promises of prosperity and provision of basic services, the gap between the wealthiest and the poorest South African has increased and is currently considered the largest gap in the world (Rawson, 2012). This has left many South Africans struggling to survive, with black women considered the most vulnerable due to poor living conditions, absent fathers, lack of economic opportunities and poor government infrastructure. This vulnerability exacerbates the situation for women, who, despite having constitutional support and near political parity between women and men, still experience domestic abuse, sexual violence, gender discrimination, and unequal economic opportunities (ONE, 2015).

Many South Africans rise above the difficult context and challenge the traditional norms that try to maintain the status quo. One such group is female football (soccer) players who are predominantly found in the townships, and participate despite their poverty level, gender discrimination, and restricted access to the meager playing grounds. Sport participation internationally is recognized as a means to improve physical, mental, emotional, and social health. The 2030 Sustainable Development Goals Agenda document includes the recognition that sport contributes to empowering women, youth, and their communities through improving health, education, and social inclusion (UN, 2015). International poverty reduction recently entered a new phase as the Millennium Development Goals met their deadlines in 2015 ushering in the more extensive Sustainable Development Goals with indicators aiming for improvements by 2030. Of the 17 new goals, one specifically focuses on achieving gender equality and empowering women and girls, while 7 others include gender-sensitive targets (UN, 2015).

This chapter uses comprehensive case studies of 21 female football players, their significant others, peers, teachers, and community members to reveal the potential of participation in football to reduce the gendered effects of poverty. Specifically, the results demonstrate how participation can increase self-confidence and create healthier relationships with boys, which lead towards better future relations, reducing the risk of teenage pregnancy, contracting HIV and AIDS, or sexual abuse.

The theoretical background for this paper rests in critical feminism, which focuses on critiquing systems and structures of power distribution in society, based on hegemonic masculinity, which result in social inequalities (Birrell, 2000). At the basis of this inequality are structural patterns of dominance based on class, gender, age and ethnicity (Connell, 2005). Sports are considered gendered activities since they reinforce dominant ideologies about masculinity and femininity through reinforcing gendered ideas about the body, sexuality and the physical self (Bryson, 1994). Female participation and access to male dominant sporting spaces is also restricted based on dominant gender ideals (Hargreaves, 2004). Feminist scholars have demonstrated how sport can be a site of resistance to these hegemonic norms and a location where changes are beginning to occur. This includes: the way women are portrayed in the media (Heywood and Dworkin, 2003); the opportunities available for women and women being viewed as positive role models (Meier, 2005); and women challenging heterosexual norms of participation (Elling and Janssens, 2009).

BACKGROUND

Female representation in South African parliament increased steadily from 1994, at 2.7% to 42% in 2014, including 41.7% in ministerial positions, 47% of deputy ministers, and 41.5% in the National Assembly (Government of South Africa, 2016). Women's issues in parliament have received notable attention since the end of apartheid, evolving from an Office on the Status of Women in 1997 to a dedicated Ministry for Women in the Presidency in 2014. This ministry is responsible to lead, coordinate and oversee the political and societal inclusion of women's socio-economic empowerment, rights and equality (Government of South Africa, 2016). Unfortunately, this political prowess has not translated into transformation at the individual level for all South African women.

Economic, racial, religious and gender divisions remain apparent in society with high unemployment, poor infrastructure, high levels of HIV/AIDS, and gender based violence. Black women are the most affected by these divisions, as they carry a double burden due to their gender and race, evident through a poverty rate of 68% (SAIRR, 2010). National unemployment levels are high, at 33.8% at the end of 2015, using the extended definition, which includes people who have stopped looking for work (Trading Economies, 2015). In some rural areas, these rates are as high as 95% (Meredeth, 2011). Among the research participants of this study, eight of the thirty-three (24%) parents and guardians were unemployed at the time of research, while nine (27%) were employed as domestic workers or gardeners, which are among the lowest paid occupations in South Africa.

Women are further affected by poor infrastructure in terms of transportation, housing, health care and education. They often spend long hours commuting to and from work due to a lack of affordable, integrated and effective public transportation (Meredith, 2011). The two locations for this research are in the South African townships, where black South Africans were relocated during apartheid. These townships continue to manifest the legacy of apartheid in poor sanitation, overcrowding, and a plethora of informal dwellings. As of 2011, the South African population was approximately 51.6 million people, of whom 18 million lacked adequate sanitation, 12 million lacked clean water, 7 million lived below the poverty line, and over 3 million lived in informal settlements (Meredith, 2011).

The context of poverty can lead to other social problems such as high incidents of alcohol and drug abuse, and violence against women. Drugs, teenage pregnancy and HIV are common problems in South Africa (Hoque, 2011; Pitpitan, Kalichman, Eaton, Sikkema, Watt, and Skinner, 2012). These problems are often found together, as young women spend time at shebeens (home based pubs or liquor stores) for lack of alternative locations in the community (Pitpitan et al., 2012). Although the presence of shebeens and alcohol abuse do not automatically lead to HIV, when individuals are inebriated they make poor decisions and are more likely to have unprotected sex, which leads to greater risk of contracting HIV, other sexually transmitted infections (STIs) or becoming pregnant (Pipitan et al., 2012). Women are more vulnerable in this context and can become involved in the practice of exchanging sex for material items, pocket money and alcohol (Forde, 2008; Hoque, 2011; Pitpitan et al., 2012). As of 2008, 24.4% of South African women aged 15-19 are mothers or have ever been pregnant (SAIRR, 2012).

South Africa has the largest antiretroviral (ARV) programme in the world, treating 3 million people as of December 2014, and reducing mother to child HIV transmission to 2.7%

in 2011 (ONE, 2015). However, 56% of the over 6 million people living with HIV/AIDS in South Africa are women and girls, who struggle to access medication, pre-natal care, and supportive hospital and clinic staff (ONE, 2015). The percentage of women affected by gender-based violence varies according to location and study, with findings ranging from 40% to 70% of female murders committed by intimate partners (ONE, 2015). According to a report by Gender Links in 2011, 51.3% of women in Gauteng have experienced emotional, economic, physical or sexual violence in their lifetime, while 75.5% of men admitted to committing at least one of these forms of violence towards women (Machisa, Jewkes, Lowe Morna, and Rama, 2011). Out of every 13 people surveyed in Gauteng, one had experienced non-partner rape, while only one in 25 rapes were reported to the police (Machisa et al., 2011). Sexual violence was experienced by 25.3% of the women and 37.4% of men admitted to sexually abusing someone in their lifetime. This was the third most prevalent type of violence, after emotional and physical violence (Machisa et al., 2011). Throughout South Africa, at least one in three women experience rape in their lifetime and one in four women experience domestic violence (Moffett, 2008).

Families living in poverty experience multiple obstacles that restrict their children's participation in sport programmes, as Kay and Spaaij (2011) found in India, Brazil and Zambia. Sport participation leads to additional costs such as transportation to practices and games, purchasing personal equipment, as well as sending food with participants for games or tournaments (Burnett, 2001). In this context, children are often required to take responsibility for domestic duties, care of younger siblings, or additional income earners, which takes away from the time that they are able to spend playing sport (Kay and Spaaij, 2011).

Sport participation for girls enhances their body image, increases their confidence, decreases dropping out of school and reduces depression (Jones-Palm and Palm, 2005). Acquiring new skills, abilities and knowledge through participation in physical activity empowers girls and women to express themselves in new ways at school, in sport and at home, building respect from their family members (Kay, 2009; Weiss and Wiese-Bjornstal, 2009). Research from the USA found that girls who participate in sport become sexually active later in life due to the increased sense of ownership, enhanced self-confidence and respect for their bodies (Sabo, Miller, Farrell, Melnick and Barnes, 1999; Erkut and Tracy, 2005). In South Africa, Pelak (2005) found that female football teams provided a space for networking and solidarity, as well as mentorship for younger players, within a context of complex social relations, such as ethnicity, race, class and gender. Physical activity has been associated with feelings of self-determination, autonomy and choice, perceived physical competence and self-efficacy, hope and optimism for the future (Weiss and Wiese-Bjornstal, 2009).

A comparison of 15-19 year old girls in Haiti that participated in an education and sport program found that those that participated in the full program had the lowest risk of early pregnancy compared to girls who participated in only the education program and girls who did not participate at all (Kaplan, Lewis, Gebrian and Theall, 2015). Research from Spain found that increased self-esteem and perceived support from family and friends was associated with lower sexual risk (Ramiro, Teva, Bermúdez and Buela-Casal, 2013). Hayhurst (2013) found that female participants in a martial arts program integrating sport, gender and development improved their self-esteem, confidence and self-responsibility, and challenged gender norms. However, the focus on the women as agents of change within

gendered structural inequalities caused the challenges to the gender norms to be limited and potentially increased the marginalization of the women (Hayhurst, 2013).

In the South African context, Frantz (2006) found that the lack of physical activity among teenagers in the Western Cape was associated with risky health behaviours such as drinking alcohol, obesity, smoking and hypertension and should be considered a public health concern in the community. Participation in physical activity, particularly team sports, has been associated with a decrease in some risky health behaviours, including substance abuse and precarious sexual behaviours; while other behaviours, such as binge drinking, are reportedly higher among team sport participants (Jones-Palm and Palm, 2005). Therefore, the impacts of sport programmes and participation are influenced by numerous variables and what is positive for one individual can be detrimental for another.

In a facilities audit of the national Sport and Recreation Mass Participation Programme (MPP), Burnett and Hollander (2005) found that football fields were available in most communities, however, they were insufficient for the demand, causing them to be over-utilised and poorly maintained. Some of the fields were only an open space without grass or lines and had makeshift poles in addition to a lack of provision for change rooms, toilets and spectator stands (Burnett and Hollander, 2005). These community spaces are traditionally dominated by men, therefore as female athletes claim space they challenge gender norms and change perceptions about women's sport and the capabilities of women in the community (Forde, 2008; Meier, 2005). Some sport for development organizations specifically target challenging gender norms. One example is the Mathare Youth Sports Association (MYSA) in Nairobi, Kenya, where traditional gender roles associated with sport are shared between the male and female participants, including looking after younger children, washing jerseys, managing the equipment, and maintaining the field (Brady, 2005). These approaches are important because social change cannot occur without the participation of all community members, particularly those in positions of power, which are generally older men.

RESEARCH METHODS

This paper uses a comprehensive case study approach (Thomas, Nelson and Silverman, 2011) which incorporates data gathered from questionnaires, interviews and focus groups to triangulate information about 21 female football players from two locations in South Africa. Two football clubs were selected that had a junior and senior team, one from a township in Cape Town and the second from a township in Johannesburg. The research was part of a PhD thesis that involved questionnaires in the two communities where the teams are located, questionnaires and focus groups at eight schools in the two locations, focus groups with the two U-15 girls' teams and interviews with 11 senior players, 48 significant others, 11 school representatives, 4 coaches and 8 administrators. The significant others included mothers, fathers, aunts, uncles, brothers, sisters, cousins, and friends.

All names used in this chapter are pseudonyms to protect the confidentiality of participants and quotations are used verbatim. The interviews were voice recorded and transcribed. The qualitative data was coded and analyzed with the computer-aided software, Atlas.ti 6.2, which assisted with open and axial coding to highlight main themes and related concepts to compare and select relevant sections of information (Fielding and Lee, 1998).

This chapter focuses on the themes of deviance avoidance, increased self-efficacy, improved male-female relationships, and changed perceptions towards females.

RESULTS

Football is considered an important distraction that keeps girls in a positive environment with adult supervision in the safe space of the football pitch that helps them to avoid deviant behaviours such as alcohol abuse, drug use, criminal activities, or teenage sex leading to pregnancy, HIV/AIDS or other STIs. Participation in football can contribute to positive relationships with boys, and increased self-efficacy that also helps them to make good decisions and negotiate gendered power relations, while challenging traditional gender norms.

Deviance Avoidance

There is a common perception that sport participation helps youth stay busy and keeps them off the streets and out of shebeens. The football pitch is considered a safe space for children to play and spend their free time, especially when adult supervision is present. Of the community questionnaire respondents, 81.3% (n = 135) agreed that football kept the girls busy and off the streets. Players and household members most frequently mentioned this topic in interviews.

The two most prevalent problems for young women in the South African townships are alcohol abuse and teenage pregnancy (Hoque, 2011; Pitpitan, et al., 2012). These lead to many other problems, the biggest of which is dropping out of school. Playing football is seen as a type of refuge from these issues, although it does not completely eliminate the chance of getting involved with alcohol or boys.

Household members frequently discussed the differences between behaviours of girls that play football compared to girls who do not play. As Lindiwe's father in Johannesburg related:

> The girls that are not participating in sport at all, because there are a lot, they end up being lefted [*sic*] with rape charges against them. They abusing alcohol, they having kids at an early age. They are uncontrollable. ... But then if you know what there's something after school that will make you to be busy, I don't think that you'll do the very same thing that they'll do. Because you can't go to gym drunk. That's impossible. You thinking, what will my coach say? My coach will tell my dad. My coach will tell my mom.

Lindiwe's father compared his daughter to other girls in the community, who get drunk, raped and become pregnant. Girls who play football, on the other hand, have an alternative activity to occupy their time and another authority figure in their lives. This authority figure encourages appropriate behaviour, while instilling a fear of reporting negative or deviant behaviour to the girl's parents.

Olwethu's father shared related sentiments, "If you play soccer you'll never have time for things that happen in the outside, you always focus on your football". It is the focus on a productive activity, as echoed by many individuals that can keep the players on the "right path and can change the lives of people ... it can keep children off the street ... it plays a very

significant role" according to the Director of Sport for the City of Cape Town. Football participation offers an alternative activity to being in the streets. It is a positive distraction that provides a productive pastime in contrast to other deviant activities youth can be involved with in the streets.

The Director of Sport in Cape Town continued to discuss the benefits for families when their children are involved in structured programmes:

> Their families, they benefit in that their children do not get caught up in bad habits, I mean as you would know, the Western Cape is rife in drug use, there's lots of pregnancy, HIV issues, you know. So they are, the youth and the children that are involved in those initiatives are able to escape those influences.

When programs and teams are available for the youth, they are provided with productive alternatives to parties, drugs and alcohol. As this administrator observed, when the girls play soccer, they 'miss out' on these deviant behaviours.

Lulama's sister stated that when she was a young girl, she was busy playing with dolls, compared to the 13 year old girls now, who are becoming romantically involved with boys. However, since Lulama was focused on football, it was only later, when she was about 18 years old, that she began to be concerned with or noticed by boys,

> Ever since she was growing up, ... she didn't care about how she looks, she just wants to go the gym all the time. Now she's starting to get the picture that I have to wear some make-up because she's a bit older now. She doesn't mind if the men don't phone. I told her don't mind about the men because sometimes the men can stop you from your dream, just go forward in life.

A focus on football changes the priorities in the girls' lives, as they are not interested in catching male attention through using make up and talking on the phone. This is seen as positive, as girls in the community seem to be getting involved with boys at a younger age, which has led to higher rates of teen pregnancy (SAIRR, 2012). Lulama's sister cautioned against letting men steal girl's dreams, as it is better to achieve personal desires without male interference, which could be linked to male dominated cultural expectations as well.

Boys as Friends

Since football is traditionally viewed as a male sport in South Africa and there are limited opportunities for girls to participate, most of the girls in this study starting playing with boys and continued to play football with boys during school breaks, after school, in their streets or in leagues. Having a common interest in football and spending time with the boys on and off the pitch created a level of friendship and mutual understanding between the girls and boys.

For instance, Azariah only recently started playing football on a club team, but has been playing with boys in the street since she was young. Her brother described the difference between her relationships with boys compared to girls who do not play sports with boys: "Those who play soccer, will only have friends with boys. But those who doesn't play soccer, they'll look for boys to be like their boyfriends." The argument is that as girls become friends

with boys, they do not try to get into romantic relationships, but continue to see their relationships platonically.

In Cape Town, Khanyesile's mother positively viewed girls who play soccer as tomboys,

> I would love a girl when she grows up to be a tomboy because she goes late to boys. Very late. For boyfriends. Than the normal one. ... There's just no interest because she's taking boys as friends. Not as looking at them as the boyfriends.

Since Khanyesile is friends with boys, it will delay the time when she sees them as something more than a friend, an appreciated detail for her mother. Similar to Azariah's brother, Khanyesile's mother recognised the importance of friendship with boys rather than romantic relationships that may result in early pregnancy.

A girl that plays soccer at a primary school in Johannesburg elaborated on how you could trust boys that are your friends and communicate with them better if they play soccer together:

> And girls if you play soccer, if you have friends and he's a boy, it's easy to communicate with him because you know him, but if you don't play soccer and you're a girl who is not playing sport, it's not easy for you to communicate with that boy who plays soccer.

There is a greater level of understanding between peers that both play soccer, they can communicate more clearly and have common interests. These are key aspects of building and maintaining a healthy, strong relationship, which can develop even further.

During a focus group at Shomang Primary school in Cape Town, a boy that plays soccer provided the male perspective of the situation. He says, "You see when they play soccer, I've get to knowing them and knowing them and then I've had a lot of information about them". Therefore as the boys get to know the girls they begin to establish an understanding that can be the basis for a healthy relationship based on mutual interests and respect.

Zongile has had a tragic past being raped twice before moving to Johannesburg. Although her mother thinks she is afraid of men, Zongile actually takes refuge with boys because girls "talk too much". Zongile describes how the boys help her in life: "boys they encourage me in life, in what you get at the end if you [are] busy sleeping with [other] boys". They give her advice on how to deal with other boys and warn her on the dangers that will come from sleeping with them. Although Zongile should be afraid of being with boys due to her past, she has embraced a different relationship with them and avoids the gossip of girls. By being friends with boys, she opens the opportunity to get quality advice from them in order to avoid future problems that will hopefully be useful in her future relationships.

Jamila has had similar friend relationships with boys as Zongile, where she spent most of her free time with boys rather than girls. She recounts how the boys treated her:

> Even if I played with them and I was with them most of the time. But they still treated me as a girl. They still respected me as a girl. ... They treated me as one of their friends. I was friends, like they would tell me things that they won't tell the other girls. ... For instance, say they wanted to tell me a secret, they will tell me but they won't tell the next girl because I'm playing with them. So they trusted me.

Jamila earned the respect of the boys by being with them on and off the field. They trusted her and would confide in her. This was different than the relationship they would have with other girls. This relationship extended to other settings, as she explained how they would treat her if they met at a party:

> Because I was playing with them, they won't come to me and ask me, don't you want to be my girlfriend. But if there's other girls around, they will do that to them.

Jamila's case demonstrates how the boys view and treat the football girls differently, as friends rather than girlfriends. The respect they earn on the field extends to social situations in the community.

Therefore, through playing soccer together and getting to know and understand each other better, positive, healthy friendships can develop. In these friendships there is mutual trust and confidence, they can tell each other secrets, share advice and will treat each other with respect both on and off the pitch.

Self-Esteem and Self-Efficacy

In addition to the friendships and healthy relationships with boys formed by female football participants, these women gain other skills to help them navigate social relationships. Two of the important skills gained are self-esteem and self-efficacy, which enables them to stand firm in risky situations. Self-esteem is how an individual feels about their personal worth; while self-efficacy is the confidence an individual has in their ability to achieve a particular outcome (McAuley, Mihalko and Bane, 1997).

Azariah's brother spoke in this regard when he stated that, "A girl who plays soccer, will behave like a boy". He agreed that she would stand up to a boy and he had seen the situation, "a lot of times". Boys are generally believed to be stronger and more confident, therefore when girls participate in activities that are traditionally male; they may learn some of the same skills that boys learn during these activities, such as physical and mental strength.

The male students at Shomang primary school agreed, as one stated,

> The football is helping girls to have more power. Other girls don't have power when someone is raped or is …, they don't have the power to push them away so when they play soccer she is fit and strong.

The boys in this focus group were primarily describing how physically strong the football girls became and would fight back when the boys hit them, with one boy exclaiming, "Ouch! You hit me like a man!" as he recounted a scenario of one of the soccer girls fighting with him. In these descriptions, the women have both the physical and emotional strength to stand up against bullying or abuse and will fight back if the boys try to pick on them or try to rape them.

A more detailed description of this situation came from the perspective of one of the teachers in Cape Town:

> I've seen these girls, I've stayed with them in my street, they become friends, they've got understand of the boys, they've got even the terms of the boys, they can speak the terms of the boys, they know the boys what they want, even when they do some advances they know. ... Because these girls who are close to boys, they become streetwise. They know what is needed out there to succeed. Because if you look at them, you find that they are doing stuff that grades, 9s, 10s, 11s, 12s and people will say, that tomboy is doing grade 12, you see, they are succeeding in life, to me. ... It's about pregnancy, most of the time and those surface things, lower self-esteem. ... Look it's important that you go to high school, then you have your self-esteem, you have your head high.

In this quote, the teacher describes how the football girls become 'streetwise', which he defines as being able to understand the boys, know their language and slang, recognise their advances and know what they really want. By knowing this they can also avoid unwanted advances and succeed in life. Success, as explained by the teacher, is not getting pregnant, but staying in school, gaining self-esteem and being able to hold their heads high with pride.

The teachers interviewed most commonly discussed self-esteem and self-efficacy in their classrooms, as the results of sport participation. One teacher stated:

> Because in sport, it's competitive, you want to win, so it builds self-esteem because you can play in front of many people, that gives you a courage to stand even in front of many people.

Therefore self-esteem on the pitch is able to translate into self-efficacy in the classroom. This teacher discussed two aspects of participation. The competitive nature of the game leads to confidence building through the desire to win, the need to be focused, strong and persevere in order to achieve victory. Secondly, playing in front of a crowd shows a willingness to be vulnerable to make mistakes, which requires boldness and can easily be transferred to courage to stand in front of a group of people in different settings.

Another Cape Town teacher shared the same view:

> These girls who play football, because of the environment, they are playing football in stadiums, they are not shy. They are not people who are shy, yes some of them in terms of their character they will not be people who like to speak that much, but if they want something, they stand up and say what they want. That's confidence, to me that shows confidence. They are not the same, there are those who do not speak that much, but if they want something they have a question, they raise their hand and ask a question. I think it's because of their environment; they are used to the stadiums.

Gaining confidence by being put in positions of pressure on the football field under the critical eye of spectators gave these players an advantage in the classroom as they were not afraid to stand up and speak or ask questions. This teacher acknowledged that women who participate in football may have a variety of personalities and react differently to situations. Regardless of how naturally shy the participant may be if they have a question in class they are not afraid to stand up and ask. This can translate out of the classroom through self-confidence to ask questions and make positive decisions in dubious situations.

Changed Perceptions

Individual changes through improved inter-gender relationships and increased self-esteem and self-efficacy are important, however, changes are also crucial throughout the community and general population to improve sustainability. A primary mode to change perceptions is personal experience that demonstrates an opposing view. When individuals witness talented women playing skilful football and succeeding, their perceptions are challenged (Forde, 2008; Meier, 2005). Even more significant is when males play against females in practices or games and the females finish victoriously.

One of the coaches in Johannesburg commented on how community members changed their view of women's football.

> They weren't yet used to seeing girls playing football, so they just thought, ah, football is not for girls, it's meant for boys. But when they saw them playing and when they saw how much they give a challenge to the boys, they started developing interest and some of them started to send their own girls to the team.

When the community members saw the girls playing against boys in the local football league and the success the girls were having, they changed from believing that football was not for girls, to sending their daughters to play as well.

Lulama's sister described how she enjoyed watching matches, particularly one match where the girls were beating their male teachers and a crowd was gathering. She went on to describe how witnessing the girls' success was beginning to change mind-sets about the girls' abilities for the primarily male spectators.

> They have a mindset that this is a man's game. Just goes to show, .. if a guy can do, so can a woman, even better. So yeah. It was quite a scene. ... so they are getting some support from guys who have that mindset, even since they played that match where they played with the teachers so they were quite taken in by surprise. So they got to be fans through that match. They could see that these girls are capable of doing that so might as well give them the chance to change that mindset of them.

Lulama's sister is saying that the mind-set that football is a man's game can be changed as men and women come out to watch talented women play and see that the girls are capable of succeeding, particularly when they defeat men. In her argument she uses a liberal feminist argument that there can be equality between men and women, as well as a radical feminist argument whereby the fans were able to change their perspective of the capabilities of the girls. This scene was particularly telling as there were gender and power dynamics involved since the teachers are assumed to have superior power and abilities and should be able to beat the girls that they are instructing.

DISCUSSION

Each of the aspects discussed in the results section work together to challenge gender norms and reduce the vulnerability of girls in the context of poverty in South Africa. The

central location and starting point is the football field, as the place where girls can find refuge and safety from the dangers of the streets. Not only is the location a positive influence, the skills and relationships built in that location are equally, or perhaps more important. Through participating in a competitive, physical sport in front of spectators, self-confidence, self-esteem and self-efficacy is developed, which increases the girls' abilities to make good decisions in uncertain situations as well as the potential to physically stand up for themselves in dangerous circumstances (Weiss and Wiese-Bjornstal, 2009). The solidarity built with team members further encourages positive and healthy life choices including avoiding alcohol and risky sexual behaviours that lead to early pregnancy and HIV/AIDS and STIs (Pelak, 2005; Ramiro et al., 2013). Through relationships built with boys by playing on the same teams and being in the same location enjoying the same sport, greater understanding and mutual respect is built, which changes the way the girls are perceived and treated. As the girls demonstrate their capabilities on and off the field they challenge traditional gender norms and some men begin to adjust their understandings of the capabilities and characteristics of women (Meier, 2005). This is an important factor, as societal change is limited when half the population does not adjust.

Since the majority of the girls in this study grew up playing football with boys at school and in their community, they accessed the social networking and solidarity that is built on teams (Pelak, 2005). These close encounters and solidarity led to the boys becoming respectful and protective of their female friends. The examples of Zongile and Jamila demonstrated this protection as the boys would confide in them, give them advice and treat them differently in social settings such as parties. This differential treatment is desired by the girls who prefer to be treated as equals rather than objects of affection.

The findings relating to sport participation and sexual activity found in these cases are similar to international research, where girls who participate in sport, gained self-confidence, respect for, and ownership of, their bodies, which led to later sexual debut and lower chances of risky behaviours (Sabo et al., 1999; Erkut and Tracey, 2005). Adding to that research, the examples in this study highlight the importance of friendships between boys and girls, where the boys respect the girls, confide in them, give them advice and treat them as a friend on and off the pitch. This can delay the start of sexual activity for the girls and result in more positive male-female relationships that could alter gender norms and in the long run change patterns of abuse entrenched in the South African society. The effects of these changed relationships remain limited with the focus on women as the agents of change (Hayhurst, 2013). In this research there are changes in the males, albeit small, who change their perceptions and actions towards girls that participate in football. While this is positive for these girls, the boys continue to treat other girls the same, as seen by the example given by Jamila, where the boys she played with continue to treat other girls at the party the same.

Household members encourage mixed-gender friendship as a celebration of going against common patterns of teenage pregnancy. Encouraging these friendships assumes deviant heterosexual teenage sexual activity (Jackson and Scott, 2010). Through the focus on heterosexuality, the social norms and desired behaviours are reinforced and the girls' bodies and freedom are monitored and policed (Hayhurst, 2013).

In Johannesburg the access to facilities is slightly better than in Cape Town, where there are more usable fields and a stadium that the women are occasionally allowed to use. There is animosity among the male community members towards the women using the facilities in both locations. However, when the girls demonstrate that they are able to play, they are given

relatively more freedom to use the facilities to support their participation than at the outset. Furthermore, the experience gained through playing with the boys gave the girls physical assets that would assist them in being accepted as a legitimate football player and access additional community resources.

When girls are able to demonstrate that they are capable of playing at the same level of boys or men, they are making a case for equal access to facilities, resources and media coverage, which is in line with liberal feminism (Hargreaves, 2004). Personal experiences and shifts in resource allocations take processes of change one step further to alter the way people think about female football, which is associated with radical and critical feminisms (Birrell, 2000).This aligns with research conducted by Forde (2008) and Meier (2005), who found that as women claimed public space in their communities, they challenged gender norms and changed perceptions of female sport capabilities. Women require the support of the men controlling the access to these fields in order to acquire the physical, cultural and social skills that will provide the means for social mobility. A cycle of impact is evident: cultural norms restrict women's access to facilities; some of the men controlling the women's access have to be willing to put the cultural norms aside to provide the women the opportunity to participate; this demonstrates to other community members that cultural norms can be different and there is potential for women to participate; which can in turn open more opportunities or facilities for participation.

CONCLUSION

For the girls that play football in South Africa, they see their participation as a place to have fun, escape the confines of family, chores, and homework, and spend time with their friends. Although they recognize the social and relational benefits of participation, it is beyond their scope to see the greater changes that can occur. Within the challenges of poverty, the statistics seem weighted against them: high levels of unemployment, HIV/AIDS, teenage pregnancy, violence against women, alcohol and drug abuse. They are vulnerable due to their age, gender, and race. Yet through their participation in football, they gain skills and personal attributes to navigate the challenges and temptations, and emerge successful, healthy, and strong.

Developing strong, confident, healthy women is insufficient to truly change the context of vulnerability and inequity in South Africa. Combatting the entrenched hegemonic views towards gender roles requires going beyond empowering women to altering the views and practices of men. As men encounter strong women, observe them active in non-traditional roles, demonstrating aptitude and success in these roles in addition to the desire to empower their wives, daughters, sisters, or nieces, changes to practices and gender roles begin to occur. When boys foster deeper friendships with girls and understand them on a different level, they treat them differently. The gender implications of these changes are limited as the same boys still treat other girls as objects of attraction.

Further research is needed to understand the longer term effects of football participation on gender relations and poverty in South Africa. As these girls grow, do they continue to participate in football or other physical activities? How do their relationships with boys change as they desire to enter into romantic relationships and start building their own

families? What are the rates of domestic abuse within those families? Additional research in similar situations of poverty across the continent and internationally would be significant in this field of discussion.

REFERENCES

Birrell, S. (2000). Feminist theories for sport. In J. Coakley, and E. Dunning (Eds.), *Handbook of sport studies* (pp. 61-76). London: Sage.

Brady, M. (2005). Creating Safe Spaces and Building Social Assets for Young Women in the Developing World: A New Role for Sports. *Women's Studies Quarterly, 33(1/2),* 35-49.

Bryson, L. (1994). Sport and the Maintenance of Masculine Hegemony. In S. Birrell and C.L. Cole (Eds.), *Women, Sport and Culture.* (pp. 47-64). Champaign, IL: Human Kinetics.

Burnett, C. (2001). Whose game is it anyway? Power, play and sport. *Agenda, 49,* 71-78.

Burnett, C. and Hollander, W.J. (2005). *Facility Audit in Hubs for Siyadlala Mass Participation Sport and Recreation Programme.* Johannesburg: Sport and Recreation South Africa.

Connell, R.W. (2005). *Masculinities. (Second Edition).* Berkley and Los Angeles, CA: University of California Press.

Elling, A. and Janssens, J. (2009). Sexuality as a Structural Principle in Sport Participation: Negotiating Sports Spaces. *International Review for the Sociology of Sport, 44(1),*71-86.

Erkut, S. and Tracy, A.J. (2005). *Sports as Protective of Girls' High-Risk Sexual Behaviour 2000-2005*. Wellesley, MA: Wellesley Centers for Women, Wellesley College. http://www.wcwonline.org/Archived-Projects/sports-as-protective-of-girls-high-risk-sexual-behavior.

Fielding, N. and Lee, R. (1998). *Computer Analysis and Qualitative Research.* London: Sage.

Forde, S. (2008). *Playing by Their Rules: coastal teenage girls in Kenya on life, love and football.* Kilifi, Kenya: Moving The Goalposts.

Frantz, J.M. (2006). Physical inactivity as one of the chronic disease risk factors among high school learners in public schools in a local community in South Africa. *South African Journal for Research in Sport, Physical Education and Recreation, 28(2),* 73-80.

Government of South Africa. (2016). Women's Month 2015. http://www.gov.za/womens-month-1-31-aug-2015

Hargreaves, J. (2004). Querying Sport Feminism: Personal or Political. In R. Giulianotti (Ed.), *Sport and modern social theorists.* (pp. 187-207). Hampshire, England: Palgrave Macmillan.

Hayhurst, L.M.C. (2013). Girls as the 'New' Agents of Social Change? Exploring the 'Girl Effect' Through Sport, Gender and Development Programs in Uganda. *Sociological Research Online,* 18(2). http://www.socresonline.org.uk/18/2/8.html

Heywood, L. and Dworkin, S.L. (2003). *Built To Win: The Female Athlete as Cultural Icon.* Minneapolis: University of Minnesota Press.

Hoque, M.E. (2011). Reported risky sexual practices amongst female undergraduate students in KwaZulu-Natal, South Africa. *African Journal of Primary Health Care and Family Medicine, 3(1),* 143-148.

Jackson, S. and Scott, S. (2010). *Theorizing Sexuality.* Berkshire, England: Open University Press.

Jones-Palm, D.H. and Palm, J. (2005). *Physical Activity and its impact on Health Behavior among Youth.* Paper commissioned by ICSSPE. http://www.icsspe.org/documente/PhysicalActivity.pdf.

Kaplan, K.C., Lewis, J., Gebrian, B. and Theall, K. (2015). Soccer and sexual health education: a promising approach for reducing adolescent births in Haiti. *Revista Panamericana de Salud Pública. 37(4/5),* 316–23.

Kay, T. (2009). Developing through sport: evidencing sport impacts on young people. *Sport in Society, 12(9),* 1177-1191.

Kay, T. and Spaaij, R. (2011). The mediating effects of family on sport in international development contexts. *International Review for the Sociology of Sport, 47(1),* 77-94.

Machisa, M., Jewkes, R., Lowe Morna, C. and Rama, K. (Editors) (2011). *The War at Home: Gender Based Violence Indicators Project, Gauteng Research Report, South Africa*. Johannesburg: Gender Links and South African Medical Research Council.

McAuley, E., Mihalko, S.L. and Bane, S.M. (1997). Exercise and Self-Esteem in Middle-Aged Adults: Multidimensional Relationships and Physical Fitness and Self-Efficacy Influences. *Journal of Behavioural Medicine, 20(1),* 67-83.

Meier, M. (2005). *Gender Equity, Sport and Development: Working Paper.* Biel, Bienne: Swiss Academy for Development.

Meredith, M. (2011). *The State of Africa: A history of the continent since independence.* London: Simon and Schester UK Ltd.

Moffett, H. (2008). Gender. In N. Sheperd and S. Robins (Eds.), *New South African Keywords.* (pp. 104-115). Johannesburg: Jacana.

ONE (2015). Status of women and girls in South Africa 2015 http://www.one.org/africa/policy/status-of-women-and-girls-in-south-africa/

Pelak, C.F. (2005). Negotiating Gender/Race/Class Constraints in the New South Africa: A Case Study of Women's Soccer. *International Review for the Sociology of Sport, 40(1),* 53-70.

Pitpitan, E.V., Kalichman, S.C., Eaton, L.A., Sikkema, K.J., Watt, M.H. and Skinner, D. (2012). Gender-based violence and HIV sexual risk behaviour: Alcohol use and mental health problems as mediators among women in drinking venues. *Social Science and Medicine, 75(8),* 1417-1425.

Ramiro, M.T., Teva, I., Bermúdez, M.P. and Buela-Casal, G. (2013). Social support, self-esteem and depression: Relationship with risk for sexually transmitted infections/HIV transmission. *International Journal of Clinical and Health Psychology. 13,* 81-188.

Rawson Property Group (2012). South Africa's Gini coefficient is the highest in the world. http://www.rawson.co.za/news/south-africas-gini-coefficient-is-the-highest-in-the-world-id-874

Sabo, D.F., Miller, K.E., Farrell, M.P., Melnick, M.J. and Barnes, G.M. (1999). High School Athletic Participation, Sexual Behavior and Adolescent Pregnancy: A Regional Study. *Journal of Adolescent Health, 25(3),* 207-216.

South African Institute of Race Relations (SAIRR). (2010). *South Africa Survey 2009/2010.* Johannesburg: South African Institute of Race Relations.

South African Institute of Race Relations (SAIRR). (2012). *Fast Facts, May 2012.* South African Institute of Race Relations.

Thomas, J.R., Nelson, J.K. and Silverman, S.J. (2011). *Research Methods in Physical Activity: Sixth Edition.* Champaign, IL: Human Kinetics.

Trading Economies (2015). *South Africa Unemployment Rate.* http://www. tradingeconomics.com/south-africa/unemployment-rate.

United Nation (UN), (2015). *Transforming our world: the 2030 Agenda for Sustainable Development.* New York: United Nations.

Weiss, M.R. and Wiese-Bjornstal, D.M. (2009). Promoting Positive Youth Development through Physical Activity. *President's Council on Physical Fitness and Sports, Research Digest, 10(3),* 1-9. https://www. presidentschallenge.org/informed/digest/docs/ september2009digest.pdf.

BIOGRAPHICAL SKETCH

Cassandra Ogunniyi

Affiliation: University of Johannesburg, Research Associate

Education:

Honours Bachelor of Arts, International Development Studies Co-op Specialist, Minor in Anthropology (University of Toronto)

Master of Social Science, Practical Anthropology (University of Cape Town)

Doctor of Philosophy, Sport Management (University of Johannesburg)

Research and Professional Experience:

Dr. Ogunniyi is currently a Research Associate in the Department of Sport and Movement Studies at the University of Johannesburg in South Africa. She has lectured at the University of Johannesburg in courses including Sport History, Philosophy of Sport, Sport Sociology and Research Methodology. She has previously held positions as Manager of the Research Office, and Research Assistant in the Department of Sport and Movement Studies at the University of Johannesburg. One of the products of this work was the publication of two manuals (co-authored with Cora Burnett, Charl Roux, and Jack Sugden) that incorporate sports and indigenous games with life skills training for primary and secondary school aged children. Her PhD thesis was focused on the social effects of participation in football for females, their households, peers, and community members, in the context of poverty in South Africa. She has conducted research on the impacts of women's participation in university level football on household dynamics; media coverage of the African Women's Championships; the social impact of the FIFA Football For Hope Festival on the host community; women in leadership positions during the FIFA 2010 World Cup; and gender relations and power dynamics in sport for development organizations. In 2012, Dr. Ogunniyi was a consultant and trainer for the Gender Awareness Manual produced by GIZ/Youth Development through Football in Pretoria, South Africa. As the Research Administrator for BH Impact Assessment Services, Dr. Ogunniyi managed monitoring and evaluation consultations with over 50 organizations across the African continent. Her international

experience includes work as a Project Coordinator for Right To Play in Kasulu, Tanzania and volunteer work in Australia, Thailand and East Timor.

Publications Last Three Years:

Ogunniyi, C. (2015). The Effects of Sport Participation on Gender Relations: Comprehensive case studies of female footballers in Johannesburg and Cape Town, South Africa. *South African Review of Sociology. Special Edition 2015, Sociology of Sport, 46(1),* 25-46.

Ogunniyi, C. (2015). Gender Discourse at the Football for Hope Festival 2010. *African Journal for Physical, Health Education, Recreation and Dance (AJPHERD), March(Supplement),* 67-79.

Ogunniyi, C. (2014). Perceptions of the African Women's Championships: female footballers as anomalies. *Sport in Society: Cultures, Commerce, Media, Politics, 17(4),* 537-549.

INDEX

D

E

F

G

H

I

K

L

M

N

O

P

R

S

T

U

V

W

Y

Z