Chapter 2

The Effects of Climate Change on Rural-Urban Migration in Sub-Saharan Africa (SSA)—The Cases of Democratic Republic of Congo, Kenya and Niger

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Additional information is available at the end of the chapter

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Abstract

Water is essential for the existence of living organisms including humans. Water is needed in farms to grow crops, firms and manufacturing industry to produce products and services. This chapter examines water resources availability and management in Sub-Saharan Africa (SSA) in climate change perspective using vector auto-regression (VAR) time series analysis. Water is known to be unevenly distributed among countries and continents around the world, particularly in Sub-Sahara Africa; the water availability varies between member countries and regions in the individual country, water supply systems experience enormous pressure to make water accessible to people in both rural and urban communities. Water security remains to be an integral part of the SSA's effort to achieve food security and supply, halve poverty and eradicate hunger. This chapter more importantly aims to investigate impact of rainfall and temperature issues—that are climate change proxy variables—on water security and people movement in three Sub-Saharan African countries that are Democratic Republic of Congo, Kenya and Niger. This article assesses some possible causes of migration from rural to urban area using VAR and granger causality tests; this process involves four variables namely Rural Migration 'MR', Urban Migration 'MU', Rainfall 'Rain' and Temperature 'Temp'. The model predicts rainfall and temperature across 10 years and examines how these changes impact water availability and people movement in relevant countries. This study finds that some countries are experiencing water security challenges upon which large numbers migrate to urban areas. The study reveals that variations in rainfall and temperature have compounded people movements from rural areas. It is noted that the agricultural production in SSA have not improved over time and in fact, it has further decreased due to the move away from rural areas by many farmers.

Keywords: Sub-Saharan African, climate change, rainfall, temperature, VAR analysis, rural-urban migration

1. Introduction

Not only countries from Sub-Saharan Africa (SSA) are experiencing water security challenges, other developing countries in the world are also facing water security problems. Water security challenges may affect the environmental, economic and social stability and wellbeing in these countries particularly those in SSA regions. The seriousness of these circumstances highlights the need to examine the impact of climate change factors—rain and temp— that may have water security and people movement in SSA. Water security in SSA has been an essential part of the SSA's attempt to achieve sustainable food security and the aim is to eradicate hunger and halve poverty. The chapter selects three Sub-Saharan African countries on the grounds of geographical location, population size and growth rates, people migration, climatic change conditions, current and projected water resources in terms of renewable fresh water resources (m^3/capita/yr), as well as economic stability and development.

Water is essential for the existence of life on the planet, it is the primary component of the ecosystem and is used for many purposes [1–3]. The three main purposes are agriculture, industry and domestic, water is also utilized in energy production, transport and recreation. Economic activities, agricultural development and environmental systems could only exist when there is water available to them [4–8]. Nelson Mandela said "*Among the many things that I learnt as president was the centrality of water in the social, political and economic affairs of the country, the continent and the world*" [9, 6, 10]. Lack of the necessary water infrastructure appears to be a major challenge faced in the developing countries, particularly those in SSA [11]. In SSA, water availability and accessibility processes are complicated and time consuming; for instance, in some SSA regions where hours are spent each day by household members to collect water for domestic consumption. It is estimated that a round trip takes an average of 36 min to collect drinking water [5]. The amount of fresh water per capita in the SSA has declined; it dropped about 30% since 1990 [11]. According to [12], 30% of world population lives in dry lands that have only 8% of the total renewable freshwater resources. Climate change is expected to exacerbate water security situation in these areas that are already under water stress. **Figure 1** presents world's environmental hotspots and migration.

To describe water scarcity, there have been several definitions that were in use in recent decades, while majority of these definitions did not receive an unreserved recommendation; however, there has been common view of the primary requirements of water scarcity definition. One of the main requirements of water scarcity definition is that it must suggest possible ways to conduct both quantitative and qualitative assessments. The World Water Development Report listed some of these definitions and defines water scarcity as "*The point at which the aggregate impact of all users impinges on the supply or quality of water under prevailing institutional arrangements to the extent that the demand by all sectors, including the environment, cannot be satisfied fully, a relative concept that can occur at any level of supply or demand. Scarcity may be a social construct (a product of affluence, expectations and customary behaviour) or the consequence of altered supply patterns stemming from climate change. Scarcity has various causes, most of which are capable of being remedied or alleviated*" [13–15].

Water scarcity is the situation where the available fresh water per capita is less than 1000 m^3 per annum—in other words, the minimum agreed amount of fresh water for human survival

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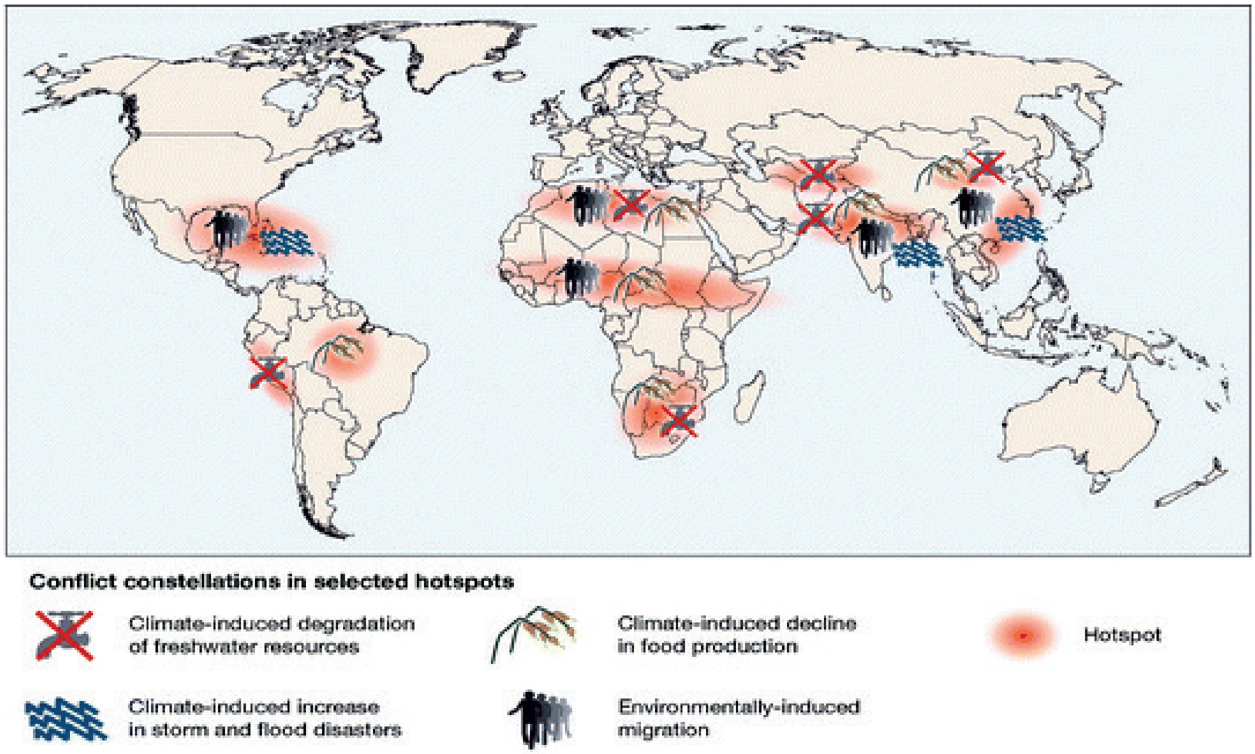

Figure 1. Environmental hotspots and migration [13].

is around 35,318.3 ft^3/yr or 1000 m^3/yr [7, 14, 15]. Further, a water stress situation exists when the available fresh water per capita per annum is higher than 1000 m^3/capita/yr and less than 1700 m^3/capita/yr [14–17]. On the other hand, water shortage is defined as the ratio of the total fresh water withdrawal to the available rainfall [18]. The condition of water scarcity (WSC) can also exist when the demand of fresh water (WD) exceeds the fresh water supply (WS) available in a certain period and/or place, that is, when water requirements of some sectors are not met. Water scarcity can also be expressed as a formula: $WSC = WD \geq WS$; [13]. **Figure 2** presents water availability for some African countries in 1999 and 2025. In fact, the World Bank reported that Niger has been under water scarcity condition since 1962 and had 183 m^3 of renewable internal freshwater resources per capita in 2014, therefore water availability condition shown for Niger in **Figure 2** seems to incorrect.

Despite that Sub-Saharan African region appears to have enough water resources all around the year [20], these waters are unevenly distributed between member states. There has been sufficient rainfall in Central Africa region due to the humid and semi-humid weather conditions, these favourable rainfall conditions resulted water resources abundance in this region. In contrast, there have been considerable rainfall fluctuations in dry and semi-dry regions that experience temperate and semi-temperate climates. The precipitation in these regions characterize high intensity but occurs within short periods of time; often producing floods and rainwater runoff washing fertile topsoil to downstream [21]. Moreover, Zambia, Angola and Mozambique experienced intense rainfalls in 2000 that caused subsequent floods. However, such heavy rainfalls seem not to have improved the water availability. In fact they have all experienced droughts over the past three decades [22]. The SSA rainfall fluctuation, frequency and amount are met by similar increases in levels of dryness in the region [23]. A period of

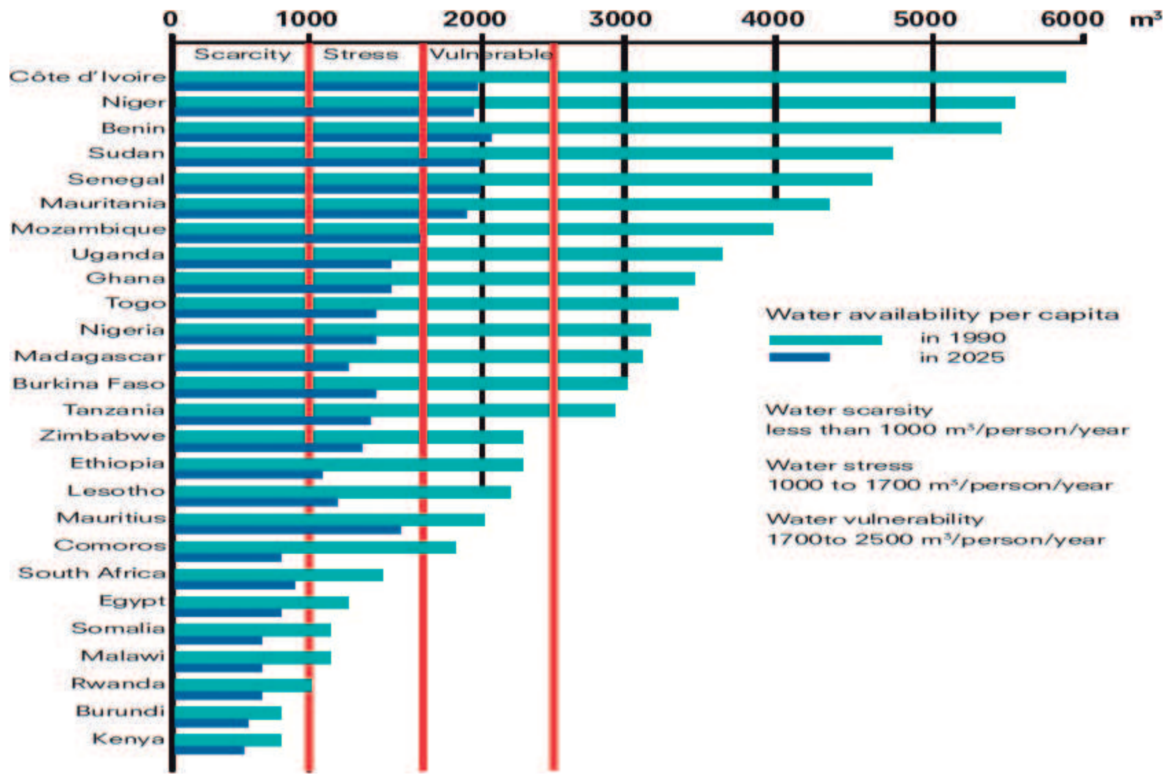

Figure 2. Water availability for some African countries in 1999 and 2025 [19].

low rainfall means a period of scarcity of both feed and water, and an increase in distances to suitable grazing areas [24]; this study also notes that among small-scale farmers, rainfall is the most important climatic factor that is critical to their survival, particularly for crop growth and livestock herds. Geographically, SSA falls below the Sahara Desert and consists of the vast majority of African countries. The countries that fall in the Northern Africa region that are Egypt, Libya, Tunisia, Algeria and Morocco are not in SSA [25]. SSA has an estimated land area of 24.24 million km^2 [26].

In this chapter, authors critically review the water security and migration situation in SSA region by using a country by country analysis of three selected countries from SSA region. The main aim of this study is to examine water resources availability and accessibility and how rainfall and temperature variations and distributions have impacted water security and people urban migration in the region. The study attempts to identify pull and push factors that appear to affect the people movement from rural to urban areas in SSA. The selected SSA countries are Democratic Republic of Congo (DRC), Kenya and Niger. This study uses VAR and Granger causality methods to analyse rainfall and temperature and their impact on rural/urban migration.

2. Background

Africa is considered to be the second driest continent in the world after Australia [27, 28]. It is predicted that 25 countries in Africa may experience water stress condition by the year 2025 [29, 30]. Nevertheless, world's longest rivers flow within Africa, the Nile River followed by other main rivers in SSA regions such as the Congo, Zambezi and Niger Rivers. In addition to that, SSA has Lake Victoria, which is the second largest lake in the world [29, 31, 32]. Approximately 53% of Africa is believed to be water abundant and about 61% of the total population live in this region which also holds about 95% of the total renewable water resources of the continent [31]. Nonetheless, it is predicted that by 2025 Africa's water abundance area may shrink to 35 and 24% of the population that will inhabit in water abundance areas that holds 78% of available renewable water resources. In contrast, the combined water scarcity and deficit areas is expected to increase from 47% of (2000) to 65% in 2025, holding only 22% of the total renewable water resources; so 76% of Africa's population will live in water scarcity and deficit areas in 2025 as shown in **Table 1**.

Sub-Saharan Africa has 24.24 million km^2 [26, 32] that is equal to 18% of the world's land [33] and the average annual rainfall of SSA is estimated to around 815 mm/yr. However, there have been considerable variations of rainfall amounts in SSA's sub regions; that may be due to climatic differences [34]. Compounding rainfall fluctuation will be the anticipated effects of climate change that will cause more challenges that are yet to be seen. For instance, this may include sudden and large increase in rainfall fluctuations and distribution in the SSA region, creating natural disasters such as floods and droughts have been noted [2, 6, 35, 36]. For instance, annual rainfalls in Sierra Leone, Liberia, Seychelles and Mauritius may reach 2000 mm/yr [34]. In contrast, parts of South Africa and eastern Namibia the annual rainfall is less than 100 mm/yr. Further rainfall in northern Niger may be as low as 10 mm/yr [34]. Hell et al. [37] reported that rainfall in the African is unevenly distributed and added that fewer people live regions that often receive higher rainfall compared to overpopulated regions that receive lower rainfall. According to Temesgen [38], in 2009 around 260 million people in SSA (41% of SSA's population) lived in dry areas that are vulnerable to drought.

Faurès and Santini [34] reported that production factors such as land and water resources may be abundant in SSA but the region continues to experience a falling GDP of 0.6% since 2004 [38]. Agriculture remains to be the main source of food to SSA's low socioeconomic communities; rainfed agriculture is anticipated to be the dominating food production system in SSA in foreseeable future. Number of people living under poverty level and undernourished worldwide has been falling in recent decades in general and in Asia in particular. In SSA, the number of people living under the poverty line has not decreased considerably compared to other world regions. Further, SSA has made limited progress in improving the lives of poor

Countries with water	**2000**			**2025**		
	Area %	**Population %**	**Water %**	**Area %**	**Population %**	**Water %**
Abundance	52.5	60.8	95.2	34.7	23.9	78.3
Scarcity	26.0	24.3	4.4	39.1	57.3	20.6
Deficit	21.5	14.9	0.4	26.2	18.8	1.1
Total African population	786 million			1428 million		

Ashton [31].

Table 1. Water availability projections according to three different conditions in Africa 2000–2025.

people and reducing the number of people living under the poverty line. In fact, number of people living below the poverty line in SSA has risen considerably due to the implementation of the new definition for poverty, where the $1.00/day has increased to $1.25/day [39]. In 2014, SSA had 214 million undernourished people (26.6% of the population) [40]. In 1990, East Asia/the Pacific and SSA's contribution to the total number of people living under poverty line in the world were 52 and 15% respectively; after 23 years and in 2013, the percentage of the East Asia/the Pacific has dropped to 9%, while SSA's contribution has increased to 51% in the same period. **Table 2** shows percentage of people living on less than $1.25/day by world region between 1981 and 2005.

According to Faurès and Santini [34], SSA boasts more than 3880 km^3/yr of internal renewable water resources. Central Africa Republic, Guinea, Madagascar and Democratic Republic of Congo are among water rich countries in SSA; in 2014 these countries had 28,776, 17,924, 13,906 and 11,648 m^3/yr of internal renewable water resources, respectively. The per capita internal renewable water resources of these countries have fallen from 90,559, 61,230, 56,106 and 62,955 m^3/yr in 1962, respectively. Central Africa Region receives about 40% of the annual rainfall in SSA around 7500 km^3/yr and only 23% of the SSA population inhabit this region. Indraratna et al. [41] suggested that the uneven distribution of rainfall in SSA necessitates the implementation of suitable policies and water supply systems to enhance the sustainability of water usage in the region. Efficient water supply systems may enable local communities to get social stability, economic development and more importantly to achieve sustainable agricultural production [42]. According to Temesgen [38], there has been number rainwater harvesting initiatives and water management systems in SSA; practices such as in situ and micro catchment are more popular than rainwater irrigation methods. The per capita share of internal

Region	1990	1993	1996	1999	2002	2005	2008	2010	2011	2012	2013
East Asia and the Pacific	966	877	684	669	535	349	288	218	167	142	71
Eastern Europe and Central Asia	9	25	34	37	29	23	15	14	13	12	10
Latin America and the Caribbean	71	68	71	72	71	61	42	39	36	34	34
Middle East and Northern Africa	14	14	12	10	10	9	7	7	7	6	6
South Asia	505	541	517	532	552	508	465	400	328	293	256
Sub-Saharan Africa (SSA)	276	323	346	371	391	382	389	399	396	393	389
SSA (percent to total)	15	17	21	22	25	29	32	37	42	45	51
World	1840	1849	1664	1692	1588	1332	1205	1077	946	880	766

Roser and Ortiz-Ospina [42].

Table 2. People living on less than $1.25/day by world region 1990–2013 (million).

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renewable water resources in SSA has experienced a substantial decline from 16,500 m^3 per inhabitant in 1960 to 5500 m^3 per capita in 2005; about 65% fall [34, 42], this falling trend is mainly due to the significant increase of SSA's population during this period. In some cases, countries like Niger, Ivory Coast and Uganda, the decline has been more dramatic, **Table 3** shows changes in available renewable internal freshwater resources per capita of six selected countries and SSA between 1962 and 2014.

Table 4 presents changes in per capita water availability by region for five decades between 1950 and 2000. Africa's per capita renewable internal freshwater resources shows the most significant decline, shrinking from 20,000 m^3 of water per person in 1950 to 5100 m^3 in 2000; this means that each person living in Africa lost about three quarters of their share of available water in just 50 years (**Table 4**). **Figure 3** illustrates that the fresh water per capita share around the world has been decreasing since and predicts a continuous fall until 2050; even though water resources per capita have declined significantly in many world regions such as the Caribbean, Latin America and Northern America since 1950s, the United Nations predicts that people living is Africa and Asia will get the least share of water resources (per capita basis) by 2050.

Despite the rainfall fluctuations, SSA experiences higher temperatures that impact on agricultural production in many parts of the region [44, 45]. Africa is a continent which is experiencing warmer seasons as part of the trend of global warming. It is predicted that temperatures will continue to rise and a growing threat to food production systems in SSA is imminent [44, 45]. In March 2013, the temperature in South Africa's Vioolsdrif village recorded its hottest day ever measured on the area at 47.3°C. Similarly, the temperature in Navrongo, Ghana, reached 43°C on March 6, 2013, the hottest ever recorded. According to Fabusoro et al. [46], the patterns of rainfall and temperatures in the studied area appear to be following a similar upward trend, with temperatures rising at about 0.4°C/month/decade in southwest Nigeria. World average temperatures have increased about 0.85°C between 1886 and 2012, and it is anticipated that average global temperature will continue to increase, reaching around 1.5°C by the middle of the twenty-first century [24]. In the face of such evidence, we must acknowledge that the effects of climate change are real. In the Sub-Saharan African region, where the average temperature is rising, it is claimed by many that climate change is already affecting agriculture and production levels [24, 47]. Between 1980 and 2000, the temperature records from the majority of weather stations in the SSA sub regions revealed progressive warming. Because of this rise in temperature, small farmers could grow crops which are tolerant to higher temperatures [24]. As shown in **Figure 4**, the annual average temperatures of three Sub-Saharan African countries considered in this study have shown a fluctuating trend between 1900 and 1960. More importantly, annual average temperatures of these countries have been rising significantly since 1960 until 2015. It is predicted that average temperatures in these countries will continue to increase.

2.1. People movement and water security in SSA

Population is Sub-Saharan Africa has been growing rapidly since mid-twentieth century, it grew from 228 million in 1962 to reach 911 million in 2012 [14, 15]. In contrast, productive lands have been shrinking and the fast population growth led that SSA's renewable fresh

Year	1962	1967	1972	1977	1982	1987	1992	1997	2002	2007	2012	2014
DRC	56,105	48,971	42,613	37,117	32,471	28,544	24,099	20,534	18,059	15,406	13,048	12,208
KEN	2399	2039	1713	1425	1179	980	829	715	623	544	474	450
NER	973	845	736	639	556	484	415	348	290	241	198	183
NIG	975	845	734	637	552	478	409	344	287	239	197	183
SOM	2088	1858	1727	1243	893	855	801	737	627	544	470	444
ZAF	2445	2149	1887	1659	1464	1300	1159	1044	977	916	853	827
SSA	18,301	16,200	14,259	12,409	10,729	9329	8133	6559	5752	5028	4210	3985

Table 3. Renewable internal freshwater resources per capita (cubic meters) in some SSA countries.

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Region	1950	1960	1970	1980	2000
Africa	20.0	16.5	12.7	9.4	5.1
Asia (excluding Oceania)	9.6	7.9	6.1	5.1	3.3
Europe (excluding the Soviet Union)	5.9	5.4	4.9	4.6	4.1
North America and Central America	37.2	30.0	25.2	21.3	17.5
South America	105.0	80.2	61.7	48.8	28.3
Rosegrant [43].					

Table 4. Water availability per capita by region, 1950–2000 (1000 m^3).

water resources (m^3/capita/yr) to decline significantly. The interaction of these circumstances have resulted a large scale people movement in SSA, where people living is rural SSA has decreased from 85% in 1962 to 63% in 2012 [14, 15]. It is predicted that 50% of SSA population will live in urban areas by 2020 thus may lead to major problems for the cities in SSA [14, 15]. There is now evidence that suggests that SSA agriculture has been suffering from multiple difficulties including water shortages, shortage of farm workers and poor productive lands over recent times. In addition to this, there is now evidence that more SSA people are leaving from their rural areas to cities in significant numbers; a phenomenon which was predicted by [1]. **Figure 5** shows the current and projected populations of the world by region.

Tularam and Hassan [14, 15] stated that decreasing water security condition in SSA will represent a major factor that causes human migration in the region. At present, SSA cities appear to be incapable to meet expectations of people migrating from their rural villages to urban areas; this led people to consider other regional and international destination. Europe remains to be the number one destination for SSA migrants crossing the Mediterranean Sea, thus refugee crisis in Europe in recent times shows that the longer term impacts of water insecurity in SSA is yet unpredictable and if major underpinning factors of the water insecurity situation in SSA are not addressed properly, there is going to be undesirable consequences in the future. It is predicted

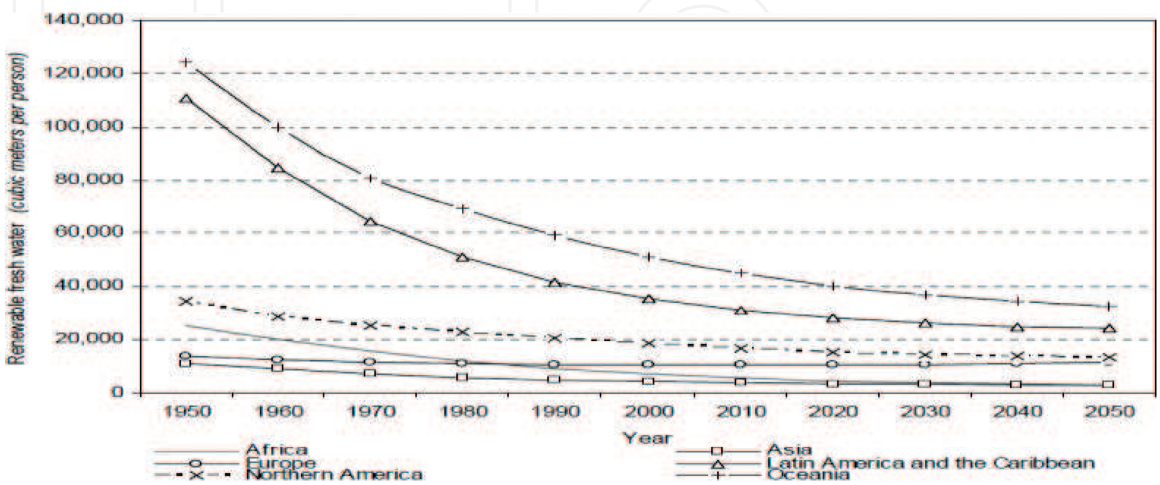

Figure 3. Water availability per capita in major world areas 1950–2050 [44].

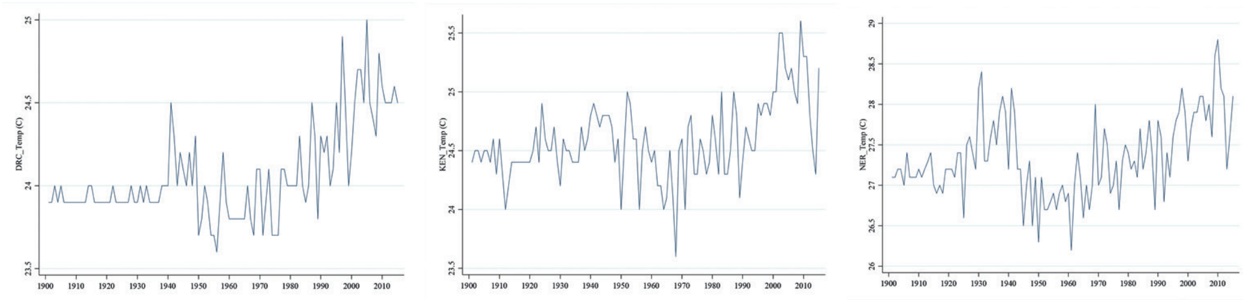

Figure 4. Average annual temperatures of Democratic Republic of Congo, Kenya and Niger 1901–2015.

that Europe may see further waves of SSA migrants coming to the advanced economies, and it is almost unquestionable that SSA migrants arriving Europe will have significant implications to the service delivery systems in place in Europe, particularly in Italy, that represents the major transit hub for SSA migrants. Likewise, other major destinations of SSA migrants include Indonesia, where in recent years migrants from several SSA countries including Sudan and Somalia as well as other migrants from other Asian countries such as Iran, Iraq, Afghanistan, Myanmar, Bangladesh and Sri Lanka are used as a major transit hub on their way to Australia.

2.2. Environmental refugees

Climate change factors such as changing rainfall and temperature have impacted rural communities of SSA and limited people's ability to establish a meaningful livelihood from their lands [52]. Norman [53] reported that the environmental refugee phenomenon emerged during twentieth century and environmental refugees are defined as *people who are forced to leave their original habitat because of some sort of environmental difficulty* [54]. As noted in [55], the term "environmental refugees" was first used by Essam El-Hinnawi in 1985 where 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"* [56]. Since 1985, researchers and experts in the people migration field have developed similar definitions

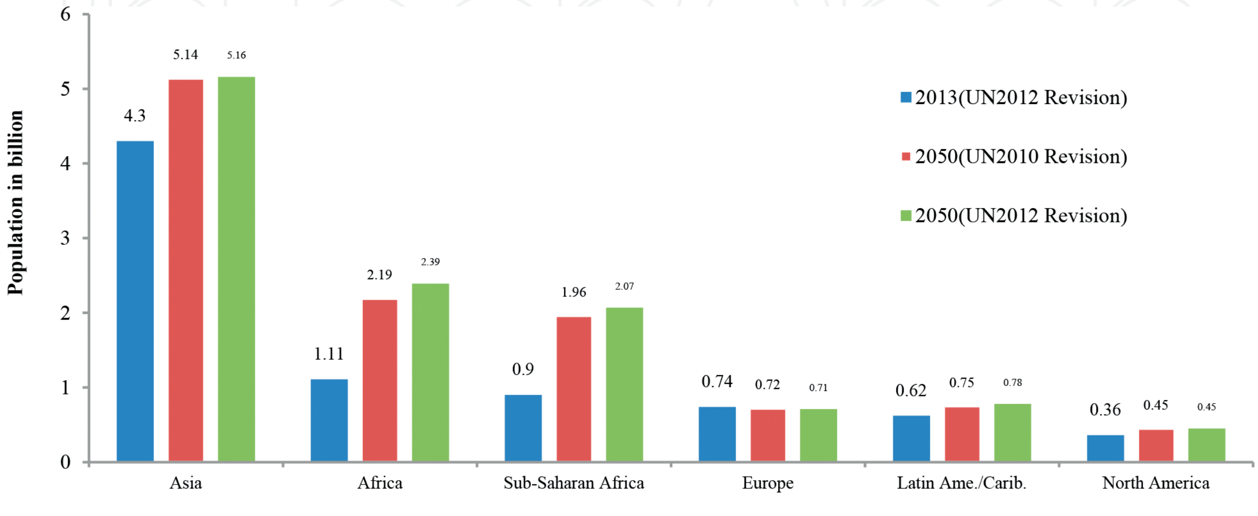

Figure 5. Current and projected populations of the world by region [49–51].

of the environmental refugee [57, 58]. Environmental refugees are 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*" [57, 58]. On the other hand, the United Nations High Commissioner for Refugees (UNHCR) has adapted a new term "*environmentally displaced persons*" aiming to minimize the use of the term "*refugee*" and refers environmentally displaced persons as 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*" [57]. About 50 million environmental refugees were recorded in 2010 and it is projected that the number of environmental refugees will increase to 200 million by the year 2050 [54, 58]. SSA appears to be a major contributor to the number of the environmental refugees in the world, and remains to hold a prime position [53]. It is crucial to adapt economic and social development strategies in SSA to improve the livelihood of SSA rural communities and to reduce poverty levels [59].

This chapter critically reviews water security and human migration issues of selected Sub-Sahara African countries. Changes in water security and human migration patterns are investigated with respect to the climate change variables of rainfall and temperature using time series framework. The authors analyse the water and population-related statistics of several SSA countries with respect to the rates of population growth, availability and accessibility of water resources, and assess possible effects of climate change factors (Rain and Temp); with regard to water resources availability and usage. Rural and urban migrations of these countries are also analysed to identify migration push and pull factors. A special consideration will be given to the migration patterns recently observed and the likelihood of water scarcity or stress in the future. In the following section, information about Democratic Republic of Congo (DRC), Kenya (KEN) and Niger (NER) is presented followed by methodology, then results and discussion and finally conclusion of the chapter.

2.3. Democratic Republic of Congo (DRC)

The Democratic Republic of Congo (DRC) also referred as Zaire, locates in the African Great Lakes region of Central Africa and borders with nine Sub-Saharan African countries namely Angola, Zambia, Tanzania, Burundi, Rwanda, Uganda, South Sudan, Central African Republic and Congo-Brazzaville. DRC is the largest country in SSA and has 2.34 million km^2 of land and considered to have large deposits of many natural resources such as oil, diamonds, copper and cobalt. Moreover, DRC is also known to as Africa's water rich country, it holds 23 and 52% of Africa's internal renewable water resources and surface water reserves, respectively [60]. DRC is the third most populated country in SSA after Nigeria and Ethiopia. Similar to most of SSA countries, the DRC population is growing fast and increased from 16.2 million in 1962 to about 69.57 million in 2012 [61]. A significant composition change in the population was noted where in 2012 around 45% of the DRC population was below the age of 15 years and only about 3% of the population was 65 years and over. In contrast, poverty is widespread in DRC and about 60% of the population lives below the poverty line ($1.25/day), and it is ranked as one of the world's poorest countries and positions number 186 out of 186 countries also co-held by Niger another in SSA country [62]. Two-thirds the country falls to the south of the Equator and one-third to the north [63]. The climate in DRC is cool and dry in the southern highlands with a cold, alpine climate in the Rwenzori Mountains and hot and humid in the river basin [64]. South of the Equator, the rainy season starts in October and lasts until May and in the north of the Equator, rain starts April and continues until November. In addition to this, rainfall is fairly regular throughout the year along the Equator [65]. The annual average rainfall in DRC ranges from 1000 to 1700 mm and average annual temperatures ranges 18–32°C. DRC experiences periodic climatic events such as seasonal flooding in the east and droughts in the south. These events are may be directly related to the significant variations of the rainfall in DRC abundance or lack of precipitation.

AGRA [24] and Chijioke et al. [44, 48] reported that the average temperature is increasing in the Sub-Saharan African region. They also noted that climate change is already affecting agriculture and production levels. Between 1980 and 2000, the temperature records from the majority of weather stations in the SSA sub regions revealed progressive warming. In line to these conditions, food security appears to be a major concern in DRC. There have been constant food insecurities in as much of DRC's rural communities and this may have resulted people movement from rural to urban areas. According to Alinovi et al. [66], the number of undernourished people in DRC has tripled from 12 to 36 million, and the prevalence increased from 31 to 72% of the population. In 2002, about 80% of the Congolese population lived below the poverty line of around US$0.2 per day [67]. Climate change also causes major events in DRC, for example, between 1974 and 2003, 19 natural disasters were recorder in DRC. Lukamba [68] noted that the Congo River of 4700 km length crosses the country from East to West and its water levels have been increasing steadily and posed risk to communities on its path including the 12 million people living in the capital Kinshasa. DRC is considered to be one of the most vulnerable and affected countries natural disasters. In some occasions, these climatic conditions trigger communities to mobilize and move to other locations seeking better food security conditions. In the following section, people movement in rural and urban areas as well as rainfall and temperature in DRC will be analysed and changes on these factors will be predicted in the next decade.

2.4. Kenya

Kenya is situated in the Eastern Africa region and borders Somalia, Ethiopia, South Sudan, Uganda, Tanzania and the Indian Ocean. Kenya has a 582,646 km^2 of land including 11,230 km^2 of water covered land. About 16% of Kenya's land is potentially suitable for agriculture, where 84% of the land is arid and semi-arid that is suitable for livestock or irrigated agriculture [69]. Kenya has dry and humid climates; that is probably the reason Kenya experiences critical water crisis. In Kenya, there has been a high variability of rainfall in terms of time and place and hence this had undesirably affected agricultural production. Presently Kenya is under water scarcity situation and the renewable fresh water per capita is 718.1 m^3/yr [61] stating that total internal renewable water resources per capita has dropped from 3558 m^3/yr in 1962 to 484.2 m^3/yr in 2011. Not surprisingly, it is predicted that the renewable freshwater per capita in Kenya will fall to 235 m^3/yr by the year 2025. UNEP (United Nations Environmental Programme) has announced the water crisis in Kenya as critical water scarce [70]. Kenya had a population of around 41 million in 2010 and it has been growing rapidly [71]. Nyanchaga [69] noted that Kenyan population has increased from 5.4 million in 1948 to 42 million in 2011. Rainfall in Kenya is highly variable and the annual average rainfall in the country is 630 mm.

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Marshall [71] reported that the annual rainfall in Mt. Kenya reached 1800 mm and that the rainfall in the northern regions of the country is below 200 mm. Rainfed agriculture is the major contributor of the Kenyan economy as to the most of SSA countries [71].

2.5. Niger

Niger is another West African country used in this study. The country borders with Algeria, Benin, Burkina Faso, Chad, Libya, Mali and Nigeria. Country has around 1.3 million km^2 of land and 15% of arable land [61]. It had a population of about 17.15 million in 2012 [72]. Niger is one the fastest growing countries in SSA in terms of population. The World Bank [72] reported that the population has quintupled within five decades, increasing from 3.33 million in 1960 to 17.15 million in 2012. Beside this population growth, Niger is the poorest country in the world out of 186 countries and positions the 186th place with DRC [62]. Approximately 61% of the population is classified as poor and live with less than $1/day. In line with other SSA countries, agriculture remains the dominant sector of the economy and accounts for 39% of the GDP in the year 2009. This means that agricultural production levels have significant impact to the annual economic growth. In fact, economic growth in Niger has been highly volatile due to the unfavourable farming conditions. EPRI [73] has noted that the economic growth rates were 3.2, 9.3 and −1.2% in 2007, 2008 and 2009, respectively. Climate change implications have affected Niger and the two main factors that affect the agricultural production are desertification and frequent drought conditions [73]. On the contrary to other SSA countries, during the past 50 years urban population has been growing slowly in Niger, while the rural population increased considerably during the same period. For the past 40 years Niger has experienced a 0.6°C increase of the average temperature with a declining annual average rainfall. Niger has total internal renewable water resources (TRWR) of 3.5 km^3; the TRWR per capita has dropped considerably from 973 m^3/yr in 1962 to 183 m^3/yr in 2014, this appears to have an inverse relationship to the rapidly growing population. Niger withdraws around 2.9% of the actual renewable water resources per year and this has affected the pressure on freshwater withdrawal. In contrast to other SSA countries, Niger has higher percentages of people with access to clean water. In 2015, 100% of people living in urban areas and 48.6% of rural populations had access to clean water sources in Niger. In fact, 58.2% of the total population has access to clean water in Niger.

3. Methodology

3.1. Data sources and procedures

Three Sub-Saharan African countries were selected to test how climate change factors and population growth have impacted people movement (rural-urban migration). The Sub-Saharan African countries involved in this study are Democratic Republic of Congo (DRC), Kenya (KEN) and Niger (NER). The data collected was over 56 year period from 1960 to 2015. The climate change proxy variable (rainfall and temperature) and the data were collected on monthly bases from the National Oceanic and Atmospheric Administration (NOAA) of USA, and then converted to annual terms (1901–2015). Due to migration, data availability issues, the annual population data (rural, urban and total populations) was collected from the World Bank. The vital statistics method has been used to indirectly measure the net internal migration (rural-unban) of these countries. The yearly natural growth rate of the population in each country accounted for and through this process the migration data were obtained. The time series data in this model consist of four variables that are Rural Migration (MR), Urban Migration (MU), Rainfall (Rain) and Temperature (Temp). The data were initially prepared in excel spreadsheets and then transferred to Stata. Stata is a comprehensive, integrated statistical software package that is used for data management, data analysis and to produce graphics to visualize the data; Stata was developed in 1985 by Stata Corporation. Hashizume et al. [74] has utilized Stata software for rainfall and temperature time series analyses, similarly Ebrahim et al. [75] has suggested the appropriateness of Stata software for the analyses of migrations time series data.

3.2. Multivariate time series analysis: (VAR)

The vector auto-regression (VAR) model is among the most flexible multivariate analysis, well established, and proven models in multivariate time series analysis. Ideally, the model provides a natural extension from the univariate autoregressive models to multivariate models that include deterministic, endogeneous and exogeneous variables. The VAR has a multivariate advantage, for the forecasts developed can be made conditional on the potential future trends in the other given variables. The proposed study will centre on the analysis of covariance stationary multivariate time series using VAR models. Suppose that $Y_t = (Y_{1,t}, \ Y_{2,t}, \ldots, Y_{n,t})'$ represents a time series variable vector $(k \times 1)$ then an autoregressive model of the basic vector, having order p, VAR (p) becomes:

$$Y_t = \mu_1 + \alpha_{11} Y_{t-1} + \alpha_{12} Y_{t-1} + \ldots + \alpha_{1p} Y_{t-p} + \beta_{11} X_{t-1} + \beta_{12} X_{t-1} + \ldots + \beta_{1p} X_{t-p} + u_t \quad (1)$$

$$X_t = \mu_2 + \alpha_{21} Y_{t-1} + \alpha_{22} Y_{t-1} + \ldots + \alpha_{2p} Y_{t-p} + \beta_{21} X_{t-1} + \beta_{22} X_{t-1} + \ldots + \beta_{2p} X_{t-p} + u_t \quad (2)$$

OR

$$Y_t = c + \prod_1 Y_{t-1} + \prod_2 Y_{t-2} + \ldots + \prod_p Y_{t-p} + u_t \quad (3)$$

where $t = 1, \ldots, T$ and $(k \times 1)$ and $\prod_i$ are coefficient matrices, c a $(k \times 1)$ constant vector and u_t a $(k \times 1)$ vector process for white noise with an unobservable zero mean, with $\sum$ covariance matrix. The Stata software was used to determine the VAR lags most appropriate for each country. The lag selection process was performed using VAR diagnostics and tests method that enables to postestimate the VAR lag order of the time series data. VAR (3) has been the best fit in most cases.

3.3. Granger causality test

A key part of the use of a VAR model is in its use for forecasting. Its structure gives information on the ability of variables or variable groups to forecast other variables. Granger [76] introduced this intuitive notion of a variable's ability to forecast. Should Y_1 variable or variable

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groups be instrumental in another Y_2variable's or variable group's prediction, then Y_1 Granger causes Y_2. In the opposite case, Y_1 does not Granger cause Y_2 if for all s > 0 the mean squared error of a forecast of $Y_{2,t+s}$ based on on $(Y_{2,t}, Y_{2,t-1}, \ldots)$ is the same as the mean squared error of a forecast of $Y_{2,t+s}$ based on $(Y_{2,t}, Y_{2,t-1}, \ldots)$ and $(Y_{1,t}, Y_{1,t-1}, \ldots)$. It is worth noting that Granger's causality notion only suggests the ability to influence another variable.

A VAR(p) bivariate model for $Y_t = (Y_{1t}, Y_{2t})'$, can be used to identify the failure of Y_2 to Granger cause Y_1, given that all p VAR matrices of coefficients are lower triangular. The Wald statistic can test p linear restrictions on coefficients. The coefficient matrices of VAR are diagonal in the event that both Y_2 and Y_1 fail to Granger cause each other. It is important to note that Granger causality is rather useful in finance and continues to be extensively used because it shows bi-directional as well as uni-directional causal nature of the time series data. In essence, how and in what manner the other variables contribute to the prediction process of a given variable; that is, which variables or which information is crucial for the prediction process.

4. Results and discussion

Descriptive statistics briefly summarizes the rural and urban migration, rainfall and temperature time series data (1962–2015) of Democratic Republic of Congo, Kenya and Niger. **Table 5** presents central tenancy, data variabilities as well as spread of the data.

The following section presents VAR results of the analysis time series data of MR, MU, Rain and Temp of DRC, KEN and NER to assess how climate change variables Rain and Temp time series may impact rural-urban migration phenomenon of these countries in the future. The first step of the VAR analysis was the lag selection process. The goodness of fit statistics of

Variable	Min	Max	Mean	Range	P50	SD	Variance
DRC_MR	−115,821	79,940	6138.33	195,761	7663.5	37464.27	1.40E^9
DRC_MU	−47,403	59,624	12386.24	107,027	9040	20682.77	4.28E^8
DRC_Rain	1208.6	1728.9	1488.00	426.5	1494.6	67.3	4534.5
DRC_Temp	23.60	25.00	24.06	1.299999	24.00	0.28	0.080
KEN_MR	−115,821	79,940	6138.33	195,761	7663.5	37464.27	1.40E^9
KEN_MU	−47,403	59,624	12386.24	107,027	9040	20682.77	4.28E^8
KEN_Rain	429.9	1005.7	645.60	527.4	640.8	100.7	10136.1
KEN_Temp	23.60	25.60	24.59	2	24.50	0.34	0.114
NER_MR	−4708	18,450	5396.98	23,158	5649	5420.30	2.94E^7
NER_MU	−13,695	7510	1782.02	21,205	1656.5	3708.77	1.38E^7
NER_Rain	106.8	269.1	185.60	162.3	183.2	32.3	1041.5
NER_Temp	26.20	28.80	27.34	2.199999	27.20	0.49	0.240

Table 5. Descriptive statistics summary of MR, MU, rain and temp time series data (1962–2015).

the VAR model gave the R^2 values shown in **Table 6**. The test of the model fit gave favourable results. As shown in **Table 6**, most of R^2 values are above 0.70.

4.1. Democratic Republic of Congo (DRC)

The lag selection process suggested lag 3 for DRC time series. VAR (3) was used to assess the interaction between climatic variables and people movement. In other words how rainfall variability and rising temperatures may have impacted people movement in Democratic Republic of Congo. VAR results have shown that temperature has a significant impact on rural and urban migrations in DRC (**Table 7**). The temperature (lag 2) is a significant variable—less than 10 and 5%—to explain DRC rural migration and urban migration, respectively. Further, the results indicate a strong relationship between rural migration and urban migration in DRC; where urban migration is statistically significant to explain changes in rural migration and vice versa.

Granger causality tests were conducted to test the VAR model and to determine whether each variable plays a significant role in each of the equations. The granger causality tests have shown that there is significant granger causality effect from Temp to both DRC MR and MU. Further, Temp may able to compensate for the other variables including rainfall and lead to a combined granger effect on DRC MR and MU. The combined effect of the rising temperature and rainfall variabilities seem to be significant at 5% level. Further, the results also suggest that there is a significant granger causes exist between rural migration and urban migration where each migration variable granger causes the other at less than 1% significance level. **Table 8** presents the granger causality Wald tests for MR and MU of DRC. The results suggest that future amounts of MR and MU in DRC can be predicted by using Eqs. (4) and (5).

$$\begin{aligned} DRC\_MR_t = {} & 355348 + 1.476MR_{t-1} - 1.237MR_{t-2} + 0.23MR_{t-3} + 1.274MU_{t-1} \\ & - 1.064MU_{t-2} + 0.531MU_{t-3} - 4.35Rain_{t-1} + 22.61Rain_{t-2} \\ & - 7.751Rain_{t-3} + 1987.52Temp_{t-1} - 11957.5Temp_{t-2} - 5619.88Temp_{t-3} + u_t \end{aligned} \tag{4}$$

$$\begin{aligned} DRC\_MU_t = {} & -384210 + 0.586MR_{t-1} - 0.36MR_{t-2} - 0.067MR_{t-3} + 0.52MU_{t-1} \\ & - 0.227MU_{t-2} + 0.142MU_{t-3} + 0.857Rain_{t-1} - 24.366Rain_{t-2} \\ & + 3.364Rain_{t-3} + 5775.5Temp_{t-1} + 11500Temp_{t-2} - 1731.45Temp_{t-3} + u_t \end{aligned} \tag{5}$$

4.2. Kenya (KEN)

The lag selection process suggested lag 3 for KEN time series. VAR (3) was conducted to assess the impact that rainfall fluctuations and rising temperatures have on rural and urban migrations in Kenya. This is to identify how rainfall variability and rising temperatures may impact rural and urban migrations. VAR results have shown that temperature has a significant impact on rural and urban migration in Kenya (**Table 9**). Both rainfall and temperature are statistically significant at less than 5% to explain rural migration in Kenya. Similarly,

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Equation	Parms	RMSE	R-sq	chi2	P-value
DRC_MR	13	10478.4	0.9439	857.9503	0.000
DRC_MU	13	7176.59	0.9128	533.7465	0.000
DRC_Rain	13	62.5479	0.3807	31.35537	0.002
DRC_Temp	13	0.203218	0.7205	131.4498	0.000
KEN_MR	13	9601.34	0.9529	1031.6	0.000
KEN_MU	13	7453.29	0.9059	491.136	0.000
KEN_Rain	13	107.421	0.1966	12.48087	0.408
KEN_Temp	13	0.31654	0.5711	67.90203	0.000
NER_MR	13	2916.02	0.7778	178.5192	0.000
NER_MU	13	2882.49	0.5537	63.27865	0.000
NER_Rain	13	29.2051	0.2938	21.21593	0.047
NER_Temp	13	0.33013	0.6683	102.7623	0.000

Table 6. Model fitting for VAR models for MR, MU, rain and temp of Congo DR, Kenya and Niger.

temperature impacts urban migration in Kenya. Further, results also suggest that there is a significant relationship between rural migration and urban migration where each variable is statistically significant to explain changes in to the other.

Granger causality tests were conducted to determine whether each variable plays a significant role in each of the equations. As shown in **Table 10**, both rain and temperature granger cause (<5%) rural migration in Kenya; rainfall and temperature together granger cause rural migration in Kenya at 1% significance level. Further, rising temperatures granger cause MU at less than 5%. The results also suggest that granger causality effects exist between rural and urban migrations, where each migration variable granger causes the other at less than 1% significance level. The VAR results suggest that future amounts of MR and MU in Kenya can be predicted by using Eqs. (6) and (7).

$$\begin{aligned} KEN\_MR_t = {} & 143048.2 + 1.527MR_{t-1} - 1.121MR_{t-2} + 0.192MR_{t-3} + 1.105MU_{t-1} \\ & - 1.096MU_{t-2} + 0.475MU_{t-3} + 15.2Rain_{t-1} + 0.786Rain_{t-2} \\ & - 27.1Rain_{t-3} + 6401.1Temp_{t-1} - 14576.6Temp_{t-2} + 2526.64Temp_{t-3} + u_t \end{aligned} \tag{6}$$

$$\begin{aligned} KEN\_MU_t = {} & -207028 + 0.619MR_{t-1} - 0.47MR_{t-2} - 0.023MR_{t-3} + 0.56MU_{t-1} \\ & - 0.273MU_{t-2} + 0.268MU_{t-3} - 5.785Rain_{t-1} + 4.024Rain_{t-2} \\ & + 12.26Rain_{t-3} - 2708.18Temp_{t-1} + 8202.4Temp_{t-2} + 2833Temp_{t-3} + u_t \end{aligned} \tag{7}$$

4.3. Niger (NER)

VAR lag 3 was used to examine the interaction between climatic variables (namely rainfall and temperature) and migration variables (rural and urban). The VAR results have shown that rainfall

	Lags	Coef.	Std. Err.	z	P-value	[95% conf. interval]	
DRC_MR							
DRC_MR	L1.	1.476003	0.133345	11.07	0.000	1.214651	1.737355
	L2.	−1.23725	0.229631	−5.39	0.000	−1.68732	−0.78718
	L3.	0.230204	0.144511	1.59	0.111	−0.05303	0.513439
DRC_MU	L1.	1.273907	0.19951	6.39	0.000	0.882875	1.66494
	L2.	−1.06411	0.216905	−4.91	0.000	−1.48924	−0.63899
	L3.	0.531081	0.185797	2.86	0.004	0.166926	0.895237
DRC_Rain	L1.	−4.34987	23.08613	−0.19	0.851	−49.5979	40.89811
	L2.	22.61041	23.87814	0.95	0.344	−24.1899	69.4107
	L3.	−7.75103	23.25511	−0.33	0.739	−53.3302	37.82815
DRC_Temp	L1.	1987.52	6380.53	0.31	0.755	−10518.1	14493.13
	L2.	−11957.5	6233.197	−1.92	0.055	−24174.3	259.3549
	L3.	−5619.88	5994.979	−0.94	0.349	−17369.8	6130.059
	Cons	355348.5	185244.5	1.92	0.055	−7723.95	718,421
DRC_MU							
DRC_MR	L1.	0.585985	0.091327	6.42	0.000	0.406987	0.764983
	L2.	−0.36227	0.157273	−2.3	0.021	−0.67052	−0.05402
	L3.	−0.06749	0.098974	−0.68	0.495	−0.26148	0.126494
DRC_MU	L1.	0.519761	0.136643	3.8	0.000	0.251946	0.787576
	L2.	−0.22655	0.148557	−1.53	0.127	−0.51772	0.064613
	L3.	0.141994	0.127251	1.12	0.264	−0.10741	0.391401
DRC_Rain	L1.	0.857312	15.81151	0.05	0.957	−30.1327	31.84731
	L2.	−24.3663	16.35395	−1.49	0.136	−56.4194	7.686882
	L3.	33.36421	15.92725	2.09	0.036	2.147376	64.58104
DRC_Temp	L1.	5775.531	4369.976	1.32	0.186	−2789.47	14340.53
	L2.	11500.03	4269.069	2.69	0.007	3132.805	19867.25
	L3.	−1731.45	4105.915	−0.42	0.673	−9778.89	6315.998
	Cons	−384,210	126872.5	−3.03	0.002	−632,875	−135,544

Table 7. Democratic Republic of Congo MR and MU VAR results.

(lags 1 and 3) impacts rural migration in Niger and statistically significant. Moreover, temperature (lag 2) impacts rural migration at less than 10% significance level. On the other hand, the VAR results have shown that rainfall impacts urban migration and statistically significant (less than 5%); while temperature (lag 2) impacts urban migration at less than 5% significance level (**Table 11**).

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Equation	Excluded	chi^2	df	P-value
DRC_MR	DRC_MU	43.642	3	0.000
DRC_MR	DRC_Rain	0.90801	3	0.823
DRC_MR	DRC_Temp	7.7732	3	0.051
DRC_MR	ALL	47.282	9	0.000
DRC_MU	DRC_MR	82.511	3	0.000
DRC_MU	DRC_Rain	5.2714	3	0.153
DRC_MU	DRC_Temp	14.913	3	0.002
DRC_MU	ALL	126.24	9	0.000

Table 8. Granger causality Wald tests for MR and MU of DRC.

	Lags	Coef.	Std. Err.	z	P-value	[95% Conf. Interval]	
KEN_MR							
KEN_MR	L1.	1.527326	0.124974	12.22	0.000	1.282381	1.772271
	L2.	−1.12056	0.200759	−5.58	0.000	−1.51404	−0.72708
	L3.	0.191674	0.130621	1.47	0.142	−0.06434	0.447688
KEN_MU	L1.	1.105072	0.173335	6.38	0.000	0.765342	1.444802
	L2.	−1.09597	0.199596	−5.49	0.000	−1.48717	−0.70477
	L3.	0.475334	0.153952	3.09	0.002	0.173592	0.777075
KEN_Rain	L1.	15.18659	12.65142	1.2	0.230	−9.60974	39.98292
	L2.	0.785979	12.16677	0.06	0.948	−23.0605	24.6324
	L3.	−27.1015	11.93806	−2.27	0.023	−50.4996	−3.70329
KEN_Temp	L1.	6401.065	3979.371	1.61	0.108	−1398.36	14200.49
	L2.	−14576.6	4502.144	−3.24	0.001	−23400.6	−5752.53
	L3.	2526.642	4568.531	0.55	0.580	−6427.51	11480.8
	Cons	143048.2	114,720	1.25	0.212	−81798.8	367895.3
KEN_MU							
KEN_MR	L1.	0.618856	0.097015	6.38	0.000	0.428711	0.809001
	L2.	−0.4728	0.155844	−3.03	0.002	−0.77825	−0.16736
	L3.	−0.02283	0.101398	−0.23	0.822	−0.22156	0.175912
KEN_MU	L1.	0.563427	0.134556	4.19	0.000	0.299703	0.827151
	L2.	−0.27283	0.154942	−1.76	0.078	−0.57651	0.030848
	L3.	0.267967	0.11951	2.24	0.025	0.033733	0.502201
KEN_Rain	L1.	−5.7853	9.820989	−0.59	0.556	−25.0341	13.46348
	L2.	4.023753	9.444765	0.43	0.670	−14.4877	22.53515
	L3.	12.26245	9.267225	1.32	0.186	−5.90098	30.42588

	Lags	Coef.	Std. Err.	z	P-value	[95% Conf. Interval]	
KEN_Temp	L1.	−2708.18	3089.089	−0.88	0.381	−8762.68	3346.322
	L2.	8202.401	3494.905	2.35	0.019	1352.513	15052.29
	L3.	2832.964	3546.439	0.8	0.424	−4117.93	9783.857
	Cons	−207,028	89054.35	−2.32	0.020	−381,572	−32485.1

Table 9. Kenya MR and MU VAR results.

Further, there is a significant relationship between urban migration and rural migration in Niger, where rural migration is statistically significant at less than 5% to explain changes that occur to urban migration in Niger.

Granger causality tests were conducted to examine whether each variable plays a significant role in each of the equations. The granger causality tests have indicated that there are granger causality effects from Rain to both MR and MU at less than 5% significance level (**Table 12**). Further, the results also suggest that there is a granger causality running from urban migration to rural migration at less than 1% significance level. The granger causality Wald tests have suggested that temperature does not granger cause people movement in Niger. The results suggest that future amounts of MR and MU in NER can be predicted by using Eqs. (8) and (9).

$$\begin{aligned} NER\_MR_t = {} & 46384.24 + 1.64MR_{t-1} - 1.26MR_{t-2} + 0.467MR_{t-3} + 1.228MU_{t-1} \\ & - 1.144MU_{t-2} + 0.378MU_{t-3} + 26.3Rain_{t-1} + 9.86Rain_{t-2} \\ & - 40.56Rain_{t-3} + 622Temp_{t-1} - 1918Temp_{t-2} - 356Temp_{t-3} + u_t \end{aligned} \tag{8}$$

$$\begin{aligned} NER\_MU_t = {} & -56334 + 0.616MR_{t-1} - 0.644MR_{t-2} + 0.15MR_{t-3} + 1.014MU_{t-1} \\ & - 0.7MU_{t-2} + 0.21MU_{t-3} - 32.82Rain_{t-1} - 8.85Rain_{t-2} \\ & + 42.987Rain_{t-3} - 498.24Temp_{t-1} + 2293.47Temp_{t-2} + 247.89Temp_{t-3} + u_t \end{aligned} \tag{9}$$

Equation	Excluded	chi^2	df	P-value
KEN_MR	KEN_MU	47.081	3	0.000
KEN_MR	KEN_Rain	7.961	3	0.047
KEN_MR	KEN_Temp	11.625	3	0.009
KEN_MR	ALL	66.058	9	0.000
KEN_MU	KEN_MR	76.582	3	0.000
KEN_MU	KEN_Rain	2.7587	3	0.430
KEN_MU	KEN_Temp	10.582	3	0.014
KEN_MU	ALL	113.33	9	0.000

Table 10. Granger causality Wald tests for MR and MU of Kenya.

	Lags	Coef.	Std. Err.	z	P-value	[95% Conf. Interval]	
NER_MR							
NER_MR	L1.	1.648669	0.548767	3	0.003	0.573106	2.724232
	L2.	−1.26126	1.001884	−1.26	0.208	−3.22492	0.702394
	L3.	0.46737	0.568036	0.82	0.411	−0.64596	1.5807
NER_MU	L1.	1.22845	0.547162	2.25	0.025	0.156032	2.300868
	L2.	−1.1438	0.997921	−1.15	0.252	−3.09969	0.812092
	L3.	0.378649	0.570321	0.66	0.507	−0.73916	1.496458
NER_Rain	L1.	26.30783	14.01253	1.88	0.060	−1.15623	53.77188
	L2.	9.863682	13.98378	0.71	0.481	−17.544	37.27138
	L3.	−40.5639	15.41653	−2.63	0.009	−70.7798	−10.3481
NER_Temp	L1.	622.3344	1061.896	0.59	0.558	−1458.94	2703.613
	L2.	−1918.36	1100.37	−1.74	0.081	−4075.05	238.3239
	L3.	−356.347	1057.053	−0.34	0.736	−2428.13	1715.438
	Cons	46384.24	39517.46	1.17	0.240	−31068.6	123,837
NER_MU							
NER_MR	L1.	0.615852	0.542456	1.14	0.256	−0.44734	1.679046
	L2.	−0.64425	0.990362	−0.65	0.515	−2.58532	1.296827
	L3.	0.149531	0.561503	0.27	0.790	−0.951	1.250057
NER_MU	L1.	1.013816	0.54087	1.87	0.061	−0.04627	2.073901
	L2.	−0.7102	0.986445	−0.72	0.472	−2.6436	1.223198
	L3.	0.207188	0.563762	0.37	0.713	−0.89777	1.312142
NER_Rain	L1.	−32.8194	13.85138	−2.37	0.018	−59.9676	−5.67121
	L2.	−8.85125	13.82296	−0.64	0.522	−35.9438	18.24125
	L3.	42.98771	15.23924	2.82	0.005	13.11935	72.85607
NER_Temp	L1.	−498.241	1049.684	−0.47	0.635	−2555.58	1559.103
	L2.	2293.472	1087.715	2.11	0.035	161.5892	4425.355
	L3.	247.8878	1044.897	0.24	0.812	−1800.07	2295.847
	Cons	−56333.9	39,063	−1.44	0.149	−132,896	20228.15

Table 11. Niger MR and MU VAR results.

Equation	Excluded	chi²	df	P-value
NER_MR	NER_MU	14.534	3	0.002
NER_MR	NER_Rain	8.5631	3	0.036
NER_MR	NER_Temp	3.4747	3	0.324
NER_MR	ALL	33.264	9	0.000
NER_MU	NER_MR	2.9754	3	0.395
NER_MU	NER_Rain	10.792	3	0.013
NER_MU	NER_Temp	4.9537	3	0.175
NER_MU	ALL	23.811	9	0.005

Table 12. Granger causality Wald tests for MR and MU of Niger.

5. Summary

As presented in the sections above, Democratic Republic of Congo, Kenya and Niger have been experiencing considerable rainfall fluctuations; that is often below average levels. In addition to that all countries have also experienced rising temperatures. As shown in **Figure 6**, it is

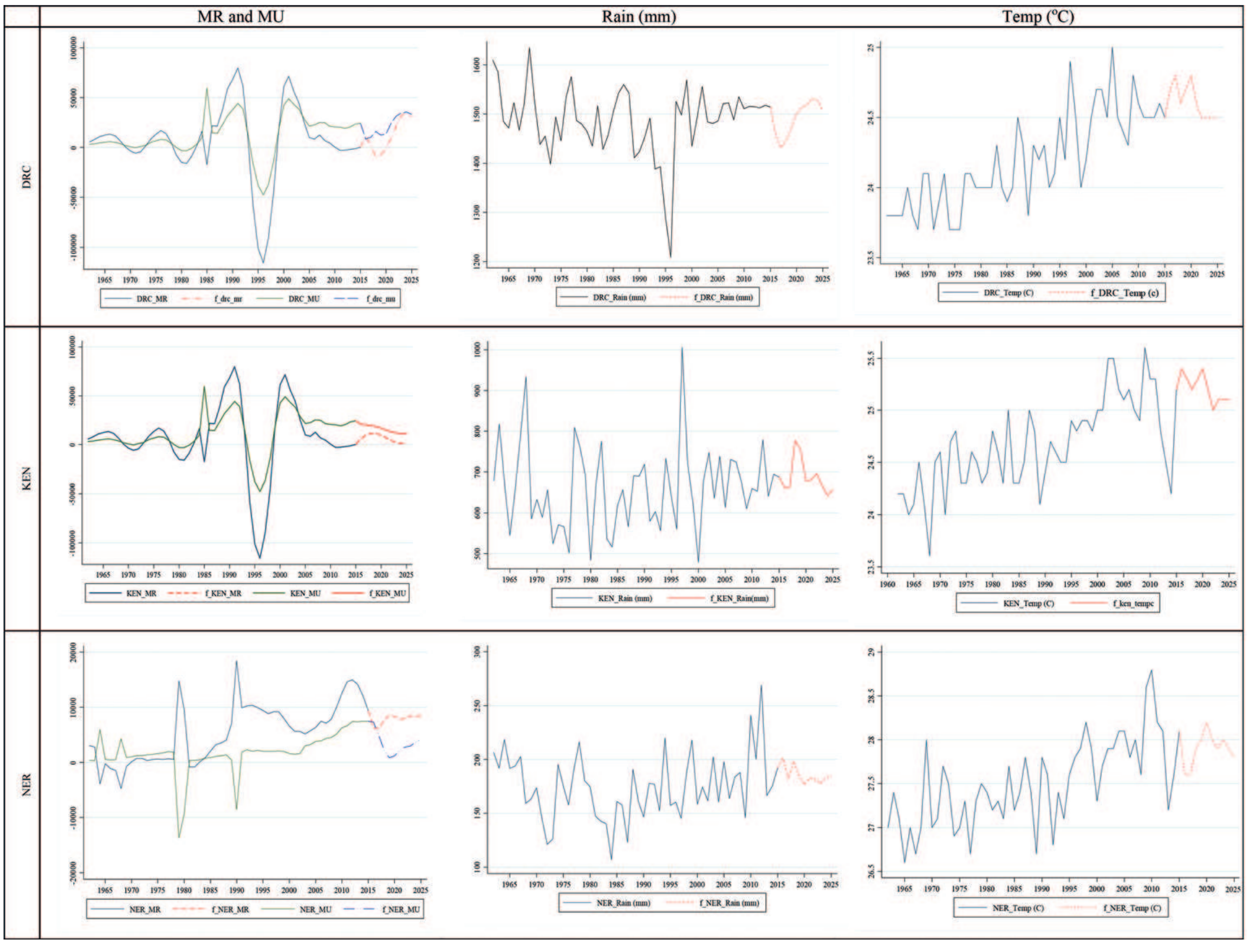

Figure 6. DRC, KEN and NER time series and forecasted line plots 1960–2025.

predicted that these climatic conditions will continue to exist. Populations in these countries have been growing rapidly. These unfavourable climatic conditions and increasing population have together compounded the water scarcity and rural-urban migration conditions in Kenya and Niger. In contacts to that, Democratic Republic of Congo receives high annual rainfalls and medium low average annual temperature. Democratic Republic of Congo has abundant water resources and the renewable internal freshwater resources per capita (m^3) is significantly high. During the vector auto-regression analyses, the lag selection process suggested lag 3 in all cases. VAR was used to investigate the interaction between climatic variables—rainfall and temperature—and people movement variables—rural and urban migrations. By using VAR (3), it was tested how rainfall variabilities and rising temperatures impact rural-urban migrations in Democratic Republic of Congo, Kenya and Niger. The VAR results have suggested that both rainfall and temperature impact rural migration and statistically significant. Further, the results also indicated that there is a significant relationship between rural and urban migrations.

Moreover, granger causality Wald tests were conducted to test the VAR model and to determine whether each variable plays a significant role in each of the equations. The granger causality tests have shown that there is significant granger causality effect from Rain and/or Temp to both rural and urban migrations in Democratic Republic of Congo and Kenya. Moreover, Rain and Temp together have a combined granger effect on MR and MU; this is statistically significant. In contrast, the granger causality test has shown that there is significant granger causality effect from Rain to both rural and urban migrations in Niger. However, rising temperatures does not appear to granger cause people movement in Niger. The results also suggest that there is a significant granger causes exist between rural migration and urban migration where each migration variable granger causes the other at less than 1% significance level. VAR auto forecasting in Stata and Eqs. (4), (5), (6), (7), (8) and (9) (inclusive) were used to predict changes of rural migration, urban migration, rainfall and temperature of Democratic Republic of Congo, Kenya and Niger in the next 10 years. The study predicts increasing rural-urban migrations in the next decade due to high rainfall variabilities and increasing temperatures. This study suggests that there will be a large number of rural communities leaving from their villages to urban areas due to water availability conditions and poor agricultural production levels.

6. Conclusion

This study investigated Sub-Saharan Africa water availability and water security conditions in relation to rural-urban migration numbers. The SSA countries considered in this study are Democratic Republic of Congo (DRC), Kenya (KEN) and Niger (NER). The countries were selected based on specific factors such as water resources availability, population growth, migration processes and urbanization situation in recent times. The study finds that all three countries have fast growing populations with Niger having the highest fertility rate in the world. The countries are experiencing rapid urbanization where rural communities have been moving to urban areas at increased rates. The study finds that the renewable internal freshwater resources per capita (cubic meters) in Niger and Kenya have reached well below the water scarcity level of 1000 m^3/capita/annum. In 2014, these countries had renewable internal freshwater resources per capita (cubic meters) of 183 m^3/capita/annum and 450 m^3/capita/annum, respectively. On the other hand, Democratic Republic of Congo is known to be the SSA's water rich state and in 2014 DRC had renewable internal freshwater resources per capita (cubic meters) of 12,208 m^3/capita/annum. Despite the water abundancy situation only 52.4% of the total population in DRC has access to improved water source. Further it is noted that 81% of urban population and 31% of rural populations had access to clean water sources in DRC in 2015. In general, many rural communities in these countries have limited access to clean water. Water availability and accessibility remains to be major challenge in rural communities of these countries.

This study reveals large rainfall variation and raising temperatures in DRC, KEN and NER. The adverse nature of climate change in these countries appears to have impacted agricultural production and likelihoods in the rural communities. These conditions led great deal of rural-urban migrations that occurred in these countries in recent times. Further, limited access to clean water in rural communities appears to have compounded the rural migration and rapid urbanization in these countries. In addition to that, the agricultural production in SSA has not been improving in recent times and this has exacerbated the move away from rural areas towards the urban. The study conducted VAR analyses and granger causality tests and concluded that rainfall and temperature have granger impact on rural and urban migrations in DRC, KEN and NER. The study predicts increasing rural and urban migrations in Democratic Republic of Congo, Kenya and Niger due to large rainfall fluctuations and rising temperatures.

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