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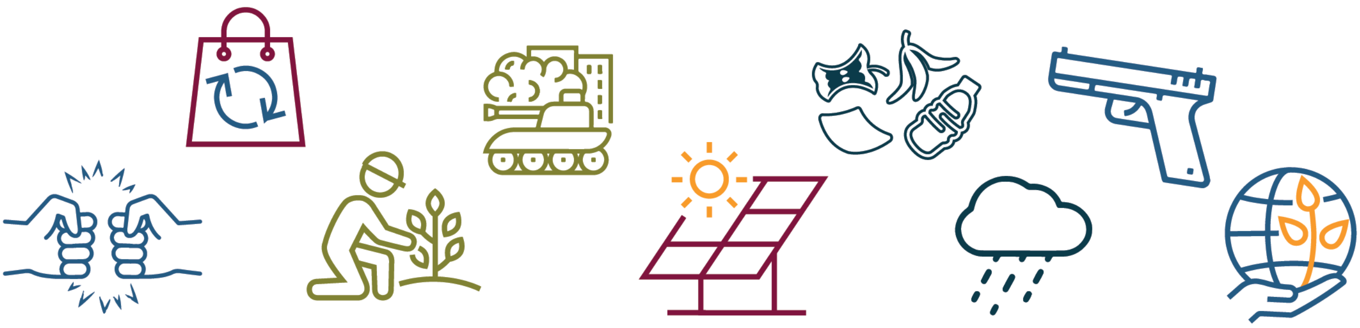

Climate Change and Conflict in the Horn

Challenges, Responses and New Mandates

#AFI2022
#HeritageForum

September 2023

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Preface

Since the beginning of the Industrial Revolution in the second half of 17th century, human activities have continued to cause the release of capacious amounts of carbon dioxide (CO2) and other greenhouse gases (GHGs) such as methane (CH4) and nitrous oxide (N2O) into the atmosphere. Greenhouse gases trap heat in the Earth's atmosphere, making the planet warmer. As the planet's average temperature continues to rise, the number of droughts, floods and hurricanes have increased in frequency and severity. Although countries differ widely in their economic and technological capacity to mitigate the impacts of climate change, nowhere is immune from the negative impacts.

In response to growing concerns about the impacts of changing climatic conditions, the Intergovernmental Panel on Climate Change (IPCC) was established in 1988 under the United Nations (UN) to collate and assess science-based published data on climate change in order to catalyze evidence-based solutions for policy makers. The extent of climate-related risks depends on many factors such as the level of development and vulnerability as well as how humans adapt to the changing climate. The latest IPCC report (2022)[1] concluded that increasing numbers of weather and climate events have exposed millions of people to acute food insecurity and reduced water security with the largest impacts observed in vulnerable regions, mostly in Africa.

Human influences on the natural environment have been devastating almost everywhere but impacts of climate change are not uniform. Consequently, it is fitting to point out the importance of evaluating at the local/regional rather than global level. Somalia is the quintessence of a fragile state where devastations of climate change impacts and political instability collide, producing persistent humanitarian crises. Data from the Notre Dame Global Adaptation Initiative (ND-GAIN)[2] shows that Somalia is the second most vulnerable country to the climate change impacts among the 182 countries assessed. It is a sad reality that countries like Somalia have contributed the least to the causes of climate change but are unable to withstand and adapt to it and, consequently, are most at risk from its negative effects. During the last decade, Somalia has experienced multiple exceptionally dry seasons, combined with excessively wet seasons and flash floods. This has contributed to widespread crop failure, water shortages, livestock losses and massive displacement. Around three million people are chronically food insecure, a situation exacerbated by more frequent and intense droughts and floods. Consecutive droughts have pushed millions of people into famine or famine-like conditions and killed millions of animals. Famine was only narrowly avoided in 2022 but remains a looming risk in the coming years. Droughts that once occurred every decade now happen every three or four years, and with greater severity. The situation will only get worse based on predictive models under all GHG emissions scenarios.

1. Intergovernmental Panel on Climate Change (IPCC), 2022. Climate change 2022: Impacts, Adaptation and Vulnerability, Summary for Policy Makers.
2. ND-GAIN, Somalia (2020). https://gain-new.crc.nd.edu/country/somalia#:~:text=The%20high%20vulnerability%20score%20and,of%20the%20ND%2DGAIN%20Matrix

The catastrophic impacts of the recurrent droughts in East Africa continue to worsen. Across the region, recurrent droughts and high food prices have undermined agro-pastoral communities' ability to grow crops, raise livestock and buy food. Continued food insecurity and poverty challenges are, therefore, due in part to extreme weather destroying livelihoods more frequently than in the past. Farmers and pastoralists have seen their livelihoods and production systems negatively affected, contributing to millions of people becoming internally displaced. In Somalia alone, an estimated 1.5 million people were displaced in 2022 which can be directly attributed to climate-related extremes[3].

Today no challenge seems more daunting than climate change. The scale of challenge in minimizing the consequences of a rapidly changing climate in the coming decades is hard to exaggerate. Responding to this growing crisis, the Heritage Institute for Policy Studies (HIPS) invited proposals for panels, posters or papers that addressed climate change-related issues such as droughts, floods, famine, and conflicts. The call for papers proposed two areas of study: 1) climate change impacts and solutions 2) the climate-security nexus. Seventy abstracts from 100 submissions were selected through rigorous peer review and presented at a conference, held in Djibouti from December 4-8, 2022. The conference provided an important platform for academics, researchers, policymakers, environmental activists and graduate students to share their regional and/or global expertise and discuss the consequences of climate change and potential solutions.

This document brings together 15 papers that aid in the understanding of climate change and the impact it has on livelihoods, conflicts and understanding the way forward in the Somali context. The document has been divided into chapters and grouped into four main themes.

- Theme 1 (Chapters 1-3) explores the broader picture of climate change and its impacts on physical environment, production sectors, on women and livelihoods in three different ecozones. Also discussed are conflict, mass displacement, resource scarcity and poverty resulting from extreme climate change events.

- Theme 2 (Chapters 4-9) examines the link between climate change and social conflicts. It explores the vicious cycle in which climate change feeds conflicts which break out over ever scarcer resources.

- Theme 3 (Chapters 10-14) discusses climate change mitigations and adaptations.

- Theme 4 (Chapter 15) examines climate finance issues using data from the Organization for Economic Co-operation and Development (OECD). This is timely as in November 2022 wealthy nations at the COP27 climate conference agreed to set up a "loss and damage" fund to help poor countries harmed by climate change. Which nations will be able to draw from the fund, where the money will come from and how much each country should get are still to be decided.

3. United Nations High Commissioner for Refugees (UNHCR) (2022).Somalia Internal Displacement. https://data.unhcr.org/en/situations/horn/location/192 (Accessed May. 20, 2023).

As the Federal Government of Somalia (FGS) and Federal Member States (FMS) work with international partners to develop national climate change mitigation and adaptation strategies, this collection of research studies will contribute to the understanding of climate change impacts and the ways in which they can be mitigated.

Finally, the editors would like to thank the contributors whose collaborative spirit made this possible as well as the HIPS staff.

Abdirashid O Elmi, PhD

Afyare Elmi, PhD

Editors

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Summary

Forum for Ideas is the largest Somali annual gathering event spearheaded by the Heritage Institute for Policy Studies (HIPS) since its inception in 2013 to share knowledge and inform evidence-based decisions. Contemporary topic(s) is/are selected each year for analysis and subsequent recommendations. In 2022, climate change and climate-related conflict was the topic of discussion.

Rising temperatures, frequent and more intense droughts, and periodic floods are fueling environmental degradation, natural disasters, weather extremes, food and water insecurity, communities' displacement, and conflicts. Across the Horn of Africa (HoA) region, recurrent droughts have undermined agro-pastoral communities' ability to grow crops, raise livestock and buy food.

The security situation on the ground is an important factor in the sense that it inhibits efforts to respond to natural disasters such as droughts, floods, etc. costing lots of lives that could have been saved if aid were able to reach them safely. Although progress has been made towards improving security in Somalia, peace still remains a tenuous goal.

In light of these challenges, the HIPS invited proposals for panels, posters or papers that addressed climate change-related issues such as droughts, floods, famine, and conflicts. The conference provided an important platform for academics, researchers, policymakers, environmental activists, and graduate students to share their regional and/or global expertise and discuss the consequences of climate change and potential solutions.

Following are the main conclusions extracted from the papers selected to be published in the proceeding:

1. Somalia has experienced serious hydrological cycle problems as a result of climate variability, compounded by decades of political instability and security challenges. Climate and weather variability are threatening agricultural and livestock production systems on which the livelihood of over 70% of Somali society depends. Poor agricultural and pastoral practices, combined with land degradation, worsen the impacts of climate shocks on the community's livelihood, chiefly food security sustainability. Agropastoral communities witness their livelihood becoming untenable as the productivity of their land shrinks due to the drought and other compounding environmental factors. In the Awdal region, for example, lack of access to climate information was identified as a major constraint to effective adaptation. The impact of climate change was shown to reduce the flow of the Shabelle River under all three emission scenarios (RCP 4.5, RCP 6.0 and RCP 8.5).

Furthermore, there is a noticeable seasonal difference in rainfall quantities, with the Deyr (dry) season receiving less rainfall than the Gu (wet) season. The model projected that annual rainfall will significantly decrease toward 2050 during the dry season, which spells potentially more intense drought periods. Water and agricultural land scarcity are likely to force inter-riverine communities to be displaced in search of survival, if model predictions prove to be accurate. Consequently, there is an exigent need for designing policies that improve water availability and food production, as well as mitigate adverse effects of climate change.

2. Climate-induced conflicts occur due to scarce resources and land disputes, especially during difficult times. Civil conflicts undermine domestic production, impede investments in the key economic sectors and increase rural-urban migration as well as the costs of production. For the last three decades, Somalia has experienced two internationally recognized famines (1991/92, 2011/12) and several near-famine crises (2002/23, 2007/2009, 2016/2017). These famines cost the lives of millions of people and displaced millions of others. Protracted armed conflict has been described as the key to explaining why food insecurity and droughts, which are common challenges across the states in the broader Horn of Africa, quickly deteriorate into famine in Somalia but not necessarily in the neighboring countries. Currently, Al-Shabaab, who still controls large swathes of territories in Jubbaland, Southwest and Hirshabele, remains the defining feature of Somalia's unending conflict landscape. A close examination of the interplay between conflict and famine sheds an important light on the cascading threats that emanate from this vicious cycle. Reliable data on resource-related conflicts is difficult to find. Resource-related conflicts are disputes over access to, control over and use of natural resources. According to some estimates, over the past few years, Somalia had over 1,000 resource-related clan conflicts. Paradoxically, conflicts are lower in areas under Al-Shabaab militia control as they impose severe punishment on those who are involved in any form of violence in its territory. One of the studies has emphasized the importance of promoting peace, beneficial partnerships and localization of climate adaptation and conflict resolution programs through collective action at the community level.

3. There are multiple, feasible and effective institutional, technological, and sectoral practices to reduce greenhouse gas emissions and help adapt to human-caused climate change. HoA is among the least developed countries that have significant capacity challenges to develop and implement climate change adaptation and mitigation policies. Somali institutions collapsed after the fall of the Somali government in 1991, and efforts to rebuild have been frustratingly slow. Weak governance compounds the effect of climate shocks. Consequently, governments in the HoA (and elsewhere) are advised to take concrete measures to close the capacity gaps and prioritize climate action though strengthened institutional capacity. Similarly, nature-based solutions (NbS) are emerging as are easily implementable adaptation strategies that help restore natural ecosystems and reduce climate vulnerability and enhance resilience.

4. Finally, responses to climate change vary widely. These can be as simple as installing an energy-efficient air conditioner to cool our homes during hot days, or as complex as establishing a sophisticated network of dams, wells and canals to prevent droughts from becoming famines and floods, respectively. In all cases, large sums of finance are required, often beyond what HoA countries can afford, rendering even basic measures to reduce greenhouse gas emissions and adapt to climate change out of reach. Inadequate climate finance will, therefore, limit the ability of developing countries to mitigate climate-change impacts. Promises made on international climate finance under the Paris agreement have not been kept and, therefore, poor countries which contribute the least to climate change have not received climate financial support.

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Simulations of Climate Change Impact on Shabelle River Using Global Circulation Model (Gcms)

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Abstract

Somalia has experienced serious challenges as a result of climate variability, which have been compounded by decades of political instability. Climate and weather variability are threatening agricultural and livestock production systems on which the livelihood of over 70% of Somali society depends. Climate extremes, such as floods and droughts, are inevitably connected with the loss of property and livelihoods, as well as the loss of lives and resources. The purpose of this study is to examine the impact of climate change on the Shabelle River using field experimental data and the Global Circulation Model (GCM) under three emission scenarios: RCP 4.5, RCP 6.0 and RCP 8.5. Baseline hydrological data was obtained from Somali Water and Land Information Management (SWALIM) and calibrated using field observed data. For all scenarios, there is a noticeable seasonal difference in expected future rainfall quantities, with the Deyr (dry) season receiving less rainfall than the Gu (wet) season. It is projected that annual rainfall will significantly decrease toward 2050 during the dry season. Under all three scenarios, the average changes for the dry season are -1.66%, -3.8%, and -4.5%, respectively. In the Gu season, the average changes are 1.3%, 1.2%, and 2.3% for RCP 4.5, 6.0, and 8.5, respectively. The output results are essential for local authorities, farmers and water resource managers to anticipate, manage and secure future irrigation water considering the impact of future climate change.

Keywords: Somali water resources, climate change, Global Circulation Models, Shabelle River

Introduction

Somalia, with a total land area of approximately 637,657 km2, is located in the Horn of Africa, which is bordered to the west by Ethiopia, south-west by Kenya, north-west by Djibouti, and north by the Gulf of Aden. The country can be divided into five distinct physio-geographic zones differentiated by topography (FAO, 1995). The climate is normally hot and dry. However, much of the north and center of the country have an arid climate whereas some of the north and south are semi-arid, which makes it a country of geographic extremes (Basnyat and Gadain, 2009). Only small areas in the south have a humid climate.

The topography is generally flat and there is seasonal variation in its climate due to its proximity to the equator. During the last few decades, Somalia has experienced unpredictable and abnormal rainfalls that caused flash floods in some parts of Hiiraan and the Shabelle River, and lack of rain in the south-west where agricultural production depends on seasonal rainfall. The mean annual rainfall is less than 100 millimeters in the north-east, about 300 millimeters in the central plateaus and between 500-600 millimeters in Awdal and south-west (Burale, 2005). The mean daily maximum temperature in most parts of the country range from 32-40°C, except in northern Somalia where the temperature occasionally surpasses 45°C during June and July and drops below freezing in December.

The country is divided into nine major river basins, namely the Gulf of Aden, Daroor, Tog Dheer, Central, Shabelle, Juba, Lag Dera, Lag Badana, and the Indian Ocean. Much of the country's water resources originate from river basin zones outside its territory. The East African Rift Valley is located to the east while the Tana River basin, the Gulf of Aden and the Indian Ocean are located to the south, north and east, respectively. Shabelle and Juba are the only two perennial rivers in the country which are suitable to irrigate agriculture. However, both rivers originate from the Ethiopian highlands and some parts of the Juba catchment in Kenya and are affected by intermittent floods (Houghton et al., 2011). During the heavy flood season, the Shabelle River joins the Juba before it flows to the Indian Ocean. Since all river basins originate from Ethiopia's eastern highlands and some parts of Kenya, there may be a concern for Somalia over what actions upstream countries may take in the future which can risk the amount of surface water resources available. This study evaluates the impact of climate change on the Shabelle River using the Global Circulation Model (GCM).

Materials and Methods

Study Area

This study focuses on the city of Beledweyne (Fig. 1). Beledweyne is a city in central Somalia, and the capital of the Hiiraan region. The town is situated in the Shabelle Valley near the Ethiopia border, some 335 kilometers north of Mogadishu. Beledweyne is divided by the Shabelle River into eastern and western sections. This study area was chosen because (1) it is the first town that the Shabelle River flows through and, (2) it is the largest and most populous city along the Shabelle River.

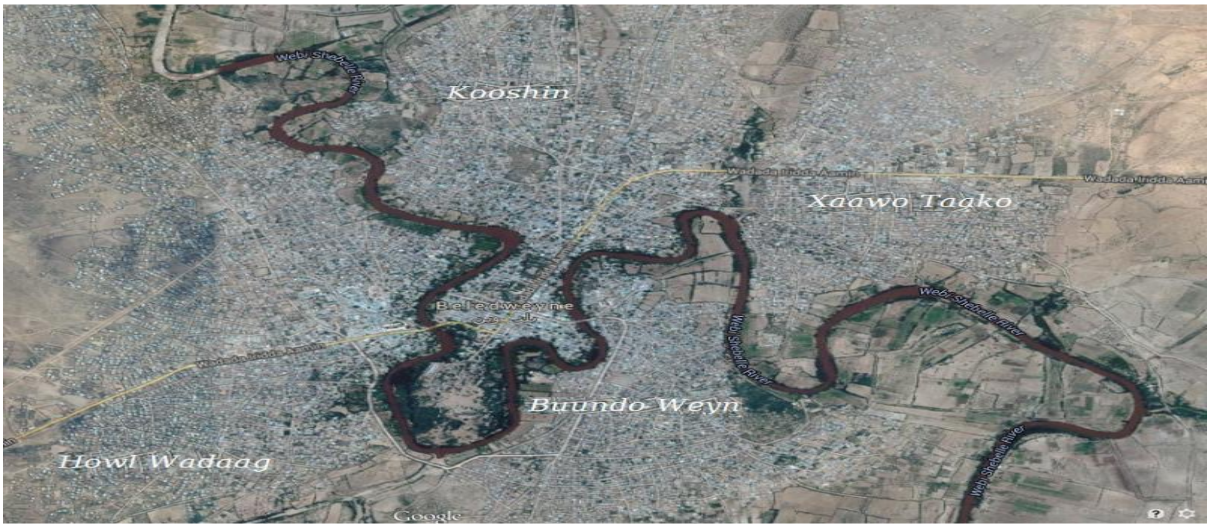

Fig. 1: Beledweyne district, Hirshabelle state

Data Collection

A lack of measured climatic data represented a major constraint. Hirshabelle state has few meteorological services. Any automatic weather stations, however, are managed by the Food and Agriculture Organization's (FAO) Somalia Water and Land Information Management (SWALIM), where data is saved on a monthly basis. From 1990 to 2016, the study analyzed precipitation data from these SWALIM-manned stations that was shared with the IGAD Climate Prediction and Applications Centre (ICPAC). This included daily rainfall, solar radiation, maximum temperature, and minimum temperature. For the base period of 1990-2016, and the future period of 2022-2099, daily climatic variables for Global Climate Models (GCMs) were acquired from the Coupled Model Intercomparison Project (CMIP5) on October 22, 2022. Due to a number of years with missing values, the observed climate data in the study area is of poor quality. This led to the use of a gridded daily hydro-meteorological dataset from Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) in this study, which covered the whole Shabelle River. Daily rainfall (millimeters/day) and daily air temperatures (°C) were the variables considered. A change factor of the mean method was then used to downscale the climate variables. Statistical downscaling techniques have been developed using statistical correlations between model output climate variables and historical climate data to simulate GCM scenarios at the local scale. In the literature, the delta change method or change factor of mean approach is commonly used. A change factor technique can be used in place of the bias correction method with the same straightforward justification. Eq. 1-4 can be used to summarize the procedure used to downscale the parameters as follows:

$$P_{delta} = (P_{future}/P_{control})_{Monthly} \quad (1)$$

$$P_{future,daily} = P_{observed,daily} \times P_{delta} \quad (2)$$

$$T_{delta} = (T_{future} - T_{control})_{Monthly} \quad (3)$$

$$T_{future,daily} = T_{observed,daily,} + T_{delta} \quad (4)$$

Where P and T stand for precipitation and temperature, respectively, the subscripts are: delta, daily represents the daily variable that has been downscaled using the delta method; daily observations are indicated by the notation observed, daily; average monthly GCM output for the future period is indicated by the notation future; average monthly GCM output for the baseline or control period is indicated by control.

Results and Discussions

Spatial and Temporal Variation of Rainfall

The country has four main seasons, namely Jiilaal, Gu, Hagaa and Deyr, which are dictated by shifts in the wind patterns. The hottest and dry season is Jilaal, which is from December to March. During this period, the Shabelle River experiences dry and hot weather. Gu is considered to be the main rainy season, lasting from April to June. The Gu season contributes almost 50% of the annual rainfall of the country. The Hagga season lasts from July to September and is referred to as the second dry season. In the Hagga season, the Shabelle basins receive 12% of their annual rainfall. The Deyr season lasts from October to December and has the shortest rainy season. The downstream receives about 600 mm at the coast, as shown in figure one. While the upstream Shabelle head water receives more than 1,500 millimeters of annual rainfall. During the two rainy seasons, the river receives a substantial amount of its annual rainfall, of which about half is contributed during Gu and one-third during Deyrb, respectively.

The downstream discharge of the Shabelle River decreases rapidly due to surface water losses (Nicholson, 1989). The rainfall pattern of the river varies considerably, which is also affecting the seasonal variability of the surface water. It is revealed that a mean annual rainfall in the Shabelle River is about 550 mm. The continental and global climate changes along with orographic and coastal influences are responsible for the spatial variability of rainfall in the Shabelle River, which flows south from eastern Ethiopian highlands, starting at an altitude of 4,230 meters above sea level. The Shabelle is a tributary of the Juba which makes a single basin. However, as the flow from the Shabelle joins the Juba only during heavy rainfall, the rivers are effectively separate. There has been a tremendous decrease in the number of rainy days and significant increases in rainfall intensities which cause extreme events such as drought and floods (Fig. 2).

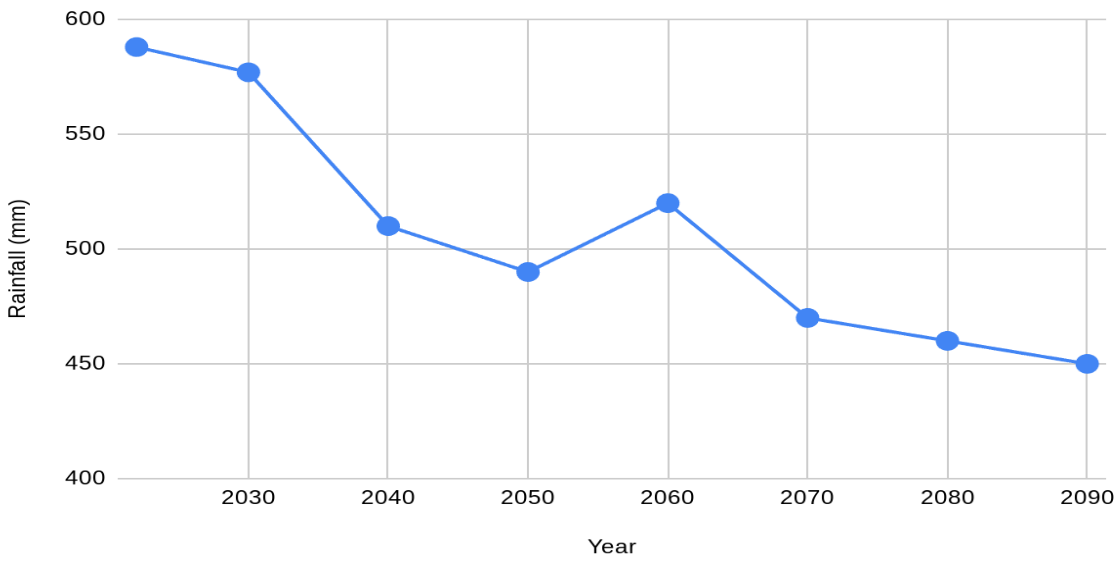

Fig. 2: Projected annual rainfall trends in the Shabelle River

Projected Rainfall and Temperature Data Analysis

The temperature time series results show that temperatures will rise in the short and long term **(Fig. 3)**, depending on the scenario considered (Table 1). This is consistent with global and regional projections that predict an increase in average temperature by 2016-2039, followed by additional increases by 2040-2069 and 2070-2099. In general, the Shabelle River projections showed an increase in mean annual temperatures in all seasons between 2030, 2060, and 2099, as shown in **figure 4**. Temperature predictions are crucial in developing effective and realistic plans for climate change adaptation and disaster risk reduction. Table 1 illustrates the annual increases in temperature ensemble predictions from GCM models under RCP 4.5, RCP 6.0, and RCP 8.5. In all future scenarios, the temperature is expected to rise. Under RCP 4.5, RCP 6.0, and RCP 8.5, the multi-model ensemble's projected temperature rises range from 0.8-1.6 ∘C, 0.7-1.9 ∘C, and 1.1-3.1 ∘C, respectively. In all models, there is a general agreement on future temperature increases under all three emission scenarios. This suggests that the Shabelle River will become warmer in the future, particularly during the dry season months. These projected changes are consistent with the IPCC's projections for East Africa.

Table 1: Annual changes of temperature under the RCP 4.5, RCP 6.0 and RCP 8.5 scenarios

Periods	Annual changes corresponding to scenarios		
	RCP 4.5	RCP 6.0	RCP 8.5
2016-2039	0.8	0.7	1.1
2040-2069	1.5	1.2	1.7
2070-2099	1.6	1.9	3.1

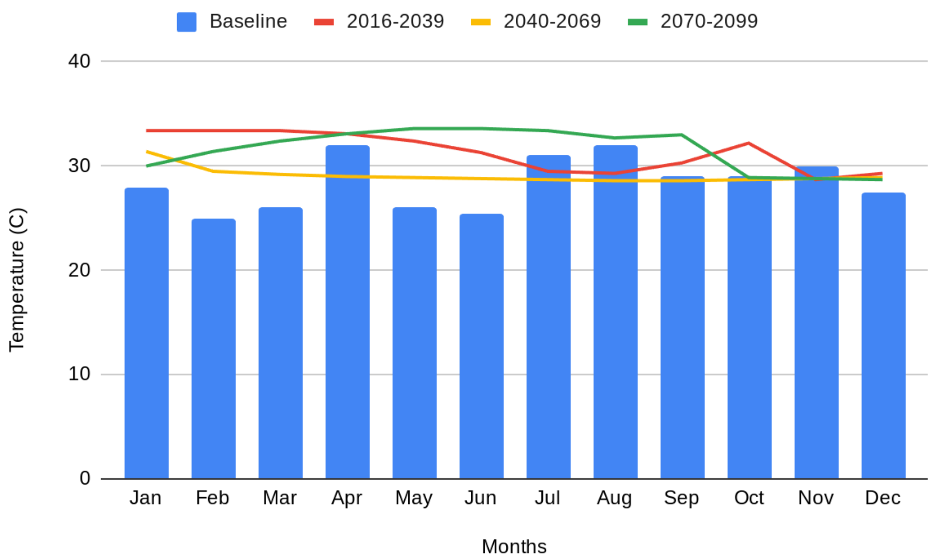

Fig. 3: Observed and predicted temperatures in the Shabelle River from 2016-2099 under emission scenarios 4.4, 6.0 and 8.5

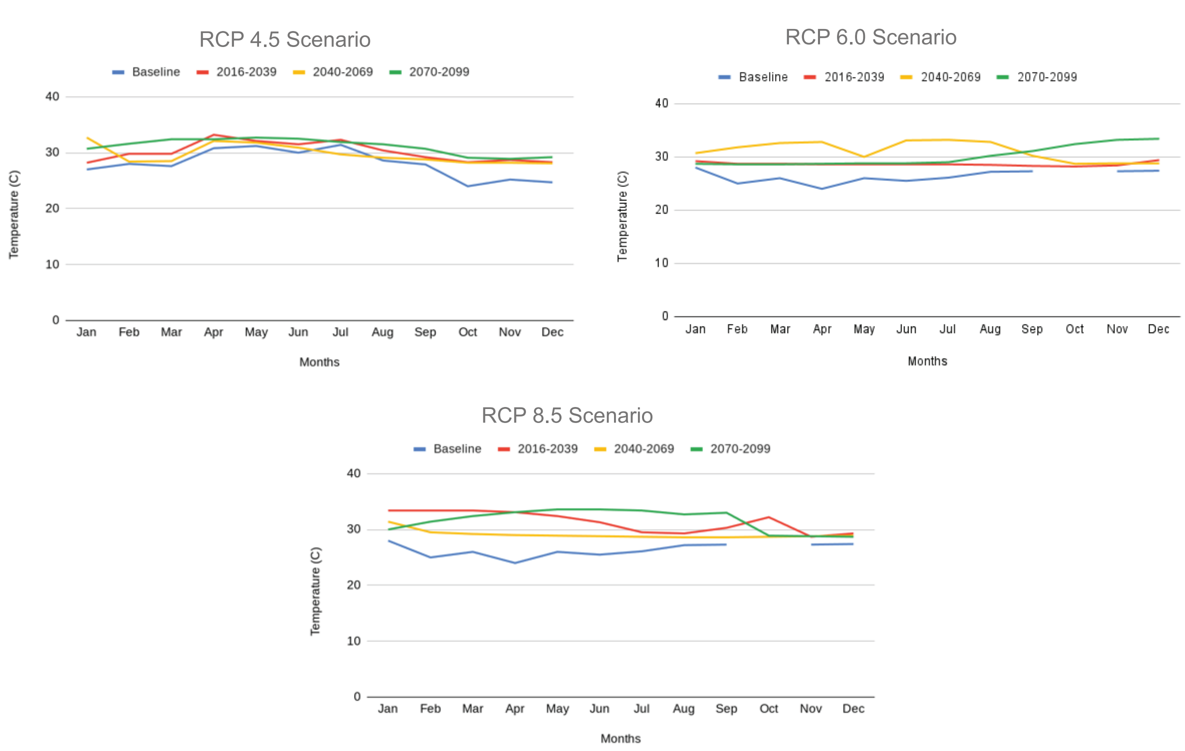

Fig. 4: Observed and predicted temperatures in the Shabelle River from 2016-2099 under emission scenarios RCP 4.4, 6.0 and 8.5

Tables 2 and 3 demonstrate predicted variations in rainfall amounts between the Deyr and Gu seasons based on the overall predictions of the GCMs, for all scenarios, there is a noticeable difference in expected future rainfall quantities, with the Deyr season receiving less rainfall than the Gu season. Under RCP 4.5, 6.0, and 8.5, the average changes for the dry season are -1.66%, -3.8%, and -4.5%, respectively. In the Gu season, the average changes are 1.3%, 1.2%, and 2.3% for RCP 4.5, 6.0, and 8.5, respectively. The Gu longer rainy season, which lasts from April to June, and the Deyr shorter rain season, which lasts from October to December, were used to analyze precipitation data. Climate predictions revealed that temperatures in the agro hydrological Shabelle River basin will rise in the future (2016–2099). For the three emission scenarios, the expected annual rainfall is 6.2% higher than its baseline magnitude (RCP 4.5, RCP 6.0, RCP 8.5). The Gu season was the focus of the simulations of rainfall, and most models displayed more accurate simulations of rainfall during this time. The rainfall distribution shows significant spatial diversity.

Table 2: Annual changes in future rainfall (Deyr) under the RCP 4.5, RCP 6.0 and RCP 8.5 scenarios

Periods	Annual changes corresponding to scenarios		
	RCP 4.5	RCP 6.0	RCP 8.5
2016-2039	-1.8	-2.8	1.1
2040-2069	-0.7	-3.5	1.7
2070-2099	-2.5	-5.2	3.1

Table 3: Annual changes in future rainfall (Gu) under the RCP 4.5, RCP 6.0 and RCP 8.5 scenarios

Periods	Annual changes corresponding to scenarios		
	RCP 4.5	RCP 6.0	RCP 8.5
2016-2039	1.1	0.9	2.7
2040-2069	0.8	2.5	2.4
2070-2099	2.0	0.3	1.8

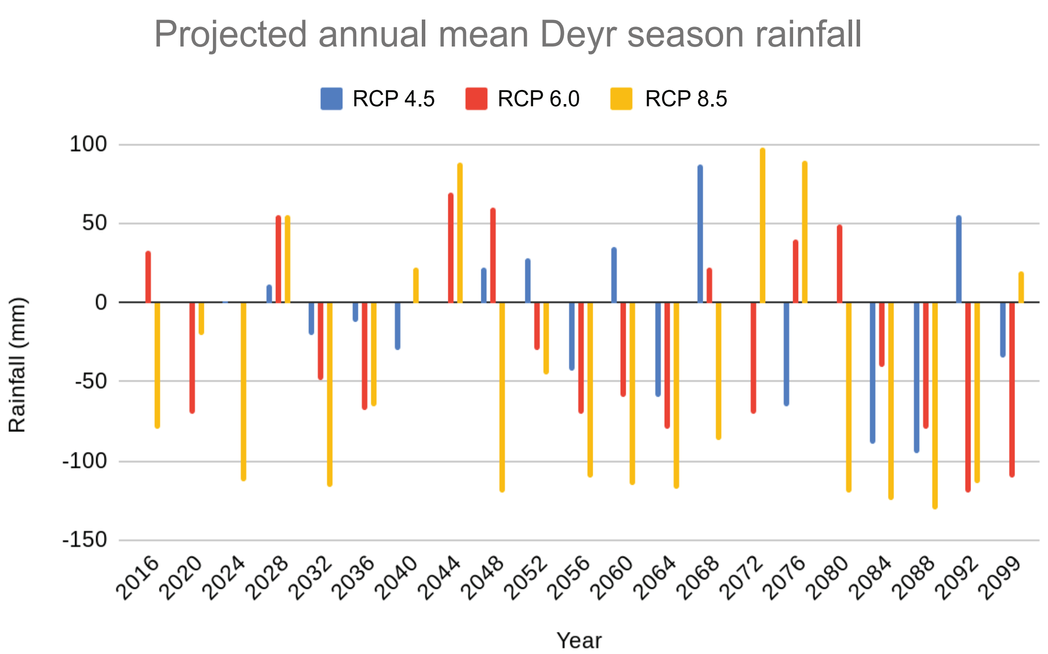

Fig. 5: Predicted yearly mean rainfall during the (dry) Deyr season under the RCP 4.5, RCP 6.0 and RCP 8.5 scenarios

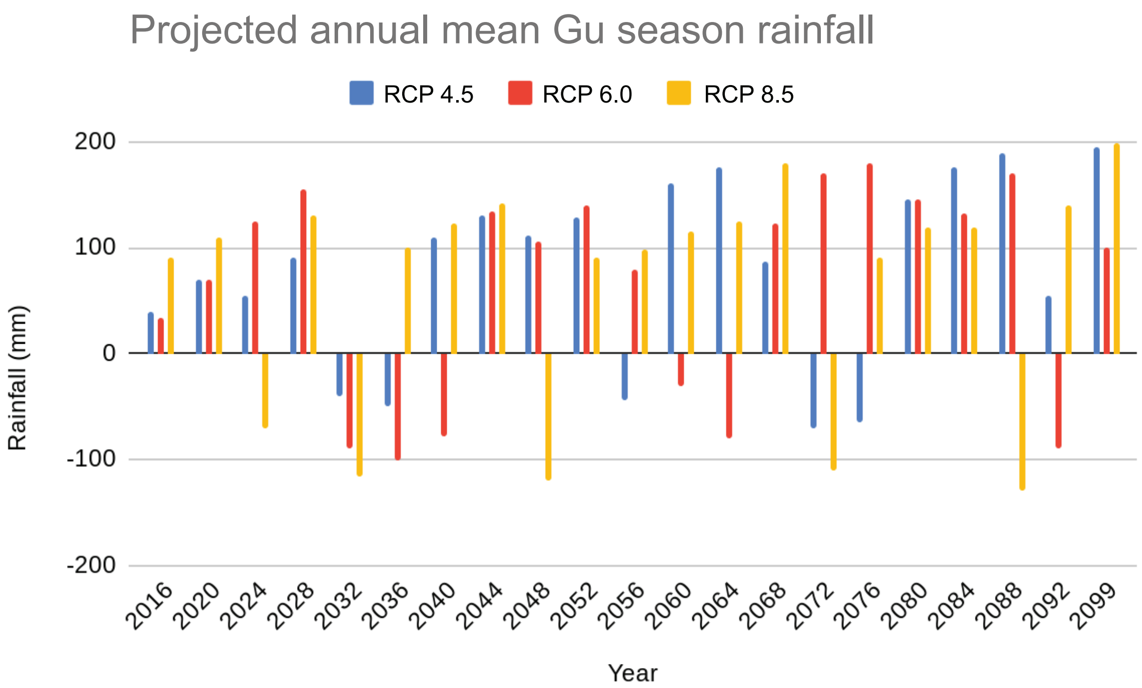

Fig. 6: Predicted yearly mean rainfall during wet (Gu) season under different scenarios.

The predicted precipitation also revealed alternating dry and wet periods will dominate the Gu season, which necessitates continued investment in early warning systems and water management systems. The projected rainfall trends' geographical representation revealed no consistent patterns. While the extended rainy season was expected to see an overall drop in rainfall in the Deyr season, the Gu season was expected to see an increase. However, the Shabelle region showed a general pattern of growth, although with varying degrees of change. The expected recurrence of low rainfall in the near future is critical for a country that is already suffering from high poverty levels and food insecurity. The consequence of a further threat to food and water security might be competition for existing resources. The occurrence of extreme below normal rainfall is frequently linked with drought. The forecasted precipitation in this study highlights the importance of finding short-term and mid-term solutions.

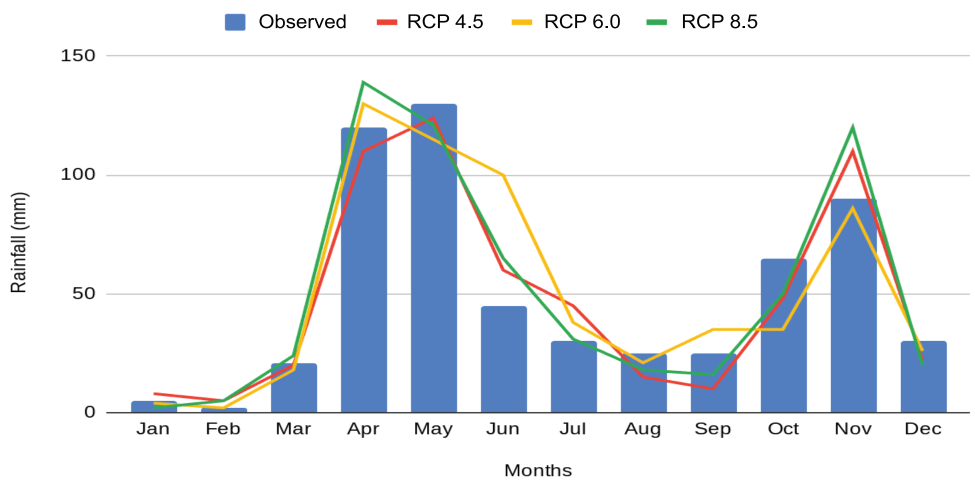

Fig. 7: Comparison between observed and GCM simulated monthly mean rainfall

The spatio-temporal variation of rainfall is also very high, which affects seasonal water availability of the river. Extreme drought events were experienced for the last few years as the Shebelle River dried out completely during the dry season, causing loss of human life and destruction of property and crops. The majority of the country's hydrological gauging stations are not in operation while others can record only a few hydrological parameters which is not sufficient. For better understanding of the current and the future impact of climate change on river flow and water availability of the river, hydrological models which require long term historical data (Moallim et al., 2018; Hutchinson and Polishchouk, 1989) are used.

Somalia is a developing country and still has not recovered from the economic damage caused by 30 years of political instability. The country has serious issues such as lack of security, healthcare and education which require huge capital investment and therefore water resources development projects do not get sufficient budget allocation. Based on the current crisis and the ongoing political instability, Somalia cannot afford to invest and develop any hydraulic structure which is expensive and needs huge investment. However, the current existing hydraulic structure is damaged and lacks seasonal maintenance.

Somalia's two major rivers, the Shabelle and the Juba, are transboundary, with about 50% of their water originating from Ethiopia. There is no formal agreement on water sharing rights between these riparian countries. It's well understood that any development of water resources projects like dams within Ethiopia are likely to decrease the downstream flow of the Shabelle within Somalia especially during the dry season. Therefore, development of such projects on shared rivers requires political discussions which is also very challenging.

Conclusions

This study focused on the impact of climate change on the Shabelle River basin. Historical rainfall from 1990 to 2016 was used to achieve this goal. Somalia Water and Land Information Management provided the hydrological data (SWALIM). The effects of rainfall variability were studied using GCM models.

The annual rainfall magnitude is 6.2% higher than its baseline magnitude, according to the temporal general trend obtained from 2016-2099. (RCP 4.5, RCP 6.0, RCP 8.5). A decrease in precipitation on river discharge, along with high interannual variability, could affect a variety of water-dependent sectors such as agriculture and hydroelectric power generation (Basnyat, 2009). The study also found the presence of significantly higher rainfall in areas near water bodies. Therefore, more research is needed to understand the physical processes that lead to frequent increases and decreases in rainfall trends in this region. Climate extremes such as floods and drought, as well as civil wars, political turbulence, and rapid population expansion, have long hindered Somalia's efforts to achieve food security. Rain is essential for most socioeconomic activity in the Shabelle region where recurring droughts and floods put a strain on a developing economy. The rate of restoration of disturbed vegetation is influenced by rainfall variability, notably the probability of occurrence of below-average extremes in the near future. This work also adds to the existing body of knowledge on rainfall variability and change in the Shabelle region, which will be included in the sixth IPCC assessment report on the state of regional climate change in Africa. The findings derived from this research on historical, current, and future rainfall patterns are critical in the formulation of any successful disaster risk reduction and climate change plans for Somalia in support of long-term development goals.

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02

Impacts of Climate Change on Pastoral and Agro-Pastoral Communities Livelihoods and Adaptation Practices: A Case Study in Awdal Region

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Abstract

The livelihoods of pastoralists and agro-pastoralists in Somaliland are increasingly threatened by uncertainties caused by weather variability and climate change. Changing climatic conditions pose significant challenges to the growth prospects and viability of traditional pastoralism and the rain-fed agriculture way of life. This is exacerbated by poor or non-existent infrastructure and lack of skills, which constrain agricultural production. Environmental degradation and increasing population trends exert enormous pressure on natural resources' sustainability and undermine the household resilience and future viability of pastoral livelihood activities. This study combines both desk research and field investigations. The field work was conducted in July 2021 in the vicinity of Borama, situated in Somaliland. During this period, semi-structured interviews were administered to experts and local communities impacted by the situation. The predominant livelihoods in the Awdal region's Quljeed, Jir Jir, Qaraaru, and Dilla villages consist of pure pastoralism (involving camels, cattle, goats and sheep) as well as agro-pastoralism. The 52 interviews were primarily focused on traditional adaptive responses. The participants included men, women, youth, and those with physical disabilities. Notably, climate change exerts severe consequences on both agriculture and pastoralism, which are pivotal to the community's sustenance. In response, communities have devised customary adaptation strategies to contend with the volatility of climate patterns and extreme occurrences. These strategies hold potential value for dissemination to other communities residing in comparable circumstances. Nevertheless, some of these adaptive methods might necessitate modifications or reinforcement to effectively confront supplementary risks associated with the changing climate.

Keywords: Climate change, extreme weather, pastoralism, adaptive capacity

Introduction

The pastoralist and agro-pastoralist ways of life in Somaliland face escalating threats stemming from the adverse effects of weather fluctuations and climate change. The repercussions of climate change, such as droughts and floods, are compounded by a complex interplay of factors encompassing environmental deterioration, feeble or lacking governance, and conflict. These elements converge to result in dire impoverishment and the mass displacement of individuals. Persistent trends, including environmental degradation and a growing population, erode the resilience of communities and create uncertainties regarding the ongoing feasibility of livelihood pursuits like pastoralism. Distressing rates of land degradation, deforestation, and excessive exploitation of natural resources heighten the susceptibility of the local inhabitants to climatic perils. The convergence of subpar agricultural and pastoral methods with land deterioration amplifies the repercussions of climate-related shocks on the community's livelihoods, particularly in terms of food security and sustainability.

The Intergovernmental Panel on Climate Change (IPCC) articulated in its initial 1990 Assessment Report that climate change would bring about severe repercussions for both human and natural systems. Follow-up IPCC assessments consistently affirmed the indisputable nature of climate change impacts, underscoring the imperative need for immediate actions in mitigation and adaptation.

Over the past 10 years, the academic and humanitarian policy sectors have achieved certain advancements in addressing fundamental inquiries, including the adaptation strategies of communities and the potential means of safeguarding them. The 1992 United Nations Framework Convention on Climate Change (UNFCCC) provided the common international framework to address the causes and consequences of climate change. In 2007, the Fourth Assessment Report of the IPCC authoritatively established that human-induced climate change is accelerating and has severely impacted the environment and human lives.

Local values and knowledge can be important components in creating robust climate change adaptation strategies for marginalized communities. Incorporating local values into the climate change planning process in a structured way and effectively using local knowledge not only improves the identification of priority actions for climate change adaptation, but also supports successful implementation. Much of climate change adaptation planning in recent years identified actions derived from expert-driven vulnerability assessments and adaptation. Yet the values of each community influence how climate change impacts are perceived, and what adaptation actions are locally acceptable and will have local buy-in for implementation. Thus, it is important that planning incorporates local values if the goal is successful adaptation to climate change.

This case study, therefore, provides a unique approach for addressing climate change impacts through a participatory, values-based process for climate change adaptation planning. The approach is contextualized through case studies in four villages of the Awdal region, which is located in north-western Somaliland.

Research methodology

In the study region, the most visible consequence of climate change is the heightened occurrence and intensity of drought events. When these hazards interact with vulnerability, they can escalate into full-fledged disasters. Analysis reveals a clear pattern: the count of documented drought incidents has doubled during the past two decades. Among the various disasters influenced by climate change, those caused by its effects were most common in the study area.

The research delves into the ramifications of climate change-induced hazards, with a particular focus on drought, on the aspects of displacement and migration, as well as the associated challenges and responses to adaptation. This investigation is underpinned by three core inquiries that shaped the trajectory of the study:

- How does the community adapt, protect itself and seek durable solutions to the extreme climatic impacts?
- What are the particular adaptation challenges for the communities?
- Are drought disasters and displacement linked in the context of climate change?

Climate change is expected to increase the risk of climatic hazards in Somaliland, which will impact access to livelihoods and exacerbate poverty. Somaliland is considered one of the countries with the highest vulnerability to climate change in the world due to its geographic location and the struggle it has dealing with extreme weather.[1]

While all the country is affected by climate change, the communities chosen for this study are especially vulnerable. Strengthening their traditional coping mechanisms may be the most practical path to making them resilient. The high dependence of farmers and pastoralists on environmental resources makes them highly vulnerable to climatic change. The IPCC (2022)[2] estimates with high confidence that people in degraded areas who directly depend on natural resources for subsistence and income, including women and youth with limited adaptation options, are especially vulnerable to land degradation.

This study encompasses both desk research and on-site investigations. The field work component took place in July 2021 within the vicinity of Borama. During this period, semi-structured interviews were conducted, involving experts and communities directly impacted by the situation. In the Awdal region, the rural populace's primary livelihoods revolve around pure pastoralism (involving camels, cattle, goats, and sheep) as well as agro-pastoralism.

The four case study villages – Quljeed, Jir Jir, Qaraaru and Dilla – are representative of this rural life. However, numerous challenges affected these communities, including limited water resources, persistent environmental degradation, and restrictions on animal grazing movements. The pastoralist way of life, which is foundational to these communities, currently faces significant threats. The communities are grappling with the impact of recurring droughts, the gradual vanishing of communal grazing lands, the partitioning of rangelands into new agricultural settlements and the appearance of invasive weeds like mesquite (prospis juliflora) (kaligii noole in Somali) in some villages has reduced the grazing areas, which restricted the size of grazing areas that previously sustained animal wealth in the region.

The interviews centered around questions relating to the traditional adaptation responses. The number of interviewees was limited (52 in total) and included men, women, youth and the physically challenged. A field study with such limitations cannot provide a detailed or comprehensive account. Rather, the intention was to sketch out findings that could provide a starting point for further research.

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Findings and implications

In the Horn of Africa (HoA), including Somaliland, a pressing humanitarian crisis has intensified due to recurring droughts, periodic flash floods, and cyclones. The region's climate is predominantly arid to semi-arid. The primary economic pillars, livestock rearing and rain-fed agriculture, are intricately linked to weather patterns and the natural environment. Reports from researchers, humanitarian agency personnel, local NGOs, and residents indicate that the drought cycle has undergone a substantial transformation. Previously occurring once every 10 years and receiving designated names, these droughts have now transitioned into a constant and exceedingly frequent occurrence, surpassing the practice of assigning individual names (Reliefweb 2021).

Population growth has shown a noticeable upward trajectory as well. A senior member of the community remarked, "The current droughts differ from those of the past: rain has diminished while our population has swelled." While the belief in a higher power causing droughts and calamities persists among many, the elderly members of the community recount their observations of change. According to one elder, "We used to perceive climate change solely as fluctuations in day-to-day weather. However, today, each of us comprehends that climate change also translates into transformations in our daily lives and means of sustenance."

At the time of the study, a press release by the Somalia NGO Consortia warned of "looming severe drought in Somalia if rains fail" and said, "the time to prepare is now."[3] It also highlighted the challenges of the third wave of COVID-19 and locust infestations increasing the number of people in need of humanitarian assistance.[4] A Village head in Quljeed mentioned that previously communities were resilient and could depend on each other, but now they are weak due to combined factors such as diseases, poor economy and frequent drought.

Cold rains that come immediately after prolonged drought often have disastrous impacts. In 2009, for example, unexpected and heavy rainfall killed off much of the livestock that was already weak from the drought.[5]

Since Somaliland has not been recognized as an autonomous country and is not party to the UN Framework Convention on Climate Change (UNFCCC), there is no national adaptation program of action nor any climate change policies (one is currently under review), meaning the country has difficulties accessing information and resources.

Drought disasters and migration

Addressing climate change involves adopting effective strategies to mitigate adverse impacts or harness potential benefits, achieved through suitable alterations and modifications. According to the IPCC (2007), adaptation encompasses the adjustments made within natural or human systems to respond to current or anticipated climatic influences or consequences, with the aim of minimizing harm or capitalizing on advantageous prospects.

3. 6 April 2021.

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It also encompasses the actions taken by individuals, nations, and societies to accommodate climate change. Adaptation pursuits are guided by three primary objectives: diminishing vulnerability to damage risks, cultivating the ability to manage unavoidable losses, and seizing emerging opportunities.

A significant correlation exists between drought-induced disasters and human mobility, specifically migration. Among the Somali population, many rely on pastoralism and have historically undertaken migrations to more fertile grazing lands during droughts. Consensus among international humanitarian agencies, local NGOs, and community members supports the notion that displacement arises when customary migratory patterns are disrupted.

A recent evaluation mission concluded that even the regions to which Somaliland's pastoralists traditionally migrated during challenging times had been impacted by drought. Consequently, the pastoralists can no longer rely on migration as their customary coping mechanism to safeguard their herds. Instead, they are compelled to adopt irregular and atypical movement patterns or even settle in one place.

Less well-off pastoral households with smaller livestock herds, as well as those unable to afford transporting their livestock by truck, typically remain in areas with lower precipitation levels. Some pastoralists face the grim outcome of losing all or nearly all of their livestock due to the scarcity of pastures and water, ultimately being compelled to relinquish their time-honored way of life. They are then left with only two options for survival – to migrate and settle permanently in the cities to join the urban poor and internally displaced people (IDPs) or stay in the countryside and create enclosures.

Strategies for coping and strengthening resilience

The concept of resilience seeks to shift the emphasis from repeatedly providing humanitarian aid to enhancing the capacities of individuals, households, and communities to withstand shocks and effectively manage their own situations, while also upholding or altering their living standards. In the context of this study, various strategies were employed to foster or bolster resilience in the face of prolonged droughts. During periods of famine and imminent famine, coping strategies generally fall into three main categories: (1) social and organizational strategies, (2) the liquidation of non-essential domestic assets, and (3) the adoption of diversified approaches to income generation and food production. Among these categories, particularly in times of famine, social and organizational strategies emerge as the most prevalent methods employed to navigate challenges.

Social and organizational coping strategies

Closer social connections are common among families, friends, gender and youth groups, clan members, acquaintances and religious alliances. These connections primarily operated on a reciprocal basis, enabling participants to support each other during crises. Links are also established between communities and authorities, which provide food, medicine or other forms of social assistance.

Social and organizational strategies for coping have employed a pivotal influence on the choices made by displaced communities concerning an array of matters linked to survival and nourishment. This extends to decisions regarding the timing of departure from their home regions and identifying more hospitable locations amid unfavorable climatic conditions. Upon relocating to these new areas, the fabric of their social networks supplied valuable insights and guidance, ranging from locating shelter and food to adapting to unfamiliar surroundings. Moreover, these networks offered an essential layer of emotional support to further bolster their coping mechanisms.

Amid famine situations, a prevalent coping mechanism involved the divestment and liquidation of non-essential assets. The effectiveness of this approach hinged on the diversity of assets within each household. Smaller livestock, like goats, chickens, and sheep, were the initial assets to be sold, followed by younger cattle, and as a last recourse, milking cows, working oxen, and camels. Due to the dilapidation of most livestock due to inadequate pasture, these sales typically garnered less than their original value. Tangible assets such as construction materials, and electronic devices (including radios) usually remained unsold. The decision to sell was primarily influenced by the scope of a household's assets, the perceived usefulness of the items up for sale, and the immediacy of household needs.

Furthermore, the diversification of income-generating activities and food production emerged as an observable coping mechanism. This encompassed endeavors such as charcoal production, remunerated domestic labor, and participation in minor trading activities within urban settings. Some families also engaged in livestock trading to generate money for food and to relieve their households of non-productive animal stocks. As a strategy for coping and risk management, such diversification involved crop production activities on their own farms, wages earned from others' farms or engagement in non-farm work. In nearly all instances, this type of diversification was for survival and had limited returns.

The recurrent and severe droughts led to a reduction in the number of individuals possessing sufficient livestock to offer assistance to others during periods of necessity. Within the study region, regulations outlined in xeer (traditional law) included the provision that pastures are accessible to all pastoralists in times of scarcity, regardless of their clan membership. It was also stipulated that pastoralists should refrain from causing harm to communal grazing areas, abstain from creating personal enclosures or farms on these lands, and that external grazers must uphold grazing-related xeer, while harmoniously coexisting with the host communities.

Role of external actors in influencing coping strategies

External stakeholders play a pivotal role in bolstering households and communities within the study area to navigate climatic emergencies. Notably, cash transfer initiatives are the principal investments extended by international non-governmental organizations (INGOs) to facilitate households in managing crises and enhancing their resilience against future shocks.

For instance, a participant in a focus group discussion in Qaraaru village emphasized that the financial aid received from international entities facilitated numerous households in obtaining sustenance, averted additional community displacement, and amplified households' capabilities to rebound and restore their livelihoods following adversities.

Beyond crisis response, remittances from the diaspora were important, not just in crisis coping but also in fostering resilience by diversifying income streams, often through the initiation of small-scale businesses. Moreover, specific communities within the study sites allocate a portion of their remittances to back infrastructure development endeavors like the restoration of water facilities.

External actors encompassing regional and internal media outlets, donors, and INGOs play an instrumental role in heightening awareness about crises and lending support to resource mobilization endeavors necessary for providing relief to impacted communities. Typically, households assemble into focus groups (Fig.1) to collaboratively formulate diverse coping strategies suitable for community-level adoption, taking into account their resource base and existing social and organizational coping mechanisms. This includes strategies like liquidating non-essential domestic assets and diversifying approaches to income generation and food production.

For example, one village head planted an irrigated sunflower farm when the rains failed (Fig. 2). The community survived the shocks through social connectedness, which aligned with the effective use of remittances to create robust mechanisms for sharing risk.

When grazing fields dried up, the only remaining option was to drive livestock towards the nearby Ethiopian border 60 kilometers away. During acute drought, there are always conflicts over the few available grazing fields. Notably, even amid periods of hostility, rival pastoral factions have demonstrated a willingness to acknowledge the challenges brought about by drought. Historical instances highlight extended migrations across this region that took place without conflict. Given that drought eventually affects everyone, this mutual recognition of the issue is regarded as a form of "survival insurance." In cases where clans are disadvantaged and lack influence, their recourse lies in seeking protection from more potent clans and relying on them to fulfill their obligations, thereby aiming to endure the ramifications of drought.

Fig. 1: Focus group discussion in Quljeed village programming for sustaining peace

Fig. 2: Irrigated sunflower farm in Quljeed village

There appeared to be a growing realization that climate variability and frequent droughts may become the norm. Consequently, farmers were in favor of shifting from a dependency on maize to more drought-resistant crops like millet and cassava as well as the revival of indigenous crops. The community appeared to be enthusiastic about these changes, driven by their aspirations for a better future and less ingrained perspectives on the social and cultural significance of different food types.

Other adaptation strategies

Labor migration: During extended periods of drought, seasonal migration emerges as a vital means of sustenance for the community. Remittances stemming from these migrations serve as a crucial strategy for coping with such circumstances. Traditionally, pastoralists have followed a practice of relocating along with their livestock from water sources to grazing areas in response to drought. The research findings indicated that the concept of migration as an answer to environmental changes extends not only to pastoralists but also to agro-pastoralists. For instance, the study illustrated that a common adaptive reaction of the community to drought involved dispatching family members to neighboring urban centers (like Borama and Hargeisa) to secure wage-based employment that could support the family until the drought situation improved.

The effects of climate-related stress are already prompting temporary migration as a coping strategy in various regions. The ability to engage in migration depends on both mobility and available resources, encompassing financial and social factors. This implies that those who are most susceptible to the impacts of climate change might not necessarily be the ones most inclined to migrate. Recent studies, similar in nature, shed light on the utilization of temporary migration as an adaptive response to climate change. In the Awdal region, which has endured prolonged drought, a representative shared that households have responded to the challenging conditions by dispatching their young men and women to seek wage labor as a way of adaptation.

Income diversification: The survey showed that farmers adapt to the effects of low yield by indulging in dry season market gardening and non-farm income sources. The community focuses on activities that are less dependent on climate which generates opportunities for long-term adaptation strategies to climate variability and change.

Lessons from the case study

Capacity building for livestock keepers: There is a need to improve the capacity of the case study community to understand and deal with climate change, increasing their awareness of global changes. There is also the need to train them in agro-ecological technologies and practices for the production and conservation of fodder to improve the supply of animal feed and reduce malnutrition and mortality in herds.

Livestock management systems: There is an urgent need for efficient and affordable local adaptation practices developed for this rural poor community which is unable to afford expensive adaptation technologies. Such technologies could include (i) provision of shade and water to reduce heat stress from increased temperature; (ii) reduction of livestock numbers – a lower number of more productive animals leads to more efficient production and lower greenhouse gas emissions from livestock production;[6] (iii) changes in livestock/herd composition (selecting large animals rather than small ones); and (iv) improved management of water resources through the introduction of simple localized techniques to harvest and store rainwater such as tanks connected to the roofs of houses and surface dams.

Breeding strategies: The study noted that the local goats, sheep, cattle and camels are adapted to harsh living conditions. There is therefore a need for technology in livestock breeding that addresses not only the tolerance of livestock to heat but also their ability to survive, grow and reproduce in conditions of poor nutrition, parasites and diseases. Such measures could include: (i) identifying and strengthening local breeds that have adapted to local climatic stress and feed sources and (ii) improving local genetics through cross-breeding with heat and disease tolerant breeds. If climate change is faster than natural selection, the risk to the survival and adaptation of the new breed becomes greater.[7]

Conclusion and recommendations

The communities in the study area are already grappling with the pressures imposed by climate stress, heightening their susceptibility to further climatic changes and diminishing their ability to adapt. The adverse consequences of climate change disproportionately impact their agricultural and pastoral activities, which serve as the cornerstones of their economic subsistence. This has led to compromised food production and widespread poverty. To counteract the challenges posed by climate variability and extreme events, the community has devised traditional adaptation methods. These encompass income diversification, the utilization of forest resources as safeguards against climate-induced crop failure, labor-driven migration, and practices for conserving soil moisture and water. Their valuable experiences should be disseminated to similar communities, albeit with adjustments to accommodate the supplementary risks linked to climate change. However, the primary obstacles to the implementation of adaptation strategies within this community encompass a general lack of awareness concerning access and utilization of climate information, the inadequate capacity of climate change institutions to tackle climate-related tasks, and the requirement for a more effective institutional framework to execute adaptation efforts. Addressing these deficiencies entails organizing training and consciousness-raising initiatives for local residents concerning climate change, alongside the adoption of agro-ecological technologies for agriculture and conservation. By proactively engaging in adaptation measures, the community can bolster its ability to navigate climate change by incorporating it into long-term decision-making processes. This involves eliminating deterrents to behavioral changes and introducing incentives to encourage modifications in conduct. Enhancing and reinforcing community capabilities through education, outreach, and extension services not only enhance decision-making competence at every tier but also augment collective adaptability.

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03

Climate Change, Transhumant Pastoralism, and Conflict in Somalia

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Abstract

We examine the effects of climate change on the dominant pastoral systems of Somalia where herds must move across territories. Traditionally, there has long been a sustainable symbiotic relationship between livestock herders and farmers whereby arable land is utilized for crop cultivation in the wet season and for animal grazing during the dry season.

Recurrent cycles of droughts, however, shifted the balance and disrupted this arrangement forcing desperate pastoral communities to migrate to agricultural regions leading conflicts to emerge.

This study reviewed the existing evidence on the impact of adverse rainfall shocks in the territories of pastoralists and their role in triggering conflict-based resources between neighboring clans. We used mixed methods of data collection and analysis to produce a set of state-level case study reports. This included a state-level analysis drawing primarily on secondary data analysis, focus group discussion and key informant interviews. We observed that recent drought waves significantly increased the migration of pastoral groups which in turn led to high risk of violent conflicts between neighboring clans as well as other pressures on health determinants including altered zoonotic diseases such as Rift Valley Fever, food insecurity, unemployment and ultimately economic recession. To mitigate these effects, governments should devise sustainable development aid programs in the remote areas and increase the national share of political representation of pastoral groups.

Keywords: Climate change, transhumant pastoralism, sedentary agriculture, seasonal migration, conflict, Somalia.

Introduction

Climate change remains one of the most pressing global challenges.[1,2,3] A fundamental concern is that the increasing occurrence of extreme weather events trigger a chain of consequences ranging from pressures on health determinants such as food insecurity, the spread of emerging infectious diseases and the risk of violent conflicts – all of which pose a challenge to geopolitical stability in fragile parts of the world. More specifically, Somalia is vulnerable to such threats, due in part to a high reliance on animal husbandry, fragile health systems, lack of economic development, weak state capacity and presence of non-state actors.[4] Climate change may reverse years of progress in tackling social, economic, and political instability.

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4. McGuirk, E. F., & Nunn, N. (2020). Transhumant Pastoralism, Climate Change, and Conflict in Africa (No. w28243). National Bureau of Economic Research.

In this paper, we study important features of the effect of climate change on seasonal migration of transhuman societies, and the nexus between cyclical droughts, pressures on health determinants and the risk of violent resources-based conflict between neighboring communities. We illustrate the national dimensions of these challenges through case studies related to resources-based conflict between transhumant pastoralists and sedentary agriculturalists in Hirshabelle, Southwest and Galmudug states.

Approximately 80% of Somalia's population derives the primary portion of its income from animal husbandry with 65% of the nation's land mass devoted to sustaining pastoral activities **(Figure 1)**

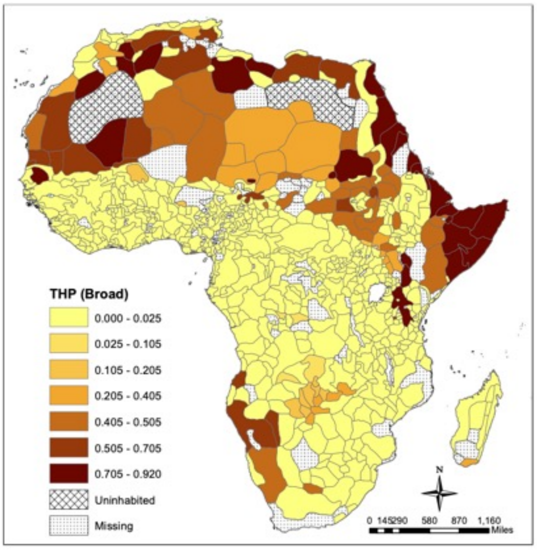

Figure 1: Cross-ethnicity measures of transhumant pastoralism in Africa (adapted from McGuirk et al.[5])

A significant proportion of these pastoral communities partake in the practice of transhumance, which is the seasonal migration of livestock for grazing.[6,7] Such transhumance fosters interconnectedness and interdependent relationships that remain potentially sensitive to the rising occurrence of droughts driven by climate change in the Horn of Africa.

For instance, in Somalia, every year millions of animals move across the country looking for better grazing areas, or to be sold for food. These movements often cause conflicts with farmers, especially during the wet growing season when animals can invade cultivated plots.[8] Livestock mobility is also a major driver of disease transmission. Livestock may cross areas with a high prevalence of diseases including water-borne, air-borne, food-borne and vector-borne pathogens (lowlands, wetlands). The contact between animals in meeting points is also conducive to pathogen circulation.[9] However, the intensity of the spread of these pathogenic hazards is not always the same but peak patterns of conflict and disease transmission have long been linked with recurrent droughts.

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In typical years, neighboring herders and sedentary agriculturalists coexist in a symbiotic relationship that is based on a mutually beneficial relationship. During the wet season, sedentary farmers cultivate crops on productive lands while pastoral groups exploit more marginal lands that produce sufficient plant biomass for their livestock. Following the harvest, transhumant pastoralists migrate to agricultural areas for the dry season benefiting the year-round availability of phytomass while providing organic fertilizer in exchange.

These migrations can span from short distances to hundreds of kilometers. However, during periods of low precipitation, the marginal grazing lands may not produce enough plant biomass to sustain the pastoralists' animals. In such cases, pastoralists are compelled to move to agricultural lands before the dry season begins. If they arrive before the final harvest, conflicts can emerge due to crop damage and competition for resources including water and pasture. There are many documented examples of this issue elsewhere in Africa.[10]

The question of whether this mechanism consistently leads to violent conflicts is a matter that requires empirical investigation. On one hand, neighboring groups might opt to avoid conflict if they perceive droughts as rare events, thus preserving the symbiotic relationship. Conversely, if groups update their expectations about drought frequency due to climate change, the symbiotic relationship becomes unsustainable, potentially leading conflicts to emerge. Furthermore, another relevant empirical question relates to the recent emergence of the militant group al-Shabaab in conflict-prone areas. Given the weak state capacity of the Federal Government of Somalia (FGS), terrorists groups present themselves as mediators for keeping peace between neighboring clans. It is possible that this mechanism also explains the rise of violence involving self-styled extremist groups. Our analysis delves into these inquiries.

Methodology

Study design and participants

The study employed a qualitative method using focus group discussions (FGDs) and key informant interviews (KIIs) to investigate the effects of adverse rainfall shocks that occur in the territories of transhumant pastoralists and the contribution of these weather events in triggering conflict-based resources between neighbouring clans in Hirshabelle, Southwest and Galmudug states.

A total of six FGDs were conducted in each state, three in an urban setting and three in rural areas. The FGDs comprised six to 12 participants and included adults, local community leaders and community healthcare workers. The categorisation of the FGD participants enabled the research team to obtain data from a given group without compromise or influence from another category. The study also used 12 KIIs to obtain the perspectives of policy makers, supra-international organizations, local NGOs, academic partners and the private sector on the impacts of climate change on socioeconomic and political stability in the pre-selected states. The KIIs were purposively selected due to their prior involvement in addressing conflict-based resource issues at both national and state levels.

10. McGuirk, E. F., & Nunn, N. (2020). Transhumant *Pastoralism, Climate Change, and Conflict in Africa* (No. w28243). National Bureau of Economic Research.

Study area and setting

The study was carried out in urban and rural settings. The urban setting was Wanlaweyn in Lower Shabelle, the Beledweyne in the Hiran region and Abudwak in the Galmudug region. The rural settings were Yaqberiwayne, Defow and Labagale. The targeted urban areas had predominantly informal settlements. The major economic activities were agricultural and livestock trading, along with small-scale businesses such as general retail shops.

Data management and analysis

The audio recordings of the FGDs and KII were transcribed verbatim and proofread by a research assistant to ensure accuracy. Given the FGDs and KIIs were mostly conducted in the Somali language, the transcripts were translated into English and subsequently validated by another team member. These translated transcripts were then imported into NVivo (2020) software for the purpose of data analysis. The thematic analysis approach was used to guide the analysis process. Two research team members read through the transcripts to develop codes which were then discussed by the entire team and refined as necessary. The codes were then meticulously defined, and a selection of quotes representing various codes were singled out to compile a comprehensive code book. Codes with commonalities or those addressing related subjects were consolidated to create sub-themes. These interconnected sub-themes were then organized to formulate overarching themes, which constitute the principal findings presented in this research paper.

Ethical considerations

The study received ethical approval from National Research Ethical Review Board (NRERB), Ministry of Health of Federal Government of Somalia. Written informed consent was obtained from all the participants on a voluntary basis. To safeguard anonymity, no identifying information about the participants was recorded in the audio data collected, and their names were not recorded. Data access was restricted solely to the research team to uphold confidentiality and was not used for any other purposes. Additionally, the focus group discussions (FGDs) adhered to COVID-19 prevention guidelines in the country. Participants were furnished with face masks, frequent hand sanitization was practiced, and social distancing measures were strictly observed during the sessions.

Results and discussion

Our results revealed that the types and frequency of the conflicts that occurred in the study area varied over time and were concentrated in agropastoral zones across the selected Federal Member States (FMS) (Figures 2-5). Galmudug accounted for the highest number of conflicts (42%) followed by Hirshabelle (37%) and Southwest (21%) (Figure 4). Most of these conflicts were caused by adverse rainfall shocks in transhumant pastoral territories which in turn forced herders to migrate to neighboring agricultural territories before the harvest, resulting in competition for resources (water wells and pastures) and the emergence of conflict (Figure 5). A similar observation was also reported in the Horn of Africa[11/12], and elsewhere in the region.[13]

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11. Mkutu, K. (2001). Pastoralism and conflict in the Horn of Africa. London: Saferworld. Organisation.

12. Ayana, E. K., Ceccato, P., Fisher, J. R., & DeFries, R. (2016). Examining the relationship between environmental factors and conflict in pastoralist areas of East Africa. *Science of The Total Environment,* 557, 601-611.

13. Ayana, E. K., Ceccato, P., Fisher, J. R., & DeFries, R. (2016). Examining the relationship between environmental factors and conflict in pastoralist areas of East Africa. Science of The Total Environment, 557, 601-611.

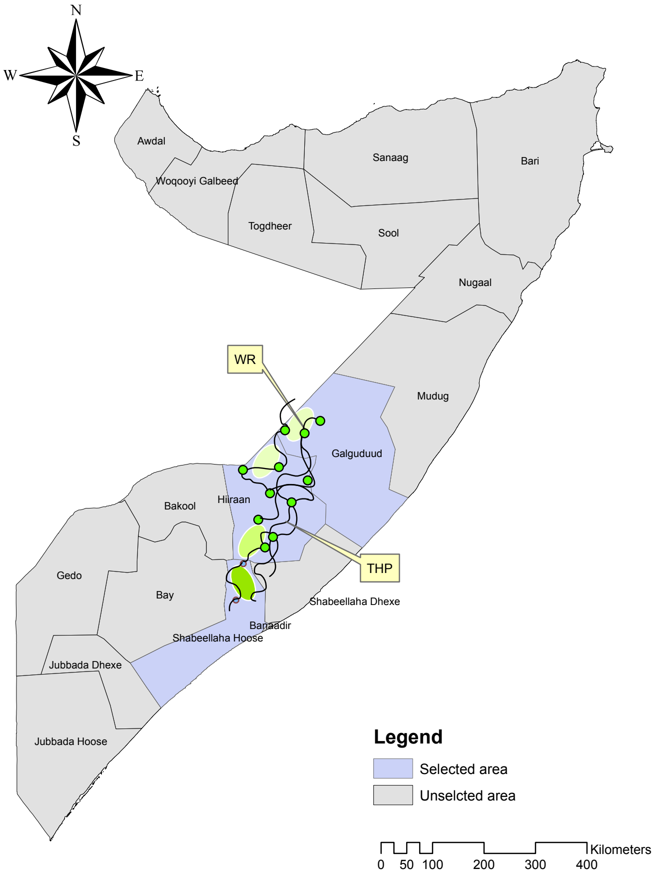

Figure 2: Concentration of conflict-based resources

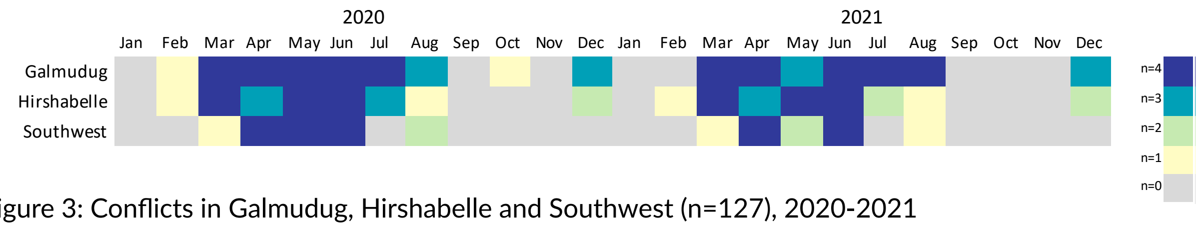

Figure 3: Conflicts in Galmudug, Hirshabelle and Southwest (n=127), 2020-2021

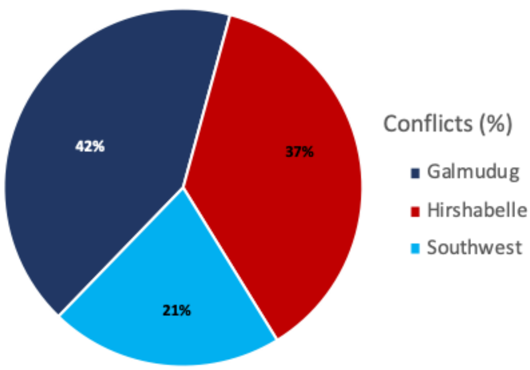

Figure 4: Frequency of resource-related conflict, 2020-2021

However, it's worth noting that the Hiraan and Lower Shabelle regions differed from Galmudug which has a high reliance on animal husbandry and agriculture and is a potential hotspot for conflict-based resources and vector-borne disease including Rift Velley Fever.[14/15] The conflicts induced by the climate shocks are concentrated in agricultural zones (Figure 2) around Beledweyne, a city in Hiaan, and in Wallawayn in Lowetshabelle. A major share of cattle movement in these areas involve transboundary movements near the main cities and lead to territorial disputes between clans. Most of the conflicts in Galmudug were linked to land expansion or permanent settlement near wells (Figure 5). Similar results were observed elsewhere in Africa[16/17] in low precipitation years. Of note, we have also observed that some conflicts were related to livestock raids during drier months and in drought years (Figure 4).

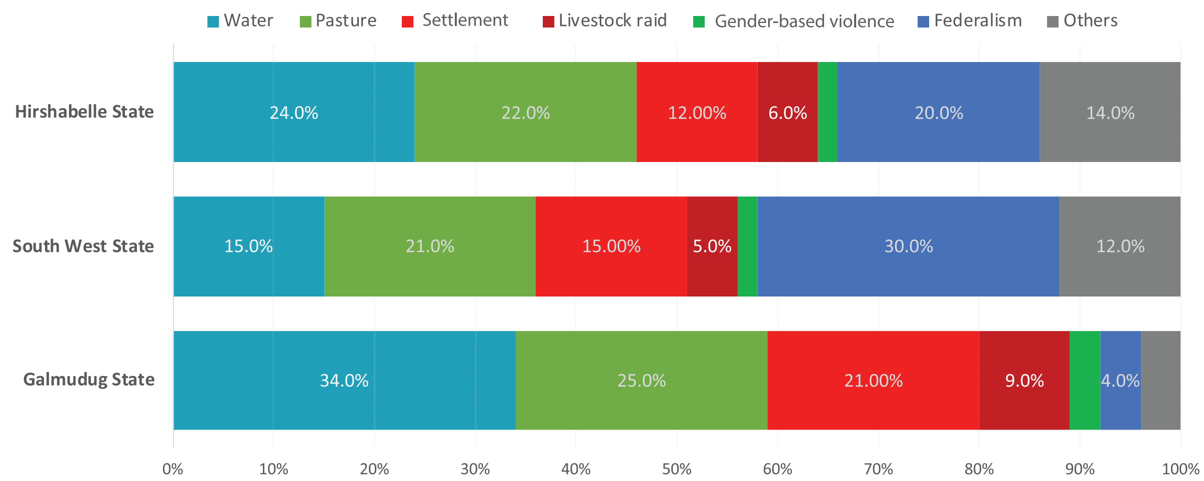

Figure 5: Breakdown of the type of resource-based conflict

This could be explained by the fact that adverse rainfall shocks increase the frequency of intergroup conflict.[18] The rape of women in both pastoral and agricultural groups was also reported in all selected states (Figure 5). This reflected the strains of climate change on social systems which disproportionately affect the most disadvantaged segments in society, amplifying inequities.[19/20] In general, Somalia has experienced extreme draught conditions and low rainfall for the last 15 years with more conflict patterns emerging in agropastoral areas. This was consistent with global data[21] indicating extreme draughts of ≤1·6 standardized precipitation-evapotranspiration index (SPEI) in the last 20 years (Figure 6)

14. Hassan-Kadle, A. A., Osman, A. M., Shair, M. A., Abdi, O. M., Yusuf, A. A., Ibrahim, A. M., & Vieira, R. F. (2021). Rift Valley fever and Brucella spp. in ruminants, Somalia. *BMC Veterinary Research,* 17(1), 1-6.

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21. Romanello, M., McGushin, A., Di Napoli, C., Drummond, P., Hughes, N., Jamart, L., ... & Hamilton, I. (2021). The 2021 report of the Lancet Countdown on health and climate change: code red for a healthy future. The Lancet, 398(10311), 1619-1662.

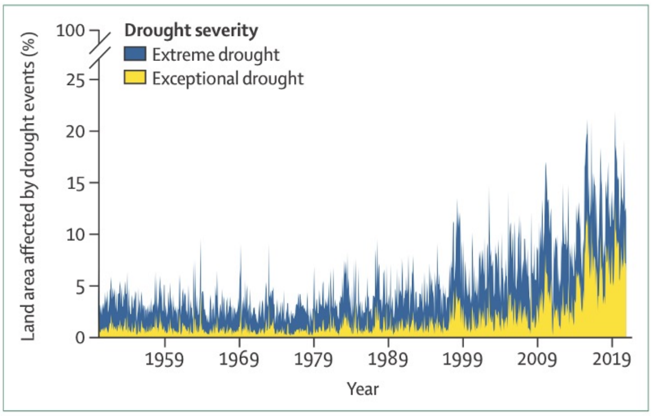

Figure 6: Global land area affected by drought events per month. Extreme drought is defined by a SPEI of ≤1·6 and exceptional drought is defined by a SPEI of ≤2. SPEI=standardised precipitation-evapotranspiration index (adapted from McGuirk et al.[22])

Conflicts are more frequent during the wet season and this indicates the effect of climate change on phytomass growth and the early migration of pastoral societies to agricultural farmlands. Similar observations were extensively documented in sub-Saharan Africa.[23/24] Our results indicated that the overall incidence of conflict is lower in areas that recorded relatively normal rainfall, enabling phytomass growth which grazing animals require for sustenance.

Rainfall during the 2021 Gu (wet season) is given in Figure 7. Lack of rain in the southern parts of Galmudug and in pockets of Hirshabelle and Southwest have led to poor vegetation conditions and reduced farmland activities in the agricultural areas.

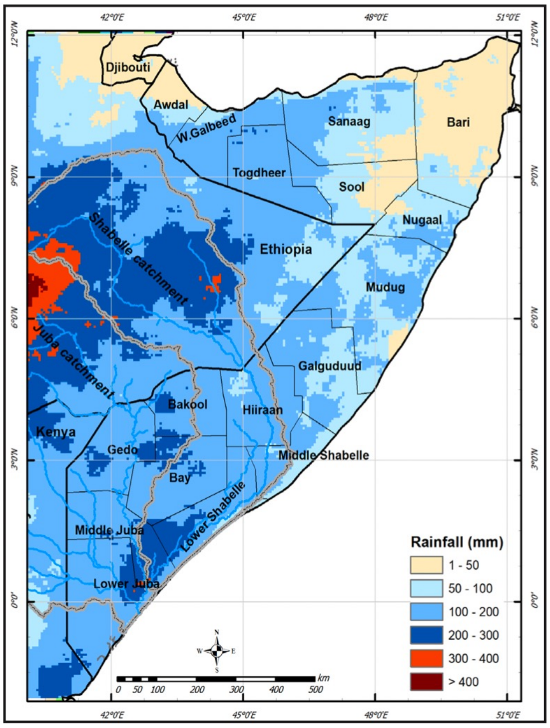

Figure 7: 2021 Gu (March to May) cumulative rainfall (mm). Source: FAO

22. Romanello, M., McGushin, A., Di Napoli, C., Drummond, P., Hughes, N., Jamart, L., ... & Hamilton, I. (2021). The 2021 report of the Lancet Countdown on health and climate change: code red for a healthy future. The Lancet, 398(10311), 1619-1662.

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Most of the states experienced the peak of the conflict waves between neighbouring groups from March to June (Figure 3). We found that some of the conflicts had deep roots in the federal system, for example in Wanlawayn in Southwest State (Figure 5). For instance, some of the major pastoral groups belong to the Gaalje'el tribe which thus far remains one of the largest Somali clans. These groups, which traditionally inhabit in many areas of Somalia including Hirshabelle, Southwest, Jubbaland and beyond borders of Somalia in Kenya and Ethiopia, do not recognise the demarcation of regional boundaries. Their seasonal migration along well-established corridors interacts with agriculturalists in other clans, leading to tension due to damaged crops and competition for water and pasture. These pastoralists are politically misrepresented in Southwest State and have therefore formed politically organized rebel groups which could contribute to the political instability of the Southwest State structure and potential interstate conflicts in Somalia.

We have also observed that clans have secretly used state forces including the police and military for small-scale conflict events. Our findings also indicated a growing number of extremist groups in conflict zones have presented themselves as vehicles for keeping the peace between neighboring clans in agropastoral zones (Figure 8). More political representation of pastoralist groups and economic development would inevitably inhibit the growth of such groups.

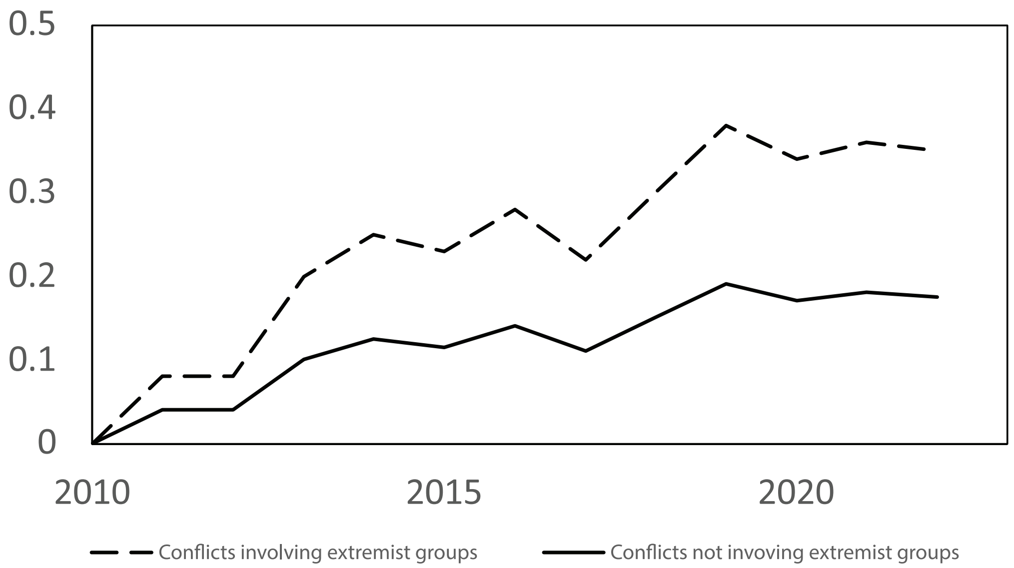

Figure 8: Extremist and non-extremist conflicts, 2010-2020

Our findings also stressed that the government is playing only a marginal role in mitigating the deleterious effects of conflicts in agropastoral zones. Other major themes emerging from the qualitative data included:

- Most respondents (85%) indicated that the recurrent conflicts affected the day-to-day lives of communities. This included access to trade; access to general health services (including maternal and neonatal child health services and vaccines); access to education; an increase in poverty; and a decrease in the well-being of individuals.

- The majority (90%) said there are few privately owned healthcare clinic in conflict areas. Women and children are forced to seek out the few hospitals that are located in the hostile territories, but they suffer from resource constraints, as well as the out-migration of skilled health care workers, hyper-inflation of user fees and poor infrastructure. Somalia's health care system has faced many human resources challenges. Doctors and nurses are concentrated in Mogadishu where pay scale and security situations are relatively better. Those who have remained in rural areas complain of low wages and poor living conditions as well as a lack of security and basic medical supplies including personal protective equipment (PPE).

- Most respondents reported that they had been impacted by recurrent extreme droughts and food insecurity since 2015.[25] Women, children and elderly people were the most affected.

- No heat-related deaths were reported across the selected states **(Figure 9).**

There were some incidences of altered infectious diseases including vector-borne, food-borne and water-borne diseases **(Figure 9).**

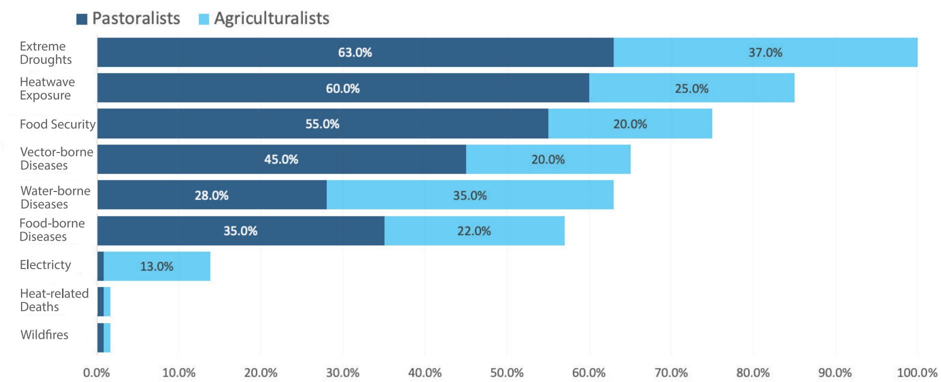

Figure 9: Impact of climate change on pastoralists and sedentary farmers

25. Thomas MA, Lin T. Illustrative analysis of probabilistic sea level rise hazard. J *Clim 2020*; 33: 1523–34.

Conclusion

This study provides contemporary evidence related to the impact of adverse rainfall shocks in transhumant pastoral regions which forces herders to migrate to neighbouring clan territories resulting in competition for resources and conflict. Territories remain important socio-economic and livelihood drivers in Somalia and are closely linked to identity and history.

Our results also confirmed the anecdotal accounts that conflicts over resources occur during the wet season when animals invade cultivated plots. Our analysis also provided important policy implications. Policies that encourage agricultural development in remote areas and increasing the political representation of pastoral groups could mitigate the deleterious effects of conflicts induced by adverse rainfall shocks. Conversely, policies that further restrict pastoral groups are counterproductive. Instead, institutions that facilitate a balanced coexistence of grazing and cultivation rights could play a pivotal role in alleviating the climate change-related challenges in agropastoral zones nationwide. Our research suggests that achieving this balance is more likely if pastoral groups are granted increased political representation in disputed areas.

Acknowledgment

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04

Conflict-Famine Nexus in Somalia: What It Takes to Break the Cycle

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Abstract

For the last 30 years, the frequency and effect of famine in Somalia have been unprecedented. However, the current literature falls short in explaining why food insecurity and droughts, which are common challenges across the states in the broader Horn of Africa, quickly deteriorate into famine in Somalia but not necessarily in the neighboring countries. In an attempt to highlight the underlying factors that make the Somalis more vulnerable to external shocks including food shortage and droughts, this policy brief argues that the protracted armed conflicts and dynamics they generated have fueled the recurrent famine. Famine and its outcomes further sustain the ongoing conflict, creating a conflict-famine nexus. This policy brief applies four analytical tools – state-collapse, displacement, poverty and environmental degradation – to highlight the nexus between conflict and famine in Somalia. It demonstrates that Somalia's protracted conflict and reoccurring famines emanate from the missing role of the state. Therefore, a durable solution for famine and the underlying factors threatening communal resilience to external shocks will require a compelling, legitimate, functioning state.

Keywords: Famine, conflict, state collapse, displacement, poverty, deforestation

Introduction

For the last three decades, Somalia has experienced two internationally recognized famines (1991/92, 2011/12) and several near-famine crises (2002/03, 2007/2009, 2016/2017). These famines cost the lives of millions of people and displaced millions of others. Understandably, the media and aid agencies often cite food insecurity and frequent droughts as the leading causes of recurrent famine in Somalia while briefly mentioning conflict as the cause without dissecting the link between conflict and famine. Food insecurity is a relatively common phenomenon experienced by close to a billion people living in both developed and developing countries. However, food insecurity rarely deteriorates into full-scale famine in other parts of the world. Similarly, due to climate change, drought has become widespread in terms of locations affected and frequency in recent years, affecting almost all countries and communities across the globe. Severe droughts now hit even countries that were traditionally immune from drought. Almost all droughts that hit Somalia over the last 30 years have also affected all countries in the Horn of Africa. However, famine stops at the border of Somalia. Therefore, the critical question this paper will answer is, "Why is there recurrent famine in Somalia?"

This policy brief forwards two main arguments:

- First, the protracted armed conflict and dynamics generated by this conflict (state collapse, displacement, poverty and environmental degradation) have led to the destruction of the social protection net, making Somalis more vulnerable to shocks including drought. Furthermore, famine and its outcomes (poverty, sickness, displacement) fuel the ongoing conflict, creating a complex web of causation (conflict-famine nexus) in Somalia.

- Second, understanding the interplay between conflict and famine and the complex web of threats that emanate from this cycle of causation (conflict-famine nexus) will be critical for formulating effective and context-specific policies and programs that can break the cycle that (re)produces famine.

This policy brief suggests four analysis tools (state collapse, displacement, poverty and environmental degradation), which provide an analytical lens through which the nexus between conflict and famine can be adequately understood.

Famine trends

The massive famine that hit the southern regions in late 1991 and early 1992 claimed an estimated 240,000 lives, mainly from Bay, Lower Shabelle and the Jubba Valley, some of the country's most productive agricultural regions (Menkhaus, 2003, p. 3). On 20 July 2011, the United Nations (UN) again declared famine in southern Somalia. The famine affected more than three million people and caused the death of 250,000, of which the majority were children (Maxwell & Fitzpatrick, 2012, p.5; ICG, 2017, p. 1).

Just six years later, Somalia faced another mass hunger affecting an estimated seven million people – almost half of the country's population, half of which were classified as facing an 'emergency' situation due to starvation and diseases (ICG, 2017, p 1). A further 700,000 people fled their homes, joining the over a million already displaced across the country by the previous famines (OCHA, 2017).

Once again, in 2022, history was at risk of tragically repeating itself as an estimated half of Somalia's population was on the verge of starvation, and about half a million people had fled their homes (WFG, 2022). Without quick action by the government of Somalia and their international humanitarian partners to help people already starving, the country could soon see another mass death. While it is essential to acknowledge the effort of the new president of Somalia and his administration in putting famine prevention at the heart of the government agenda - the appointment of a Special Envoy for Drought Response - clear, practical measures and serious coordination efforts will be needed in the days and months ahead to prevent another famine.

Protracted armed conflict trends

Since independence in 1960, Somalia has experienced different forms of armed conflicts with varying intensities: from inter-state to intra-state; from clan-based to ideology-based; from wild and widespread to localized and shorter; and from proxy wars to the so-called war on terror. These armed conflicts have happened alongside traditional conflicts over arable land and water among pastoral and agro-pastoral communities.

Pre-state collapse armed conflicts

Though brief, the first inter-state war between two sovereign states in the Horn of Africa occurred in 1964 between Somalia and Ethiopia (Bekereteab, 2013, p. 15). However, the largest in terms of duration, scale and devastation was from 1977 to 1978, fought between Somalia and Ethiopia. In addition to the 25,000 Somalis who lost their lives and over one million refugees from Ethiopia coming to Somalia, the legacy of the war continues to undermine the healthy relationship between the two countries. The second major armed conflict was guerrilla warfare between the Somali military and the Somali Democratic Front (SDF) for control over regions dominated by the Majerteen clan. In an attempt to silence the armed opposition movement, the government undertook a massive military offensive against the Majerteen clan, including destroying water sources, towns and cities, jailing key people and indiscriminately terrorizing civilians in the regions inhabited by the Majerteen (Adam, 1992, p. 118; Ahmed & Green, 1999, p. 118).

The third and perhaps the most destructive civil war was between the Somali military and the Somali National Movement (SNM) in 1988 over control of the northwest regions dominated by the Isaaq clan. In response to SNM's attack on the cities of Hargeisa and Burao in 1988, the military reaction was brutal. Aerial bombardments levelled Hargeisa and Burao, and an estimated 50,000-60,000 civilians died. Nearly half a million people fled across the Ethiopian border as refugees, and another 500,000 were internally displaced (Africa Watch, 1990, p. 3). The fourth wave of these clan-based armed conflicts against the authoritarian military regime was led by the United Somali Congress (USC). It concentrated on the Somali capital Mogadishu and the neighboring regions dominated by the Hawiye clan. The cumulative outcome of these guerrilla wars against the military was the fall of the regime and the collapse of the entire Somali state (World Bank, 2005, p. 11).

Post-state collapse armed conflicts

From1995 to 2006, the most significant conflicts were between neighboring sub-clans (Menkhaus, 2003; World Bank, 2005). These conflicts were shorter in duration and resulted in less fatalities but allowed warlordism, pirates and other war-related criminal activities to flourish (Menkhaus, 2003).

In the post-9/11 world, Somalia was presented as a potential breeding ground for Islamist extremists and a threat to the region and international peace and order. When it appeared that local warlords were losing momentum, foreign interventions added fuel to the fire by encouraging the proliferation of warring factions and changing the political dynamics of the conflict in pursuit of their interests (Ingiriis, 2018).

Supported by the US, Ethiopia made ample use of the war on terror rhetoric in December 2006 when it launched an attack against the Union of Islamic Courts – a moderate Islamist group that briefly controlled a large share of southern and central Somalia including Mogadishu after defeating a ragtag coalition of warlords who had controlled these areas since the fall of the Barre regime in 1991 (Harper, 2012, p. 82). However, Ethiopia and its allies quickly defeated the UIC militants and tried to impose victor's peace in the country. Many Somalis saw this as a humiliating and unacceptable assault by a traditional regional rival. Strong resistance from a mixture of clan militias and remnants of UIC militants forced Ethiopia to withdraw the bulk of its troops from Somalia in 2009. However, the new conflict sparked by the Ethiopian invasion was devasting. In addition to the 15,000 civilians who lost their lives and close to one million people displaced from their homes, a new generation of Somalis was radicalized, some of whom formed a more radical and deadly militant group, al-Shabaab, which continues to destabilize the country today.

Al-Shabaab remains the defining feature of Somalia's conflict landscape. The group still controls significant territories in Jubbaland, Southwest and Hirshabele and operates more or less freely in other areas. Although al-Shabaab is a very secretive organization, experts estimate it has 5,000-7,000 active combatants (Felbab-Brown, 2020, p. 120). The group officially acknowledged its ties to the al-Qaeda terrorist network in 2012. It routinely launches deadly attacks on military and civilian targets, causing massive death, destruction of private and public infrastructure, loss of livestock and denial of access to humanitarian aid for communities.

Some of the deadly attacks included the massive truck bomb detonated at a busy junction at the heart of the city on 14 October 2017 in which 512 innocent civilians were killed and another 316 injured (UN Human Rights, 2017, p. 5). The al-Shabaab attack on the Hotel Shamo on 3 December 2009 killed 25 people including three ministers from the Transitional Federal Government. It also injured 60 people, primarily students who were attending their university graduation in Mogadishu. On 29 October 2022, al-Shabaab bombed a busy intersection in Mogadishu causing hundreds of deaths and injuries.

The protracted nature of al-Shabaab-induced insecurity and criminality has caused acute humanitarian crises. The ongoing large-scale offensive against the group led by the Somali government in partnership with the local clan militias, which started in Hiran in September 2022 and quickly spread to other regions of Galmudug, Southwest and Jubbaland, could be the turning point if adequately managed and if there is clear policy and strategy for post-al-Shabaab security and administrative arrangements for areas taken back from the militants.

Conflict- famine nexus in Somalia

The protracted nature of Somalia's armed conflict has spawned multiple factors that underpin the country's current chronic humanitarian crises and vulnerability. Similarly, the dynamics generated by the conflict have degraded and, in some instances, destroyed all forms of social protection nets and resilience, making Somalis vulnerable to unnatural or natural disasters including droughts and floods. Therefore, droughts that should have been easily predicted or responded to instead turn into catastrophic famines. For this paper, we discuss four factors (state collapse, underdevelopment, displacement, and environmental degradation) that are the product of the protracted armed conflict and analyze the interplay between these factors and famine.

State collapse and crises in governance

The protracted nature of the state collapse in Somalia has been described as the most dramatic and unique feature of the Somali crisis (Menkhaus, 2003, p. 407). The collapse of the Somali state was "the longest-running instance of complete state collapse in postcolonial history" (Menkhaus, 2006/2007, p. 74). States provide security, education, health, economic opportunities, fundamental infrastructure, environmental protection and law and order (Rotberg, 2002, p.87). Therefore, the state is critical for the survival of humanity in the modern world. While some progress has been made since 2000 when the Transitional National Government (TNG) was formed in Arta, Djibouti, the inability of the authorities (federal and regional) to have a physical presence in all the territories they claim to control and their lack of capacity to deliver services in areas they do control means Somalia is still a failed state.

The connection between state collapse and famine is multifaceted, but four critical implications stand out:

- **Lawlessness and criminality:** As the state was unable to provide basic security to its citizens, lawless and criminal behavior including land grabbing, aid theft, piracy, terrorism, blocking access to aid, illegal checkpoints, kidnapping, civilian extortion and illicit fees has directly or indirectly caused famine in Somalia. The massive famine in 1991 and 1992 was a manufactured disaster (Samatar, 2011; ICG, 2017). The epicentre of the 2011/2012 famine and 2017 extreme humanitarian crises were the areas controlled by al-Shabaab which blocked aid from reaching drought victims and prevented people from migrating out of the areas under its control (Maxwell & Fitzpatrick, 2012, p. 9; Maxwell & Majid, 2016). Furthermore, conflict spreads in famine areas and other places where food and resources are scarce (IRC, 2022).

- **Need for a national early warning system monitoring drought conditions.** The government has been unable to generate evidence-based early warning for the detection and prevention of famine (Diamond, 2011; Heritage Institute for Policy Studies, 2022, p. 9). As a result, famines are declared by the United Nations and other affiliated humanitarian agencies (Maxwell & Majid, 2016).

- **External intervention and proxy wars:** The absence of a strong central government capable of protecting its citizens from external interventions has allowed foreign actors to meddle with Somalia's internal affairs in pursuit of their narrow national interests. Many of these interventions and proxy wars have created or worsened tensions and violence in Somalia, aggravating humanitarian crises (Menkhaus, 2009). For example, the Ethiopian intervention of 2006 and 2007 created massive displacement and destruction of the local economy and infrastructure and set the stage for the 2011 famine (Bruton, 2010, p. 18; Maxwell & Majid, 2016, p. 97).

- **Chronic crises in governance have led to the collapse of most public health services in Somalia:** As a result, the country continues to be vulnerable to periodic outbreaks of cholera, diarrhoea and measles (Menkhaus, 2003, p. 10). In addition, poor sanitation and lack of potable water in most parts of the country make Somalia an ideal environment for epidemics (Menkhaus, 2003, pp. 19-20). Somalia has one of the highest rates of acute malnutrition, child mortality and mental health problems globally. Widespread malnutrition and diseases among a large portion of the population imply that minor setbacks can have enormous humanitarian consequences. Poor health facilities, malnutrition and diseases aggravate famine. Famine destroys future generations, as the children who survive will live with the consequences (IRC, 2022).

Massive displacement

Multiple armed conflicts and famine have produced mass displacement. As of January 2021, there were almost three million IDPs (Kamer, 2022) and another 500,000 people displaced by the ongoing humanitarian crises. Most have been displaced to more than 2,400 sub-standard IDP sites in government-controlled urban and peri-urban areas, where humanitarian assistance is more accessible (UNHCR, 2022). For instance, in the city of Baidoa in Southwest state, the number of IDP sites increased from 70 in 2016 to 435 in 2019. In Mogadishu, an estimated 1,808 IDP sites were identified just in the districts of Dayniile and Khada, hosting close to one million displaced individuals (UNHCR, 2021).

Evidence shows that in the 1992, 2011 and 2017 famines, most of the reported excess mortality was from internally displaced people (Majid et al., 2022). For example, an elevated mortality risk was reported among IDP children aged five years or younger, exceeding the extreme emergency threshold of four deaths per 10,000 children per day, during May and June 2017 (Majid et al., 2022). Children who survive chronic malnutrition and sickness in their infancy are at higher risk for cardiovascular diseases in adult life (Moore, 1992).

The vulnerability of displaced persons is an important way in which famine fuels conflict:

- First, IDPs participate in conflicts due to extreme poverty and unemployment. For instance, in 2011, amid the worse famine in the country, al-Shabaab intensified its recruitment campaign by giving people money to pay soaring food prices (Heilprin, 2012).
- Second, there is growing evidence in the literature that a lack of economic and employment opportunities has the potential to reinforce criminal and armed conflict which stifles development, creating a "conflict trap" (World Bank, 2003). In Somalia, the interplay between poverty, unemployment and civil war is well established (Menkhaus, 2004). Having a population of close to three million displaced people vulnerable to exploitation and recruitment for criminal activities undermines the country's prospect for peace and state-building.

Underdevelopment and poverty

Armed conflict has damaged the country's public sector institutions and led to the loss of the economic and social services provided by the state (Mubarak, 1997, p. 2030). As the violence spread to rural areas, the rural economy that provided the livelihood for most Somalis was severely affected (Mubarak, 1997, p. 2030). The agricultural sector was disproportionately hit and there has been a drastic decline in crop production. For example, production of the critical cereals – maize and sorghum – decreased from 91 kilograms per capita in 1972 to just 30 kilograms in 2012 (The Conversation, 2021). Primary food production decline has led to chronic food insecurity and food aid dependence. Further complicating the problem are livestock sector import bans by Saudi Arabia and other Gulf countries, drought, and deforestation (Menkhaus, 2003).

The wealth generated from the informal market economy that developed as a result of the state collapse accumulated in the hands of a small portion of the population, leaving most people extremely poor. Consequently, youth unemployment in 2019 was around 19.82%, one of the highest on the continent (Macrotends, 2021). Nine out of 10 households were deprived of at least one critical basic service. Moreover, absolute poverty is more prevalent (64%) in urban areas, (Pape and Karamba, 2019). Poor revenue collection means that the government cannot even afford essential operations, let alone set up an early warning systems for farming or feeding those who are starving.

Environmental degradation

Deforestation is the leading driver of environmental degradation in the least developed countries including Somalia (Warsame et al., 2022, p. 1185). Deforestation directly affects economic activities and threatens the livelihood sources of poor rural communities (Warsame et al., 2022).

Somalia is currently facing energy insecurity, and 82% of the country's total energy consumption consists of traditional biomass including charcoal and firewood (Warsame & Sarkodie, 2022). In addition to the four million tons consumed by the country per year as energy, charcoal is also exported through trade to the Gulf countries, further accelerating the rate of deforestation (Warsame & Sarkodie, 2022).

Agricultural and livestock rearing, which together form the backbone of the country's economy and job creation, still practice environmentally unfriendly traditional methods, leading to resources depletion, destruction of the ecosystem and environmental degradation (Warsame, Mohamed, Mohamed, 2022, p. 3). These unsustainable energy consumption and agricultural practices have already affected limited resources, leading to desertification and loss of grazing and arable land.

In Somalia, increased arable land area due to deforestation does not stimulate agricultural production (Warsame, Mohamed, Mohamed, 2022, p. 3). Consequently, since the beginning of the armed conflict in 1990, Somalia has become increasingly dependent on food imports and food aid, with an estimated 60% of its overall food supply being imported, making the country extremely vulnerable to fluctuations in the global economy. For example, prior to the 2011/12 famine and 2016/17 near-famine, escalating food and fuel prices were reported, which alongside the droughts triggered famine (Majid et al., 202, p. 8-9).

Similarly, soaring global food and fuel prices prompted by the war in Ukraine, the legacy of the Covid-19 pandemic and prolonged drought are driving the ongoing food insecurity (*The Guardian*, 2022). The price of a kilogram of rice doubled from 7.5 cents to $2, while three liters of cooking oil rose from $4.50 to $9.50 (*The Guardian*, 2022). As food prices skyrocketed, the purchasing power of typical households declined, leading to malnutrition and starvation. In the 2016/2017 near-famine crisis, there was a 20% food price increase in some areas in the north and a 60% increase in the hard-hit areas in the south, as well as heavy losses of livestock (*African Research Bulletin*, 2017). Deforestation is one of the significant contributors to global warming, constituting approximately 20% of global CO2 emissions (Warsame et al., 2022).

At the country level, a recent study showed a causal relationship between climate change and armed conflict (Maystadt & Ecker, 2014). Their analysis also suggested that "local livestock markets are the primary channels through which drought fuels conflict" (Warsame & Sarkodie, 2022). When livestock prices fall due to famine or drought and there is a loss of income among herders, there is a risk that pastoralists may participate in conflict (Warsame & Sarkodie, 2022). Environmental degradation is one area with a strong connection between conflict and famine. Deforestation and poor agricultural practices lead to cyclic droughts, which trigger famine and loss of livestock. In turn, the loss of income among pastoralists due to decreased livestock can potentially increase conflict incidents.

Conclusion

Using state collapse, mass displacement, poverty and environmental degradation as an analytical lens through which the connections between conflict and famine are understood, this policy brief concludes that:

- While food insecurity and drought are the proximal triggers of recurrent famines, protracted armed conflict and its products remain the principal underlying cause of the chronic vulnerability that makes most of the Somali population susceptible to droughts and other setbacks.
- Governance deficit-induced crises such as lawlessness, criminality, poor public health facilities and external interventions, have gradually eroded social protection nets and resilience, meaning there is no proper protection from external calamities like drought.
- Conflict and famine-induced massive displacement have forced millions of people to abandon their livelihoods and families to live in IDP camps with limited health facilities, sanitation and food. Furthermore, extreme poverty and unemployment have made this large group of society vulnerable to possible recruitment by militants, fuelling the protracted armed conflict.
- Poor health facilities, malnutrition and diseases caused by conflict aggravate incidents of famine. In turn, famine destroys future generations as the children who survived must live with the consequences for the rest of their lives or die from famine-related complications. Losing entire generations further sustains conflict and undermines peace prospects.

Recommendations to break the cycle

Short term

The Federal Government of Somalia and its international partners should massively scale up their humanitarian response to prevent the current humanitarian emergency from deteriorating into full-scale famine.

Medium and long term

- **Neutralizing the threat imposed by al-Shabaab:** As clearly demonstrated by this research, al-Shabaab remains a severe threat to the security and survival of the Somali people. The group fuels much of the armed conflicts and crimes committed in modern Somalia and remains an essential multiplier for recurring famines. The current offensive against the group is a turning point for the security and state-building endeavour, and momentum must not be lost.

- **Enhancing the capacity, legitimacy and accountability of the Federal Government of Somalia:** It is evident from the analysis presented in this policy brief that the protracted conflict and recurring famines are caused by the lack of response by the central government. Since the collapse of the state in 1991, Somalis have tried different forms of polities (shadow states, de factor states, Islamic emirates, clan hegemony, warlordism, building blocks) in an attempt to develop an effective and functioning modern state and by doing so have paid a high price. Applying the experience gaining during statelessness, it is time for Somalis to come together and agree on how to improve the existing system's capacity, legitimacy and accountability.

- **Establish a rudimentary famine early warning system:** An early warning system is critical for detecting and preventing famine, as well as loss of life. Since a robust early warning system is expensive and beyond the financial and technical capability of the government in the foreseeable future, it is recommended that a basic system be set up. This should include information sharing among government agents and federal ministries on the country's famine hotspots. This is vital for quick resource mobilization and resource allocation.

- **Securitization of famine:** Famine has killed more people than protracted armed conflict. It is an existential threat to the state and its citizens. No responsible authority can tolerate watching millions of its people starving to death due to a lack of food and water. Securitization will help famine to be placed at the top of the government priority and attract the appropriate amount of attention and resources needed to prevent, detect and respond.

- **Sustainable strategic policy for IDPs:** No country or community can move forward with almost one-fourth of its population living in makeshift camps in awful conditions. Therefore, the Somali government and its international partners should work together to develop a long-term strategy that moves away from the current feeding system to one which focuses on greater self-reliance. This includes incentivizing IDPs to voluntarily return to their areas of origin and ensuring they are supported until they are self-reliant. Another option could be to give them the training and support they need to integrate into their host communities.

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05

Linkage between Climate Change and Gender Vulnerability in Somalia

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Abstract

Global warming and environmental change are already having serious impacts on the lives of millions of people across the world. Climate change opens gates to new waves of disasters such as floods, droughts, rising sea levels and glacial melting. Climate change is a challenge for both developed and developing countries. However, the impact of climate change varies significantly depending on geography, gender and income. Its impact on vulnerable societies is far more devastating. Domestic work, which is traditionally the responsibility of women and girls, is becoming more demanding. Both firewood and water are becoming scarce, forcing women and girls to walk long distances to access them, all while domestic violence is on the rise. These circumstances increase women/girls' exposure to rape, early marriage, and other forms of sexual assaults. Meanwhile, more girls are forced to drop out of school to support their families as parents prioritize boys' education. This paper will adopt a qualitative approach to analyze both primary and secondary sources of data to understand how climate change, in this case repeated droughts, increase the vulnerability of Somali women to a wide range of abuses. It will focus on how climate change has touched gender livelihoods and how Somali women are impacted by climate change-induced extremes. This paper advocates for a focus on gender analysis in climate change studies as women are most vulnerable to climate change shocks.

Keywords: Climate change, gender vulnerability, Somalia

Introduction

Global warming and environmental change are already having serious impacts on the lives of millions of people across the world, causing unprecedented disasters such as floods, droughts, rising sea levels, glacial melting and changing rainfall patterns. Mega disasters caused by climate change are negatively affecting nearly everyone on the planet.

However, women are especially vulnerable to the climate crisis, especially those from underdeveloped countries. In Somalia, women have been forced to migrate from their homes as they are no longer able to meet the basic daily needs of their children.

As the world struggles to cope with the challenges of climate change, developing countries are the most vulnerable due to lack of adaptation, inadequate technology, poverty and poor governance. Somalia is one of the countries most affected by climate change. The collapse of the central government in the 1990s plunged the country into an ocean of chaos and conflicts and made it more vulnerable to the climate crisis than other countries in the Horn of Africa. Severe droughts and flash floods occur nearly every year, causing repeated loss of life and property. More than one million people have been internally displaced, and others have crossed borders to find food, water and shelter. The study is based on desk review.

Climate challenges

Droughts have been hitting Somalia more frequently and more severely over the past few decades. The UN estimates that between November 2016 and October 2017, a drought caused 943,000 people to flee their homes in Somalia, and this number is expected to rise. The Sendai Framework (2015–2030) emphasizes how challenging it is to achieve sustainable development in the absence of the creation of contemporary climatic systems. According to predictions, the effects of climate change would hinder economic growth, making it impossible to reduce poverty and widening the socioeconomic class divide (Warsame et al., 2021).

The effects of the climate catastrophe on basic livelihoods, food security, health, and other socioeconomic factors are all at risk. Climate change-expected increases in the frequency and severity of extreme weather, caused by climate and Somalia's lack of an adequate adaptation strategy will compromise ecosystem health and safety. Given that the nation is still embroiled in a lengthy civil conflict, Somalia's capacity to deal with disasters like extended droughts and floods remains crucial and unpredictable (Ogallo et al., 2018).

The severe food insecurity in Somalia has been getting worse since the beginning of 2020. Almost 4.8 million people (31% of the population) are already facing food insecurity. More than six million people (38% of the population) are at risk of food insecurity (Andree, B. P. J., 2022).

The recurrence of multi-seasonal droughts has created persistent food insecurity, which risks becoming a famine in central and southern Somalia. Large numbers of livestock have died of starvation and diseases and there have been crop failures. Rising domestic and foreign food prices have caused huge population displacement. It is estimated that nearly six million people were facing acute severe food insecurity in May 2022 as successive poor rainy seasons since late 2020 seriously impacted crop and livestock production. If humanitarian aid is not scaled up, the number of people facing food insecurity was expected to reach 7.11 million (45% of the total population) by February 2023 (Gebremichael et al, 2022).

Lack of sustainable food security and livelihoods, poor marine and coastal management, the absence of drought mitigations and rapid deforestation are all accelerating the wave of climate change in Somalia. It is estimated, for example, that four trees are cut to produce one sack of charcoal. Between 1990 and 2005 around 13.9 percent, or 1,151,000 hectares, of forest were lost due to charcoal production or agriculture (FAO, 2011).

Deforestation, land degradation, increasing aridity and overgrazing, and water scarcity are major causes of climate change. Land degradation is closely related to desertification, drought and unsustainable livestock and agricultural practices which are also driving disputes and internal conflicts. These conflicts also lead to land degradation as they disrupt and prevent sustainable agricultural practices.

According to the World Bank, approximately 60 percent of Somalia's population is engaged in pastoralism. Additionally, 40 percent of the country's national GDP comes from livestock and animal rearing which are central to local communities. Pastoralism has been badly affected by climate crisis. Over the last 30 years, it has been greatly affected by the massive shift to wet and winter grazing patterns, the loss of natural habitats and frequent droughts.

In pastoralist communities, men own and manage livestock, set policies and make decisions. Society and cultural norms position women to take supporting role in livestock production. They are denied ownership, power participation and decision-making rights on issues that affect their communities, and most live under the control of men.

Women are involved in activities such as building houses, milking, management of sheep and goats, small businesses and the production of cheese and butter. Men care for and move livestock, manage pastures, and water resources, collect water, trade livestock, tame predators, and provide security. In recent years, men's work has shifted to non-pastoral activities in cities. This has increased the workload of women. Girls have been removed from school to support their families. Women are working longer and harder to generate family income and to be the breadwinners of the family. The research showed that a portion of family income is being used by men to buy the stimulant khat, a leafy green plant very popular in Somalia, Ethiopia and Yemen, to help them overcome depression caused by droughts and the loss of animals (Gebremichae et al,2022).

Gender and climate change crisis

Gender inequality in Somalia was already high before the current climate crisis: women have less access to power participation and limited access to education and the political sphere.

Despite much research on climate change issues, less attention has been paid to climate-gender relations. The unequal impacts of climate change on women are accelerating and have far-reaching consequences. Women play a major role in managing the natural resources on which pastoralists and farmers are heavily dependent for survival during difficult times. In developing countries, women are involved in the production of 45 to 80 percent of all food. Women also play central roles in the fetching of water and firewood (Denton, 2002).

Because of their role in the social structure, women are also the most affected group, or the most vulnerable victims of climate change, especially in communities where women's livelihoods are dependent on natural resources. In the Horn of Africa, gender dynamics in rural communities put women and girls at the forefront of domestic responsibilities, many of which involve the use of natural resources. Despite being the most affected by climate change, women are excluded from land ownership, which limits the role they can play in mitigating the impacts (Ali & Mwasiggwa, 2022).

Gender-based violence

The consequences of climate change have increased levels of domestic violence which were already high in Somalia's deep-rooted patriarchal culture where violence against women is seen as normal or a form of discipline. Female genital mutilation (FGM), rape, forced marriage, murder and domestic violence have increased in recent years. Violence against women and girls is practiced almost every day and has increased due to resource scarcity and livelihood stress which have changed many cultural norms in Somali society (Lwanga-Ntale at al, 2020).

Impact on health

Drought and climate change are putting women's health in danger. As many are illiterate or poorly educated, they have almost zero access to primary health care, especially in rural areas. Maternal mortality rates, which were already high in Somalia, are accelerating. Most women do not give birth at hospitals but are instead cared for by a traditional birth attendant. Lack of food makes pregnant women and new mothers vulnerable to protein deficiency and malnutrition as they traditionally eat after the men (Beier & Stephansson, 2012). Dalfelt (1998) argued that the effect of climate change on gender vulnerability has not been studied due to gender blindness that still haunts policymaking and the slow response of development agencies to challenges posed by climate change. The issue of gender has gained more recognition and has been considered an important factor in policy development since the 1970s. However, gender studies still lack the proper application of words and definitions. Gender discrimination and segregation have been common practices in many parts of the world, especially in developing countries.

Conclusion

Despite the fact that gender is important, the bulk of climate change-related initiatives being implemented in Somalia do not define or indicate how gender concerns and dimensions should be taken into account or handled. Most programs do not specify what activities to take, that gender be mainstreamed or that gender equality be upheld. The effects of climate change on women have been made worse by the many pre-existing vulnerabilities they already face and by the absence of Somali women in positions of authority and leadership.

Most climate change projects are implemented by the government or non-governmental organizations without regard for the differential effects of climate change on men and women. This has led to a disregard in planned interventions for the requirements of women, such as those related to their reproductive health, the need to lessen the burden of care and work during catastrophes, and the need to continue with their education, which is frequently disrupted by the effects of climate change.

This is evidenced by the fact that their intervention is predicated on periodic food supplies rather than skills acquisition and education, which would provide women with some relief from the inconsistency of income generation from the natural ecosystem. This would equip women with some protection against the challenges posed by the effects of climate change.

Women make up the majority of those whose lives are negatively impacted by climate change, but few women are invited to participate in activities related to climate change. There is a striking lack of female representation in the decision-making process on climate change. The topic of climate change did not attempt to address the prejudice that still exists against women or the need to involve them in decision-making.

To mitigate and adapt to climate change, which negatively affects the lives of thousands of Somali women, it is necessary for the community to make a collective decision that would make it cognizant of climate change and resilient to it. As literature demonstrates that women play a significant role in climate change adaptation and mitigation efforts, the study concluded that women require knowledge and training to be ready for climate change.

There are several contributing elements that make women more susceptible to the effects of climate change: (a) women are required to perform strenuous labor, such as gathering food, water, and fuel; (b) women have restricted access to both material and non-material resources, such as information and skills; c) women have limited prospects for educational advancement and access to essential services, resulting in a higher likelihood of enduring persistent poverty and being subjected to a lifelong cycle of economic deprivation; d) in Somalia, gender inequality leads to culturally established gender norms, underrepresentation in decision-making, and poor engagement in the public sector, politics, and economics, making women more susceptible to climate change; e) women are required to first feed the children and the rest of the family before eating themselves, which compromises their food security. Women in Somalia are subjected to significant discrimination and inequality in every aspect of life, including their health, work, and involvement in the labor market. This is a direct result of the prevalent and deeply ingrained patriarchal culture. Girls in Somalia are married at extremely young ages, and there is a pervasive culture of abuse against women and girls. Women face a significant amount of discrimination under customary law, which is frequently substituted for the judicial system of the state (Beier & Stephansson, 2012)

Analysis and recommendation

Although climate change has a negative consequence on most of the Somali population, women and girls have been identified as the most vulnerable group. Somalia's women are poorer than men and face many risks and challenges from the effects of climate change.

Pre-existing gender inequality in decision-making processes and accessing and controlling resources make them especially vulnerable. Their workloads have increased, and the analysis also found that women were disadvantaged due to low levels of education and limited access to resources. The literature review emphasizes the urgent need to tackle the negative climate and poverty patterns that exist within certain livelihoods, with particular focus on rural and nomadic communities. Development plans should be designed to address the underlying causes of vulnerability to climate change. It is important to actively include local populations in the process of formulating adaptation measures. By including men and women equally in the design, implementation, monitoring, and assessment of policies and programs in all political, economic, and social realms, gender should be mainstreamed to reduce current inequalities and increase the ability of both sexes.

Female-headed small-scale agricultural households have been struck the hardest by the drought caused by climate change. The consequences of the drought on livestock are especially felt by women since they are actively involved in subsistence farming (producing milk, marketing meat, and raising poultry). Agricultural, and livestock, production inputs and technologies are not equally accessible to Somali women. Drought has exacerbated challenges connected to displacement in the livestock industry by causing a major population shift in search of grazing pasture and water. The absence of women from planning, policy making and implementation in the public and private sectors has contributed to their vulnerability to climate change.

Recommendation

Recommendation to local and central government

To address the elements that render women more liable to climate change dangers and their repercussions, policies, laws, strategies, and development initiatives should be created that target these areas specifically.

With the support of the international community and key stakeholders, climate change adaptation and mitigation should take primacy over the nation's sustainable development objective.

By allocating more resources towards climate change investments and campaigning for increased financing from relevant organizations, a larger proportion of the affected community, population and households would be able to effectively develop climate adaptation and coping strategies.

Although there is a pressing need to increase awareness and educate the Somali community about climate change adaptation and mitigation, the awareness campaign should concentrate on gender issues since women are more susceptible to the negative effects of climate change.

Efforts should be made to eliminate the systemic prejudice and oppression faced by women, ensuring them equitable access to many socio-economic domains such as education, healthcare, business opportunities, power, and political participation.

Recommendation to international organizations

It is recommended that organizations adopt participatory approaches and tools as a normal practice in their climate change projects to ensure the meaningful and equal participation of both men and women. The purpose of this discourse is to provide the community with an understanding of the importance of inclusive and active participation of persons from all genders in climate change activities. Moreover, the objective is to enhance the capacities of individuals, regardless of gender, to actively engage in discussions and make meaningful contributions to the process of decision-making.

Promote the inclusion of more women in efforts to reduce climate change and build community resilience. To increase women's participation in climate change mitigation, adaptation, and community resilience, it is critical to apply their unique understanding and expertise in natural resource utilization and administration, as well as their traditional leadership capacities within local communities.

Programs and assessments related to climate change should be implemented in accordance with the fundamental needs and interests of both men and women. The requirements of women and the risks they face due to climate change must be considered.

Recommendation to community

The community members who receive knowledge on climate change from various organizations should possess the ability to develop a robust capacity to modify their lifestyles and effectively adapt to the challenges posed by climate change and drought.

It is essential for community leaders to advocate for the alignment of government, development partners, and other organizations involved in climate change initiatives with the community's climate adaptation strategies.

Community leaders should advocate for the use of the community-prepared climate adaptation plans as the foundation for all government, development partners, and other organizations executing climate change programs.

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06

Climate change and conflict in the Horn of Africa

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The views expressed are those of the author and do not necessarily reflect the views of the United Nations.

Abstract

Climate change-related disasters have displaced millions of people in the Horn of Africa and continue to wreak havoc on their livelihoods. Hot weather, recurring droughts and floods have forced farmers and pastoralists to fight over farmland, water, and pasture for survival. Climate-induced disasters deplete natural resources and force migration and competition over scarce resources, which causes a vicious cycle of conflicts, displacements and humanitarian crises. In addition, destitute and internally displaced people, mainly youth, become vulnerable to joining extremist groups and local clan militias, instigating insecurities and reactivating unresolved grievances and conflicts. This paper sheds light on the interlinkages between climate change and conflicts. It unpacks how climate change impacts peace and security, and how meagre and ungoverned natural resources contribute to conflicts. It focuses specifically on climate-related conflict hotspots in Somalia. This article builds on the climate change and security in the Horn of Africa policy paper by Sagal Abshir (2020). It urges policymakers to adopt a climate lens and to streamline upcoming peacebuilding and conflict prevention projects. The paper concludes by proposing an entry point for integrated climate adaptation mechanisms and an environmental mediation approach for climate-related conflicts.

Keywords: Climate change, conflict, droughts, resources, pastoralists, vulnerabilities

Introduction

The Horn of Africa is home to 230 million people, and it extends 5.2 million square kilometres.[1] The main regional organization, the Intergovernmental Authority on Development (IGAD), was formed due to the devastating droughts in the Horn during the 1980s. The region is in the midst of a climate change induced humanitarian crisis, ecological degradation and economic hardships. Climate projections indicate that Horn of Africa countries are warming more quickly than the global average, with dangerous implications for unrest and conflict within and across their borders.[2] Research findings link high temperatures and extreme climate changes with violence.[3] Climate-sensitive Somali pastoralists whose livelihoods depend on rainfalls suffer as seasons become unpredictable. They are compelled to migrate in search of shrinking water and grazing land, and competition for such resources causes deadly conflicts.

Country rankings on climate vulnerabilities and readiness by the Notre Dame Global Adaptation Initiative (ND-GAIN) ranks Somali, Sudan and Eritrea among the top-10 most climate-vulnerable countries. Somalia is the second most climate-vulnerable. Kenya, Ethiopia, Uganda, Sudan and South Sudan also show high levels of climate vulnerabilities. Djibouti performs better than its peers in the region, yet it also requires investment and innovations to improve its climate-change readiness.[4] Climate change-related threats are causing havoc, especially in Somalia which exhibits multiple weaknesses in its ability to adapt to the negative impacts of climate change.

Somalia might soon become the most climate-vulnerable country in the world due to the prevailing impacts of the drought and climate change projections. The current drought has destroyed the lives and livelihoods of over six million people, which is about half of Somalia's population. Around 6.7 million people will likely experience high levels of acute food insecurity in the last quarter of 2022, of which 300,000 are likely to face catastrophic conditions. Furthermore, about two million children under the age of five will likely face acute malnutrition.[5] The drought has already killed over three million livestock due to lack of water and food and to widespread animal diseases. Pastoralists whose livelihoods depend on those animals have been severely affected, and drought-related displacements have exceeded one million people.[6] Thus, existing social vulnerabilities coupled with extreme weather, erratic rainfalls and drought-induced dust storms, have forced pastoralists to fight over ungoverned and scarce resources such as water and rangeland. This leads to territorial-based conflicts and a vicious cycle of revenge killings. Hence, Somalia urgently needs to adopt new strategies to manage scarce natural resources and to reduce the negative impacts of climate change.

Research methods and structure of paper

This paper is based on desk research that reviewed the available literature in the public domain. The researcher also interviewed 20 people including clan elders and internally displaced persons (IDPs) in Galmudug State, Hirshabelle State, Southwest State and Jubaland State.

It briefly outlines the nexuses between climate change and insecurity, highlights climate related conflict hotspots in Somalia, and concludes with key findings and policy recommendations for an integrated climate-mediation approach for climate-related conflicts.

Understanding links between climate change and inssecurity

Understanding the links, impacts and interconnections between climate change, peace and security has been an ongoing global discussion. However, peace entails more than the absence of armed conflicts.[7] Neighbors, communities and even states fight over territorial disputes, natural resources and geopolitical issues. Extreme weather events driven by climate change alter the way of life of pastoralist communities in Somalia and force them into unavoidable migration and competition for natural resources. The United Nations Secretary General Antonio Guterres said, "Climate change is the defining issue of our time - and we are at a defining moment. If we do not change course … we might miss our chance to avoid the disastrous consequences of climate change."[8]

Disasters related to climate change disrupt the lives and livelihoods of people in many parts of the world. In 2021 alone, the Emergency Event Database (EM-DAT) recorded 432 disastrous events related to natural hazards worldwide. Overall, these accounted for 10,492 deaths, affected 101.8 million people and caused approximately US$252.1 billion worth of economic losses.[9] Similarly, the International Federation of Red Cross (IFRC) issued a disturbing *World Disasters Report* in 2020. The report elaborated an unprecedented death toll, displacement and destruction caused by climate change which continues to instigate natural disasters. Over the past decade, 83 per cent of all disasters were caused by extreme weather and climate-related events such as floods, droughts, storms and heatwaves. Together, these disasters killed more than 410,000 people and affected a staggering 1.7 billion people. It noted that the most affected people were from low and lower middle-income countries.[10]

At the time this study was written (late 2022), Somalia is experiencing the worst drought in four decades after rains failed for the fourth consecutive year. According to the Food and Agricultural Organization (FAO), the drought in Somalia killed over three million livestock in 2021. In addition, the pastoral households which financially depended on the perished livestock accumulated very high debt burdens driven by the prohibitive costs of water and fodder for those that survived. Many were forced to leave their ancestral lands and live as IDPs in cities.[11] Climate change threatens human peace and security as "it undermines livelihoods, compromises culture and individual identity, increases involuntary migration".[12] In addition, it undermines the ability of states to provide the conditions necessary for human security. Climate changes may also influence many of the factors that disrupt peace. Situations of acute food insecurity, conflict and socio-political instability almost always emerge from the interaction of multiple social and institutional factors. Most of the Horn countries perform poorly on most global measures for a well-functioning government.[13] More importantly, most climate-vulnerable countries are mainly from the low-income, conflict or post conflict countries, as protracted conflicts undermine capacities to cope with climate change-related disasters. The Organization for Economic Cooperation and Development (OECD) has developed a multi-dimensional fragility framework to guide effective action in fragile contexts. The framework assesses risks and coping capacities across six dimensions, such as economic, environmental, human, political, security and societal. Of the 15 extremely fragile countries, four are from the Horn of Africa. Somalia is the most fragile country on all dimensions.[14]

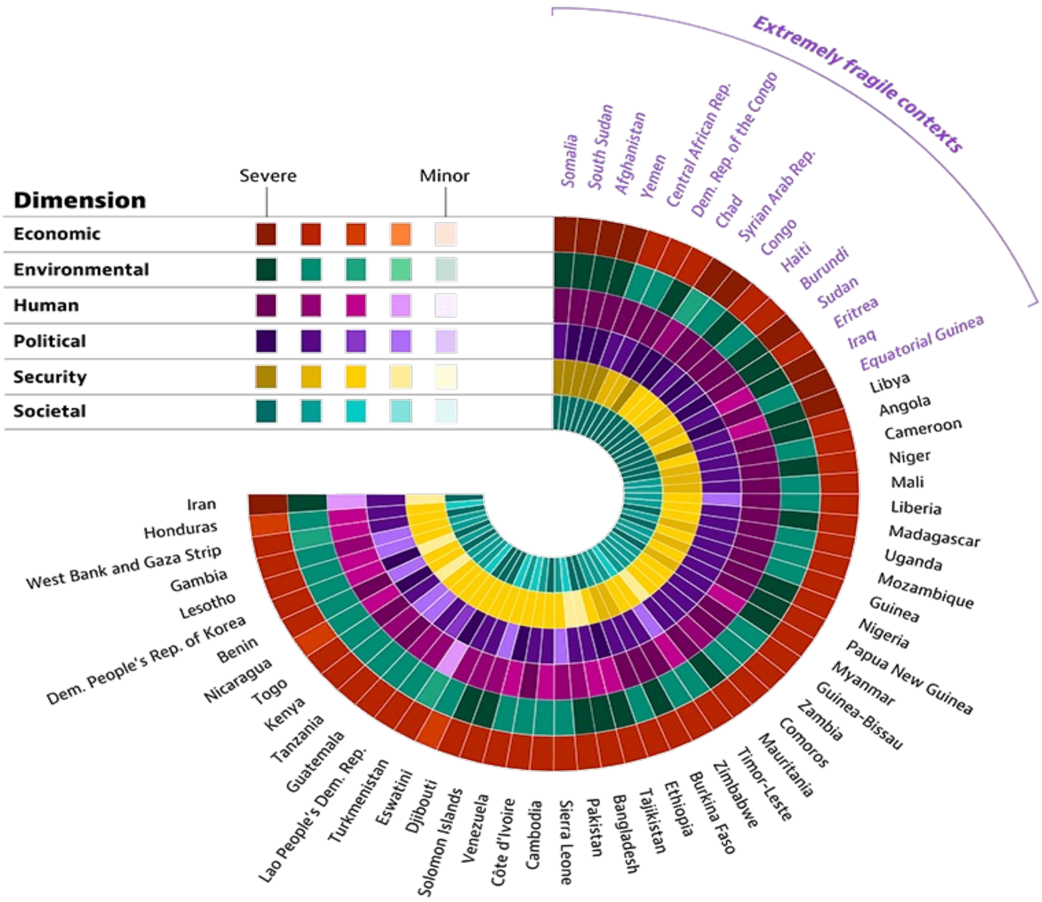

Figure 1. The OECD's multi-dimensional fragility framework

So, does climate change cause conflicts? The Intergovernmental Panel on Climate Change (IPCC), a United Nations body that assesses the science related to climate change, states that "there is no direct and automatic link between climate change and conflict." It also underlines that "there is no consensus on the causal association between observed climate change and conflicts."[15] Nevertheless, the IPCC confirmed that a large part of the climate-security research community agreed that climate change does contribute to increased conflict, but along indirect pathways. There are a variety of contextual factors — in particular socio-economic conditions, governance and political factors — that interact and play a key role in translating climate change into conflict risks."

There is a general agreement amongst members of the United Nations Security Council (UNSC) that climate change poses an existential threat to human civilisation. However, divisions remain over the council's role in addressing climate and security issues. Several UNSC members believe that drought, water scarcity, food insecurity and desertification caused or exacerbated by climate change increase the risk of violence.[15] Meanwhile, Uhuru Kenyatta, the former President of Kenya, asserted that "climate change induced droughts worsened economic vulnerabilities, setting in motion political demographic and migratory dynamics that increase the threat of insurgency and violent extremist."[16] For its part, Somalia's Nationally Determined Contributions report stated that "climate change has threatened the existence of livestock as well as the livelihoods of nomadic and pastoralist communities due to the loss of pasture lands and reduced access to water resources, resulting in deadly conflicts among the pastoralist communities that have claimed many lives."[17] The links between climate change and conflicts are not simple causal links. Climate change compounds existing socio-economic and environmental factors, existing social and political grievances and therefore emboldens security and humanitarian crises. Figure 2 elaborates pathways to climate-induced conflicts which have social, political and economic aspects.

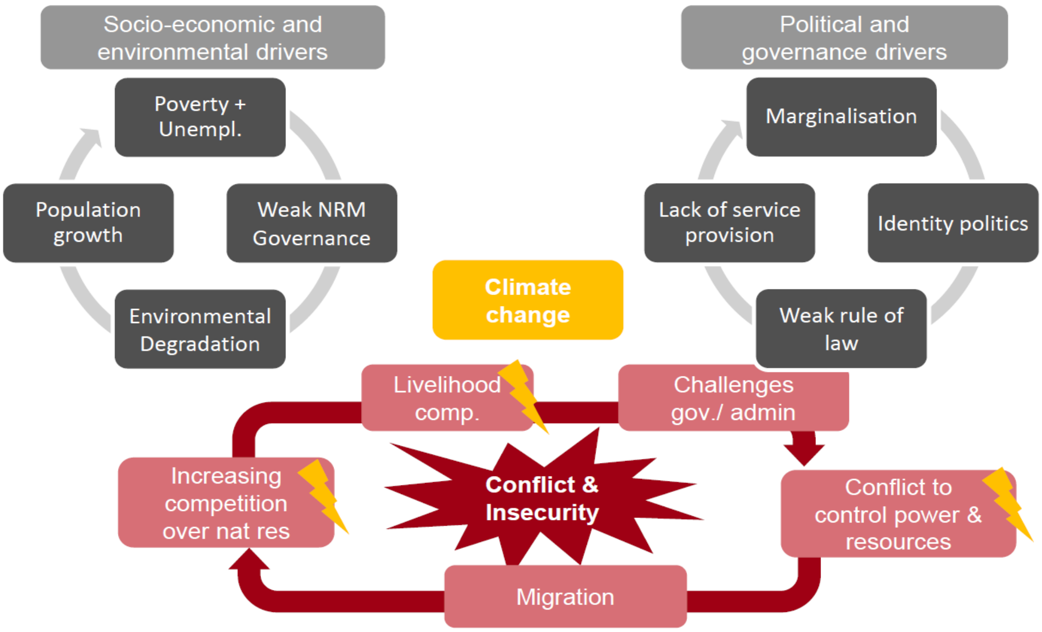

Figure 2. Adelphi (2022) climate-sensitive programming for sustaining peace

According to Miguel (2013), climatic change may be particularly significant for Africa as models predict that temperature increases for Africa by 2050, at 20 °C on average and, thus, violence related to land grabs, riots, irregular transformations of power, and civil war might increase significantly.

Somali pastoralists: Climate and conflict

According to Hodder (2022), since 1990, Somalia has seen a threefold increase in severe climatic events and has experienced three major droughts since 2010. Recurring droughts, floods and locust swarms continue to destroy crops and vegetation. Climate predictions indicate that by 2080, temperatures might rise by 3.4 degrees Celsius if the current path of climate change and temperature rise continues. This would earn "Somalia an additional 152 very hot days per year — where the maximum temperatures will surpass 35 degrees Celsius. It's also expected that water availability will decline by half during that time."[18] In 2021, three-quarters of all displacement in Somalia was due to floods or drought. These increasingly frequent events are likely to have drastic effects, with recent research showing that Somalia is most vulnerable for near-term climate impacts on food security, migration, displacement and conflicts.[19] Pastoralist communities in Somalia fight over meagre resources, i.e., water, grazing land, farmland and land ownership, as the drought keeps recurring and killing their livestock and destroying their livelihoods. Those pastoralists endeavour to sustain an unsustainable livelihood as the productivity of their land shrinks due to the drought and other compounding environmental factors. For them, however, pastoralism is a way of life to be kept and handed down. To change and adapt to this reality is not easy for the Somali pastoralist. Water and grazing land insecurities are forcing them to be on the move. Such movements have taken pastoralists to an an unsafe and un-demarcated territory of antagonistic pastoralist clans, who attempt to share ungoverned meagre resources. This causes pastoralists to fight or reignite unresolved grievances of the past, which leads to a vicious cycle of revenge killings. Figure 3 shows resource-related clan conflicts in Somalia over the past six years.

January 2017 - September 2022

Number of Resource-Related Clan Conflicts in Somalia

Years	Galmudug	Hirshabelle	Jubaland	Mogadishu	Puntland	South West	Somaliland	Grand Total
2017	28	33			36	27	26	**150**
2018	30	33	1		22	17	28	**131**
2019	35	54	4	4	27	20	44	**188**
2020	47	53	15	2	32	28	42	**219**
2021	70	55	8		21	8	45	**207**
2022	32	15	5	1	20	9	12	**94**
Grand Total	**242**	**243**	**33**	**7**	**158**	**109**	**197**	**989**

Figure 3: The International NGO Safety Organization (INSO). Aggregated data from 2017-22.[20]

According to INSO, over the past six years, Somalia had around 1,000 resource-related clan conflicts. Hirshabelle had 243, the highest number of incidents compared to other Federal Member States (FMS). Galmudug State was not far behind at 242 clan conflicts. Somaliland, recorded 197 clan conflicts which is unexpectedly high given its relative political stability. Casualties were low in Somaliland, however, as the clans were disarmed and demobilized in the early 1990s. During the same period, Puntland and Southwest experienced 158 and 108 resource-related clan conflicts respectively. Jubaland registered 33 clan conflicts. Mogadishu, the capital city of Somalia, recorded seven clan conflict incidents over the same period, all related to land ownership disputes that turned violent. Conflicts were fewer in Jubaland and Southwest due to the strong presence of al-Shabaab militia which maintains a monopoly on violence in areas under it controls and banishes clans that fight in its territory.[21] Clans that dominate these two states are comparatively less armed. An accurate record of the number of people who have been killed, wounded or displaced in resource related clan conflicts is difficult to find. The available information indicated that these conflicts continue to claim lives all over Somalia. They also fuel clan animosities, revenge killings and social division and as these conflicts persist, they hamper state building, reconciliation and inclusive resource sharing.

Key findings: The causes of climate-related conflicts

Climate-induced conflicts occur due to scarce resources and land disputes. Pastoralist communities are climate sensitive, as their livestock and livelihoods depend on the seasonal rains. Due to droughts and unpredictable rainfall, pastoralist communities are compelled to migrate in search of water and pastureland for their animals. Such migration brings together armed pastoralist clans who compete for these scarce resources. Interview respondents indicated that water and grazing land disputes intensify during the droughts. However, land ownership disputes cause prolonged conflicts during all seasons and trigger cycles of violence and revenge killings. Land ownership conflicts start when one clan migrates to a certain area for pasture and begins to build permanent structures like boreholes and claims the area as their land. Other clan(s) in the area feel threatened, disputes arise and usually turn into armed conflicts that might claim lives and cause displacements. Local authorities and clan elders have no knowledge of the climate and security nexus. Thus, they don't put their mediation and reconciliation activities under a climate lens. The following types of conflicts are the result.

Resource-related conflicts

Pastoralism is a way of life that Somali clans have sustained for centuries. Migration is part of that. Herders move from one area to another to satisfy their animals' needs, mainly water and grazing. These migrations are modest when seasons are good and the land is productive. However, prolonged droughts caused by erratic rainfalls force pastoralist communities to cross un-demarcated clan territories and share scarce resources. Thus, pastoralist communities fight over water and grazing land during such harsh weather. The following armed clashes were resource-related clan conflicts which severely affected the peaceful coexistence of pastoralists.

- On 5 May 2020 in Kalan-kale and Hanabure villages, Galgudud region, Galmudug State, clan militia from Saleban and Ayr, both Habar-gidir sub-clans, fought over grazing land. Reportedly five people died after negotiations failed. On 26 June 2021, more than 10 people died including Dahir Shidane Abdi, the former Galmudug minister of labour who went to mediate between the warring clans. Twenty wounded militia members were admitted in Adaado and Dhusamereb hospitals. [22] Similar resource-related conflicts took place around Balanbale and Galinsor districts of Galgudud region and Saho and Da'dher villages of Mudug region, both in Galmudug State, during the same period.
- In 2017 in Koogar village, Adale district, deadly clan conflicts over water and grazing land erupted and claimed the lives of more than 10 people. The village was burned, and people were displaced.[23] If Gariley, Dalsan and Dif are three different villages in Lower Juba region had the same deadly conflicts.[24] Similarly, Wanlaweyn district and surrounding villages in Southwest State have seen recurring and increasing resource-related conflict over past five years. Puntland and Somaliland, which are relatively stable and peaceful compared with the rest of Somalia, have also suffered from climate-induced resource-related conflicts. In December 2017, a land-related conflict erupted between the Omar Mohamud and Bahrarsame clans in Xoorre village. In Burtinle district more than 10 people were killed and another seven injured.[25] In Dhumeys village, on the outskirts of Las'anod district two, the Dhulbahante sub-clan fought against Somaliland. Similarly, El-afweyn district has recently experienced deadly resource-related conflicts.

Rangeland conflicts

Land dispute and conflicts are at the centre of climate-induced conflicts in Somalia. Most respondents indicated that rangeland-related conflicts are more dangerous, deadlier, and more protracted than water-related conflicts. Certain clan(s) might claim ownership of the same land. However, such claims might be motivated by the pressures of the environment as pastoralist clans migrate in search of pasture and water for their animals. Making new settlement(s) in disputed areas also triggers land-related conflicts. Competition and conflict over land has become an unresolvable issue that has significant political implications as the following incidents clearly demonstrate:

- There was a dispute in Saah-maygaag and Sangejabiye villages about whether they belong to the Sool or Nugal region. The Isse Mohamud clan wanted the villages to be part of the Nugal region which is closely linked with the Puntland State administration. The Hassan Ugaas clan said that the villages were part of the Sool region which comes under the Somaliland administration. In January 2022, fighting between the two clans caused the death of 20 people with many more wounded.[26]

- December 2019, in Tawfiiq and Afbarwaqo villages, Mudug region, the Habar Gidir/Sacad and Surre/Dir clans fought over land. Revenge killings related to these disputes spilt over into Galkayo and claimed the lives of 40 people from both sides with 60 more injured. The conflict was resolved in 2020 but could re-erupt at any time.[27]

Revenge killings

Other causes of climate-related conflicts such as water, grazing land and land disputes usually involve clan militias who fight to gain access and control over these resources. Revenge killings, however, are both the cause and effect of conflicts. The clan elders interviewed for this report indicated that revenge killing are often carried out by family members of the victim. Often a revenge killing will reignite a dormant conflict. One respondent said, "Brothers, sons and cousins and even sisters of the victims are encouraged to revenge their father, uncle or brother who was killed in a conflict or previous revenge. Thus, the vicious cycle of revenge killings continues and pastoralist clans in the rural areas and their relatives in cities including Mogadishu and elsewhere in Somalia live in perpetual fear of being killed."

Conclusion and policy recommendations

Climate security, specifically conflicts over resources, require deep understanding of the Somali pastoralist communities' behaviours and their interconnections in order to find the most suitable way to restore and sustain their devastated livelihoods. Doing so requires care and thorough consultation with all stakeholders including effected communities/clans, IDPs and the hosting communities. The Somali government's lack of economic capacity and unified policies to address climate vulnerabilities provide an opportunity for non-state actors including clan militia and al-Shabaab to exploit the situation.

Pastoralist clans are heavily reliant on seasonal rainfalls and rain-fed livestock, so when rains fail they suffer and their livestock-dependent economy plummets. Moreover, the fabric of Somali society and its resilience have been devasted by the decades of civil war. The civil war has also undermined the trust between people and the government. Erratic rainfalls and recurring droughts have led to resource-related conflicts. The following recommendations might be considered as a solution to the climate-induced conflicts:

1. Strengthen climate awareness by using all forms of media and inform people about climate-related pressures. Special emphasis should be placed on the climate-security nexus in order to reinforce and implement environmental policies all over Somalia and increased climate change-related discussions.

2. Urge national and international organizations working in Somalia to link climate security to humanitarian, development, and peace efforts when developing their projects by consulting with local communities and authorities.

3. Coordinate INGOs and local civil society organizations (CSOs), youth, clan elders and Islamic scholars to promote an environmentally sensitive mediation strategy in their peacebuilding and reconciliation activities.

4. Review the National Reconciliation Framework and add sections on the nexus between climate change and security. Every conflict resolution that is related to resources might add a discussion of climate change and security effects on the pastoralist communities.

5. Introduce land management policies and laws, keeping in mind marginalized groups including women, youth and pastoralists communities, and strengthen law enforcement agencies by including the climate-change lens.

6. Develop sustainable resettlement plans and policies for IDPs , especially for youth who are vulnerable to joining al-Shabaab and other extremist organisations.

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07

Effect of Climate Change and Civil Conflicts on Food Security in Somalia

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Abstract

Global food insecurity is predicted to worsen in the coming years, which represents a huge obstacle to achieving UN Sustainable Development Goal 2, zero hunger by 2030. Recent reports and studies showed that climate change and civil conflict are the biggest challenges confronted by less developed and developing countries in overcoming food insecurity and hunger. This study investigates the impact of civil conflict and climate change on food security in Somalia. The Johansen cointegration method, fully modified ordinary least square (FMOLS), and dynamic ordinary least square (DOLS) are used with annual data from 1975 through 2016. The results of the Johansen cointegration method showed that the explanatory variables and the dependent variable are cointegrated in the long run. Moreover, the results of DOLS and FMOLS showed that civil conflicts decreased food security while rainfall increased food security. However, civil conflict had a greater impact on food security than did climate change. Among other determinants, exchange rates enhanced food security, while population growth had a significant negative affect. Land under cereal production had no significant influence on food security. Our study underlined the importance of de-escalating Somalia's long-running civil wars as well as the need for policies that improve water availability to mitigate the negative effects of climate change.

Introduction

Some of the most pressing challenges of the 21st century are the elimination of hunger, food scarcity and malnutrition. The United Nations has set the Sustainable Development Goals (SDGs, 2015-2030) and Millennium Development Goals (MDGs, 2000-2015) to eradicate hunger and make food available to all. Undernourishment was estimated to have affected 690 million people in 2019, a decrease of more than 260 million in the last decade and 320 million from 1990 to 1992 globally. However, malnutrition and acute food insecurity continue to rise in most of Africa and South America, while the situation of food insecurity and undernourishment in Asia is stable (FAO et al, 2020; Dorosh et al, 2016). If this continues, the number of people without food will reach 840 million worldwide by 2030. The world is not on track to meet the second goal of the global SDGs, eradicating hunger and achieving food security by 2030 (FAO et al., 2020).

Climate change and civil conflict are major challenges undermining efforts to eradicate chronic food insecurity, malnutrition and hunger (FAO et al., 2018 & 2017). Conflicts cause both immediate and long-term food insecurity. Conflicts frequently hamper productive capacity, trade and food access (United Nations, 1993). However, a number of studies have supported arguments that civil conflicts worsen malnutrition and threaten food security. They also emphasized that conflict-prone areas are more susceptible to food shortages than stable ones (Kinda et al., 2019; Souza et al., 2013; and Dabalen et al., 2014). Countries with weak economies and fragile institutions are more susceptible to food shortages (Hudson et al., 2015).

Food security encompasses four dimensions: the food system, food accessibility, food safety and food availability. Climate change threatens all four by affecting food production and distribution, livelihoods, human health, trends in market flow and purchasing power (Rosenzwelg et al., 1994; FAO, 2008; Buhaug et al., 2015; Ray et al., 2019). In particular, climate change, especially an irregular rain pattern, hampers food security, while increased rainfall improves food security (Akbar et al., 2018; Buhaug et al., 2015; Kinda, 2017). People who were already susceptible and exposed to hunger are the most likely to be influenced by climate changes and conflicts.

In the Somalia context, climate change-related natural disasters, primarily droughts and floods, have exacerbated the country's protracted crisis. The most detrimental effect has been its impact on Somali households' resilience and wellbeing—by deepening poverty, rising food insecurity, and losing assets and livelihoods (FAO, 2011-2015). Food insecurity is widespread among poor rural populations and the displaced, whose household food and sources of income are influenced by natural disasters (Federal Government of Somalia, 2018). Currently, the number of food-insecure people in Somalia is estimated at around 3.5 million. As a result of the poor rainfall expected in the autumn and spring seasons, respectively, this number is predicted to increase in the long run (Famine Early Warning Systems Network, 2020).

It is worth noting that the majority of livelihoods in Somalia depend on rain-fed agriculture. Climate variability is hampering agricultural production, which results in lower domestic production (Warsame et al.,2021). In addition, conflicts also impede agricultural output by forcing people to flee their settlements and farms due to insecurity. As a consequence, famine, malnutrition and massive local immigration occur. The effects of climate change are exacerbated by civil conflicts that sometimes turn into widespread hunger. Conflicts and droughts are intertwined and are considered inseparable causal mechanisms (Clover, 2003). Classic examples are the droughts that hit Somalia in 1992 and 2011. As a result of the 1991–1992 and 2010–2011 droughts, 200,000 and 280,000 people died, respectively. Both droughts started in the same way: rainfall failure that affected agricultural production. Conflict exacerbated the devastating effects of the disaster, threatening livelihoods and disrupting food aid to those most in need (Federal Government of Somalia, 2018; Maxwell et al., 2012; Nestle et al., 1994).

However, this study builds on the reports of FAO et al. (2018) that showed climate variability and conflict as major challenges facing developing countries, including Somalia, to overcome food insecurity, hunger and malnutrition. It is also motivated by SDG 2's goal of achieving zero hunger by 2030. It is important to develop policies that ensure food security by identifying the factors that cause food insecurity. The empirical evidence on the determinants of food insecurity in Somalia is limited. The few studies on this topic were neither rigorously conducted nor used adequate data. For example, Maxwell & Fitzpatrick (2012) linked Somalia's 2011 famine to droughts, which were fueled by severe conflict. There is no empirical research on the impact of climate change and civil conflicts on food security conducted in Somalia using historical data through econometric assessment.

This is the first study to investigate the impact of climate change and civil conflict on food security in Somalia. It contributes to a new dimension in which climate and conflict variables are included in the same model to test the validity of socio-political and agricultural impacts on food security. There have been few empirical studies that have used such important variables in the context of countries that are prone to conflict. This study also uses different economic techniques and measurements of food security and conflict to obtain robust evidence that is not sensitive to changes in proxies for variables and econometric methodologies.

The objectives of this study are as follows:

1. Examine the long-term effect of climate change on food security in Somalia from 1975-2016; and

2. Analyze the long-term impact of civil conflict on food security in Somalia from 1975-2016.

Data and methodology

This study examines the effect of socio-political dynamics and climate change on food security in Somalia using annual data series from the World Bank, the International Monetary Fund (IMF), and FAO from 1975 through 2016. We use the food production index as a proxy for food security, and it is used as the dependent variable in this study (Ujunwa et al., 2019). Although food security is considered a complex and multifaceted term, most previous studies have used food availability. Thus, food production plays an important role in ensuring food availability.

Table 1 Description of variables and data sources

Variables	Codes	Proxies	Sources
Food production index	FPI	Food production index (2004-2006 index) is a proxy of food security	World Bank
Rainfall	AR	Average annual precipitation (mm)	World Bank
Population growth	PG	Population growth (annual %)	World Bank
Civil conflict	CC	It is a dummy variable. It was given a value of '0' during the stable period, and '1' during the unstable period.	
Exchange rata	ER	Unit of Somali Shilling per one dollar	IMF and World Bank
Land under cereal cultivation	LUC	Land under cereal cultivation (hectares)	World Bank

To achieve our goal, we have specified an econometric model that considers the impact of climate change and civil conflict on Somalia's food security. In addition to the primary variables, we included other important control variables identified in the literature that have an influence on food security. These variables include land under cereal cultivation, the exchange rate and population growth. The mathematical formulation of our model is as follows.

$$lnFSt = \beta 0 + \quad \beta 1 lnARt + \beta 2 lnPGt + \beta 3 CCt + \beta 4 lnLUCt + \beta 5 lnERt + \mathcal{E}t$$
(1)

$lnFSt$ is the log of food security in year t; $lnARt$ is the log of average rainfall id the log of average rainfall in year t; $lnPGt$ is the log of population growth in year t; CCt represents a dummy variable that captures the effect of civil conflicts on food security, thus it was given a value of '0' during the stable period, and '1' during the unstable period; $lnLUCt$ is the log of land under cereal cultivation in year t; $lnER$ is the log exchange rate in year t; and $\mathcal{E}t$ is the disturbance term in time t.

Our model's specification is consistent with earlier empirical literature. We followed the work of Kinda et al., (2019) and Badolo et al. (2014) to consider the effect of climate change as measured by rainfall and population growth. We chose rainfall over other climate change factors because it is the main cause of Somalia's food insecurity. The agriculture sector in Somalia depends heavily on rain, and its productivity will decline significantly during rainfall failures. Thus, droughts will lead to decreased food availability, per capita consumption and purchasing power. Additionally, by using the model specifications from Kinda et al. (2019), Badolo et al. (2014) and Souza et al. (2013), we have included civil conflicts in our model.

In addition, we included an exchange rate variable in our model, following the work of Kinda (2017) and Applanaidu et al. (2014). We hypothesize that the exchange rate plays an important role in food security due to its importance in the agricultural trade and, therefore, is a determinant factor of income levels. Because food preferences in agriculturally based developing countries are dominated by grains and cereals, cereals are considered an important indicator of famine. In order to account for such dimensions, we introduce land under cereal cultivation in line with the work of Osabohien et al. (2018).

Before estimating the cointegration relationship between model variables and carrying out other time series analysis, it is standard procedure to first evaluate the order of integration of the variables. In order to determine the degree of stationary for each variable, this study employed the Augmented Dickey-Fuller (ADF) and Philips Perron (PP) tests. When it is determined that all variables are integrated in order I, the study will continue on to cointegration analysis (1). This study applies the Johansen and Juselius (1990) cointegration method to determine the existence of long-run cointegration between the model's variables. In the framework developed by Johansen and Juselius for cointegration, the number of cointegrating vectors in an unrestricted vector autoregressive (VAR) system is first identified using a maximum likelihood method.

We first confirmed that our model's variables had a cointegration relationship before estimating their long-term relationships. To this end, we employed the fully modified ordinary least squares (FMOLS) method and the dynamic ordinary least squares (DOLS) estimator. These two estimators were chosen because they were more effective at addressing serial correlation and endogeneity issues (Yorucu et al., 2015; and Pedroni, 2000). DOLS is a parametric method that includes the lags, leads and contemporaneous values of the regressors in the model along with the residuals (Kao et al.,2000).

Literature review

Eradicating poverty, hunger and malnutrition have been outlined in Sustainable Development Goals 1 and 2 (no poverty and zero hungry). To achieve SDG 1 and 2, food security is required. So, determinants of food security are extensively investigated in the empirical literature. Climate change and civil conflicts are considered key factors that hamper food security in the 21st century. The empirical literature related to the effect of conflicts and climate changes on food security have been examined in many countries. Food security is essential for the livelihoods of populations. The majority of these examinations have established that climate change – rising temperature and extreme rainfall pattern changes – impedes food security via agriculture production that affects food availability.

Climate change impacts food security in developed and developing countries. It severely affects food security in sub-Saharan African countries. This is attributed to the recurrent conflicts, poor government institutions and the vulnerability of countries to climate change. Climate variabilities not only undermine food availability per capita and food security but also raise the percentage of undernourished people. Rainfall enhances food security in African countries by increasing agriculture production.

Empirical studies on the conflict-food security nexus are scant in the literature. The few available studies on this theme underscored that conflicts impede food security. It is noteworthy that climate change's influence on food security is larger in nations where there are conflicts. Conflicts add fuel to climatic impacts on food security in developing countries. Similarly, armed conflicts are observed to have adverse effects on food security in West Africa. They also pose a severe threat to food availability in Afghanistan, according to household survey data. Notably, conflicts do not inhibit food security directly but adversely affect dietary diversity.

Based on the reviewed literature, it seems that the climate change-conflicts-food security nexus is scanty in least-developed countries including Somalia.

Results and discussion

Descriptive statistics

Descriptive statistics are important for displaying the main characteristics of the data such as mean, median, maximum and normality. According to Table 2, the means of food security, land under cereal cultivation and exchange rate are 4.5, 13.2, and 7.1 respectively. When it comes to the maximum values, land under cereal cultivation, exchange rate and food security have the highest values (13.8, 10.3 and 4.7 respectively). Additionally, exchange rate has the highest value of standard deviation (3.3), which indicates the dispersion between its mean and values. Moreover, Jarque-Bera indicated that most of the variables are normally and identically distributed. Table 2 also presents the correlation between the variables. Population growth, rainfall, civil conflicts and exchange rate have a positive correlation with food security, whereas lands under cereal cultivation and food security are negatively correlated.

Additionally, population growth does have a negative correlation with exchange rate, civil conflicts and land under cereal cultivation. Conversely, rainfall, and population growth are positively correlated. More importantly, the variables do not have perfect co-linearity among them, except for civil conflicts and exchange rates. However, to address the endogeneity problem and serial correlation, we use FMOLS and DOLS which are critical to dealing with multicollinearity and serial correlation (Yorucu et al., 2015; Pedroni 2000).

Cointegration test

Subsequently, after assessing descriptive analysis, the next step is to check the existence of the long-run cointegration of the variables. The Johansen and Juselius (J&J) Cointegration method is used to test the long-run relationship. Hence, the result of J&J Cointegration reported in Table 4 found that at least three cointegrating vectors exist among the variables indicated by Trace and Maximum Eigenvalue tests in Table 4. In other words, there is a long-run cointegration between food security, population growth, exchange rate, rainfall, civil conflict, and land under cereal cultivation.

In contrast, the DOLS results show that rainfall has a positive effect on food security, even though it is insignificant. A one unit increase in civil conflicts causes food security to decline by 0.41% in the long run. A 1% increase in population growth and land under cereal cultivation will lead to food security decreases by 0.068% and 0.16%, respectively. Exchange rate depreciation enhances food security by 0.068% for a 1% increase in SOS depreciation. In both models (FMOLS and DOLS), the findings of rainfall, civil conflicts, population growth, land under cereal cultivation, and exchange rate, their coefficient elasticities are similar. However, our results of positive rainfall effect on food security are in line with previous studies (Kinda & Badolo, 2019; Mahrous 2019). Moreover, the inhibitory impacts of civil conflicts on food security contrast with previous results (Souza & Jolliffe, 2013; Dabalen & Paul, 2014; Ujunwa, Okoyeuzu, & Kalu, 2019). The results of the growth-inhibitory effect of population on food security are consistent with other findings (Akbar et al., 2018).

Table 2: Descriptive Statistics

	lnFS	lnPG	lnAR	lnLUC	CC	lnER
Mean	4.5119	0.8353	3.113046	13.20831	0.619048	7.117808
Median	4.5184	1.0537	3.106666	13.24717	1.000000	8.886420
Maximum	4.7619	2.4693	3.509205	13.80283	1.000000	10.36045
Minimum	4.2081	-2.1685	2.656198	12.46843	0.000000	1.839756
Std. Dev.	0.1339	0.9392	0.192697	0.294110	0.491507	3.300520
Skewness	-0.4273	-0.9113	-0.182033	-0.540499	-0.490290	-0.646065
Jarque-Bera	1.5132	9.7842	0.338444	2.099619	7.101123	5.891857
Probability	0.4693	0.0075	0.844321	0.350004	0.028709	0.052553
Sum	189.5006	35.0840	130.7479	554.7492	26.00000	298.9480
Sum Sq. Dev.	0.7351	36.1630	1.522418	3.546522	9.904762	446.6308
lnFS	1					
lnPG	0.0547	1				
lnAR	0.3789	0.2553	1			
lnLUC	-0.2338	-0.1035	0.1174	1		
CC	0.4159	-0.0370	-0.0275	-0.5613	1	
lnER	0.6100	-0.0897	0.0552	-0.5007	0.9433	1

Table 3 Result of the cointegration test

Hypotheses				
	Trace Test	Test Statistic	5% Critical Value	Trace Test
	r ≤ 0	183.4556***	95.75366	0.0000
	r ≤ 1	116.4772***	69.81889	0.0000
	r ≤ 2	67.69354***	47.85613	0.0003
	r ≤ 3	38.77545***	29.79707	0.0036
	r ≤ 4	18.64616**	15.49471	0.0162
	r ≤ 5	0.647936	3.841466	0.4209
	Maximum Eigenvalue			
	r ≤ 0	66.97838***	40.07757	0.0000
	r ≤ 1	48.78367***	33.87687	0.0004
	r ≤ 2	28.91809**	27.58434	0.0336
	r ≤ 3	20.12929*	21.13162	0.0686
	r ≤ 4	17.99822**	14.26460	0.0123
	r ≤ 5	0.647936	3.841466	0.4209

Rainfall induces a rise in food security for several reasons. First, precipitation is an important source of irrigation for agricultural production in developing and in less developed countries, including Somalia. In Somalia, agriculture is an essential source of food, income and employment opportunities to meet livelihoods in households. Domestic production covers 50 percent of cereal demands of the population, however, the irrigation system of the country is not diversified (FAO, 2012). The main source of water for irrigation is precipitation—implying that agricultural cultivation in the nation is confined to specific seasons. Spring (from April to June) and autumn (from October to December) are the two main seasons of agricultural cultivation in the country, due to the availability of irrigation water from precipitation. Sixty percent of annual cereal output is produced during the spring season in south and central Somalia (dominant agriculture production area) (GIEWS, 2020). A high rainfall pattern means high agricultural harvesting. In contrast, missing one or both seasons leads to an acute shortage of domestic production, which in turn results in an increased number of people who suffer from food insecurity, hunger and malnutrition.

Second, rainfall is not only important to agriculture cultivation but also to livestock production on which the livelihoods of pastoral households depend. Half of pastoralists' annual income is generated from the sales of livestock. However, livestock products such as camel milk also represent a secondary source of income. Hence, precipitation is important to the sustainability and growth of the livestock sector and its impact on food security. Rainfall enhances the growth of fodders and crops eaten by the herds, and also serves as the main source of drinking water.

The adverse impact of civil conflicts on food security in Somalia can be adjusted for several reasons. First, civil conflicts such as wars force millions of people to flee from their homes and abandon their livelihoods—which are either dependent on livestock rearing or farming cultivation. Consequently, food production declines, and food prices spike up—which will ultimately lead to hunger and malnutrition. Second, conflicts destroy infrastructure, institutions and social cohesion, and ultimately undermine investments and food production. Moreover, conflicts not only impede food production directly but also disturb food aid distribution to the people in dire need during the period of crisis. A clear example of this is the 2011 famine that hit Somalia due to droughts in 2010-2011 and the sacking of aid distributors from territories controlled by Islamists (Maxwell & Fitzpatrick, 2012). Thus, Somalia experienced a famine caused by droughts but chiefly aided by conflicts, affecting food security.

An interesting finding in this study is that exchange rate depreciation enhances food security. This is due to the measurement of food security (food production index) used in the study. Justifiably, exchange rate depreciation enhances food security (rising domestic food production) by exerting import limitations, making food imports more expensive; hence, demand centers more on domestic food production rather than on imports due to their high prices.

Table 4 Long-run coefficient elasticities

	Method	FMOLS	DOLS
DV: lnFS	Variable	Coefficient	Coefficient
	lnPG	-0.00746 (-0.5122)	-0.0689*** (-3.4170)
	lnAR	0.1758** (2.3936)	0.2840 (1.3069)
	lnLUC	-0.0689 (-1.3215)	-0.1653** (-2.2920)
	CC	-0.4721***	-0.4142*** (-3.9357)
	lnER	0.08822*** (7.3723)	0.0681*** (4.3448)
	C	4.5348*** (6.3832)	5.7104*** (4.8122)
	Adjusted R-squared	0.534669	0.928143
	S.E. of regression	0.087695	0.031769
	Sum squared resid	0.269167	0.012111

Impact accounting

The results of the Impulse Response function indicate that food security responds negatively for one standard deviation shock occurring in land under cereal cultivation from period 2.5 to 5.5, but from period 6 to 10 the response turns positive. Additionally, food security responds positively from period 2 to 10 for one standard deviation shock change in exchange rate. Thus, this finding is consistent with the long-run results of DOLS and FMOLS that indicate exchange rate depreciation enhances food security. Also, one standard deviation shock in civil conflicts leads food security to respond positively from period 2 to 10. This finding is contradictory to the long-run results of DOLS, FMOLS and OLS. A shock in rainfall results in food security responds negatively in the first 5.5 periods and from period 7 to 10. Food security responds positively from period 3 to the rest of the periods. The response turns negative if a one standard deviation shock occurs in population growth.

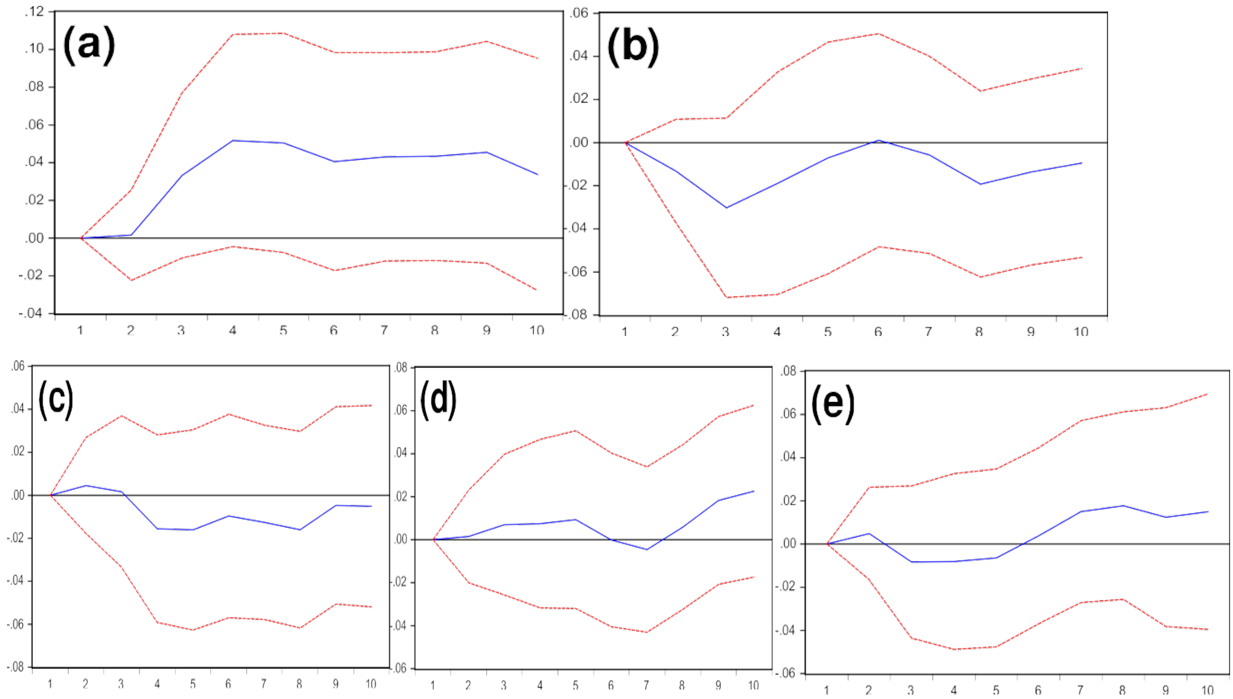

Figure 2: Impulse Response function of (a) food security vs. civil conflicts (b) food security vs. average rainfall (c) food security vs. exchange rate (d) food security vs. population growth (e) food security vs. land under cereal cultivation. Legend: The short, red dashes signify the 95% confidence interval whereas the blue line represents the estimated Impulse Response function.

Diagnostic tests

Reset test	0.9805 [0.3511]
Adjusted R-square	0.439513
Serial correlation	0.0554 [0.8897]
Jarque-Bera	4.5285 [0.1039]
Heteroskedasticity	0.5779 [0.6015]
Durbin-Watson	1.3894
Multicollinearity test	No Multicollinearity

Conclusion

This study empirically examined the effect of rainfall, population growth, exchange rate, civil conflicts and land under cereal cultivation on food security (measured by the food production index) for the period 1985-2016. Using the Johansen and Juselius Cointegration method, the study confirmed a stable long-run association between the variables under investigation. Subsequently, the study estimated the long-run coefficient elasticities of the variables using FMOLS and DOLS methods. Overall, the empirical findings from FMOLS model showed that an increase in rainfall and exchange rate deprecation have a positive impact on food security in Somalia, while civil conflicts, population growth and land under cereal cultivation have unfavorable effects on food security. However, population growth and land under cereal cultivation are statistically insignificant. The DOLS results indicated a rise in rainfall and exchange rate depreciation has a positive effect on food security, even though they are statistically insignificant. Civil conflicts, population growth and land under cereal cultivation have significant negative impacts on food security.

To alleviate food insecurity in Somalia, our empirical findings offered some policies that could be pursued. The study emphasized the importance of ending the prolonged civil conflicts in Somalia—as they play a major role in accelerating and significantly contributing to hunger and food insecurity. Civil conflicts undermine domestic production, impede investments in the key economic sectors and increase rural-urban migration as well the costs of production. Notably, all these factors will directly or indirectly affect food security. Eliminating the conflicts should be the first priority because they impact food security more than the climatic effects, as shown by the results. The study suggested the need for designing policies that improve water availability and food production, as well as mitigate adverse effects of climate change. The study strongly supported the current exchange rate depreciation policy since it encourages domestic food production to rise, which in turn generates more employment opportunities for rural households that are highly dependent on the agricultural sector.

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08

Promoting Partnership and Local Ownership: A Case Study of How Donors Engage the Government in Containing Climate Induced Risks Exacerbating Conflicts in Somalia

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Abstract

Climate change-induced threats have caused what the United Nations describes as the greatest challenge of the 21st century. Somalia is severely affected by climate change and its consequences for human security, which have been compounded by prolonged civil conflict and political fragilities (Ogallo, 2018). Clan competition over resources, which partly fueled the outbreak of civil war in 1991, continues to raise tensions and threaten stability (Krieger, 2020). However, the issue of resource-based conflicts in Somalia is complex and clan is only one of the variables at play. At the same time, international development partners face the dual challenges of coordinating and promoting the intertwined goals of partnerships and local ownership in a complex and context-specific situation characterized by climate-induced disasters that often trigger conflicts. The aim of this study was to investigate how donors and the government promote partnership and local ownership in the context of conflicts exacerbated by climate change. The findings and recommendations of this policy paper will help support the government and donors in improving how they manage climate and conflict programming. This will help other actors to mainstream climate and peace-building lenses into their programs and take advantage of climate finance and other related donor funding.

Keywords: Climate change, conflict, human security, peacebuilding, partnership

Introduction

International financial institutions used to impose policy conditionalities on the poor and underdeveloped nations they supported (Koeberle, 2003). Under Structural Adjustment Policies (SAPs), aid programs became a key instrument to provide access to aid contingent upon the acceptance of policy conditionalities (Maxwell and Riddell, 1998). The use of conditionalities was aimed at increasing aid effectiveness and promoting better living conditions for people in developing nations. However, critics opposed the idea, saying that economic conditionalities, through the use of market-oriented policies, might enhance development but only at the expense of the deprived and poor majority (Pincus and Winters, 2001). In other words, SAP programs had a negative impact on aid recipient nations.

More recently, in the face of criticism concerning the lack of local ownership of donor and aid funded programs and an associated lack of local commitment, international donors have shifted from aid conditionalities to developing working partnerships with aid-recipient governments. This shift has been supported by bilateral donors, multilateral agencies and governments with the aim of increasing the effectiveness of development assistance (Abrahamsen, 2004). For example, in the African context, the New Partnership for Africa's Development (NEPAD) and the African Union (AU) have developed policy frameworks that seek to promote sustainable growth and development (Lewis, 2005).

However, there is ongoing critical debate as to how the interests and motives of individual donors helped to shape such interventions and the ways in which appealing buzzwords such as "partnership" and "ownership" are operationalized in practice (Abrahamsen 2004; Crawford 2003). This is evident in both historical and current development aid practices - where donors use powers to influence certain priorities and interests with many aid recipient nations (Stiglitz, 2002). Mosley (1992) believes that the objective in giving aid is to maintain power. In the same vein, Moyo (2009) believes aid paradoxically poses a barrier to recipient countries through overreliance and dependency that often make donors' objectives fail in recipient nations.

In more recent research on aid, the concept of partnership and local ownership has become crucially important when discussing the climate-financing concept. The multilateral climate funds – of which the Green Climate Fund (GCF, 2011), the Global Environmental Facility (GEF Report 2015), the Adaptation Fund (AF Report 2010) and the Climate Investment Funds (CIF Report 2009) are the largest – play a significant role in the architecture of international climate finance. Only one-third of the GEF's portfolio has been spent in nations experiencing major conflicts while over 50 percent of the recipient nations have been afflicted by violent conflict in the last three decades (Aberg, 2015).

Undeniably, like development and humanitarian projects, climate-change interventions can have a significant impact on power relations and political dynamics and as a result this can have an adverse impact on people's livelihoods, assets, and access to natural resources. However, the existing literature on aid doesn't consider the relationships between the donors and recipients in the context of promoting partnerships and local ownership of climate and conflict-related projects in the Horn of Africa. This case study is a contemporary analysis of the relationship between donors and recipients in a post-conflict context. While there is now substantial literature on the approaches to PCR utilized by various nations to address problems related to aid effectiveness, there is very little information on how partnership and ownership work in the context of unequal relationships. This novel and unique approach of extending the debate on partnerships and ownership in the context of climate-induced conflicts to Somalia is an advancement in the methodological basis of the paper.

Methodology

This study looks at the implications of partnership and local ownership in the context of environmental peacebuilding and climate resilience in Somalia. As a single case study, the report is limited in regard to how the finding could be applied beyond the case of Somalia. The study serves as an eye-opener to policy makers and researchers and guides future inquiries into the research question of how climate financing could be improved using meaningful partnerships and localization of environmental peacebuilding and climate-resilience programing.

A combination of primary and secondary data has been collected and analyzed including existing academic literature on how donors engage the Somali government in climate and conflict situations. The study builds on a unique set of 15 interviews with climate experts and peacebuilders that have previously, or are currently, working in Somalia. This has been complemented by interviews with representatives from the donor community based in Nairobi, Kenya, and the United Kingdom. The information generated from these interactions serves as a lens through which key decisions related to the themes under investigations are interpreted. Ethical aspects of the study have been considered throughout the data collection, analysis and writing up period.

Analytical strategy

Partnership and ownership concepts can be readily mapped along two main dimensions of power. First, in common with much political science and international relations scholarship, discussions of partnerships tend to draw on a conception of power as domination (Barnett and Duvall, 2003). The traditional formula of understanding power and domination comes from Robert Dahl who defined power as the ability of A to get B to do what B would not otherwise do (1957). Similarly, in a more recent work by Pfeffer (1981), power is defined as "the ability to get things done the way one wants them done; it is the latent ability to influence people". Pfeffer's work investigated how power influences performance and the desired outcome in organizations. His work, unlike Dahl's, provides a broader definition and understanding of power. Power, in this definition, is coercive and intentional, leading to observable behavioral change in its target population (Pfeffer, 1981). This study was enriched by Pfeffer's conceptualization of the relativity of power. Pfeffer's work serves as an analytical framework to examine the unequal relationship between the donors and the recipient government in the context of environmental peacebuilding and climate-resilient programing.

The indirect use of power is the other type of power relevant in the analysis of donors' relationships with the Somali government. Foucault (1976) believes indirect use of power "can be achieved by instilling some form of discipline to change the behavior and attitude of the people". His view on power has been utilized in this study to complement the work of Pfeffer. As such, both Foucault's and Pfeffer's approaches to power prove very useful for analyzing the relationship and interaction between donors and the government. The two power approaches, though different, complement each other.

Findings and analyses

The Global Environmental Facility's (GEF) Scientific and Technical Advisory Panel (2018) noted that almost half of nations receiving their support experienced some sort of conflicts since its inception in the early 1990s. There is, therefore, a need for a greater understanding of how climate change and conflict interventions are managed, given the complexity and challenges prevalent in fragile and conflict-affected environments. Somalia is one of the most challenging environments in the Horn of Africa in which to operate and is home to one of the most complex aid operations. Billions of dollars of overseas development assistance (ODI) are spent on programing in the country every year, largely on humanitarian assistance, in the midst of a long-running conflict that continues to evolve. ODI has been one of the most significant external resource inputs into the country for close to three decades and has been integrated into the fabric of the economy and even social structures. International programing through meaningful partnership arrangement is therefore deeply enmeshed with conflict dynamics, able to be utilized by all sides to support their local, national or transnational political objectives. However, there is still a significant gap in how the donors and government promote partnership and local ownership in the context of managing conflicts triggered by climate change.

Even more surprisingly, there are no existing meaningful partnership and coordination frameworks that support environmental and climate-resilience programs. From the 1990s until now, the government has heavily relied on humanitarian and disaster management frameworks which do not directly and explicitly address challenges of promoting partnership and local ownership in a context of climate-induced conflicts. This has resulted in ambiguity and mismatch between the donors and the government in their efforts to promote meaningful partnerships and local ownerships.

Similarly, the federal government system with various layers of vertical and horizontal structures of administration has further complicated the aid management landscape making it difficult for governments at local, regional and national levels to better manage environmental peacebuilding and climate-resiliient programing. Conversely, the donors collectively lack a consolidated coordination framework and mechanism to help reduce duplications, multiplicity and overlapping of work when managing climate and conflict programing.

There is clear evidence of power relations at play between the government and donors in Somalia. This power imbalance has a negative impact on participation and localization of crucial programs such as climate and conflict management. Several people interviewed for this project have mentioned that "climate and conflict affect people differently". However, donors in most cases have given little attention to the incorporation of culture and value systems of the Somali people as a basis for better management of climate and conflict programing. The different ways in which people are affected by climate-induced disasters are often overlooked, and assistance is provided based on what has been remotely developed in Western donor countries, neglecting the different needs of affected persons.

There is clear evidence that climate change triggers conflict in Somalia and vulnerable groups such as women are the most affected in terms of displacements and accessing housing, land and property rights (HLP). This situation is even more problematic in the context of women with overlapping identities living in a "patriarchal male-dominated system" where security of tenure is only achieved through their relationship with men. By building on the intersectionality theory (Crenshaw 1989), we argue that there is an intersectionality of disadvantage that affects women in accessing and experiencing HLP rights in the context of climate-induced conflicts. In other words – there are specific women who encounter "a triple intersection of identities" in their daily life during the process of resettlement and integration. Such women are highly likely to suffer "an intersectionality disadvantage" in accessing HLP rights in the context of increased rapid urbanization and fragilities. For example, a disabled IDP woman from a minority clan carries three different identities and therefore is more likely to be disadvantaged compared to other women in accessing HLP rights.

Conclusion

This paper has examined the importance of partnerships and localization of climate and conflict programing in the context of unequal relations between donors and recipients. Donors in weak and fragile governments are often faced with the challenges of better delivery and management of aid. There are different priorities and needs among the various actors involved in the implementation of aid programs. However, climate and conflict interventions are the worst affected sector within the aid management landscape.

Donors and the Somali government should explore opportunities to establish a facility that provides constructive, practical support to multilaterals, donors, national and state governments and implementing partners and other relevant international, national and local actors in enabling significant and measurable improvements in the extent to which climate and conflict are well managed and adapted, both to avoid the risks of manipulation or misinterpretation by parties affected by climate-induced risk leading to conflict. They should also take every opportunity to promote inclusion and support stability and peace. This should build upon good practice and lessons identified from other relevant contexts where similar facilities have been established. They should also take account of experiences of facilities already developed in Somalia which, though having different purposes, have useful lessons to impart. The facility should also be developed in a manner which builds upon existing capacities and evolves based on demand.

Recommendations

1. The government should take advantage of the donors' shift from placing stark conditionalities towards development to the promotion of meaningful partnership and localization ideation.

2. Donors and the government should work together to understand how people are affected differently in the context of conflict triggered by climate shocks. Women and other less vulnerable groups should be given priority in terms of their own needs, for example addressing intersectional disadvantage, against a backdrop of increasing conflicts triggered by climate change affecting women.

3. Climate change and resilience-building should be given much more attention, with a view to creating sustainable remedies against climate-induced vagaries affecting local populations in Somalia.

4. Further research needs to be undertaken to determine the relationships between climate change on the one hand and the donors and the local communities on the other.

5. Donors should minimize using a direct coercive form of power and instead increase civil engagement using an indirect power approach. This would change the behavior and attitudes of government and the people.

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09

Climate Change Awareness and Adaptation in Somalia: Promoting Peace through Collective Actions

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Abstract

Over the past two decades, climate-related disasters such as droughts and flooding have taken human life, undermined livelihoods, destroyed infrastructure, shaken economies and stressed state budgets. One of the objectives of Somalia's National Adaptation Program of Action on Climate Change Plan (NAPA) was to implement immediate and urgent projects based on climate change-adaptation activities while also building community awareness and the capacity of communities to withstand climate change impacts. This study aims to assess and define the level of awareness of the community and government stakeholders on climate change-adaptation plans and practice. We collected primary and secondary data through key informant interviews (KII) with government ministers and local NGOs as well as two focus group discussions with community members in Puntland and south and central Somalia. Most stakeholders in our sample had not considered integrating national adaptation plans into program outcomes. Findings also showed that the majority of respondents from the community had little knowledge about climate change and limited communication skills but had experienced challenging livelihood situations due to frequent droughts and floods. The lack of awareness programs addressing climate change meant there have been no actions to mitigate the impacts. This has hindered the climate change-adaptation plan in Somalia. Our analysis also concluded that 1) education institutions should include awareness-raising programs on climate change adaptations in their curriculums, and 2) adequate investment in research and capacity building is important in order to build resilience to climate change impacts.

Introduction

There is unequivocal evidence that climate change has the potential to affect millions of lives and livelihoods worldwide (IPCC, 2007). Somalia is one of the countries most vulnerable to climate variability and change due to its high dependence on rain-fed agro-pastoral practices and natural resources as well as its low adaptive capacity.

Stakeholder engagement can be a key factor in creating the conditions that make adaptive decision making easier to implement at the community level. Stakeholder engagement is also the vulnerability assessment that can help gather information during project design and be incorporated into the implementation phase.

The overarching goal of the NAPA is to make the Somali people more resilient to climate change, recognizing their high vulnerability in an economy that is dominated by dependence on agriculture and livestock rearing and undermined by the heterogeneity of clan-based conflicts. The NAPA recognizes that climate change will have far-reaching impacts on, and across, many sectors and that the knowledge and capacity to respond to it are lacking.

The climate change-adaptation framework will also provide an effective way to strengthen regional cooperation. As the first national planning document on climate change-adaptation, NAPA is a great starting point for integration. IGAD, which provides a solid basis for better regional cooperation to address issues related to shared ecosystems and natural resources, is another way in which regional neighbours can work together on climate change issues.

Development assistance to Somalia must ensure that all projects and programs address climate change issues. Developing and implementing adaptation strategies also require the engagement of multiple stakeholders and innovative ways to pool their efforts, commitment, and knowledge.

The international community has established legally binding goals for worldwide net reductions in greenhouse gas emissions. However, there is no obligation to implement them. Therefore, the 2015 Paris agreement's success depends on the signatories' willingness and the ability of the parties to implement it in national policies. To combat climate change, all nations that ratified the United Nations Framework Convention on Climate Change (UNFCCC) were required to submit nationally determined contributions (NDCs) and coordinated efforts to maintain global warming within the 1.5 °C or 2°C targets. The agreement also calls for improving climate change education, training, public awareness, participation and public access to information. Somalia's goal is to reduce climate change-induced vulnerabilities for the poorest communities, which are around 65% of the population who depend on natural resources through pastoralism and agriculture. These sectors are most affected by climate change impacts yet are the most unaware of how to adapt.

Droughts and flooding have taken human life, undermined livelihoods, destroyed infrastructure, shaken national economies, and stressed state budgets and peace in Somalia. The country has suffered five successive droughts that have devastated livestock and crop production. The consequences are food insecurity, hunger, malnutrition, displacement, and loss of lives. Several flood disasters, the most recent in 2018 in the Hiiraan, Middle/Lower Shabelle, and Bari (Qardho) regions, resulted in loss of life and displacement. Because of erratic rainfall, local people, particularly the farming communities, have witnessed the shift in rainy seasons, affecting agricultural practice and livelihoods.

According to studies, agro-pastoralists will continue to suffer from climate change if there is no collective adaptation process that could significantly decrease the impacts of climate change. Adaptive capacities influence the ability of the community to adjust and adapt to exteme climate-change events, to lessen the potential harm, to take advantage of the opportunities and to deal with the consequences, especially in rural areas. Thus, the awareness and adaptive capacity of a society describe practices that are characteristic of being better able to cope with the changes in the external conditions.

Somalia is characterized by arid and semi-arid lands, with biannual rainfall seasons, the Deyr and Gu seasonal rains. It is also prone to extreme droughts, erratic rain and floods, affecting rural livelihoods and agricultural economic opportunities. The situation is compounded by dependency on rain-fed agriculture, which leaves crop and animal production to the mercies of nature. Within the rural economy, agriculture (including livestock and fisheries) is the most important economic sector, making up 75 percent of GDP and employing about 70 percent of the labor force. Somalia's rural population largely derives its livelihood from a combination of pastoralism and crop cultivation, with 4 percent making a living from fishing.

The main climate change drivers in Somalia are land degradation, deforestation, and population growth, leading to frequent and intense droughts and floods, which negatively impact production systems and livelihoods. The rainfall pattern in Somalia is highly unpredictable. There are heavy rains that result in flooding and destruction of property, or below-average rain which does not appropriately support production. In some cases, an early cessation of the rainy season results in impaired pasture regeneration, poor crop performance and water scarcity for domestic use.

Uncertainties are an integral part of climate change projections. They arise from various factors including natural variabilities, uncertainties in GHG emissions scenarios, and differences in the models used. Consequently, poor integration of adaptation into climate change programs will hinder NAPA's goals from being implemented.

Literature review

Widespread drought has occurred in sub-Saharan Africa for the past three decades. One-third of the population lives in drought-prone areas, and Africa has the highest drought-related mortality rate. The Horn of Africa experienced its worst drought between 2008 and 2010, which devastated humans, the environment, and economics. Numerous regions of Somalia were deemed to be in famine, and tens of thousands of Somalis fled across borders to refugee camps in Kenya and Ethiopia. More than 13 million people were impacted.

Climate change and violence had displaced approximately 2.6 million Somalis as of August 2019. Flash floods in southern and central areas displaced 215,000 people in only a few months in 2018. The loss of livelihoods has led many displaced persons to migrate towards urban centers such as Mogadishu and smaller cities like Baidoa in southwestern Somalia, where more than 320,000 people live in improvised internally displaced person (IDP) camps. Many live on private land without access to social services and without rights of tenure, meaning that they risk eviction. In such circumstances, micro conflicts are not unusual. The main climate change drivers in Somalia are droughts and floods. Land degradation and deforestation also worsen the negative impacts of climate change.

Any natural adjustment to climatic change that mitigates harm or takes advantage of opportunities in place in response to current or anticipated climate-related environmental changes is referred to as adaptation to climate change (IPCC Third Assessment Report). Developing countries are frequently the most vulnerable and least prepared to protect themselves from climate change impacts. They must learn to adapt to the effects of climate change. Adaptation allows farmers and herders to meet their goals for food, income and livelihood security in the face of shifting climatic and socioeconomic conditions such as climate variability, extreme weather events and volatile short-term changes in local and large-scale markets. As a result, adaptation is widely acknowledged as a crucial component of any policy response to climate change.

Adaptation allows communities to anticipate the effects of climate change. Climate change education is an important part of this. Farmers and herders must first recognize the effects of climate change, then choose a plan and apply practical adaptation strategies.

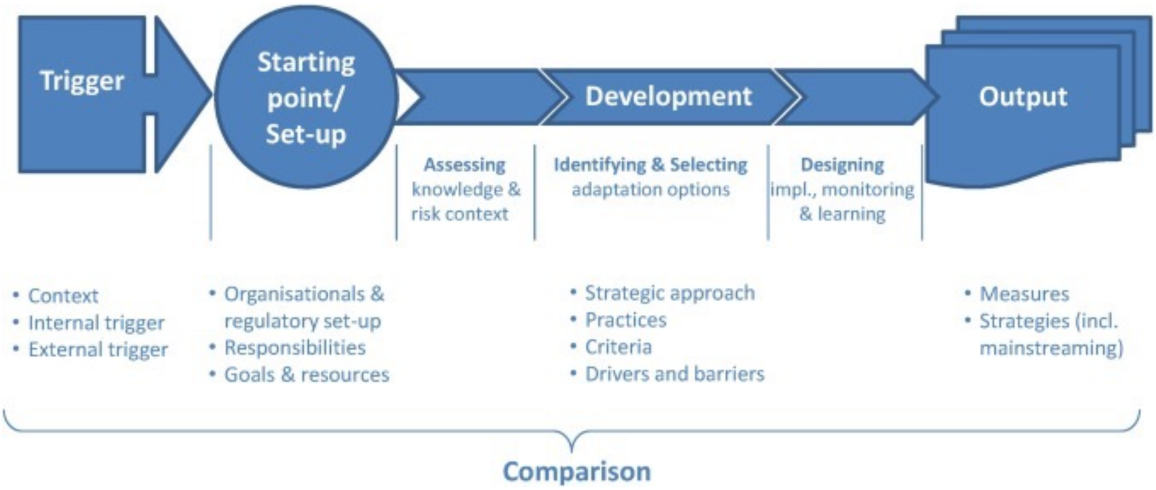
Local knowledge is essential for understanding the effects of climate change on rural communities. Their way of existence is fundamentally based on paying attention to environmental unpredictability, shifts and patterns. Community-based knowledge may provide insightful information on how the ecosystem is changing because of climate change and can add local specificity and subtlety to more general scientific studies.

Rural communities have developed coping mechanisms to deal with uncertain conditions and in some cases are already making active adjustments. Although it is anticipated that the changes brought on by climate change will be unprecedented, societies' knowledge and coping mechanisms serve as a critical foundation for community-based adaptation efforts.

Stakeholder engagement is paramount in assessing adaptation options. Members of the public, the scientific community and government agencies can play an important role in assessing the baseline feasibility of adaptation options and creating proposals. Members of the public can also contribute, potentially saving money and improving project efficiency. Coordination and collaboration between agencies and stakeholders can help foster collaboration and synergies while averting conflicts that could be difficult and costly to fix in the future.

Methodology

Primary data gathered for this study included five KIIs and three focus group discussions held in Puntland and south and central Somalia. Those involved included government ministries, NGOs, village elders, local government, farmers, civil society organizations and village development committees. Questionnaires and observations were analyzed to compute the climate-risk graph. The tables below show the level of awareness of the community and government on climate-change adaptation plans and practice. The full process is depicted in the diagram below.



Result and discussion

We found that in some cases multiple stakeholders were involved in one area but had left the national adaptation plan out of their work. This has significantly impacted on the establishment of decision-making bodies and priorities, as well as the overall policy-making process.

Our results indicated that stakeholders need more involvement in climate change programs, particularly those implemented by humanitarian agencies. Communities are already trying in a limited way to implement traditional coping mechanisms but have very little knowledge about climate change and have no reliable sources of information to turn to for help in tackling the issue.

There has been limited public engagement and collective action to build community-based mechanism strategies to tackle climate change and a lack of climate change-related awareness programming.

Strengthening traditional knowledge could contribute significantly toward communities' resilience practices. However, despite facing the challenges of deforestation, heatwaves, disasters and temperature rise, few of the surveyed stakeholders considered climate change adaptation to be a priority.

Somalia is one of the states most vulnerable to climate change and is ranked as the second-most fragile (Crawford, A., & Church, C. (2020). Thus, the poorer the people are, the more difficult it is to recover from climate change impacts such as livestock loss, crop failures, home destruction, and health crises. The highlighted areas in the climate-risk maps indicate the Nugaal region has experienced less increase in extreme events compared to southern Somalia without significant changes in precipitation.

Table 1: Knowledge of climate change stakeholders in the surveyed areas

Knowledge	Statements
Knowledge about climate change	Very little
Stakeholder participation on CC	Weak
Development programs	Limited formal programs on climate change
Traditional knowledge present	Limited impacts
Climate change in education system	Lacking
Representation from stakeholders	Little engagement
Adaptive capacity	Moderate coping mechanisms strategy
Communities rely on external support	Limited government climate change actions
Integration of NAPA to the other programs	Very limited

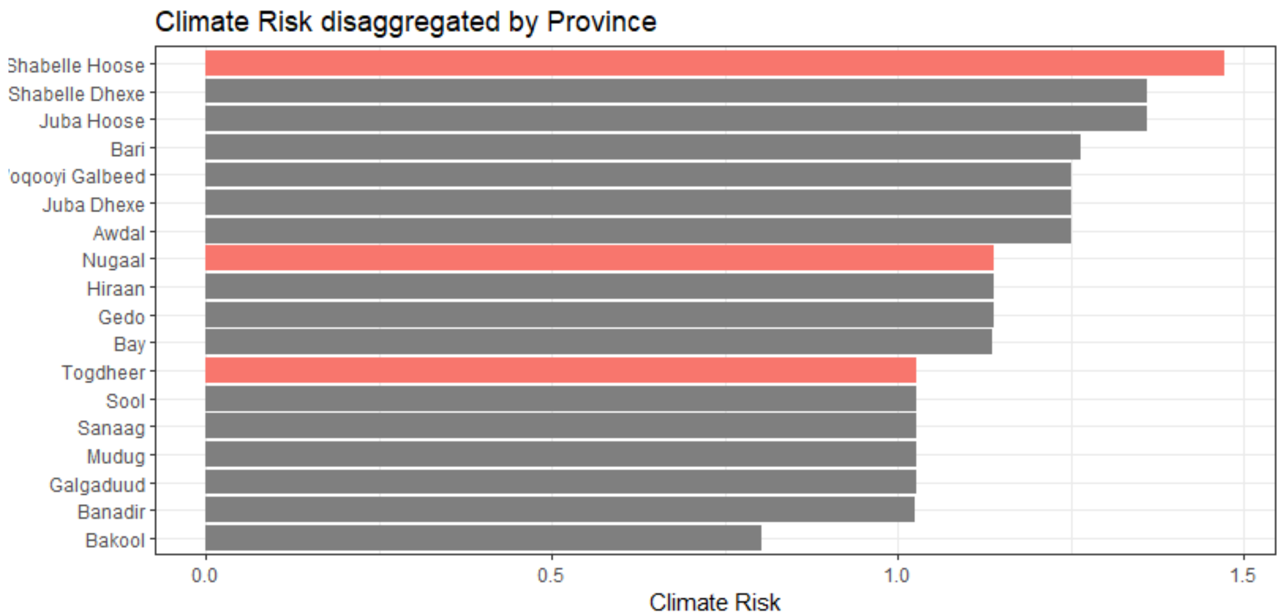


Figure 1: Climate risk values by province in Somalia for the baseline period. Climate risk is calculated according to the Sixth Assessment Report (AR6) of the United Nations (UN) Intergovernmental Panel on Climate Change (IPCC) IPCC AR6.

Conclusion

The impacts of climate change are occurring in all the districts of Somalia. Extreme drought, wind, land degradation and water scarcity are affecting all the agropastoral communities in the surveyed area. Most respondents had a limited awareness about climate change and there are no structured plans and actions being implemented to mitigate the impact of climate change on communities.

Evidence showed that participation from various stakeholders is a key element of integrating climate change adaptation into development programs. Awareness at the community and stakeholder levels plays a fundamental role in making available knowledge a useful tool to assess the immediate adaptation needs of the community and to make it a part of development programs.

Efficient networking services need to be embedded in Somali institutions and be rooted at the local level with a territorial approach to provide an overview of program areas and recommended outcome activities for Somalia's NAPA adaptation priority actions at national, regional, district, and community levels.

Stakeholders have not been consulted about the impacts of droughts and floods, nor involved in developing adaptation strategies. Reaching a consensus on actions needed to respond to climate problems in each region needs combined efforts to create unified programs. Climate-change awareness raising can be lifesaving and placing the final decision-making in the hands of the stakeholders is a crucial aspect of implementing adaptation strategies effectively.

Recommendations

- Increase the capacities of stakeholders to own the process of advocating for climate-change adaptation.
- Share accurate and objective information with stakeholders to help them to understand problems, alternatives, opportunities and/or solutions.
- Promote regular awareness raising and information campaigns addressed to the different segments of the population to improve understanding of climate change and to foster preparedness and adaptation.
- Develop advance knowledge-sharing and capacity-development initiatives in farming and livestock practices through communication approaches, social innovation and digital literacy, focusing on women, youth, and vulnerable communities. Ensure the adoption of relevant content through formal and non-formal education.
- Identify the appropriate level of engagement impact for each stakeholder. Some stakeholders may want only information about ongoing processes, while others may want to influence the outcomes.
- Implement an integrated program proposal design system to promote information and knowledge uptake and community mobilization for climate adaptation.

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10

Assessing Somali Government's Institutional Capacity for Climate Change: Gaps and Way Forward

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Abstract

Institutional capacity is important for effectively addressing climate change. By understanding current capacity gaps, interventions can be implemented to increase adaptation capacity and contribute to reconstruction and reconciliation efforts. However, countries like Somalia are particularly vulnerable to climate change due to their low adaptive capacity and limited institutional capacity to assess and monitor climate risks and implement risk reduction measures. Without proper mitigation and adaptation measures, the population's livelihood options will be negatively affected, potentially impacting peace and conflict dynamics. This study assesses the capacity of government institutions in Somalia to address climate change issues. Using existing frameworks, it analyses the government's capacity to design and execute climate-change policies and programs through document analysis and interviews. The results of the study show that there are significant capacity gaps hindering the government's efforts to address climate change, and existing capacities are fragmented and not effectively coordinated. Therefore, it is recommended that the government invest in institutional capacity-building to strengthen and create new institutions to address these issues.

Keywords: Climate change, governance, institutions, institutional capacity

Introduction

Climate change, exacerbated by conflict, environmental degradation and limited government institutional capacity, poses the greatest threat to Somalia, all at a time when the country is recovering from more than three decades of protracted conflict. The effects of climate change are greatest in places like Somalia because of geography, reliance on agriculture and a lack of adaptive capacity. Climate change is felt most often by the poor who rely on subsistence agriculture.

Somalia is suffering from heat waves, droughts and floods, which are causing deaths, livelihood destruction and mass displacements. The effects of climate change are also felt economically while new research claims that climate change affects Somalia's stability and security by undermining food security, fuelling displacements, increasing tensions and vulnerabilities in the community and igniting resource-based and identity-related conflicts. The literature also confirms that climate change is one of the many "contributing drivers of conflict" with some evidence that droughts and heatwaves have led to an increase in livestock raids and recruitment by armed groups. The recent locust outbreak, which resulted in the destruction of farmland, is also attributed to climate change. The government has identified vulnerability to environmental risks as one of the major causes of poverty in its ninth National Development Plan.

Future climate-change projections for Somalia indicate that the country will experience high temperatures, water shortage and significant droughts unless action is taken. These effects and threats of climate change have sparked a response from the national and regional governments, the private sector, non-governmental organizations and the international community. Responses include adaptation or mitigation efforts and building institutional capacity for climate change.

In 2013, the Federal Government of Somalia (FGS) launched a National Adaption Programme of Action (NAPA), in line with the United Nations Framework Convention on Climate Change, to address the risks associated with a changing climate. Earlier this year, the government created a new environment and climate change ministry and appointed a presidential envoy for drought response. Somalia's Federal Member States (FMS) have also instituted various institutional mechanisms and programs to combat climate change. The UN in Somalia has climate change programs and has committed to strengthening the federal government's institutional capacity to design adaptation plans and environmental policies. It has recently brought on board an environmental security advisor to support the UN in considering the implications of climate change in their programs. These efforts are in line with Goal 13 of the Sustainable Development Goals, which includes specific targets for strengthening adaptive capacity for climate-related hazards and improving capacity for effective climate-change planning and management in countries like Somalia.

Despite the new focus on climate change, many countries face significant capacity constraints that prevent them from taking effective action. Somalia is among the least developed countries that have significant capacity challenges to develop and implement climate-change adaptation and mitigation policies and programs. Even though it is widely known that there are institutional capacity gaps, not much is known about what exactly they are. Considering Somalia's challenges with climate change and governance capacity, it is essential to have a better understanding of the country's institutional capacity to manage the effects of climate change. This could improve programming and stakeholders' efforts to strengthen the government's capacity to design and implement policies and put in place capabilities to track, monitor and respond to climate-related incidents.

Institutional capacity means having an enabling environment with the right competencies, resources and structures to perform the functions of an institution. There are several technical and functional capacities, at the level of the individual, organization and broader environment, required to enable climate-change adaptation and mitigation efforts. The OECD draws a distinction between "climate-specific" capacity, which is devoted to issues regarding climate change, and "climate-relevant" capacity, which is geared towards non-climate actions but may help in mitigating or adapting to climate change. All parties to the Paris Agreement committed to responding to the needs and contexts of developing countries that are least able and prone to adverse consequences from climate change. Article 11 states that capacity-building must be an effective, iterative process that is participatory, cross-cutting and gender-responsive.

The aim of this study is to assess the "climate-specific" capacity of Somali government institutions, with the goal of identifying specific gaps. Closing these gaps and improving the government's adaptive capacity could assist in broader peacebuilding, reconstruction and reconciliation efforts. The study will adopt existing frameworks to assess the level of government capacity to design policies and strategies to combat climate change, evaluate vulnerabilities and monitor climate-change risks, manage climate-change information, coordinate climate-change mitigation and adaptation efforts and implement climate-change actions. The paper concludes with a discussion of the results of the assessment and suggests opportunities for improving the level of institutional capacity to design policies to adapt to climate change.

Methodology

This research article follows a qualitative research methodology and combines content analysis of documents with select key informant interviews, in addition to presenting the grey literature on the nexus of climate change and institutional capacity. In this study, we assessed the capacity of formal government institutions tasked with leading and coordinating climate-change interventions. Efforts were made to gather official government documents and reports including NAPA and other climate-change related policies and plans. These documents were supplemented by interviews with key informants selected based on their knowledge of the workings of the government and its institutional mechanisms for climate change.

The World Bank's climate-change institutional capacity assessment framework was used as a guiding lens to assess the government's capabilities to take meaningful action on climate change, with the goal of identifying gaps and priorities that could inform future institutional reforms. The framework was selected because of its practicality and the specific domains that it covers. It comprises of five pillars that cover the assessment of regulatory frameworks, mandates, coordination arrangements, technical capacity to support climate-change policy, processes for vulnerability assessments and planning systems, monitoring and evaluation, resource mobilization, integration of climate strategies into fiscal and public financial management practices, capacity of sub-national governments and incentives for climate actions, access to climate information and engagement mechanisms for civil society, the private sector and other stakeholders.

Institutional instruments for climate change

Somali institutions collapsed after the fall of General Mohammad Siad Barre's regime on 27 January 1991. Twenty years later, in 2011, the then Transitional Federal Government set up a disaster management agency to coordinate the humanitarian response to the devastating droughts ravaging the country.

The 2012 Provisional Constitution set the foundation for environmental protection, land rights, and management of natural resources in Somalia. According to Article 25, citizens have the right to a healthy and safe environment that is free from pollution and harmful materials. Citizens are also guaranteed a share of the country's natural resources and are protected against excessive and damaging exploitation of these resources. Article 45 tasks both government and citizens to protect and enhance the environment. It also calls on the Federal Government to adopt environmental policies, enact legislation and take the necessary steps to reverse desertification, deforestation and environmental degradation, as well as to prevent activities that harm natural resources and the environment. Somalia has ratified several multilateral agreements on environmental and climate change issues including the UN Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol.

In 2013, for the first time, the Federal Government formulated a nationwide strategy (the National Adaptation Programme of Action on Climate Change) in response to the growing climate threats and to increase the resiliency of its people. The plan recognized the limitations of the government in terms of human and financial capacity, as well as the gaps in policy and regulatory mechanisms. The government committed to a set of climate actions in the areas of sustainable land management, water resource management and disaster management. For each of those areas, there were commitments to develop specific plans, raise awareness, undertake infrastructure projects and take specific measures such as curbing charcoal production, conducting environmental impact assessments and developing early warning systems.

Somalia's National Development Plan has recognized the recurring drought and changing climate as drivers of poverty. The plan outlines interventions to strengthen the government's institutional capacity for effective environmental governance. Through the National Environmental Policy, the government established a Directorate of Environment and Climate Change to oversee the design and implementation of policies related to environmental matters. It also highlighted the need to develop government institutions' capacity to support climate change integration in all aspects of the economy and to support climate resilience.

The Federal Government also instituted a National Climate Change Policy and a National Drought Plan to manage droughts and climate-change effects. The climate-change policy envisioned the establishment of several entities yet to be fully operationalized including a National Designated Authority to act as the focal point for the green climate fund, a center for climate-change research, a national climate-change committee and cross-sectoral committee on climate change.

In 2022, the Federal Government established a dedicated ministry for climate change for the first time to lead and coordinate climate-change mitigation and adaptation efforts. The Federal Member States have also adopted policies and established disaster management agencies, in addition to maintaining several sector-based ministries including the ministry of environment.

The government's National Bureau of Statistics has expanded its capabilities to collect, analyze and disseminate national statistical information including data on climate change. It has taken on national data collection and analysis functions and recently signed an agreement with FAO to assume data and analysis functions related to food security, nutrition, markets, livestock, livelihoods and natural resources.

In addition to the formal government structures, there have been mechanisms put in place by the international community, UN organizations and other non-state actors. They include:

- FAO manages Somalia's Water and Land Information Management project (SWALIM) designed to provide up-to-date data and information on climate-change related topics such as water, floods, drought and charcoal. SWALIM has a range of tools to monitor floods and droughts. The project also maintains various monitoring stations that collect data related to weather (11 stations), rainfall (111 stations), synoptic (9 stations) and ground water (9 stations). The initiative also leverages remote sensors to gather information remotely that can be used to monitor water catchments, irrigation canals and other infrastructure.

- Under its revised mandate, the United Nations Assistance Mission in Somalia (UNSOM) now has an environmental and climate advisor, making it the first UN mission with such a role. The advisor's responsibilities include mainstreaming climate change throughout the mission, coordinating UN efforts to address climate change and supporting the government in developing climate-change policies and plans.

- UNDP supports the government in institutionalizing climate-risk management in addition to implementing projects related to climate resilience. Recently UNDP and the Global Environmental Facility (GEF) launched a USD 10 million program to develop Somalia's first hydro-meteorological monitoring station to help forecast flooding and droughts. Other UN agencies and non-governmental organizations are also delivering programs on climate-related topics such as food security, water and sanitation, infrastructure and housing.

- A new climate-change research center has been established in Somalia by the Intergovernmental Authority on Development (IGAD) to collect and analyze data and disseminate new information on climate change.

Climate change-related multilateral agreements

- 1986: Convention on the International Trade in Endangered Species of Wild Flora and Fauna (CITES)
- 1986: Convention on the Conservation of Migratory Species of Wild Animals
- 1989: United Nations Convention on the Law of the Sea
- 2001: Vienna Convention for the Protection of the Ozone Layer
- 2001: Montreal Protocol on Substances that Deplete the Ozone Layer
- 2001: Amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer
- 2002: United Nations Convention to Combat Desertification
- 2009: United Nations Framework Convention on Climate Change
- 2009: United Nations Convention on Biological Diversity
- 2010: Basel Convention on the Control of Transboundary Movements of Hazardous Waste and Their Disposal
- 2010: Cartagena Protocol of the CBD
- 2010: Kyoto Protocol to the UNFCCC
- 2010: Stockholm Convention on Persistent Organic Pollutants
- 2012: Nagoya Protocol to the UNFCCC
- 2016: Paris Agreement

Climate change-related national policy/strategy documents

- 2013: The National Adaptation Programme of Actions (NAPA)
- 2015: The National Biodiversity Strategy and Action Plan
- 2016: Somalia National Action Programme for the UN Convention to Combat Desertification
- 2016: National Disaster Management Policy
- 2017: National Capacity Assessment Towards Implementing the Environmental Treaties of the Rio Convention
- 2018: Somali National Disaster Management Policy
- 2018: Recovery and Resilience Framework
- 2018: The Initial National Communication to UNFCC
- 2018: National Energy Policy 2018
- 2019: The Power Master Plan for Somalia
- 2019: The National Environment Policy
- 2019: Integrated Water Resources Management Strategic Plan (expiring in 2023)
- 2019: The National Electricity Bill
- 2019: Somalia National Water Policy and National Water Resource Law
- 2019: National Fertilizer Policy
- 2019: National Pesticide Policy
- 2020: National Climate Change Policy
- 2020: 9th National Development Plan (expiring in 2024)
- 2020: National Environmental Management Bill (draft)
- 2020: National Voluntary Land Degradation Neutrality Targets
- 2020: National Food Security and Nutrition Policy
- 2020: National Drought Plan
- 2021: National Water Resource Strategy (expiring in 2025)

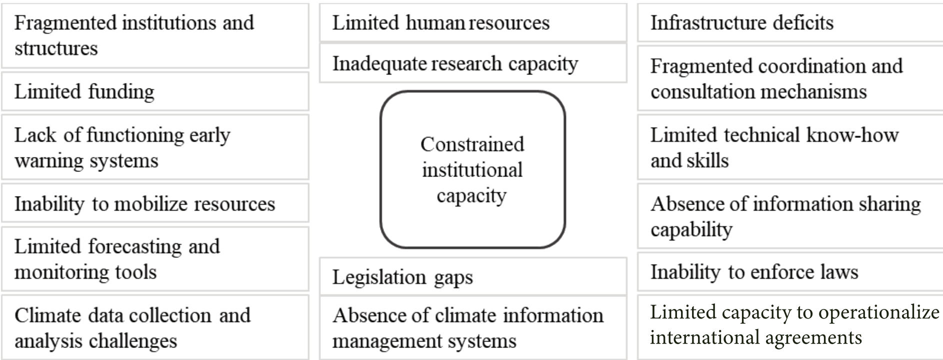
Climate change-related institutions (ministries/agencies/departments)
• Ministry of Environment and Climate Change (established in 2022) • Directorate of Environment and Climate Change (replaced by a ministry) • Somali Disaster Management Agency • National Climate Change Committee • Cross-Sectoral Committee on Climate Change • Special Presidential Envoy for Drought Response (established in 2022) • Somali National Bureau of Statistics • Puntland Ministry of Environment Agriculture and Climate Change • Galmudug Ministry of Environment, Climate Change and Rural Development • Jubbaland Ministry of Environment and Tourism • Southwest Ministry of Environment and Wildlife • Hirshabelle Ministry of Environment, Climate Change and Rural Development • Various sectoral-based ministries and agencies at the federal and regional level

A review of the various climate change-related government policies and plans identified a set of required capabilities, systems and processes.

Capabilities	Systems & tools	Processes & arrangements
• Policy formulation and planning • Hydrological analyses • Geoinformatics • Drought monitoring • Flood management • Forecasting and predictive analytics • Risk management • Community mobilization • Vulnerability assessments • Geospatial mapping • Climate data management • Disaster management • Land management • Mapping climate-related conflicts • Environmental impact assessments • Climate financing • Research • Capacity building • Monitoring and reporting • Negotiations • Coordination • Partnerships	• Early warning and forecasting systems • Flood and drought monitoring and control systems • Earth observation technologies • Geospatial science and tools • Drainage systems • Monitoring, reporting and verification systems • Carbon registry and accounting system • Health surveillance systems • Knowledge management and information management systems. • Climate-related conflict monitoring and reporting system • Environmental management system • Waste management system for cities • Hazardous waste monitoring system	• Intergovernmental / inter-agency coordination and information sharing mechanism • Stakeholder consultations • Annual reporting process /data collection • Exchange of ideas forum • Climate change governance • Research dissemination • Cross-sectoral and technical working groups • Climate change champions and focal points • Public-private partnerships • National communication to UNFCC

Institutional challenges and capacity gaps

According to documents examined for this study, Somalia is facing a variety of challenges and capacity gaps that prevent it from responding appropriately to the threats posed by climate change. The biggest capacity gaps are related to the political and security situation, limited environmental governance and the lack of financial and human resources.



Summary of challenges and capacity gaps to address climate change

The political situation has impeded the implementation of legislation and policies designed to protect the environment and address climate change threats. Key institutions such as the national meteorological agency are either non-existent or not fully operational, and there is a lack of clear coordination mechanisms and information exchange between decision makers. The security situation has also hindered the government's ability to reach affected areas and collect data, establish institutional mechanisms and install monitoring equipment.

Although Somalia has ratified several international agreements on climate change and adopted climate-change policies at the federal level, the legislative and regulatory frameworks are weak and do not adequately define authority, roles and responsibilities and accountability for climate-change issues. Several climate-change laws have not been passed by parliament despite receiving cabinet approval. This is partly due to inadequate funding for climate initiatives, a lack of skilled personnel and fragmentation within the government.

"[The recently created Ministry of Environment and Climate Change] lacks the necessary human and financial resources necessary to discharge its mandate like other ministries of environment in the Global South. A particular impediment on this ministry is that it is new. It has no offices, no budget, no transportation and no act of establishment." – Senior Ministry Official

The funding gap is exacerbated by the government's limited capacity to mobilize resources. Stakeholders believe that it is difficult to access funding for climate change due to the complex requirements, conditions and paperwork involved. The government is also constrained by a lack of financial and human resources, with ministries and agencies being understaffed and current environmental policies underfunded. The government lacks the capacity to fully implement policies, enact legislation and acquire the necessary technologies, equipment, and materials for managing climate change. In addition, coordination capabilities and information-sharing mechanisms between government agencies are limited, leading to little interaction between the central government and subnational governments. The government's engagement capacity to create awareness and consult with the private sector, civil society, affected communities, international organizations and other stakeholders is also limited and requires significant investments. It has limited technical capacity and understanding of the importance of environmental protection and the impacts of climate change.

"A comprehensive analysis of the state of the country's climate change institutions during the [Nationally Determined Contributions] updating process revealed structural and systemic weaknesses in the institutional bedrock. This includes the lack of the necessary capacity to address climate change and its associated challenges, financial weaknesses, the dearth of appropriate policies and an inability to enforce laws. Most of the institutions suffer from a considerable deficiency in human, financial, organizational and institutional capacity to manage the environment and natural resources and respond to the specific challenges that climate change brought to Somalia." Federal Government of Somalia, 2021.

"The ministry is facing tremendous challenges when it comes to finding Somalis who are experts in the fields of environment, meteorology, climate, biodiversity and wildlife" – staff member in the Environment and Climate Change Ministry of Somalia's systems for managing climate change information.

The country lacks functioning early warning systems and forecasting tools, and there has been no systematic data collection by the government to monitor the changing climate. Ministries do not have adequate information management systems or the technical capacity to use data and information produced by international organizations. The country's ability to conduct and utilize research is also hindered by various capacity gaps, including a lack of infrastructure for climate research such as global positioning systems, high-definition cameras, advanced research technologies and other survey systems.

The government's information-sharing capability is also limited, as citizens cannot easily access information on climate change. It is unclear what role higher education institutions, civil society and grassroots community organizations play in addressing climate change, and there is a lack of coordination and collaboration between these groups and the government. Overall, Somalia's capacity gaps and challenges in addressing climate change highlight the need for increased support and investment in environmental governance and management systems.

Conclusion and policy recommendations

While Somalia has made significant advances in the building of its state and democratization, the country is still considered fragile, low-income and vulnerable to climate change due to insecurity and limited institutional capacity. Though this study has not fully and systematically assessed the government's institutional capacity to combat climate change, an effort has been made to present the gaps. It also presents the existing institutional capabilities and arrangements that could increase capacity if they were to be strengthened.

Results showed that in spite of the prolonged conflict and instability, the government has taken concrete steps to put in place institutional mechanisms for climate change and to ratify international agreements. However, there is evidence that limited environmental governance, inadequate coordination mechanisms, underfunded policies and financial, technical and human resource constraints are hampering the government's capabilities to monitor and respond to the growing climate change threats.

- Going forward, the government is advised to take concrete measures to close the capacity gaps and prioritize climate action though strengthened institutional capacity.
- It should adopt an institutional development framework that strengthens existing capacities and builds new capabilities in the areas of climate financing, regulations, monitoring, forecasting and coordination.
- It should absorb capabilities in non-government entities and promote country systems while upgrading existing infrastructure for climate change. The infrastructure upgrade should be accompanied by staff capacity-building and by recruiting talented technical staff.
- It is crucial that the government and international partners prioritize funding for climate-change initiatives with the government incorporating climate financing into the budget and financial processes. They should also strengthen the country's climate-change research capacity and facilitate academic exchanges and collaborations among universities, thinktanks and government institutions.
- A deliberate policy on climate conflict would be effective in mitigating and responding to the climate-change-related violence and conflict.
- Finally, the government should enact relevant legislations, operationalize new institutions such as the national meteorological agency and install a multi-governance coordination mechanism to facilitate information sharing, consultations and decision making.

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11

Engineering Solution to Climate Change: A Special Focus on East Africa

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Abstract

Climate change is considered one of the significant challenges of the 21st century. Its impact on humanity is far-reaching and could have catastrophic consequences if not curtailed. Increasing global temperatures, ocean acidification, drought, floods and other environmental problems are all consequences of increased quantities of greenhouse gases such as CO_2 which are constantly being emitted into the atmosphere. This article explores the causes and evidence of climate change, as well as possible scientific and engineering solutions, focusing on East Africa, in particular the catastrophic events caused by drought in the region. Policy changes and solutions to address climate change in East Africa are also discussed. The paper is aimed at a non-specialist audience, outside the scientific and engineering communities.

Introduction

Some experts have called climate change the crisis of the 21st century, and the United Nations regards it as the defining issue of our time.[1] Climate change is defined as a region's long-term shifts in temperatures and weather patterns. It is an aggregate of the average temperatures meaning that the local temperatures of an area might fluctuate but for a climate change to occur in that region, its average weather patterns must have changed.

A closely related term sometimes used interchangeably with climate change is global warming. Global warming is the long-term heating of the earth's surface (increase in the earth's average temperatures) due to the build-up of greenhouse gases in the atmosphere caused by human activities, primarily fossil fuel burning, which increases the heat-trapping greenhouse gas levels in the earth's atmosphere. Greenhouse gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), water vapor, and some fluorinated carbons.

Carbon dioxide, the most-frequently emitted greenhouse gas, comes mainly from burning fossil fuels such as coal, natural gas and oil. It is also produced from solid waste and chemical industries such as steel and cement industrial plants. Methane, another major greenhouse gas that is 25 times as potent as carbon dioxide, enters our atmosphere from burning coal, natural gas and oil, livestock and other agricultural practices, land use and decay of organic waste in municipal solid waste landfills. The continuous addition of these gases into the atmosphere will eventually lead to artificial climate change.

Climate activists worldwide are demanding that politicians and lawmakers make policy changes that address these issues.

How humans cause climate change – the greenhouse effect

The earth is naturally surrounded by a thin layer of greenhouse gases. These greenhouse gases are in the earth's lower atmosphere (troposphere). When sunlight (electromagnetic radiation) hits the earth's surface, some of it is reflected in space. The rest is absorbed by the earth (infrared radiation), causing the earth to heat up. Some of this heat is reflected into the atmosphere. The greenhouse gases in the atmosphere then absorb and reflect heat radiated by the earth, preventing the heat from escaping into space. This continual reflection of infrared radiation back to earth keeps the earth warm enough to sustain life. However, if excessive levels of greenhouse gases are emitted into the atmosphere, they trap heat, leading to a rise in global temperatures.

CO2 emissions and the world economy

If the emissions of greenhouse gases into the atmosphere have such a detrimental impact on our planet, why would we keep burning fossil fuels? The simple answer is that we need the energy produced by fossil fuels to satisfy the demands of the growing global population. Currently, 80% of the energy consumed worldwide comes from fossil fuels such as oil, coal and natural gas. [2] Oil produces the largest amount of energy consumed globally, followed by coal and natural gas. A small percentage of global energy comes from wind, hydroelectric power, nuclear, solar, biofuels and other renewables, as illustrated in **Figure 1.**

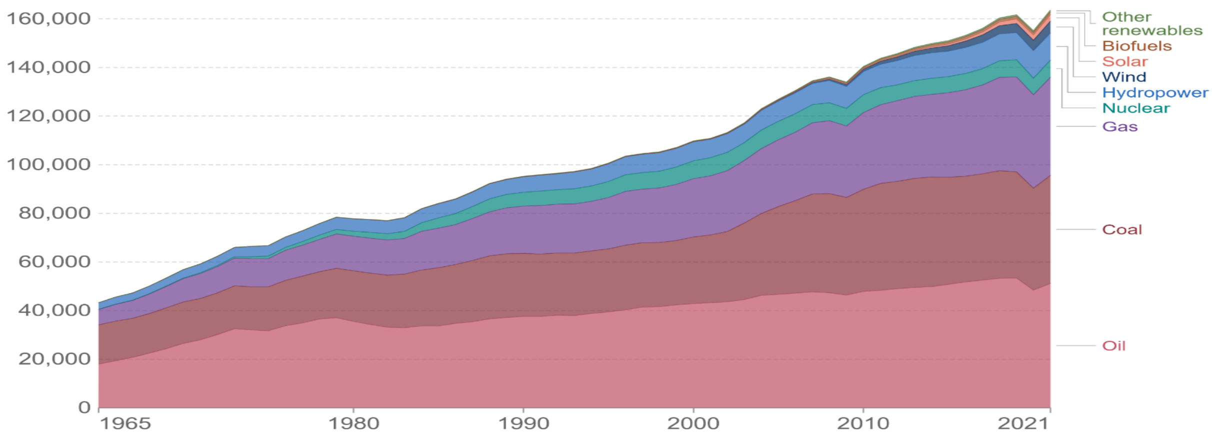

Figure 1: Primary global energy consumption measured in terawatt-hours over the last five decades.[2]

Although China and the United States dominate global energy consumption, per capita it is Canada that consumes the most: 65,231 kWh of fossil fuels, though it also has a substantial amount of renewable energy per capita at its disposal (30,394 kWh), as shown in **Figure 2**. The consumption of these fossil fuels is responsible for substantial emissions of air pollutants. It accounts for well over half of the total greenhouse gas emissions leading to enhanced global warming.[3]

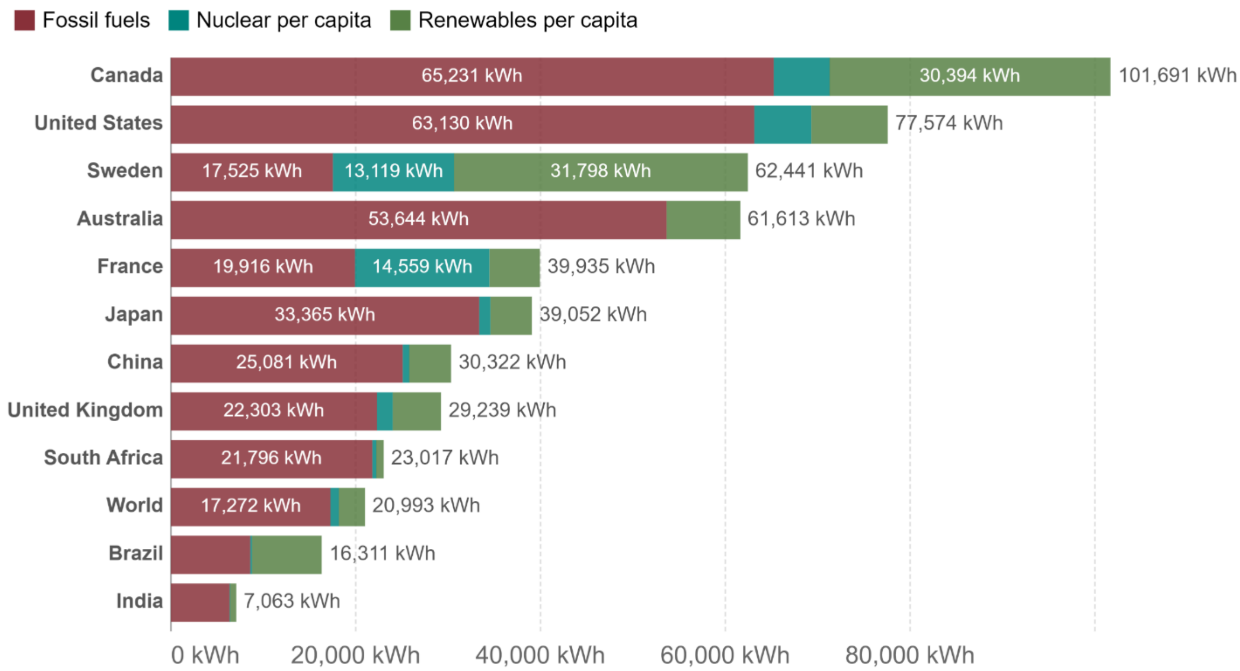

Figure 2: Energy consumption per capita.[2]

There are international efforts to move away from fossil fuels and to explore solar, wind and low-carbon sources. The Paris Agreement goal is to decarbonize the global economy and reach net zero carbon emission by 2050. The 2015 Paris Agreement, a legally binding international treaty signed by 194 parties including China and the United States, was seen as a landmark and an important step towards limiting global warming to well below 2 degrees Celsius compared to pre-industrial levels. Each country has promised to develop long-term strategies to reduce greenhouse gas emissions to meet the Paris Agreement's goals. Despite these efforts, the latest report from the Intergovernmental Panel on Climate Change (IPCC) shows that global temperatures are still rising. The level of CO2 in the atmosphere is at its highest ever recorded in history.[4]

Evidence of anthropogenic climate change

Leading climate scientists have concluded that there is unequivocal evidence that the earth is warming up and that human activity is the prime cause. Although climate change is a natural phenomenon that occurred throughout history, the rate at which the earth is warming up is unprecedented and global temperatures are constantly rising. Average surface temperatures have increased by one degree Celsius since the end of the 19th century, with most of the warming taking place in the last 50 years.[5] The ocean is also warming up (by 0.33 degrees Celsius since 1969), and sea levels are rising.[6]

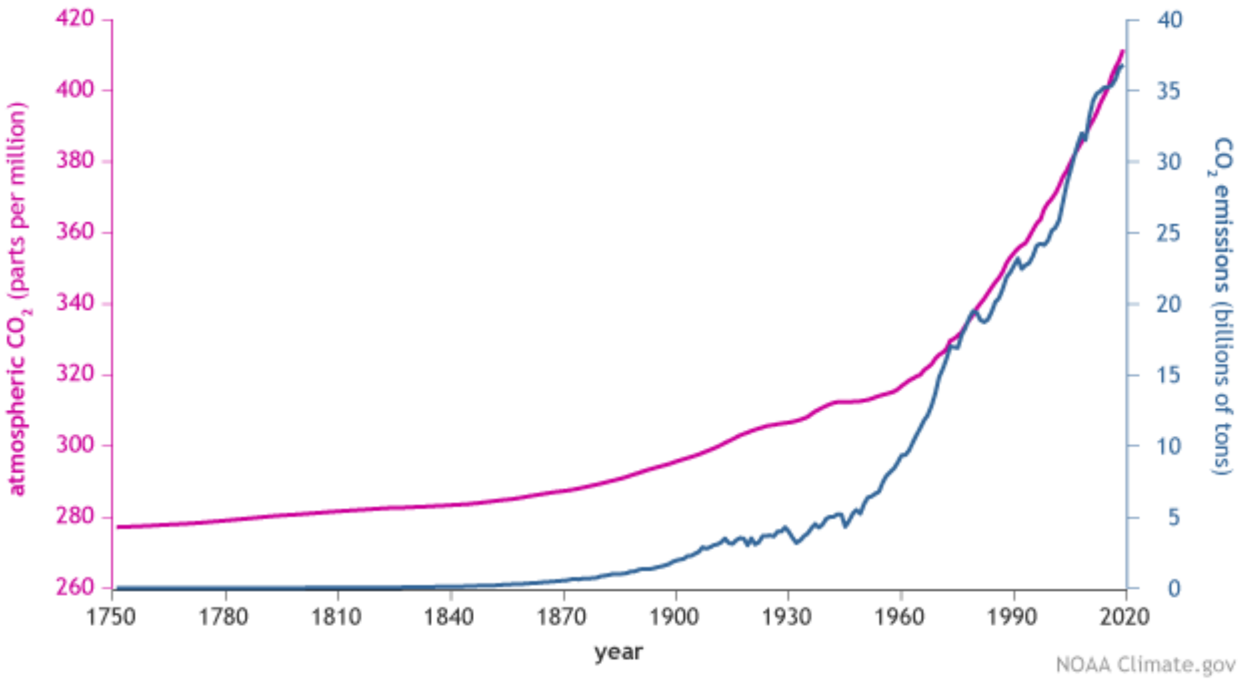

Figure 3: Annual CO2 concentrations in the atmosphere (pink line) and the annual emissions (blue line) between 1750 and 2020.[7]

The Greenland and Antarctica ice sheets are shrinking, glaciers are melting, the oceans are acidifying, and the frequency of extreme storms, heat waves and droughts are increasing. These events have coincided with massive industrialization which produced large amounts of CO2 released into the atmosphere, as seen in **Figure 3**. The amount of CO2 in the atmosphere has increased along with human emissions since the start of the Industrial Revolution in 1750. Therefore, it has been concluded that there is a greater than 95% probability that human activities such as burning fossil fuels, deforestation, modern agriculture and industrialization, have significantly increased climate warming since the 1950s.[8]

Engineering solutions to climate change

Biological CO2-removing processes such as the ocean, biomass and soil, can no longer keep up with the gigatons of CO2 emitted into the atmosphere. These emissions, if not reduced, could have catastrophic consequences. [9] If the current emission trends continue, global temperatures could rise by 2 to 4 degrees Celsius, rising sea levels could swamp many coastal cities and severe weather conditions such as storms, cyclones and drought could have disastrous consequences.[8]

The question then becomes, what can we do to mitigate anthropogenic climate change? Scientists have proposed a few options.

1) Avoid or, at the very least, decrease CO2 emissions by using alternative renewable clean energy sources such as solar, wind or hydroelectric power. These sources of energy are becoming more and more effective over time. We could also increase the efficiency of the current energy sources and minimize waste. However, relying only on renewable energy sources is challenging because the currently available technologies cannot meet our insatiable energy needs. Moreover, they are costly and require the building of new infrastructure.

2) A second approach proposed by climate scientists is the removal of CO2 from the atmosphere through biological or chemical processes. Plants use CO2 during photosynthesis to make food. Therefore, planting trees (reforestation) and decreasing deforestation will undoubtedly decrease the concentration of CO2 in the atmosphere. CO2 could also be chemically removed from the atmosphere through carbon capture and storage (CCS).[10] This process involves capturing CO2 from the atmosphere or sources such as chemical industries and storing it underground or under the deep sea.

3) Capturing CO2 from the atmosphere and using it to produce fuels, chemicals and feedstocks, a process known as carbon capture and utilization (CCU), is another approach.

Carbon capture and storage

Carbon capture and storage (CCS) involves capturing CO2 from coal-powered plants, oil refineries, steel plants and natural gas power plants. It is then compressed and liquefied for easy transportation to storage sites deep in the ground where rocks, mainly sedimentary reservoirs, occur. These sedimentary rocks are porous and contain salty brine water that provides secure storage for CO2.

There are three major carbon capture technologies from a point source used today: post-combustion, pre-combustion and oxyfuel, as shown in **Figure 4**. In post-combustion, as the name suggests, carbon capture is done after burning the fuel. The fuel is first ignited in the air in a boiler to generate heat that can be used for different purposes, such as steam turbines to generate electricity. The flue gas generated then goes through an absorber tower where the CO2 is removed as a solvent CO2 solution. This CO2 solution then goes through a stripper tower, which is heated to regenerate the CO2 gas. The CO2 is then compressed and transported to storage sites. This process captures over 90% high-purity CO2 and is compatible with the power industry infrastructure.[11] However, it is highly capital-intensive, and huge investments are required to make it work properly.[12]

In pre-combustion, an air separator unit separates oxygen from the air. This oxygen is then injected into the gasifier along with the fuel. This process produces synthetic gas (syngas) composed of carbon monoxide (CO) and hydrogen gas (H2). This syngas goes through a water gas shift reactor to produce CO2 and H2. The CO2 is then captured, and the H2 can be used to generate electricity. Pre-combustion is not as popular as post-combustion because its practical application is limited. The pre-combustion process can capture 90% of CO2 and is less energy intensive than the post-combustion process.[13] However, it is highly capital-intensive and can't be retrofitted to existing industrial power plants.[14]

As the name suggests, in oxyfuel, the fuel is burned with pure oxygen in a boiler, producing heat to generate electricity.[15] The flue gas produced in the boiler consists mainly of CO2 and H2O.[16] This flue gas goes through a condenser where the CO2 is separated from the water. The CO2 is then captured, compressed, and transported to underground storage sites.

Another suitable storage site for CO2 is oil fields where production is slowing down. Here, compressed liquid CO2 is injected into an oil reservoir where it acts like a solvent that makes the oil flow more easily.

Today, there are 30 commercial carbon capture and storage facilities worldwide, and this list is increasing. The number of carbon capture and storage facilities increased by 44% in 2022 alone.[18] There are 11 facilities under construction and 153 under development, bringing the total capacity to 244 million tons of CO2 per year being captured from the atmosphere using CCS technologies.[18]

Although carbon capture and storage technologies could potentially reduce total CO2 emissions by 30% by 2050, there are a few obstacles to developing CCS. Apart from the high costs involved in building such facilities, there are safety concerns about CO2 storage in geological sites.[19] Any leakage could cause catastrophic destruction to humanity.[19]

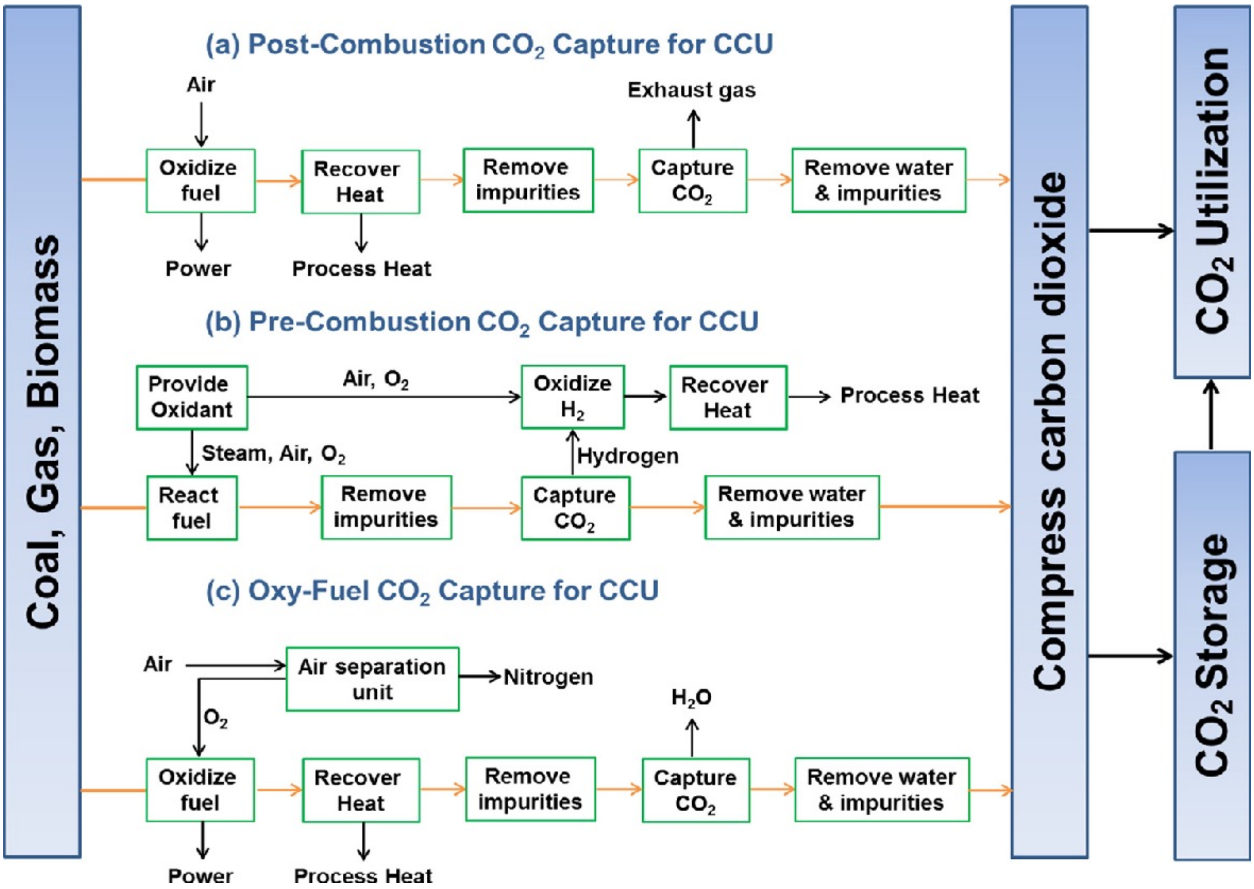

Figure 4: CO2 capture technologies: post-combustion, pre-combustion and oxyfuel.[17]

Carbon capture and utilization

CO2 utilization technologies are any technologies that target the removal of carbon dioxide from the atmosphere and convert it into sustainable carbon-based products. Carbon capture from the atmosphere or a point source which is then converted into products such as chemicals and fuels is a prime example of CO2 capture and utilization technology.[20] Carbon utilization technologies are essential because they remove carbon dioxide from the atmosphere and convert it into valuable chemicals and feedstocks that would have otherwise been obtained from fossil fuels.

Furthermore, CO2 utilization technologies can store renewable electricity in the carbon bonds allowing for safe electricity storage. This creates a circular carbon economy. In addition, a large array of products can be made out of CO2 including pharmaceuticals, polymers and plastics, structural materials like mineral carbonates, alternative fuels like hydrogen and other hydrocarbons and advanced materials.[20]

However, CO_2 is a highly stable material that requires large amounts of energy to convert into valuable products such as chemicals and fuels. Large quantities of renewable energy are needed to make these products and will therefore be more costly compared to products obtained from fossil sources. Therefore, the production of these renewable products is not economically viable yet and will require the development of innovative technologies to bring the cost of production down to compete with products that use fossil fuels. Consumers will also need to be willing to pay extra to buy low-carbon-footprint products and policymakers must be brave enough to implement policies that apply carbon taxes and other incentives.

Carbon capture and utilization are technologies that must be developed to reach the proposed zero emission targets by 2050. However, numerous studies show that the target is highly ambitious and requires the development of innovative renewable energy technologies and a complete lifestyle change effort.[21] It is therefore projected to take longer to develop, deploy and scale up these proposed new technologies. Some of the CO_2 utilization approaches currently used to convert CO_2 into value-added products include thermal, photocatalytic, electrochemical and biochemical reduction of CO_2.

Case study: Drought in East Africa

The causes of drought in East Africa can be broadly categorized into human activities (anthropogenic) and climate variability. Human activities include expanding cultivation and grazing lands, misuse and underutilization of water resource, development of new settlements and urbanization impact droughts.

However, beyond the impacts of human activities, there are also variabilities in climate systems that are causing drought in East Africa. The intersection between human activities and climate variabilities greatly exacerbates droughts' frequency, duration and severity.[22] Droughts tend to be extended and harsher during the boreal spring and summer in East Africa, as overall precipitation and water storage considerably decline. Decreased drought frequency is observed during the boreal autumn season, in October and November.[22] Between the severe droughts are also periods of extreme flood conditions that have an equally devastating effect. The intense and persistent droughts followed by floods have created a constant crisis in East Africa.[23]

Impacts of climate change on water resources

Droughts in East Africa have impacted the availability of water by reducing supply and quality. Rivers and lakes are under constant pressure due to droughts which leads to lack of water for domestic use and the reduction in water-dependent economic activities such as crop cultivation and animal husbandry, as well as power generation.

Impact on agriculture

Almost 40% of East Africa's Gross Domestic Product is from agriculture,[24] and over 70% of its labor force is dependent on agriculture.[25] Therefore, the disastrous consequences of drought cannot be overestimated. In 2011, drought led to a devastating famine when lack of rain caused crops to fail.[26]

Impact on human beings

There has been an increasing number of people suffering from frequent drought events in East Africa.[27] From the catastrophic mid-1980s famine in Ethiopia to frequent drought-related food shortages in the last decades, the region's population continues to bear the brunt of droughts. Somalia lost a quarter of a million people to the 2011 famine.[28] Currently, the country is facing another disastrous drought, coupled with regional insecurity, which could have catastrophic consequences.

Policy changes and solutions

Climate change is a serious threat to East Africa where the population has historically been pastoralists and herders. Extreme weather has had a substantial social and economic impact, resulting in conflict, food insecurity and displacement.[29] In 2015, a drought in Ethiopia caused an estimated 22 million people to rely on food aid. Between 2010 and 2020, 26 separate floods, droughts and storm occurrences were reported in Somalia.[29]

Droughts, tsunamis, water-borne illnesses, heatwaves, storm winds, floods, landslides and other threats associated with a changing climate are devastating communities which are incurring enormous losses. Due to their inadequate risk awareness, lack of adaptability and financial limitations, the poor and vulnerable are disproportionately affected.[30]

Communities lack, or have restricted access to, news, as well as to telephones, radios and televisions. Poverty weakens their ability to use strong materials and build sturdy infrastructure to prevent the devastating impacts of floods.[30] If early adaptation techniques and development programs are not implemented more effectively and urgently, food and water insecurity due to climate change will likely worsen.[31]

The close correlation between climatic conditions and livelihood quality means that climate change might significantly impact East Africa's socioeconomic foundation, even with limited or reduced global warming.[31] As aridification and repeated droughts continue, these effects are especially severe in East African countries. Reduced inter-annual rainfall variability, which has been a long-standing phenomenon, may also worsen droughts.[31] These imply a growing risk of pressures associated with drought for both natural and human systems, indicating the urgent need to quantitatively study the expected changes in drought conditions and their potential adverse effects.

If drought prevention and adaptation measures are not implemented, studies indicate that East Africa will experience historic increases in the frequency of drought events by the end of the 21st century.[31]

Adaptation mechanisms and policy implications

Farmers in East Africa choose their coping mechanisms for climate change based on livelihood, gender, age, education, family work, livestock ownership, household assets, food security, training, credit and membership in a community organization.[32] Gender is significant, notably the restricted capacity of female heads of households for adaptation. Men are more inclined to change farming methods and seek employment than women who prefer to cut back on consumption and rely on borrowing and savings. To help women better adapt to climate threats, gender parity needs to be improved, particularly regarding their access to non-farm jobs and training.

Similarly, older farmers rely more on lowering consumption than adding new occupations to adapt to weather threats. This may result from their health issues, highlighting the urgent need for more government assistance for older farmers of any gender. The household assets index, cropland and animal holdings also influence the choice of adaption method by farm households. Large farm families typically alter their farming methods to account for climatic concerns.[32] Because their livestock serves as an insurance mechanism, those who own more cattle rely on savings and borrowing as an adaptation method. Better-educated households seek assistance from government and non-profit organizations and work more hours but don't cut back on consumption. Farmers who have received training in farming and climate-related issues alter their farming operations and take on more work.

Recommended mitigation measures

1. Broader application of water resource management techniques and environmental rehabilitation methods to tackle future water shortages and soil degradation in East Africa is crucial.

2. For drought-vulnerable societies to be better equipped to cope with early drought warnings, it is necessary to build resilient economies. These could aid in minimizing the effects of future droughts on East African socioeconomic activity and environmental functioning.

3. Special consideration should be given to vulnerable regions in need of immediate support and assistance.

4. The provision of effective drought forecasts and early warning systems needs to be significantly improved throughout East Africa.

Conclusions

In this paper, some basic notions about climate change were introduced to the reader, as well as the greenhouse effect and how it causes climate change. We also presented the relationship between global energy demands and CO2 emissions and showed evidence of artificial climate changes documented over the last century. The paper discussed the engineering solutions to climate change such as carbon capture and storage (CCS) and carbon capture and utilization (CCU) technologies and how they play a critical role in removing CO2 from the atmosphere.

The paper also presented a case study of the catastrophic impacts of drought in East Africa. We concluded with policy changes that need to be implemented to address climate change in East Africa along with adaptation mechanisms, policy implications and essential mitigation measures.

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12

Sustainable Transport Policies for Addressing the Impact of Climate Change in Somalia

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Abstract

Greenhouse gas emissions from transportation primarily come from burning fossil fuels which are used to power our cars, trucks, ships, trains and planes. The transport industry is one of the major sources of urban air pollution worldwide, contributing 24% of the Earth's carbon dioxide (CO2) emissions. This rising trend in CO2 emissions has implications on economic livelihoods through global warming and climate change. The increasing pressure of urban air pollution from transportation results in microclimate conditions, coupled with climate change. This will result in a trade-off between economic growth and sustainable development, requiring thoughtful and sound policies. In this study, we reviewed Somali transport policies that specifically address the emissions and pollution that are impacting environmental quality, transportation safety and air pollution. The findings suggested that policy reform is needed, based on localized experiences with sustainable transport policies.

Introduction

The requirement for transportation is a fundamental human need that grows along with population, industrialization and commercial activity. However, the transportation system is one of the largest energy consumers globally with a negative impact on the environment and release of CO2 (Saifullah and Supriya, 2016). Furthermore, it is one of the major sources of urban air pollution, contributing 24% of the world's CO2 emissions. It forms the largest proportion of greenhouse gases that contribute to climate change (IEA, 2020; Siskos and Moysoglou, 2019). A large proportion of greenhouse gas (GHG) emissions can be attributed to transportation, specifically from the burning of gasoline, diesel and other fuels derived from petroleum. The conflict in Somalia has destroyed most of the country's infrastructure such as roads, but the federal government (FGS) and federal member states (FMS) are working to reconstruct them. Although there are no detailed statistics on urban road networks, studies by the World Bank and the African Development Bank (Table 1) indicated that the country has 21,933 kilometers of roads, 13% of which are paved, while more than 90% of the roads have deteriorated and are beyond their service life (NDP, 2016). This paper examines the literature on Somalia's existing transport policies, focusing on how emissions and pollutants affect the environment, transportation safety, air quality and public health.

Table1. Road types (Source: NDP, 2016)

Road type	Primary (km)	Secondary (km)	Rural roads (km)	All roads (km)	Percentage (%)
Paved	2,442	418		2,860	13
Gravel		844		844	4
Earth	220	3,588	14,421	18,229	83
Total	2,662	4,850	14,421	21,933	100

For the last 10 years, Somalia's situation has been returning to normal and this has led to an increase in private transportation, mainly new and used cars, pickups and minibuses imported from Asian countries (Remy Sketching et al., 2012). According to the 2016 African Development Bank report on the country's transport industry (AfDB, 2016), there were 131,523 different types of vehicles in Somalia, as shown in **Table 2.**

Table 2. Estimated number of vehicles by type (AfDB, 2016)

Description	Cars/pickups	Vans/minibuses	Trucks	Total
Total	54,685	66,838	10,000	131,523
Percentage	42%	51%	8%	

Methodology

The methodology and data for this study were based on a desk review of the relevant literature as well as an evaluation of publicly available information. The majority of the data used in the study came from online databases from the African Development Bank Group and the United Nations.

Transportation impact on climate change

Transport is arguably the primary force underlying climate change and contributes significantly to the documented rise in CO2 emissions (IPCC, 2013). The increase in urban air pollution is a result of the use of fossil fuels like gasoline and diesel, which release the greenhouse gas carbon dioxide into the atmosphere. Climate change is a result of CO2 emissions from the burning of fossil fuels, which also causes global warming. CO2 emissions (and other GHGs) are now considered to be the major cause of the observed climatic changes.

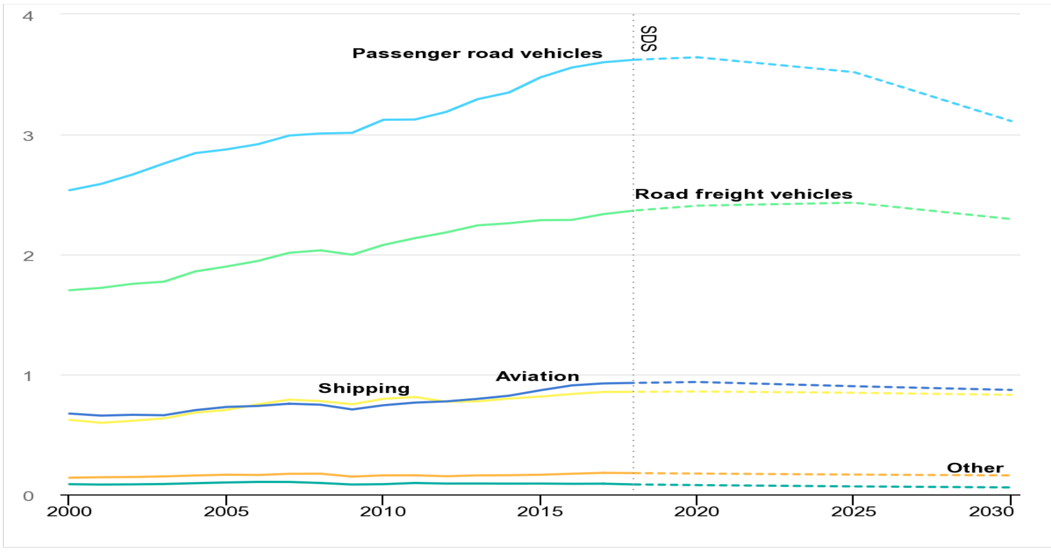

Figure 1. Transport sector CO2 emissions, 2000-2030, https://ourworldindata.org/co2-emissions-from-transport

Several studies have demonstrated the impact of air pollution on people's health globally, but in Africa, the effects are becoming more visible in the form of floods, droughts and altered rain patterns.

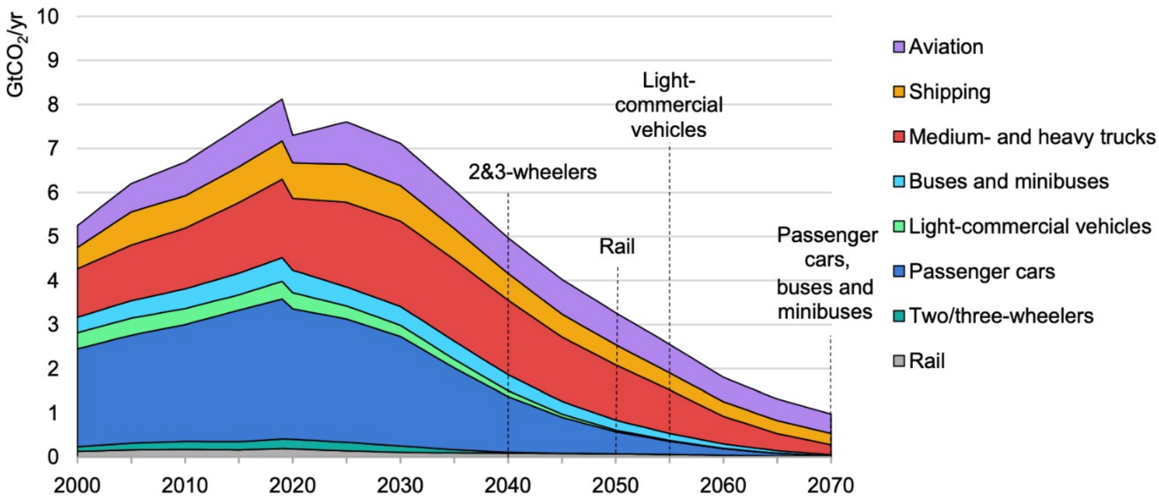

Figure 2. Global CO2 emissions from transport, 2000-2070, IEA (2020). From the Technology Perspective report, which outlines strategies for achieving net-zero CO2 emissions from global energy by 2070.

The United States produces the most CO_2 emissions, followed by Russia, China, Japan, Brazil, Western Europe, Australia and India. CO_2 emissions have been rising (on average) over the previous few decades in the UNECE region (UN, 2015).

Challenges in reducing transport related GHG emissions

Reducing the negative effects of transportation on the environment is a difficult task. Policymakers and academic researchers frequently promote the switch to more effective sustainable transport modes. However, lowering GHG emissions from the transportation industry will likely require a broader range of strategies. The two most industrialized nations in Europe, the United Kingdom and Germany, consistently set their goals higher than those established by other nations, particularly when it comes to cutting CO_2 emissions (Qian Wang, 2016). Africa lacks adequate air quality monitoring systems, making it difficult to implement effective air pollution regulation policy into practice (Mboup and Oyelaran-Oyeyinka, 2019). In October 2014, a framework for the transition to sustainable transportation was adopted by African nations intending to curb air pollution, increase the use of sustainable fuels and improve road safety. The roadmap sought to lower GHG emissions through the use of low-emission non-motorized transportation, improve the standard of public transportation and invest in clean technologies. However, sustainable transport efforts have always varied from one country. In July 2018, the government of Uganda banned the import of vehicles that are more than 15 years old. By lowering import taxes for used hybrid vehicles, Mauritius was able to migrate towards more energy-efficient vehicles. The tax benefit amounted to a 30% discount for hybrids, which resulted in a 50-fold increase in the use of hybrid vehicles imported between 2010 to 2017. The motorcycle is a dominant mode of transport in Rwanda but this leads to high levels of air pollution and rising demand for fuel. In 2015, Rwanda's Ministry of Environment reported that road transport contributed to 13% of the total GHG emissions. Motorcycles accounted for more than a quarter of these emissions. In response, the government introduced a policy to substitute electric motorcycles as an alternative to decrease pollution, petrol and cheap hydro-powered electricity. Despite these efforts, it is widely agreed that low-income countries in Africa have the fewest number of options to adopt sustainable transport systems due to financial restrictions and the lack of functioning institutions to implement the necessary strategies.

Climate and environmental change issues in Somalia

Somalia is currently dealing with challenges including instability, the consequences of climate change and socioeconomic problems such as poverty, inadequate infrastructure, weak institutions and insufficient access to finance. It is experiencing more and more indicators of climate change including changes in weather patterns, rising sea levels, degradation of the land, irregular precipitation and the recurrence of extreme weather.

Infrastructure, forestry, biodiversity, water, marine resources, livestock, agriculture and cities/towns are all expected to be impacted by climate change (INC, 2018). Ongoing security challenges such as armed conflict and terrorism can make it difficult to implement policies to reduce greenhouse gas emissions from transportation, as access to certain areas is limited, making it difficult to improve infrastructure and implement policies.

In Somalia, the energy sector emissions profile is similar to that of the least developed countries. Carbon dioxide (CO2) and methane are the largest contributors to GHG emissions, accounting for 49% and 44% respectively in 2015. Most of the estimated emissions of CO2 resulted from the transport sector, as shown in Figure 2. The CO2 emissions from other industries such as manufacturing, residential and commercial and transportation are relatively insignificant, and from 2000-2014 were greatly reduced due to conflict-related factors.

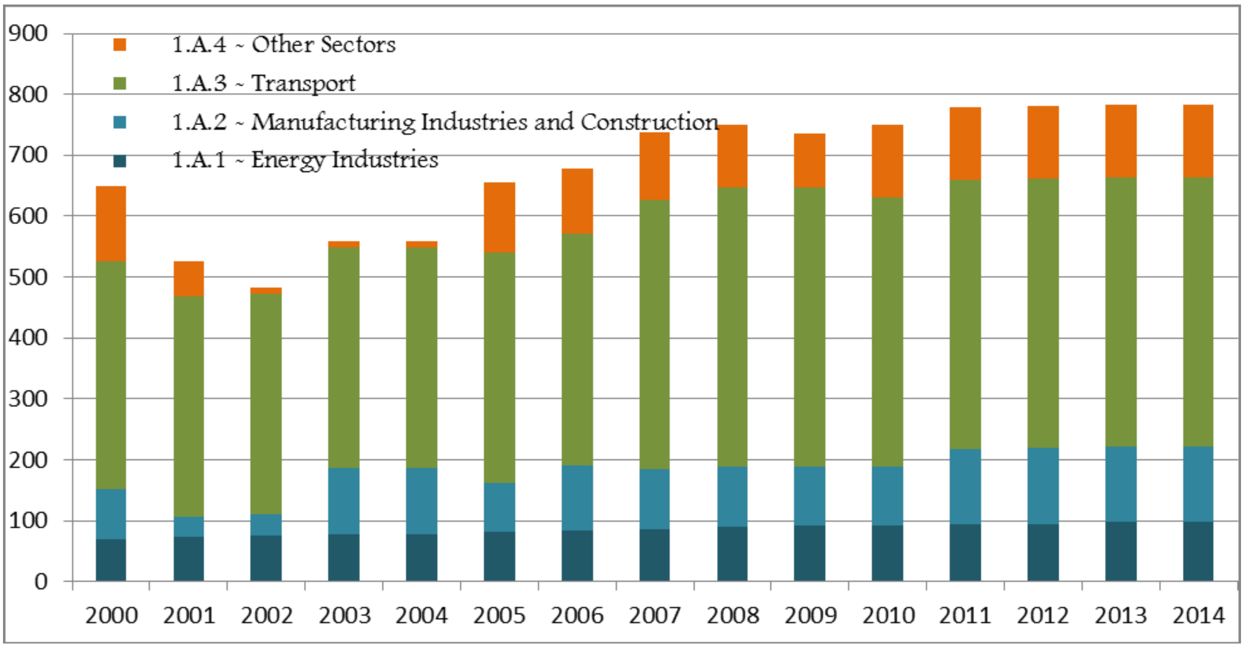

Figure 3: Carbon dioxide emissions (in Gg) from the energy sector Source: OPM, 2018

Cities in Somalia are struggling with severe traffic congestion as the road infrastructure can no longer support the sharp increase in the number of motor vehicles. This has led to an increase in air pollution. Severe floods and desert locust infestations have exacerbated existing vulnerabilities and slowed down necessary reforms.

Figure 4. Typical Mogadishu traffic during peak hours Source: https://www.alamy.com

Most African cities struggle with challenges that include old vehicles without emissions controls, poor vehicle maintenance, a lack of cleaner fuel options, an ineffective regulatory framework for vehicle emissions and poorly enforced laws and regulations where they do exist. There are limited public transportation systems and a heavy reliance on mini-buses, three-wheeled vehicles and Bajaj motorcycles which Somali youths use to make their living. These commercial motorcycles are easy to manoeuvre and can travel on poor roads. However, their popularity has resulted in more accidents, traffic congestion and local air pollution and GHG emissions.

Transport policies to address climate change

Somalia and the rest of Africa are particularly vulnerable to the impacts of climate change which include more frequent droughts, floods and other extreme weather events, as well as reductions in agricultural productivity, risks to food security and conflicts over scarce land and water resources. Climate change is a major threat to sustainable development in Africa and the achievement of the Millennium Development Goals. Africa has the lowest historical GHG emissions of any continent (Gary and Dieter, 2012). The Somali National Adaptation Program was developed with the support of the United Nations Development Program (UNDP) and other international partners and was approved by the Somali cabinet in 2019. The NAP aims to enhance Somalia's adaptive capacity to climate change, reduce its vulnerability and increase its resilience.

The NAP identifies priority sectors that are most vulnerable to the impacts of climate change including agriculture, livestock, fisheries, water resources and energy. It also outlines a range of adaptation measures that can be taken including improving water management, enhancing soil conservation practices, promoting climate-smart agriculture and developing early warning systems for extreme weather events. Reducing CO2 emissions from transportation was not prioritized as Somali cities lack a well-established single authority to address issues with urban transportation and mobility. Instead, the federal government, federal member states and municipal entities are responsible, resulting in confusion and lack of action. The federal government and member states need to agree on a robust capacity enhancement of the environmental management skills of state agencies and municipal authorities. This could involve setting up an independent climate change authority.

Developing an effective climate policy is becoming more and more urgent (Millar et.al., 2017). This study recommends some specific sustainable transport policies that can help address the impact of climate change in Somalia. They include:

Short-term policies

1. Effective regulations must be implemented to ensure old vehicles are taken off the street and technical standards are met for those that are in use. Licenses should only be handed out under strict conditions.

2. The Somali government should work with international partners to ensure that the fuels being imported and sold in the country meet minimum standards. This would help to reduce air pollution, protect public health and support the development of a more sustainable transportation sector.

3. The government should establish regulations that require vehicles to meet minimum fuel efficiency standards. This could be achieved through initiatives such as fuel economy labeling and consumer education campaigns.

Long-term policies.

1. Centers of training and excellence should be set up at universities in Somalia, which could train competent staff who could regulate environmental resources.

2. Professional bodies consisting of Somali experts could be established for those involved in the planning, design and operation of climate-sensitive infrastructure.

3. Climate change must be taken into account while planning and building transportation infrastructure.

Conclusion

Real political courage is needed to take strong action and develop strict polices. The FGS and FMS must establish a national objective for lowering GHG emissions. To meet this target, we must understand the sources of the emissions and have efficient policies in place to do so. More awareness is also needed among urban planners about the detrimental impact of transport on the environment. There is a significant need to address urban transport issues in order to reduce air pollution and the related health impacts, reduce injuries and deaths from road traffic accidents, alleviate congestion and reduce GHG emissions. Federal and regional transportation bodies that are responsible for providing advice on transport-related issues and the effect on climate are also needed. Policies must be tailored to the specific needs and circumstances of the country and implemented in a way that is sustainable and equitable.

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13

Biomimetics for Climate Adaptation: An Analysis of Nature-Inspired Solutions Deployed in Africa's Climate Action

Adewale Opeyemi

Abstract

The Intergovernmental Panel on Climate Change (IPCC) has affirmed that Africa is warming more rapidly than the global average and the world is at the threshold of exceeding a global mean surface temperature of 1.5°C. Mitigation of climate change is crucial for the global community. At the local level, however, the existing effects of climate change in communities have to be addressed with adaptation strategies. Adaptation is a set of responses that help to reduce climate vulnerability and enhance resilience. Nature-based solutions such as the Great Green Wall in Djibouti are commonly used as adaptation strategies. Biomimetics is the study of nature's mechanisms for the purpose of manufacturing new products and solving multifaceted problems. This study looks at the use of nature-based solutions in the Horn of Africa and how biomimetics can be applied in adaptive climate action. The researcher gathered data by desktop investigation, carried out its problem identification by examining relevant case studies and performed a qualitative analysis of biomimetic designs. The study presents developmental policy ideas and discusses biomimetic adaptation responses.

Introduction

Anthropogenic climate change is one of the most significant human-caused occurrences of the last hundred years. Extreme weather events such as flash floods, hurricanes, heavy precipitation and heat waves are happening with a higher intensity and greater frequency. Seven of the 10 countries that are most vulnerable to climate change are in Africa. In 2015, four African countries ranked among the 10 countries most affected.[1]

In Africa, high water stress is estimated to affect about 250 million people and displace up to 700 million by 2030.[2] Drought in East Africa has worsened following consecutive failed rainy seasons combined with heightened conflict, related population displacement and COVID-19 restrictions.[3] All this has occurred while the continent is experiencing a 1.1°C increase from pre-industrial temperatures. Scientific prognostications put the world on the path to a 2.8°C rise by the end of the century.[4]

As climate changes and environmental conditions become more dire, efforts to reverse the trend and maintain temperature increases below a global mean of 1.5°C is imperative. This can be accomplished through the adoption of active and practical climate mitigation techniques. Actions in climate mitigation lead to the reduction of greenhouse gas emissions and therefore limit global warming. As mitigation activities progress, they also need to be merged with adaptation actions. These are risk management activities that help people and societies facing extreme weather events and climate shocks.

Climate adaptation increases the climate resilience of societies susceptible to climate shocks and reduces their vulnerability. It influences their responses to floods, famines, droughts and other climate-related risks and shocks. Adaptation is a sustainable investment in climate resilience and its inclusion in developmental strategies all over Africa is paramount. As climate mitigation technologies are conceived and developed, many have the potential to be applied and used in adaptive capacities. Adaptation technologies and ideas are more effective when they are embedded in the social context and have a sense of culture and place. This often involves the intentional inclusion of various marginalized groups, vulnerable members of the population like women and the physically challenged and indigenous people.

Climate shocks threaten both food and water security and, consequently, jeopardize human safety. In the Horn of Africa, four consecutive rainy seasons have failed since late 2020, a climatic event not seen in at least 40 years. This meteorological drought has resulted in a loss of soil moisture, caused waterways to dry up and led to the deaths of millions of livestock.[5] The IPCC report says, "ecosystem-based adaptation can reduce climate risk while providing social, economic and environmental benefits (high confidence). Direct human dependence on ecosystem services in Africa is high. Ecosystem protection and restoration, conservation agriculture practices, sustainable land management, and integrated catchment management can support climate resilience. Ecosystem-based adaptation can cost less than grey infrastructure in human settlements (e.g., using wetlands and mangroves as coastal protection)."[6]

The Horn of Africa is suffering from some of the most severe droughts in the history of official record keeping. This has led to cyclical famines that threaten the lives of over 50 million people in the region who were suffering from acute food insecurity in 2022.[7] The rise of terror groups in the region is another of the concomitant effects of the climate crisis.

Biomimetics as a technique for adaptation which taps into the ingenuity of nature and the innovation it has developed over billions of years. Harnessing nature and emulating its solutions brings to the fore the ability not only to adapt to a changing climate but to also bring about a long-term solution to some of the intractable problems that people encounter. Nature has evolved ecologically friendly solutions, which generate no waste, consume only the required energy and utilize biodegradable materials.

Statement of purpose

The Horn of Africa has an arid climate and cyclical droughts are not uncommon. However, with increasing climatic shocks, seasonal rainfall has been at its lowest in recorded history since 1981. The poor rainy seasons and the consequent drought have displaced three million people and killed 1.5 million livestock. The searing drought has triggered internecine conflict and territorialism. Groups of herders and pastureland owners have clashed over limited land resources. The herders also attack farmers, displace them and then convert their farmlands into grazing fields. In 2018, this kind of violence displaced one million Somalis.

The United Nations says that people in the Horn of Africa are among the least able to adapt to the effects of climate change due to protracted conflicts that have lasted almost three decades. Weak governance also compounds the effect of these climatic shocks. On the international front, the war in Ukraine has captured the world's attention and the global economy is still recovering from the economic effects of the pandemic which has limited the amount of aid coming into the region.

This study examines the use of nature-based and nature-inspired solutions, which have taken 3.8 billion years of natural evolution to optimize, to the climate crisis in Africa and extrapolate possible applications in the Horn of Africa region.

Methodology

The data was gathered through an extensive desktop investigation, which looked at the importance of nature-based solutions to climate change. It also looked at technologies that can be utilized for both mitigative and adaptive purposes as two edges of a broad sword. Several case studies were examined. The approach was adequate for understanding existing examples of nature-based solutions and their efficacy in tackling the climate crisis and easing the environmental stress it has caused in countless African communities. The researcher also performed a qualitative analysis of biomimetic designs and technologies.

Literature review

Biomimicry is from the Greek words *bios* meaning life and *mimesis* meaning imitation. Biomimicry (also referred to as biomimetics) is an emergent discipline which places an emphasis on nature-inspired innovations. These innovations draw their analogies and concepts from the adaptation and survival of species which have occurred over billions of years. It is defined as a conscious emulation of form, as well as an emulation of natural processes.[8] The field of biomimetics is highly interdisciplinary. It involves the understanding of biological functions, structures and principles of various objects that biologists, physicists, chemists and material scientists find in nature.[9] It can also lead to biologically inspired designs, adaptations or derivations from living nature. In biomimicry, nature is used as a model, as a measure and as a mentor.[10]

Biomimicry poses a specific question as part of the innovative process: "How would nature and organisms within it, whether flora or fauna, solve this problem?" There are a large number of flora and fauna with properties of commercial interest. Molecular scale devices, self-cleaning, drag reduction in fluid flow, antifouling, energy conversion and conservation, reversible adhesion, aerodynamic lift, materials and fibers with high mechanical strength, biological self-assembly, painless piercing, anti-reflection, structural coloration, thermal insulation, self-healing, and sensory aid mechanisms are examples of functionalities found in living nature that are of commercial interest.[11]

These are the kinds of properties which can be used in solving some of the most pressing and intractable problems of our time. The design challenges associated with vision, movement in diverse environments and temperature control have already been solved in myriad ways over millions of years of evolution, providing rich opportunities for the development of biomimetic and bio-inspired materials.[12] Nature is a great model for methods to address our needs and a source for inspiring algorithms, processes, mechanisms, and devices. Implementing innovation based on nature can result in benefits such as improved drugs, stronger and multifunctional materials and superior robots.[13]

We can learn manufacturing techniques from animals and plants including the use of sunlight and the production of materials with no pollution, including the development of biodegradable fibers, ceramics, and plastics. Observing the strategy of nature at both the ecosystem and organism levels improves the understanding of nature's functional attributes.

This understanding is used to create a more sustainable world, better eco-friendly products, and well-grounded green policies.[14] Biomimicry is a way to seek sustainable solutions and it is a unique method of inventing and innovating. Nature-inspired design is inherently regenerative, resilient and reusable.

Biomimicry is one of the best sources of solutions that will allow us to create a positive future and make the shift from the industrial age to the ecological age of humankind.[15] Trans-disciplinary design methods rooted in biomimetics such as eco-mimetics, a reference to the design of buildings that mimic ecosystem processes and functions, provide potential opportunities for climate change adaptation and mitigation. This is accomplished through the optimization of a building's resources.[16]

Biomimetic solutions could also alleviate the effects of climate change on planetary health and human health. For example, activation of the transcription factor Nrf2 (a defense gene) may play a role in protecting animals living in extreme environments, or animals exposed to heat stress, pollution and pesticides.[17]

This is a form of climate change adaptation. Therefore, developing new technologies that support life on Earth shifts biomimetics from a desirable means of technological development to an obligate means for society's adaptation to the climate crisis.[18]

The application of biomimicry in climate adaptation technologies

1. Eradication of disease vectors

Climate change-induced flooding has increased the occurrence of disease vectors such as mosquitoes due to waterlogged spaces. Biomimetic devices have been engineered that help with the removal of mosquito larvae without the use of pesticides or chemicals. An example is the Upod. The Upod is a solar-powered device for killing mosquito larvae inspired by the bladderwort (Ultricularia Vulgaris) – a carnivorous plant that traps and digests insects.

2. Reduction of heat stress and passive cooling

Heat waves are becoming more frequent due to rising temperatures. Mechanical ventilation appliances such as air conditioning units are used in most buildings for alleviating the ensuing discomfort. This puts pressure on the electrical grid which ultimately affects the environment.

Phalanx is an example of a biomimetic passive cooling device. The product is an architectural cladding material which reduces the interior temperature of buildings. The cactus and the termite mound are inspirations for the Phalanx which achieves an average of 30°C in internal temperature reduction. It has both adaptive and mitigative characteristics.

3. Treatment of sewage

The treatment of sewage is an energy-intensive process. It also involves the use of deleterious chemicals which are harmful to the environment. Anaerobic digesters mimic the natural process of digestion in the stomach of ruminants such as cows. This kind of biomimetic process can clean wastewater generated from homes and make stormwater or flood runoff potable.

4. Improved water filtration

This technology mimics nature's filtration process through proteins known as aquaporins and helps alleviate water stress. Kidney cells use aquaporins to move water through their membranes. When aquaporins are used in water purification, water can be purified 50% faster than with conventional technology technology.[19]

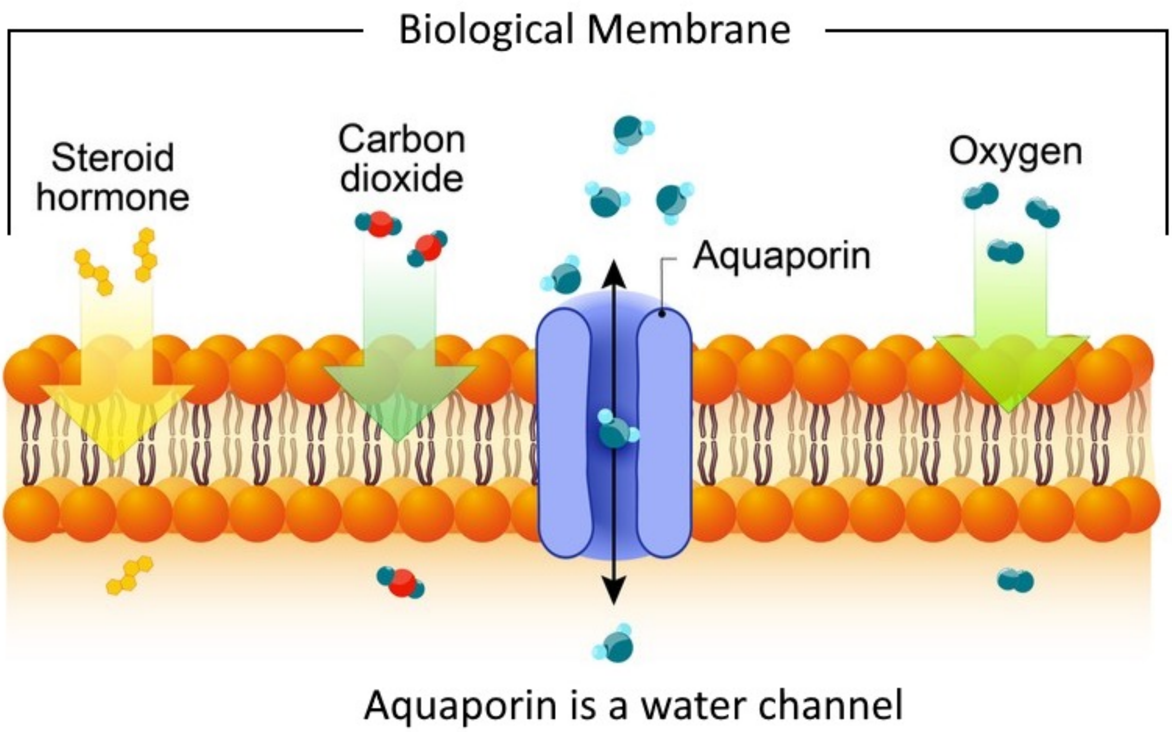

Figure 1. Cross section of a biological membrane with an aquaporin protein[20]

5. Tree planting, reforestation and carbon sequestration

Human incursions into forests, along with wildfires and droughts have caused extensive deforestation. This has led to the vast depletion of the carbon sinks trees provide for the planet and reduced the food resources that they offer. Nucleário is a biomimetic reforestation solution that is designed for use in remote and isolated areas. It is a biodegradable ring that protects tree saplings. The device provides a controlled release of rainwater and a protective barrier from weeds and leaf-destroying insects.[21] Winged seeds, herbaceous plants and forest leaf litter were biomimetic inspirations for Nucleario which serves both mitigation and adaptation purposes.

Figure 2. A Nucleário with a tree sapling growing from its center[22]

6. Fog-catching technologies and water generation

One of the most brutal impacts of climate change on the planet is its effect on water and water sources. Droughts, heat waves and climbing temperatures bring with them water distress which has major consequences on humans, animals and plant life.

Fog catching is a method of generating water from fog condensation. Even without rain, water can be pulled out of the air for drinking and irrigation. The Namibian Desert Beetle is the inspiration for the most effective fog-catching devices.[23] The beetle has hydrophilic (water adherent) bumps on the hydrophobic (water repellent) surface of its body making this phenomenon of fog harvesting possible.

Figure 3. The Namibian Desert Beetle[24]

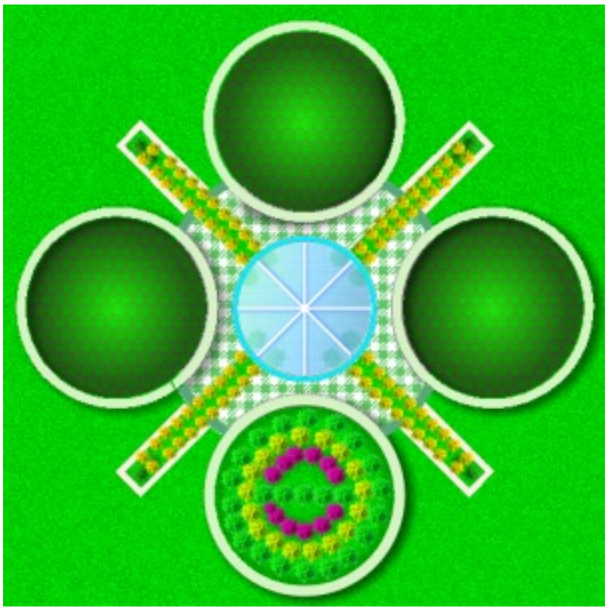

Figure 4. The Namibian Desert Beetle inspired this biomimetic roof design
Source: Author's design portfolio

Figure 5. Front view of the building with the biomimetic roof. The three domical forms and the hydrophilic bumps are seen. Source: Author's design portfolio

Biomimetics and nature-based solutions

Effective climate action requires both nature-based solutions and nature-inspired solutions - the main thrust of biomimetics. Nature-based solutions are actions to protect, sustainably manage or restore natural ecosystems that address societal challenges such as climate change, human health, food and water security and disaster risk reduction effectively and adaptively, simultaneously providing human well-being and biodiversity benefits.[25]

Similarities between nature-inspired and nature-based solutions

Nature-based solutions to climate change		Nature-inspired solutions to climate change (biomimicry)
Similarities		
1.	Both are reliant on nature.	
2.	Both are used for adaptation and mitigation purposes in climate action.	
3.	Both require deliberate human action and intervention.	
4.	Both involve planning.	
5.	Innovative thinking drives both solutions.	
6.	Both help build climate resilience.	
7.	Both can help protect, restore and rejuvenate climate change-distressed landscapes and ecosystems.	
8.	Both are veritable methods for climate risk management.	
9.	Both have huge benefits for biodiversity.	
10.	Both are cost-efficient when weighed against the overall cost of climate change and inaction.	

Table 1. Similarities between nature-inspired and nature-based solutions

Case studies of nature-based and nature-inspired solutions in africa

1. Tree planting in Freetown is reducing flood and landslide risks.

Several years of civil conflict, environmental neglect and exposure to climate change have resulted in the extensive denudation and deforestation of Freetown, Sierra Leone. This has led to an increase in environmentally distressing floods and landslides within the city. With several lives lost and vast infrastructural damage suffered, the project 'Freetown the Treetown' was initiated to grow a million trees in 2022.

The project has set a goal of a 50% increase in green canopy coverage.[26] Community-based tree planters use the TreeTracker app to create a unique geo-tagged record for each new tree planted. The seedlings are monitored and nurtured, and their growth and survival are verified and documented. The growers receive mobile money micropayments for their efforts.[27]

2. South Africa: Biomimicry is used in cleaning storm and wastewater.

The Western Cape in South Africa is home to the Langrug, a slum area on the banks of the River Berg. This informal settlement has limited resources and the river it abuts has become heavily polluted with wastewater and sewage. The resolution of this environmental problem involved the downstream placement of a biomimetic gravity-powered device called the Eco-Machine which prevented stormwater from entering the river. The machine's water treatment system mimics the process of natural ecosystems in cleaning contaminated water. The machine was designed in a site-specific, location-relevant way and it integrates dendritic principles based on energy and water flow in nature. The Eco-Machines are modular and can be merged to form larger systems. This makes the solution economically scalable.[28]

3. The Great Green Wall in the African Sahel

The Great Green Wall is an African initiative which aims to grow an 8,000-kilometer band of greenery across the breadth of the continent – specifically within the Sahel region south of the Sahara desert. The ambitious project is already rejuvenating blighted landscapes, providing food security, restoring ecological systems, creating job opportunities, and reducing heat stress and surface runoff in areas where it is situated. Djibouti is one of the African countries involved in the project. When it is completed it is estimated that it will be three times the size of the Great Barrier Reef and by 2030 will have generated 10 million jobs in rural areas.[29]

	Adaptation technologies[30]	Available biomimetic technology and nature-based solutions	Mimicked natural processes and inspiration
1.	Innovations around infectious diseases	Upod, self-cleaning surfaces	Bladderwort, shark skin
2.	Flood safeguards	Manmade seawalls with mangrove roots; nature-based solutions include widening of natural flood plains, protecting and expanding wetlands, restoring oyster and coral reefs and investing in urban green spaces to reduce run-off[31]	Mangroves
3.	Water purification	Aquaporins	Proteins, kidney cells
4.	Efficient irrigation systems	Fog catching	Namibian Desert Beetle
5.	Agricultural innovation and strategies	Drought-resistant crops, resilient crops,crop rotation, flood-resistant crops, floating agriculture	Drought-tolerant plants such as ice plants, cactus
6.	Water recycling, water capture	Anaerobic digesters, rain harvesting, fog catching	Namibian Desert Beetle
7.	Passive cooling and heating technology	Ventilation, moisture absorption, more efficient fans	Termite mound, ant hill, ticks,
8.	Architectural innovation	Floating homes, stilted homes,	
9.	Carbon sequestration	Trees, bio-cement	Coral reefs
10.	Sensors	Biomimetic algorithms	Swarms of bees

Table 2. Adaptation technologies, available biomimetic technologies and nature-based solutions

Findings and analyses

The study found that biomimicry and biomimetic design are an eco-friendly and effective means of achieving climate adaptation and mitigation. Using nature-based solutions, climate-related problems are solved without the further emission of greenhouse gases. Additionally, the methods are easy to deploy in areas of need. The research found that certain biomimetic water filtration methods like aquaporins purified water with greater efficacy and speed than conventional filtration methods and depended less on electricity.

Buildings that used biomimetic devices for passive cooling, self-cleaning and water recycling put less burden on the power grid and were able to create a richer self-supporting ecosystem. This positions the community for a circular economy with minimal waste. Climate adaptation technologies such as fog-catching devices will help lessen drought-induced water stress in the Horn of Africa.

This study found that these devices, depending on their size, produce several liters of water for households every day while creating a better irrigation plan for farms and subsistence agriculture. Adaptation costs are occasionally high especially when novel forms of technology are under consideration. However, the cost of inaction is higher and more devastating.

Conclusion

Climate change and extreme weather have become major contributors to humanitarian crises all over Africa. It is a stressor of already tenuous socio-economic circumstances, making citizens of these areas more susceptible to prolonged poverty, hunger, malnutrition and illnesses. Several parts of East Africa are facing the most severe droughts the region has ever experienced. This specifically includes the Horn of Arica region. Climate change needs the concerted joint effort of policymakers, academia and citizens of the planet. As the world runs the risk of warming up over 1.5°C above pre-industrial records, action has become imperative. Climate adaptation helps communities manage the impacts of climate change even while the entire global community works hard towards reducing the emission of greenhouse gases and sequestering already emitted carbon dioxide.

Adaptation is of great benefit to us all. It will save lives, protect nature, reduce inequalities and provide new opportunities. It will enhance growth and development. As nature-based and nature-inspired solutions become more commonplace, and their value and efficacy are better understood, they will hopefully be an integral part of every adaptation plan. Adaptation in Africa will reduce vulnerability and increase the resilience of local populations, especially within the Horn of Africa.

Policy outline and recommendations

Public policy is a set of laws passed or actions taken by public officials within government, and by extension the citizens they represent, to address public problems for the benefit of the society.[32] These problems could include social ills such as pervasive poverty, unemployment, pollution, or climate change.

Types of public policy:

1. Distributive policy: Government provides funds to pay for public goods. These include economic assistance like grants, subsidies and aid programs.

2. Redistributive policy: This is the redistributing of government allocations to pay for public goods. It includes progressive taxation, land ownership and welfare policies.

3. Regulatory policy: These are laws and guidelines to define what is allowed and otherwise. They include policies on environmental protection, consumer protection and migration. [33]

Public policy development involves several steps:

1. Problem identification;

2. Setting the policy agenda;

3. Public policy drafting and approval;

4. Public policy implementation; and

5. Public policy evaluation.

Climate adaptation policy: A global perspective

The United Nations Development Program – Global Environment Facility (UNDP-GEF) – established the Adaptation Policy Framework (APF) as a guide for creating and implementing climate adaptation policies.

Four major principles are embedded in the APF and provide a foundation for the development of integrated climate change adaptation actions:

1. The reduction of vulnerability to long-term climate change begins with adaptation to short-term climate variability and extreme events;

2. Climate adaptation takes place at different levels in society including the local level;

3. The assessment of adaptation policies should take place within the context of development; and

4. It is important to develop an adaptation strategy and to implement the strategy through stakeholder involvement. [34]

Environmental policy instruments:

1. Prescriptive regulations
2. Property rights
3. Penalties: taxes, fines, levies
4. Payments: financial incentives
5. Persuasion: awareness campaigns, stakeholder education
6. Provision
7. Environmental reporting: Environmental Impact Assessments (EIA)
8. Precautionary principle

Recommendations

Policy type: Regulatory

Instrument: Prescriptive regulations, persuasion and provision

Policy initiatives for climate adaptation should include broader adoption of nature-based and nature-inspired solutions in regions suffering from climate shocks or at climate risk. This process should include the addition of biomimetics and nature-based solutions to national adaptation plans.

Policy type: Regulatory

Instrument: Persuasion, penalties

There should also be more public education and awareness campaigns around the importance and significance of nature-based and nature-inspired solutions. There should be an emphasis on the protection of animals and plants because of the role they play in providing scientists and other professionals with biomimetic ideas for climate action.

Policy type: Distributive

Instrument: Payments

National and regional competitions should be held to discover cutting-edge ideas in biomimetic innovation around the continent. This type of challenge induces creative thinking along the path of specific enumerated objectives.

Policy type: Regulatory

Instrument: Prescriptive regulations, penalties

Policies around building codes and town planning laws should strongly advise that new buildings include rainwater harvesting facilities and fog-catching devices. This would alleviate water stress when rainfall is low.

Policy type: Distributive

Instrument: Provision, payments

Biomimetic rejuvenation programs should be created for areas exposed to climate-induced blight.

Policy type: Distributive

Instrument: Provision, payments

Government should invest in some of these biomimetic options for climate adaptation. They are nature's perfected solutions to some of the intractable climate-induced problems.

Policy type: Distributive

Instrument: Payments

It is important to support and train African experts in the field of adaptation technology. This can be accomplished through educational institutions and academia. These professionals will help build and design adaptation projects across the continent. This will also help improve capacity building and infrastructural development.

Policy type: Distributive

Instrument: Payments

Government can give financial incentives such as subsidies to companies innovating in biomimetics for climate adaptation. There can also be a tax rebate for homeowners who purchase the technology for climate adaptation. This would lead to a rapid and broad adoption of the technology.

Policy type: Distributive

Instrument: Payments

Government needs to support innovation in the field of biomimetics by funding research and development and incentivizing start-ups founded around the technology.

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14

Accessing to a More Predictable, equitable, and Sustainable Climate Finance

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Abstract

This study aims to model climate finance using the ARIMA approach. This study used data from the OECD development finance statistics to analyze climate-related developments, adaptation and mitigation finance. We used three samples for this study: less developed countries (LDCs), low middle income countries (LMICs) and the East African region and Somalia. After comparing 25 ARIMA models, we chose the one that fit best and used it to forecast future climate finance. The empirical findings indicated that the forecasted climate finance figures deviated significantly from the actual figures, indicating that climate-financing is unpredictable. In addition, Somalia has received inadequate climate-related finance so will not reach its climate financing targets of $48.5 billion for adaptation and $6.96 billion for mitigation. Since climate funding is inadequate and unpredictable, the Somali government (and other governments in the region) cannot develop programs with long-term impacts. The country's economic quality and its citizens' living conditions will be adversely affected. Further, limited climate finance will exacerbate climate-related conflicts and increase the likelihood of violent armed conflict in the future.

Keywords: Climate finance, mitigation; adaptation; climate change

JEL classification: Q54; F64; E6; F37; O16;

Introduction

The long-term shift in temperatures is known as climate change (Rahman 2009, Wild, Folini et al. 2015, Zareian, Eslamian et al. 2017). The fluctuations in temperatures observed around the globe are taking place due to human activities, which are causing life on earth to vanish (Haeberli and Beniston 1998, Steffen, Sanderson et al. 2006, Chen, Zhu et al. 2013). Human behavior has been the key driver of climate change due to the burning of fossil fuels which produces heat-trapping gases (McCaffrey and Buhr 2008, VijayaVenkataRaman, Iniyan et al. 2012, Baldwin and Lenton 2020, Soeder 2021). The impacts of climate change are now observable on all continents, with less developed areas facing the most significant risk (Abram, Henley et al. 2021, Papa, Crétaux et al. 2022, Strugnell, McGregor et al. 2022).

Global warming has pervasive, harsh and irreversible effects on the communities and ecologies in less developed countries (Frölicher, Fischer et al. 2018, Molua 2019, Bergstrom, Wienecke et al. 2021, Abbass, Qasim et al. 2022). These countries are facing a climate crisis affecting their livelihoods and also their security (Ahmed, Ayeb-Karlsson et al. 2019, Farbotko and McMichael 2019, Hossain, Sohel et al. 2020, Shaffril, Ahmad et al. 2020, Rasul 2021). These security threats caused by climate change have extensive implications for the less developed regions (Krampe and Mobjörk 2018, Zougmoré, Partey et al. 2018, Bremberg, Sonnsjö et al. 2019, Spratt, Dunlop et al. 2019, Aminga and Krampe 2020). Many LDC countries like Somalia are suffering from recurrent droughts and floods, which have caused many communities to leave their villages, resulting in climate migration (Eklöw and Krampe 2019, Chaudhry and Ouda 2021, Ahmed, Mohamed et al. 2022, SAĞIR and SAHAL 2022, Song, Scognamillo et al. 2022).

Climate migration has created pressure on host communities with potential conflict between the hosts and the hosted (Alshoubaki and Harris 2018, Estevens 2018, Kudrat-E-Khuda 2020, Kamta and Scheffran 2022, Ronald 2022). Climate migration in Somalia also affects the neighboring countries, creating security concerns in the Horn of Africa (Oğultürk , Eklöw and Krampe 2019, Marsai and Szalai 2021, Seife 2021, Corbet and Záhořík 2022, Regan and Young 2022, Ronald 2022).

Immediate climate interventions are critical for countries like Somalia to live in peace with themselves and with their neighboring countries (Eklöw and Krampe 2019, Thulstrup, Habimana et al. 2020, Warsame, Sheik-Ali et al. 2021, Warsame, Sheik-Ali et al. 2022). There must be short, medium and long-term interventions to curb the impact of climate change and sufficient funds allocated. Without sufficient funding, developing countries' efforts to curb climate change cannot be realized (Campiglio, Dafermos et al. 2018, Pierrehumbert 2019, Samuwai and Hills 2019, Stiglitz 2019). Although channeling funds to developing countries to fight climate change remains one of the primary metrics for success at the Glasgow climate summit (COP26), wealthy nations have failed to fulfil their promises (Lenaerts and Tagliapietra 2021, Mountford, Waskow et al. 2021, Shawoo, Maltais et al. 2021). More than a decade ago, at the 2009 Copenhagen climate talks, rich countries committed $100 billion annually by 2020 to tackle the effects of climate change on underdeveloped nations (Bhattacharya, Calland et al. 2020, Doni, Gasperini et al. 2020, Bhaskar and Srivastava 2021, Seo, Felson et al. 2022). They have reiterated their promises to provide climate funding for those most vulnerable (Cinner, Adger et al. 2018, Harvey, Saborio-Rodríguez et al. 2018, Pörtner, Roberts et al. 2022), but environmental groups say they have already broken their promises (Morriss, Bogart et al. 2011, Ahtuangaruak 2015, Ruiz-Tagle 2016). Whether the climate finance goal is reached or not, it is improbable that the least developed countries (LDCs) will have their climate finance needs met due to the complex and challenging procedures put forward to access the money.

Somalia remains one of the poorest nations on earth, with more than 69 percent of the population living below the international poverty line (Pape and Wollburg 2019, Hanmer, Rubiano-Matulevich et al. 2021). This country is also battling with a flimsy political landscape, lack of security, environmental shocks and the COVID-19 pandemic (Hoehne and Gaas , Belay 2019, Keating and Waldman 2019, Ali 2020). In addition to COVID, the economy is hampered by a reduction in foreign direct investment (FDI), livestock export bans by Gulf nations, derailed national elections and the global recession (Mohamed, Mukhtar et al. , Nor and Masron 2018, Omar 2018, Mohomud 2021, Mtimet, Wanyoike et al. 2021). Consequently, gross domestic product (GDP) dropped by 1.5 percent in 2020 in comparison to the 2.9 percent growth reported in 2019 (Bank 2019, Omar and Ibrahim 2021). It is uncontested that climate change is profoundly unfair (Corbera, Roth et al. 2019, Plein 2019, Taylor and Mikulewicz 2019, Work, Rong et al. 2019, Franco and Borras Jr 2021). The world's most impoverished nations did the least to contribute to global emissions historically, and poorer households in these countries emit less than their wealthy neighbors (Baloch, Khan et al. 2020, Ritchie, Roser et al. 2020, Imran, Zahid et al. 2022, Mignamissi and Djeufack 2022).

Nevertheless, poorer nations and poorer people are more endangered by climate impacts (Javadinejad, Dara et al. 2019, Thomas, Hardy et al. 2019, Maja and Ayano 2021), as they live in areas vulnerable to floods, lack access to clean water and work in jobs like agriculture (Hossain, Sohel et al. 2020, Dryden, Anand et al. 2021, Hoq, Raha et al. 2021, Twinomuhangi, Sseviiri et al. 2021). The situation worsens because LDCs have fewer resources to adapt and invest in protecting their citizens (Radović and Iglesias 2019, Ciplet, Falzon et al. 2022, Scott Cato 2022, Tenzing and Conway 2022).

Somalia contributes almost nothing to changes in the climate but suffers from the consequences (Fruh and Hedahl 2019, Thomas and Warner 2019, Brooks 2020, Al-Delaimy 2022, Kingdon and Gray 2022). It is experiencing irregular floods, recurrent droughts and desert locust infestations resulting in the loss of agricultural and livestock production (Pape and Wollburg 2019, Musei, Nyaga et al. 2021, Bank 2022, Carr 2022). The Somali economy is at risk of collapsing as livestock and agriculture production constitute more than 70 percent of GDP and create millions of jobs directly and indirectly (Majid and McDowell 2012, Shortland 2012, Maystadt and Ecker 2014, Anderson, Bayer et al. 2020, Ismail 2021, Mtimet, Wanyoike et al. 2021). All over Somalia, the devastation of livelihoods continues to rise along with the number of IDPs (Ahmed 1999, Le Sage and Majid 2002, Hemrich 2005, Alinovi, Hemrich et al. 2007, Little 2008, Majid and McDowell 2012). Moreover, the effects of climate change and conflicts are interlinked (Maystadt and Ecker 2014, Koubi 2019, Lwanga-Ntale and Owino 2020, Salih, Baraibar et al. 2020, Song, Scognamillo et al. 2022). Women and children are suffering the most (Payet and Obura 2004, Tadesse 2010, Verhoeven 2011, Hendrix and Salehyan 2012, Pricope, Husak et al. 2013, Devlin and Hendrix 2014). With such complex social, political and economic challenges (Leeson 2007, Powell, Ford et al. 2008, Nur 2017, Nyadera and Ahmed 2020, Hussein, Law et al. 2021, Mohamed, Billa et al. 2022, Yabarow, Mohamed et al. 2022), Somalia's priority is to foster sustainable economic growth and improve living conditions over the next decade.

Somalia presented its first Nationally Determined Contribution (NDC) in 2015.[1] Peacebuilding, adaptation to climate change and sustainable development were the uppermost priorities (Eklöw and Krampe 2019, Crawford and Church 2020, Sitati, Joe et al. 2021). Somalia has submitted an enhanced NDC that is in line with UNFCCC decisions and guidelines which will direct its agenda on climate change for the coming decade and contribute to the global efforts to combat climate change.[2] Somalia acknowledges the urgency of the climate crisis by underscoring adaptation with mitigation co-benefits (Muller 2014, Jayawardhan 2017, Duenwald, Abdih et al. 2022). Somalia remains vulnerable to climate change as approximately 80 percent of the country is regarded as arid and semi-arid lands (Maestre, Salguero-Gómez et al. 2012, Thalheimer and Webersik 2020, Warsame, Sheik-Ali et al. 2021, Warsame, Sheik-Ali et al. 2022). The livestock and agriculture sectors represent more than 70 percent of Somali livelihoods (Beier and Stephansson 2012, Maystadt and Ecker 2014, Warsame, Sheik-Ali et al. 2021, Warsame, Mohamed et al. 2022, Warsame, Sheik-Ali et al. 2022, Warsame, Sheik-Ali et al. 2022).

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1. https://ndcpartnership.org/news/somalia-submits-enhanced-ndc-recognizing-climate-crisis%E2%80%99-urgency-emphasizing-adaptation

2. https://unfccc.int/sites/default/files/NDC/2022-06/Final%20Updated%20NDC%20for%20Somalia%202021.pdf

Somalia is moving ahead with an ambitious, redrafted NDC, reiterating its commitment to the Paris Agreement goals.[3] Likewise, recent stability in the country has allowed the government to invest in institution building, facilitating the creation of a more conducive environment for policies and legislative frameworks (Hamdok 2001, Ottaway 2002, Ahrens and Rudolph 2006, Kimenyi, Mbaku et al. 2010, Fartaag 2013, Osman 2022). The governance of natural resource and climate change initiatives are examples .

In its NDC,[4] Somalia committed to lowering emissions by 30 percent with the Business-As-Usual (BAU) scenario estimate of 107.39 MtCO2eq by 2030—equal to about 32.40 MtCO2eq.[5] The mitigation measures in the NDC will cost around $6.96 billion, but adaptation and improvement of resilience are a matter of national urgency (Amegavi, Langnel et al. 2021, Birkmann, Jamshed et al. 2022, Litardo, Del Pero et al. 2022, Ranger and Mullan 2022, Warsame, Sheik-Ali et al. 2022). Consequently, the NDC suggests numerous adaptation arrangements relating to water resources management, disaster preparedness and management, human settlement, and infrastructure. These resilience and adaptation initiatives will cost $48.5 billion between 2021 and 2030. Climate financing will be essential to meet these goals, meaning cooperation, support and investments from national stakeholders and international partners will be needed (Yu, Evans et al. 2018, Mahat, Bláha et al. 2019, Abi Suroso, Setiawan et al. 2022, Belianska, Bohme et al. 2022, Gomez-Echeverri 2022, Tomlinson 2022). This study investigates climate finance in the LDCs with a special emphasis on Somalia.

Literature review

Climate researchers examined how competing preferences among climate finance donors and domestic players impact the transmission of evolving international rules on climate finance coordination at the national and subnational levels in Zambia (Funder and Dupuy 2022, Shawoo, Dzebo et al. 2022). This study stated that despite the World Bank's early effect on implementing coordination standards, domestic players have gradually weakened and restructured coordination arrangements to better reflect their preferences. Chelminski (2022) examined the effects of climate finance on geothermal development in Indonesia and the Philippines through a comparative case study. Three climate finance mechanisms — utility modifiers, social learning and capacity building — were found to significantly impact the financial, regulatory and technical barriers to geothermal development in Indonesia and the Philippines. However, each one alone is not sufficient to scale the industry. Political will and energy shocks also play an important role. This study addresses policy implications for the success of climate funding and the deployment of renewable energy technologies in emerging nations.

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3. https://ndcpartnership.org/news/somalia-submits-enhanced-ndc-recognizing-climate-crisis%E2%80%99-urgency-emphasizing-adaptation

4. Submitted on 31 July 2021.

5. https://ndcpartnership.org/news/somalia-submits-enhanced-ndc-recognizing-climate-crisis%E2%80%99-urgency-emphasizing-adaptation

While studying Indonesia's political and institutional limits on green financing, researchers indicated that financing markets for green bonds backing renewable energy projects are in high demand (Azhgaliyeva and Liddle 2020, Guild 2020, Setyowati 2020, Bhatnagar and Sharma 2022, Huang, Chau et al. 2022). Nonetheless, the organizational architecture of the renewable energy division has produced a skewed incentive system for Indonesia's political class. For infrastructure, poor institutions and immature financial markets, an absence of viable green projects, and low levels of human capital are additional issues. Japan's sustainable finance sector was also examined and it was discovered that it was considering "climate-related risks and aligning itself with sustainable development goals" (Park and Kim 2020, Schumacher, Chenet et al. 2020, Popescu, Hitaj et al. 2021, Robins, Dikau et al. 2021). To expand sustainable finance and ESG policy integration, the Japanese financial sector needs to take more decisive action.

Mahat, Bláha et al. (2019) studied climate financing and green growth, reevaluating climate-related priorities, institutions and investments in Nepal. This study found that Nepal has begun formulating CF and has incorporated it into the national budget. Other players, such as I/NGOs and civil society, will likely follow the government's lead in establishing coherent, coordinated, and successful climate initiatives. The study suggested establishing a set of long-term adaptation and impact mitigation methods for environmental change precisely and in general. Gutiérrez and Gutiérrez (2019) explored bottom-up perspectives on climate finance which revealed that large national and multinational initiatives draw the majority of climate money and that political leaders' lack of commitment is one of the primary obstacles to climate action. Political leaders must also be willing to confront climate change concerns. After examining the green economy's importance in sustainable development in the EU states, researchers found out that it balances economic development and environmental damage (Lavrinenko, Ignatjeva et al. 2019, Rabe, Streimikiene et al. 2020, Wang and He 2022, Yang, Du et al. 2022).

Hafner, Jones et al. (2020) studied a systems approach to bridging the green financing gap. Policy unpredictability and short-termism in the banking sector were the two most significant impediments to investment. The results demonstrated that identified obstacles constituted a complex system marked by route dependence, lock-in and non-linearity. To guide policy discussions, the paper suggested using systems theory. While planning a long-term policy intervention based on a systems approach, it suggested expanding or developing sustainable investment vehicles. Wang, Tsai et al. (2019) investigated internet finance, green finance and sustainability. The development of a society is accompanied by constrained access to and usage of resources, as well as by adverse environmental repercussions, resulting in limitations and conflicts. Developing a low-carbon economy requires governments to create an enabling environment for green-finance lenders and manufacturers.

Similarly, a study into the comparison of the costs and benefits of green and conventional buildings found that green buildings are more expensive than conventional structures, but they provide a greater return on investment in the long term (Krogstrup and Oman 2019, Sachs, Woo et al. 2019, Guo, Zhou et al. 2021, Ojo-Fafore, Aigbavboa et al. 2021, Shen, Su et al. 2021, Khan, Riaz et al. 2022).

Considering the long-term benefits, the building sector should warm up to green finance to cover the high construction costs. While investigating central banking, climate change and green finance, studies found that environmental concerns can significantly affect financial and macroeconomic stability (Dikau and Volz 2018, Durrani, Rosmin et al. 2020, Khan, Riaz et al. 2022, Madaleno, Dogan et al. 2022). Therefore, it is the role of the government to build effective financial systems to address climate change issues and to aid in generating sustainable green financing by transforming banks into public organizations. Government policy employs a variety of tools to encourage or discourage green loans and investment.

Materials and methods

This study explored whether climate finance is accessible, predictable, equitable and sustainable. It employed climate finance data from OECD, distributed into adaptation, mitigation and climate development finance. This dataset covered climate-related development finance around the world. As shown in the descriptive statistics, the dataset provided some essential data in climate-related development finance from 2000 to 2020. Though this data is considered time series, the time within the year is not specified. For example, there were 6,378 observations in 2010, but the interval between any two observations is unknown. Some observations may have daily or weekly intervals, whereas others may have monthly or quarterly observations. This study emphasized LDC's data in general and Somalia in particular, with comparisons to the region (Burundi, Democratic Republic of the Congo, Djibouti, Eritrea, Ethiopia, Kenya, Rwanda, South Sudan, Sudan, Tanzania and Uganda).

Tests of the Unit Roots hypothesis

The stationarity of the data is examined by utilizing the Augmented Dickey-Fuller (ADF) test. The ADF test is employed to identify whether climate development finance, adaptation development finance and mitigation development finance are stationary or nonstationary.

Autoregressive integrated moving average (ARIMA)

Statistical models such as moving averages, exponential smoothing and ARIMA can be used to model time series (Zhang 2003, de Oliveira and Oliveira 2018, ArunKumar, Kalaga et al. 2022). Since the future values are linear functions of the past values, these models are linear. There has been a great deal of research on linear models in the past few decades since they have proven to be simple to comprehend and apply (Fattah, Ezzine et al. 2018). Time series forecasting models are primarily employed to predict financial and economic outcomes (Siami-Namini, Tavakoli et al. 2019, Sezer, Gudelek et al. 2020, Yu and Yan 2020). The ARIMA method, also known as the Box-Jenkins method, relates to fitting a mixed ARIMA model to a given data set (Khashei, Bijari et al. 2009, Asadi, Tavakoli et al. 2012, Khashei, Rafiei et al. 2013, Khan and Gupta 2020).

Furthermore, ARIMA is a class of models that explain a given time series based on its own lags and the lagged forecast errors (Meyler, Kenny et al. 1998, Zhang and Qi 2005). Hence, its equation can be employed to forecast future values. However, the classical ARIMA approach might become prohibitive (Fattah, Ezzine et al. 2018, Benvenuto, Giovanetti et al. 2020, Hernandez-Matamoros, Fujita et al. 2020, Shahid, Zameer et al. 2020). In many cases, a model cannot be determined when the seasonal adjustment order is high or its diagnostics don't indicate that the time series is stationary after seasonal adjustment. (Burman 1980, Bell and Hillmer 1984, Findley, Monsell et al. 1998, Dagum and Bianconcini 2016). To forecast high variable seasonal demand, the static parameters of the classical ARIMA model are considered the primary constraint (Li, Wong et al. 2006, Choi, Hui et al. 2014, El Bahi, Ezzine et al. 2018, Fattah, Ezzine et al. 2018). Besides requiring a large number of observations to determine the best fit model, the classical ARIMA approach also requires a large number of observations. (Montanari, Rosso et al. 1997, Zhang 2003, Khashei and Bijari 2011, Bontempi, Ben Taieb et al. 2012, Fattah, Ezzine et al. 2018). Likewise, estimating parameters require a large number of observations (Rao 1948, Jackson 2001, Stock and Watson 2002, Peters, Miller et al. 2005, Tian, Alizadeh et al. 2014, Ramey 2016). Therefore, there are some limits to using the ARIMA model. Nonetheless, high quality is reached once the ARIMA model is applied (Faruk 2010, Calheiros, Masoumi et al. 2014, Fattah, Ezzine et al. 2018, Alabdulrazzaq, Alenezi et al. 2021).

Based on the contributions of Yule and Wold, Box and Jenkins devised a practical approach to performing ARIMA models (Fattah, Ezzine et al. 2018, Ghosh 2020). In the Box-Jenkins theory there are three iterative steps: a) identifying the model, b) estimating the parameters, and c) testing the model. In general, if a time series is acquired from the ARIMA technique, it should have some theoretical autocorrelation properties (Harvey 1990, Adhikari and Agrawal 2013, Granger and Newbold 2014, Box, Jenkins et al. 2015, Fattah, Ezzine et al. 2018). Then, for a given time series, one or several possible models should be identified by matching theoretical and empirical autocorrelation patterns (Zhang 2003, Khashei and Bijari 2011, Khashei and Bijari 2012). To identify the order of the ARIMA model, Box and Jenkins recommend using the autocorrelation function (ACF) and the partial autocorrelation function (PACF) of the sample data (Ramsey 1974, Flores, Engel et al. 2012).

For the identification step, a stationary time series must be produced in order to determine the ARIMA model. A stationary time series has constant statistical characteristics including the mean and autocorrelation structure. (Whittle 1953, Rao and Gabr 1980, Zhang 2003, Nason 2006, Grenander and Rosenblatt 2008). As a result, differencing and power transformation are usually necessary to remove the trend and stabilize the variance before fitting an ARIMA model (Zhang 2003, Khashei, Bijari et al. 2009, Fattah, Ezzine et al. 2018, Beard, Marsden et al. 2019). Then the model parameters can be estimated and the model specified.

Finally, the adequacy of the model is evaluated by diagnostic testing. A diagnostic statistic and residual plot can then be used to determine if future values match the current data. Parameters should be estimated and the model validated if it is inadequate. Using diagnostic information can help us develop new models. The Box-Jenkins model uses a strategy of repeating until a high degree of satisfaction and error reduction is achieved (Lu and AbouRizk 2009, Anvari, Tuna et al. 2016, Berríos 2019, Jafarian-Namin, Goli et al. 2019, Sharma, Verma et al. 2022). As a result, the variables can be freely forecast using this model. The future value of a variable in an ARIMA model is a linear combination of its past values and errors. This process can be represented as follows:

$$Y = \emptyset_0 + \emptyset_1 Y_{t-1} + \emptyset_2 Y_{t-2} + \cdots + \emptyset_p Y_{t-p} + \varepsilon_t - \theta_1 \varepsilon_{t-1} - \theta_2 \epsilon_{t-2} - \cdots - \theta_q \epsilon_{t-q}$$

Where,

Y_t = the actual value

Ɛ = the random error at t

$\emptyset_i$ *and* θ_j = the coefficients

p = AR

q = MA

Empirical results

Summary statistics

Based on the summary statistics of the sample 1 (LDCs and LMICs), the study found that the average climate finance (CF) were about $4,723,922, whereas the average of the adaptation finance (AF) and mitigation finance (MF) were about $1,992,831 and $3,140,896 respectively. For sample 2 (East African region), the research identified that the means (averages) of the climate finance, adaptation finance and mitigation were $2,954,370, $1,828,768 and $1,548,938 respectively. This confirmed important inferences as the means of the three variables of sample 2 were less than that of sample 1. On the other hand, the study discovered that the average climate finance for sample 3 (Somalia) was $6,110,003, whereas the average finances for adaptation and mitigation were $5,204,229 and $978,251 respectively. The average CF and AF of sample 3 were more than the average of the other two samples, whereas the average funds for mitigation were smaller.

As a measure of symmetry, skewness is used and a dataset is symmetric if its normal distribution is zero or near to zero (Brys, Hubert et al. 2004, Joh and Malaiya 2014). All of the three samples, as shown in Table 1, had a high positive skewness. A positive skewness indicates data is skewed to the right, which implies that the right tail is longer relative to the left tail. Similarly, all three samples had high kurtosis. As a measure of whether the data are heavy-tailed or light-tailed compared to that of a normal distribution, kurtosis is used (DeCarlo 1997, Westfall 2014). It is likely that datasets with high kurtosis have heavy tails, indicating that these datasets contain outliers. A significant number of outliers were in the data, which suggested disproportionate flows and values of climate finance. This further suggested that climate finance flows were difficult to predict. It was also observed that most climate finance goes to short-term solo projects instead of long-term programs that contributes to the adaptation process effectively or mitigation efforts efficiently.

Table 1: Summary Statistics

	Sample 1		Sample 2			Sample 3		
Stat.	**CDF**	**MDF**	**CDF**	**ADF**	**MDF**	**CDF**	**ADF**	**MDF**
Mean	4723.922	3140.896	2954.370	1992.831	1548.938	6110.003	5204.229	978.2506
Skewness	23.24015	28.01707	14.27760	26.83667	19.66442	3.065088	3.215490	3.797522
Kurtosis	864.1721	1196.668	303.3574	1245.771	608.9700	13.03564	13.70605	18.16659
Jarque-Bera	2.32E+09	4.46E+09	52163960	4.83E+09	2.11E+08	224.7264	253.4626	467.5291
Probability	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Observations	74984	74984	13753	74984	13753	39	39	39

Correlation analysis

A correlation matrix measures the degree of linear relationship between each pair of variables, which can have positive or negative values (between +1 and -1) (Lindley 1990, Wang, Shen et al. 2005, Prematunga 2012). Additionally, a correlation matrix determines the strength and direction of a relationship between two variables. A strong positive relationship existed between CF and MF in all samples, except for sample 3 in which CDF and ADF had a strong positive relationship. Except for sample 3, there was a moderate positive relationship between CF and AF. On the other hand, AF and MF had a weak positive relationship in all samples, except for sample 3, where surprisingly there was a negative relationship. The correlation between CF and MF implied that, as climate finance increases, mitigation finance also increased, whereas AF did not increase in line with MF, except for the sample. On the contrary, the increase of MF was not associated with an increase in AF. This has important policy and practical implications. It shows that the bulk of climate finance goes to mitigation projects of which very little is given to LDCs and MLICs. As shown in the summary statistics, the mean of MF was more than the mean of AF for sample 1, while the mean of AF was more than the mean of the MF for samples 2 and 3. This shows that although the majority of climate finance goes to mitigation-related programs, very little goes to countries in the region including Somalia. These projects do not help poor and low-income households to adapt to the devastations caused by climate change. The study also uncovered that, as illustrated in Table 3, the East African region received about 11% of the global adaptation finance, but only 5% of the mitigation finance.

Table 2 Correlation Matrix

Variable	Sample 1			Sample 2			Sample 3		
	CDF	ADF	MDF	CDF	ADF	MDF	CDF	ADF	MDF
CDF	1	0.44	0.90	1	0.71	0.73	1	0.97	0.09
ADF	0.44	1	0.04	0.71	1	0.08	0.97	1	-0.16
MDF	0.9	0.04	1	0.73	0.08	1	0.09	-0.16	1

The experimental results

Based on real-world data, a financial forecast of climate-related development finance was conducted, and its accuracy and attributes were analyzed. This study also examined the predictability of adaptation and mitigation financing.

i. Tests of the Unit Roots hypothesis

Before starting the modeling state, the Unit Root analysis of the variables was carried out. Results of the Unit Root test for the three variables (CDF, AF and MF) of the three samples (LDCs & LMICs, East African region and Somalia) were conducted employing the augmented Dickey-Fuller (ADF) test. The null hypothesis of the ADF test is a unit root. The Schwarz information criterion chooses the optimal log length of the ADF test. This test is used to examine the stationarity of the data. As reported in Table 4, the results rejected the null hypothesis of a unit root for all three variables (in the levels). This indicated that CDF, AF and MF were stationary at the level.

Table 4: Unit Root Analysis

Variable	Augmented Dickey-Fuller (ADF) test		
	Sample 1	Sample 2	Sample 3
CF	-35.5351***	-34.7426***	-5.0208***
AF	-43.2079***	-42.0011***	-4.7974***
MF	-46.4803***	-48.6882***	-6.5820***

Notes: *** indicates significance at the 1% level.

ii. Modeling stage

Based on the Box-Jenkins approach, this study was divided into three parts: identification, estimation and verification. Based on the three samples explained earlier, Tables 5, 6 and 7 present models that were derived from the data presented in these tables. Time series autocorrelations can be computed and plotted using the Autocorrelation Function (ACF) and the Partial Autocorrelation Function (PACF) (Hipel, McLeod et al. 1977, Abdel-Aal and Mangoud 1998, Khan and Gupta 2020). Autocorrelation is the correlation between observations of a time series separated by k time units, while the ACF is the plot used to show the correlation between the points, up to and including the lag unit (Godeke, Malik et al. 2020, Kim and King 2020, Katrakazas, Michelaraki et al. 2021, Vig and Kaur 2022). In ACF, the coefficient of correlation is shown on the x-axis, while the number of lags is shown on the y-axis. A partial autocorrelation measures how well the term is related to other terms that have been considered (Afyouni, Smith et al. 2019, Khan and Gupta 2020, Tay 2021).

The ACF and PACF of the three variables of the three samples are given in Figures 1, 4 and 7. As shown in the ACF and PACF of CDF and evidenced by other econometrics tests (such as the method of ARMA Maximum Likelihood (BFGS)), the variable needs no differentiation, implying the use of data at level (0). Similar to CDF, the MF does not require any differentiation as shown in the method of ARMA Maximum Likelihood (BFGS) and the results of ACF and PACF. Nonetheless, the third variable (AF) needs to be differentiated as one (1) as evidenced by the method of ARMA Maximum Likelihood (BFGS). The logic behind the model's use of data at difference (1) might be due to the presence of seasonality or outliers in the data, which may affect the mean, variance and other properties of the data (a condition for stationary data).

After the modeling stage was completed, the next step was to proceed to the forecasting stage to identify the predictability of the variables. After analysis, we found that the predicted values of climate finance are far bigger than the actual values, indicating that prediction in climate change funding is unlikely.

Sample 1: LDCs and LMICs

For sample 1, the study explored 79,240 observations of which 240 were used for forecasting. CDF is modeled employing ARIMA. As CDF was stationary at level (0), CDF (0) was used for the ARIMA modeling. Twenty-five ARIMA models were estimated. Out of the 25, ARIMA (4,4) was selected as it has the lowest AIC value (see Fig. 3). AF was modeled using the same approach. Out of the 79,228 observations considered for analysis, 228 were reserved for forecasting. After estimating 25 ARIMA models, the study found that ARIMA(4,4) was the best fitted model as it showed the lowest AIC value (see Fig. 3). Likewise, the study modeled MF using 79,240 observations. Approximately 240 were used for forecasting. Unlike CDF and AF, the study identified that ARMA(4,2) was the best model as it provided the lowest AIC value (see Fig. 3).

Climate Finance (CF)								Adaptation Finance (AF)								Mitigation Finance (MF)							
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob		Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob		Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob	
		1	0.177	0.177	2487.1	0.000				1	0.100	0.100	776.62	0.000				1	0.101	0.101	790.35	0.000	
		2	0.195	0.169	5510.1	0.000				2	0.089	0.080	1390.5	0.000				2	0.155	0.146	2643.3	0.000	
		3	0.141	0.088	7092.4	0.000				3	0.075	0.060	1824.3	0.000				3	0.095	0.069	3339.6	0.000	
		4	0.132	0.072	8467.5	0.000				4	0.091	0.073	2463.7	0.000				4	0.098	0.064	4079.6	0.000	
		5	0.131	0.071	9822.7	0.000				5	0.063	0.039	2770.9	0.000				5	0.081	0.047	4584.0	0.000	
		6	0.112	0.047	10813.	0.000				6	0.090	0.067	3395.1	0.000				6	0.074	0.038	5005.6	0.000	
		7	0.111	0.046	11788.	0.000				7	0.103	0.076	4222.4	0.000				7	0.066	0.031	5344.4	0.000	
		8	0.101	0.036	12591.	0.000				8	0.058	0.022	4482.4	0.000				8	0.059	0.024	5609.2	0.000	
		9	0.103	0.039	13424.	0.000				9	0.050	0.017	4678.7	0.000				9	0.064	0.031	5922.6	0.000	
		1...	0.083	0.018	13968.	0.000				1...	0.059	0.027	4947.1	0.000				1...	0.054	0.021	6145.5	0.000	
		1...	0.090	0.029	14610.	0.000				1...	0.055	0.022	5177.9	0.000				1...	0.055	0.023	6380.8	0.000	
		1...	0.075	0.015	15058.	0.000				1...	0.057	0.026	5428.9	0.000				1...	0.048	0.016	6557.5	0.000	
		1...	0.087	0.030	15656.	0.000				1...	0.067	0.034	5775.7	0.000				1...	0.063	0.032	6859.1	0.000	
		1...	0.074	0.016	16088.	0.000				1...	0.055	0.021	6013.0	0.000				1...	0.048	0.016	7032.8	0.000	
		1...	0.069	0.012	16469.	0.000				1...	0.043	0.011	6157.9	0.000				1...	0.041	0.007	7159.3	0.000	

Fig. 1: ACF and PACF

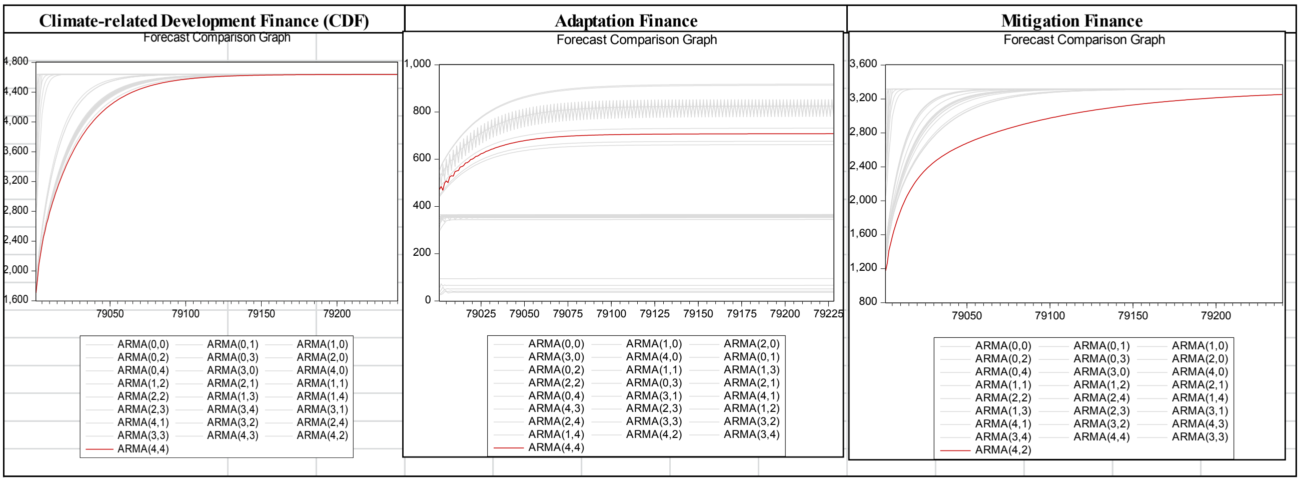


Fig. 2: Forecast Comparison Graph

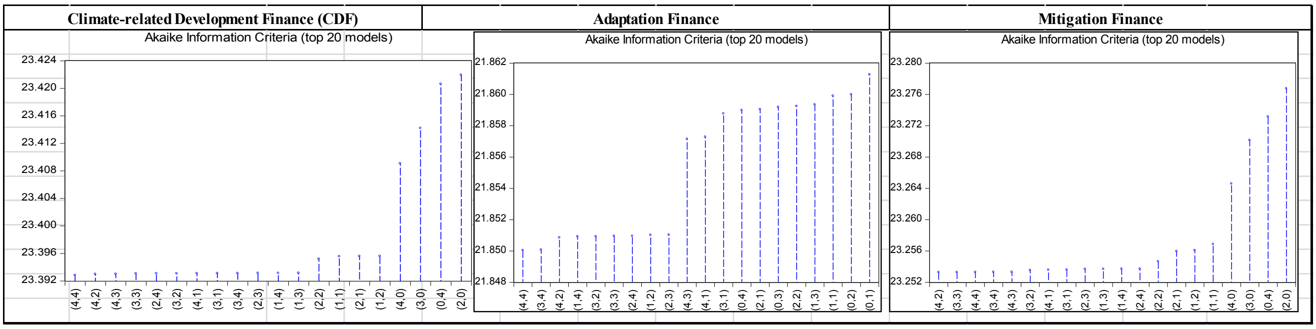


Fig. 3: Akaike Information Criteria (AIC)

Table 5 shows the findings of the predicted values of ARIMA (4, 0, 4), ARIMA (4, 0, 4) and ARIMA (4, 0, 2) which were considered the best models for CDF, AF, and MF respectively. Figure 4 shows graphic illustration of the accuracy level of the predicted climate finance against actual climate finance to check the performance of the fitted ARIMA model. Figure 4 demonstrates that the performance is not satisfactory as the forecast values deviate significantly from the actual values.

Table 5: Summary of the Fitted Models (Sample 1)

Parameter	CDF		AF		MF	
	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
C	4637.868	0.00	0.008998	0.96	3315.341	0.00
AR(1)	0.082572	0.00	-0.05081	0.00	1.890799	0.00
AR(2)	1.203386	0.00	0.163522	0.00	-0.82388	0.00
AR(3)	0.051765	0.00	0.755107	0.00	-0.12201	0.00
AR(4)	-0.379438	0.00	0.010065	0.00	0.054074	0.00
MA(1)	0.025366	0.14	-0.88116	0.00	-1.81645	0.00
MA(2)	-1.076325	0.00	-0.22989	0.00	0.819472	0.00
MA(3)	-0.108243	0.00	-0.61169	0.00	n.a	n.a
MA(4)	0.284985	0.00	0.722997	0.00	n.a	n.a
R-squared (R2)	0.09		0.47		0.07	

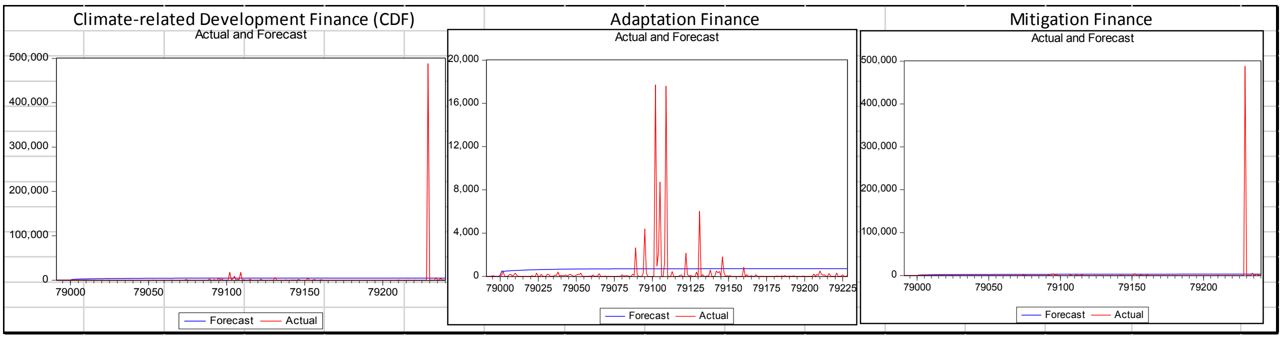
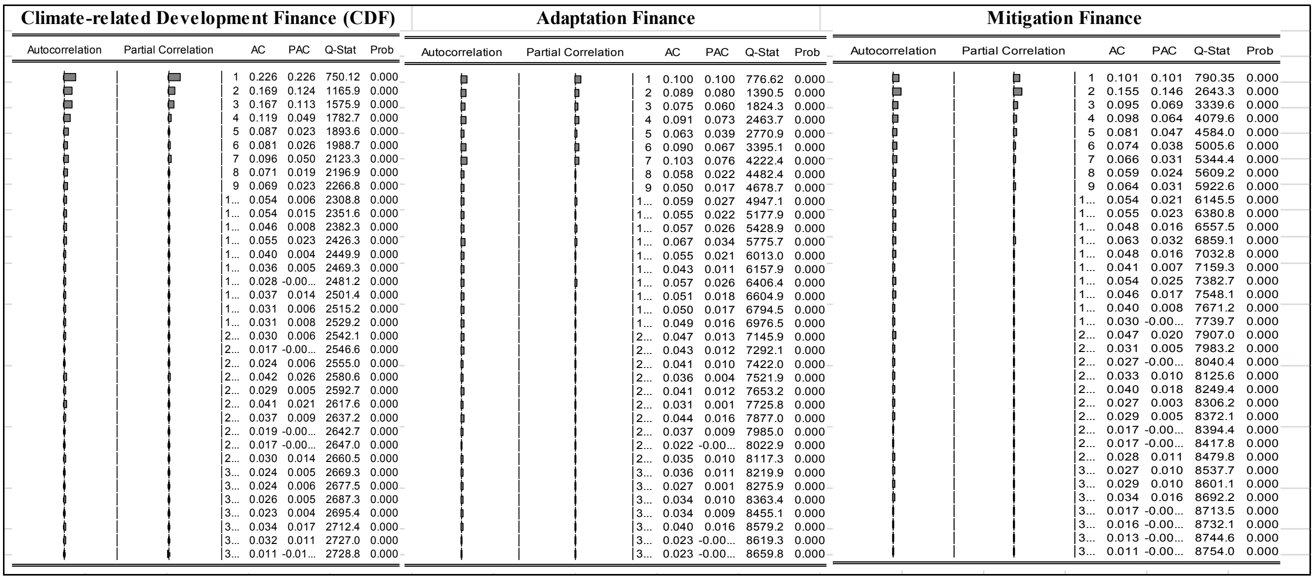


Fig. 4: Actual Values vs Predicted Values of Climate Finance (Sample 1)

Sample 2: East African region

For sample 2, the study explored 14,635 observations of which 635 were used for forecasting. The three variables (CDF, AF and MF) were modeled utilizing the ARIMA model. For each variable, the study estimated 25 ARIMA models. ARMA (4,4), ARMA (4,4) and ARIMA(4,2) were selected for CDF, AF and MF respectively as they had the lowest AIC value (see Fig. 6).



Climate-related Development Finance (CDF)

	AC	PAC	Q-Stat	Prob
1	0.226	0.226	750.12	0.000
2	0.169	0.124	1165.9	0.000
3	0.167	0.113	1575.9	0.000
4	0.119	0.049	1782.7	0.000
5	0.087	0.023	1893.6	0.000
6	0.081	0.026	1988.7	0.000
7	0.096	0.050	2123.3	0.000
8	0.071	0.019	2196.9	0.000
9	0.069	0.023	2266.8	0.000
1...	0.054	0.006	2308.8	0.000
1...	0.054	0.015	2351.6	0.000
1...	0.046	0.008	2382.3	0.000
1...	0.055	0.023	2426.3	0.000
1...	0.040	0.004	2449.9	0.000
1...	0.036	0.005	2469.3	0.000
1...	0.028	-0.00...	2481.2	0.000
1...	0.037	0.014	2501.4	0.000
1...	0.031	0.006	2515.2	0.000
1...	0.031	0.008	2529.2	0.000
2...	0.030	0.006	2542.1	0.000
2...	0.017	-0.00...	2546.6	0.000
2...	0.024	0.006	2555.0	0.000
2...	0.042	0.026	2580.6	0.000
2...	0.029	0.005	2592.7	0.000
2...	0.041	0.021	2617.6	0.000
2...	0.037	0.009	2637.2	0.000
2...	0.019	-0.00...	2642.7	0.000
2...	0.017	-0.00...	2647.0	0.000
2...	0.030	0.014	2660.5	0.000
3...	0.024	0.005	2669.3	0.000
3...	0.024	0.006	2677.5	0.000
3...	0.026	0.005	2687.3	0.000
3...	0.023	0.004	2695.4	0.000
3...	0.034	0.017	2712.4	0.000
3...	0.032	0.011	2727.0	0.000
3...	0.011	-0.01...	2728.8	0.000

Adaptation Finance

	AC	PAC	Q-Stat	Prob
1	0.100	0.100	776.62	0.000
2	0.089	0.080	1390.5	0.000
3	0.075	0.060	1824.3	0.000
4	0.091	0.073	2463.7	0.000
5	0.063	0.039	2770.9	0.000
6	0.090	0.067	3395.1	0.000
7	0.103	0.076	4222.4	0.000
8	0.058	0.022	4482.4	0.000
9	0.050	0.017	4678.7	0.000
1...	0.059	0.027	4947.1	0.000
1...	0.055	0.022	5177.9	0.000
1...	0.057	0.026	5428.9	0.000
1...	0.067	0.034	5775.7	0.000
1...	0.055	0.021	6013.0	0.000
1...	0.043	0.011	6157.9	0.000
1...	0.057	0.026	6406.4	0.000
1...	0.051	0.018	6604.9	0.000
1...	0.050	0.017	6794.5	0.000
1...	0.049	0.016	6976.5	0.000
2...	0.047	0.013	7145.9	0.000
2...	0.043	0.012	7292.1	0.000
2...	0.041	0.010	7422.0	0.000
2...	0.036	0.004	7521.9	0.000
2...	0.041	0.012	7653.2	0.000
2...	0.031	0.001	7725.8	0.000
2...	0.044	0.016	7877.0	0.000
2...	0.037	0.009	7985.0	0.000
2...	0.022	-0.00...	8022.9	0.000
2...	0.035	0.010	8117.3	0.000
3...	0.036	0.011	8219.9	0.000
3...	0.027	0.001	8275.9	0.000
3...	0.034	0.010	8363.4	0.000
3...	0.034	0.009	8455.1	0.000
3...	0.040	0.016	8579.2	0.000
3...	0.023	-0.00...	8619.3	0.000
3...	0.023	-0.00...	8659.8	0.000

Mitigation Finance

	AC	PAC	Q-Stat	Prob
1	0.101	0.101	790.35	0.000
2	0.155	0.146	2643.3	0.000
3	0.095	0.069	3339.6	0.000
4	0.098	0.064	4079.6	0.000
5	0.081	0.047	4584.0	0.000
6	0.074	0.038	5005.6	0.000
7	0.066	0.031	5344.4	0.000
8	0.059	0.024	5609.2	0.000
9	0.064	0.031	5922.6	0.000
1...	0.054	0.021	6145.5	0.000
1...	0.055	0.023	6380.8	0.000
1...	0.048	0.016	6557.5	0.000
1...	0.063	0.032	6859.1	0.000
1...	0.048	0.016	7032.8	0.000
1...	0.041	0.007	7159.3	0.000
1...	0.054	0.025	7382.7	0.000
1...	0.046	0.017	7548.1	0.000
1...	0.040	0.008	7671.2	0.000
1...	0.030	-0.00...	7739.7	0.000
2...	0.047	0.020	7907.0	0.000
2...	0.031	0.005	7983.2	0.000
2...	0.027	-0.00...	8040.4	0.000
2...	0.033	0.010	8125.6	0.000
2...	0.040	0.018	8249.4	0.000
2...	0.027	0.003	8306.2	0.000
2...	0.029	0.005	8372.1	0.000
2...	0.017	-0.00...	8394.4	0.000
2...	0.017	-0.00...	8417.8	0.000
2...	0.028	0.011	8479.8	0.000
3...	0.027	0.010	8537.7	0.000
3...	0.029	0.010	8601.1	0.000
3...	0.034	0.016	8692.2	0.000
3...	0.017	-0.00...	8713.5	0.000
3...	0.016	-0.00...	8732.1	0.000
3...	0.013	-0.00...	8744.6	0.000
3...	0.011	-0.00...	8754.0	0.000

Fig. 5: ACF and PACF

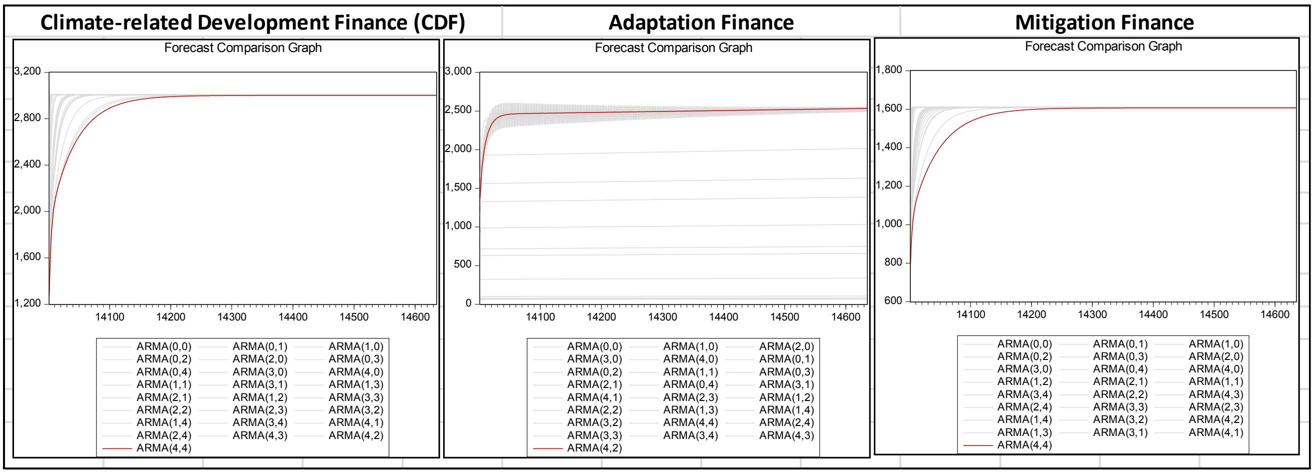


Fig. 6: Forecast Comparison Graph

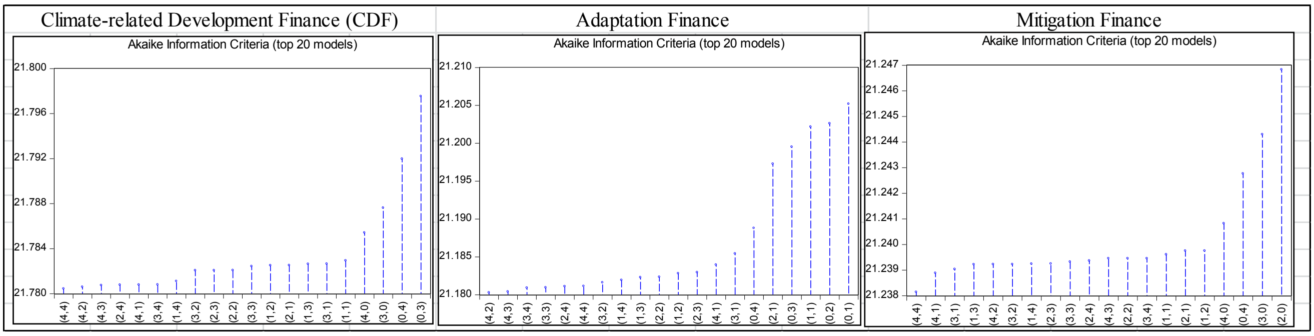


Fig. 7: Akaike Information Criteria (AIC)

As shown in Table 6, the results of the projected values of ARIMA (4, 0, 4), ARIMA (4, 0, 2) and ARIMA (4, 0, 4) were considered the best models for CDF, AF and MF respectively. The graphic illustration of the accuracy level of the predicted values against actual values are shown in Figure 8 to see the performance of the fitted ARIMA model. Figure 4 established that the performance was not satisfactory as the forecast values deviated significantly from the actual values.

Table 6: Summary of the Fitted Models (Sample 2)

Parameter	CDF		AF		MF	
	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
C	3001.3300	0.00	0.1179	0.45	1606.8150	0.00
AR(1)	1.3663	0.00	0.9174	0.00	-0.0804	0.58
AR(2)	-0.7351	0.00	0.0105	0.01	1.4980	0.00
AR(3)	0.7562	0.00	0.0453	0.00	0.1032	0.36
AR(4)	-0.4003	0.00	-0.0602	0.00	-0.5428	0.00
MA(1)	-1.1949	0.00	-1.8383	0.00	0.1757	0.23
MA(2)	0.6195	0.00	0.8384	0.00	-1.3924	0.00
MA(3)	-0.6635	0.00	n.a	n.a	-0.1846	0.10
MA(4)	0.2744	0.00	n.a	n.a	0.4492	0.00
R-squared (R2)	0.08		0.46		0.03	

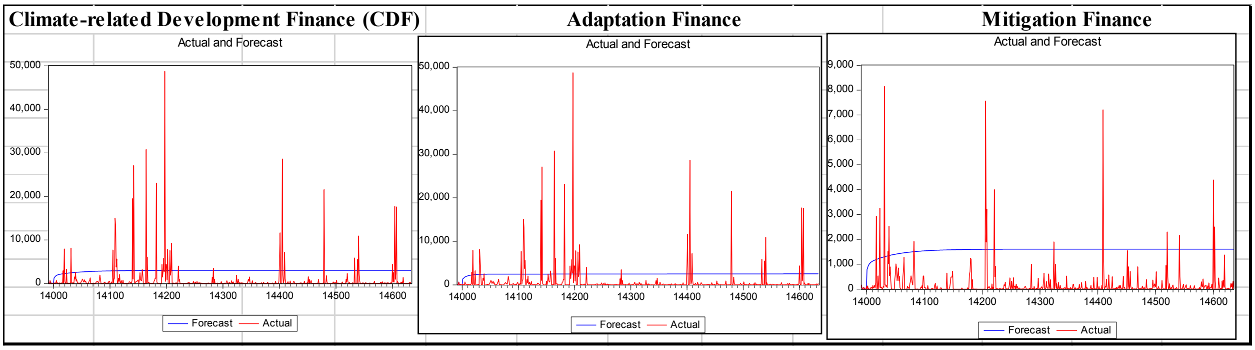


Fig. 8: Graph of Actual Values vs Predicted Values of Climate Finance (Sample 2)

Sample 3: Somalia

For sample 3, the research explored 50 observations of which five were used for forecasting. The ARIMA models of the three variables (CDF, AF and MF) were estimated. Similar to other samples, the study estimated 25 ARIMA models for each variable. Out of the 25 models, ARIMA (4,4), ARIMA (4,4), and ARIMA(4,2) were selected for CDF, A and MF respectively as they had the lowest AIC value (see Fig. 6).

Climate-related Development Finance (CDF)

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.334	0.334	5.9114	0.015
		2	0.075	-0.04...	6.2201	0.045
		3	-0.00...	-0.02...	6.2234	0.101
		4	-0.05...	-0.04...	6.3980	0.171
		5	-0.08...	-0.05...	6.7821	0.237
		6	-0.07...	-0.03...	7.1546	0.307
		7	-0.10...	-0.07...	7.7976	0.351
		8	-0.04...	0.015	7.9002	0.443
		9	-0.00...	-0.00...	7.9029	0.544
		1...	-0.02...	-0.04...	7.9585	0.633
		1...	-0.01...	-0.00...	7.9773	0.715
		1...	-0.05...	-0.06...	8.1627	0.772
		1...	-0.05...	-0.03...	8.4005	0.817
		1...	-0.07...	-0.06...	8.8244	0.842
		1...	-0.07...	-0.04...	9.2430	0.864

Adaptation Finance

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.329	0.329	5.7281	0.017
		2	-0.00...	-0.12...	5.7308	0.057
		3	0.029	0.084	5.7766	0.123
		4	-0.07...	-0.13...	6.0797	0.193
		5	-0.09...	-0.02...	6.6087	0.251
		6	-0.06...	-0.03...	6.8192	0.338
		7	-0.06...	-0.04...	7.1100	0.418
		8	-0.01...	0.028	7.1165	0.524
		9	-0.03...	-0.07...	7.2098	0.615
		1...	-0.01...	0.033	7.2158	0.705
		1...	0.012	-0.02...	7.2256	0.781
		1...	-0.07...	-0.08...	7.6262	0.814
		1...	-0.05...	-0.00...	7.8575	0.853
		1...	-0.05...	-0.06...	8.0672	0.886
		1...	-0.04...	-0.00...	8.2325	0.914

Mitigation Finance

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.08...	-0.08...	0.4067	0.524
		2	0.116	0.109	1.1336	0.567
		3	0.029	0.049	1.1801	0.758
		4	0.154	0.151	2.5201	0.641
		5	0.066	0.087	2.7726	0.735
		6	0.132	0.119	3.8067	0.703
		7	0.009	0.007	3.8114	0.801
		8	-0.02...	-0.08...	3.8528	0.870
		9	0.094	0.050	4.4115	0.882
		1...	-0.12...	-0.15...	5.4318	0.861
		1...	0.244	0.204	9.4143	0.584
		1...	-0.10...	-0.05...	10.163	0.602
		1...	-0.08...	-0.15...	10.693	0.637
		1...	-0.07...	-0.06...	11.146	0.675
		1...	-0.11...	-0.20...	12.171	0.666

Fig. 9: ACF and PACF

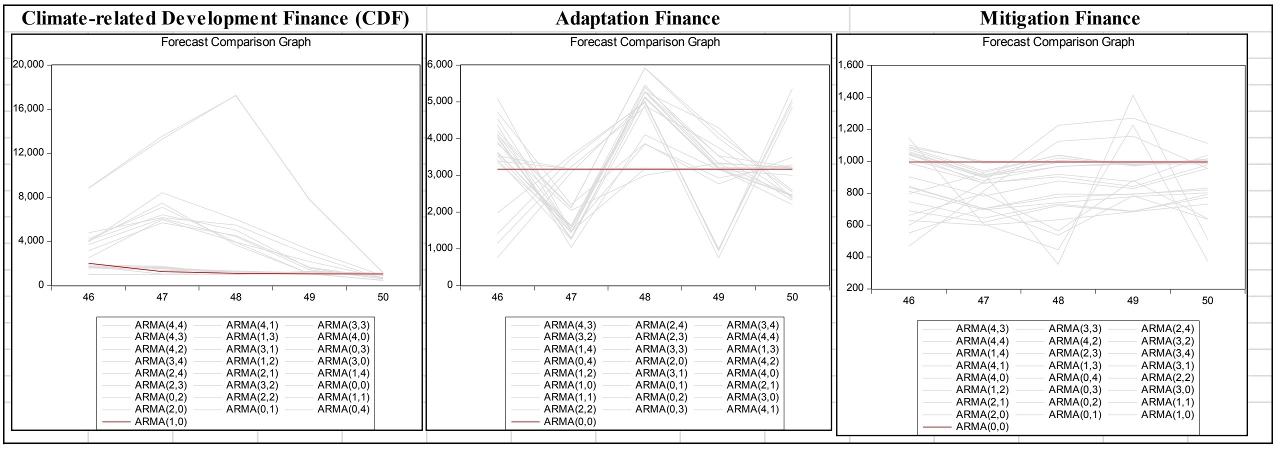


Fig. 10: Forecast Comparison Graph

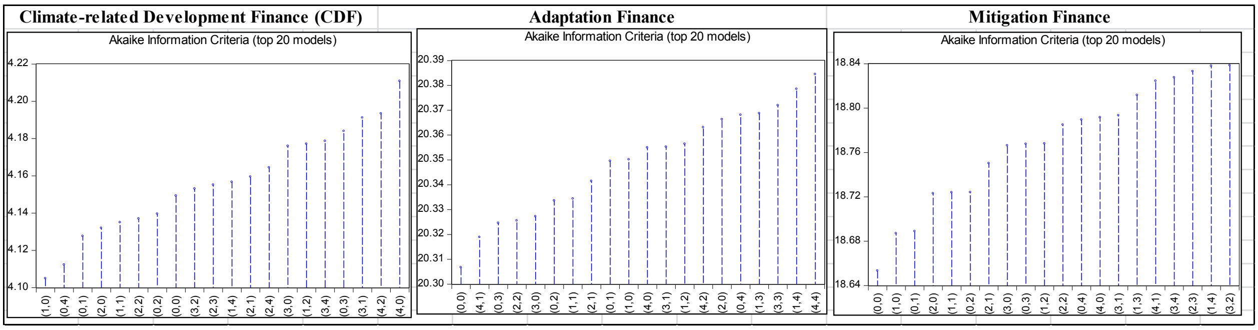


Fig. 11: Akaike Information Criteria (AIC)

The results of the predicted values of ARIMA (1, 0), ARIMA (0, 0) and ARIMA (0, 0) are shown in Table 7 as the best models for CDF, AF and MF respectively. The figure depicts a visual image of the level of accuracy of the predicted value of the variables against their actual value to see the performance of the fitted ARIMA model. Figure 12 shows that the forecasts were not acceptable as the predicted values deviated significantly from the actual values. Furthermore, Table 8 contains the predicted values of the fitted model against the actual values of the last five (out of 50) grants forecasted. From the table, it is evident that the forecasts were not acceptable as the predicated values deviated significantly from the actual values. For CDF and AF, the predicted values were very low compared to the actual values, whereas the predicted values were very high compared to the actual values for MA.

Table 7: Summary of the Fitted Models (Sample 3)

Parameter	CDF		AF		MF	
	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
C	6.9534	0.00	3167.701	0.00	995.3928	0.01
AR(1)	0.2933	0.05	n.a	n.a	n.a	n.a
MA(1)	n.a	n.a	n.a	n.a	n.a	n.a
R-squared (R2)	**0.09**		**0.00**		**0.00**	

Table 8: Sample of Empirical Results of ARMA (1, 0), ARMA (0, 0) and ARMA (0, 0)

Observations	Climate-related Development Finance (CDF)		Adaptation Finance		Mitigation Finance	
	Actual Values	Predicted Values	Actual Values	Predicted Values	Actual Values	Predicted Values
1	10,000,000	2,028,977.59	10,000,000	3,167,700.90	54,500	1,117,530
2	58,038,750	1,270,951.00	58,038,750	3,167,700.90	54,500	1,117,530
3	28,875,000	1,108,034.62	28,875,000	3,167,700.90	54,500	1,117,530
4	1,815,000	1,064,344.39	1,815,000	3,167,700.90	54,500	1,117,530
5	100,000	1,051,861.53	100,000	3,167,700.90	54,500	1,117,530

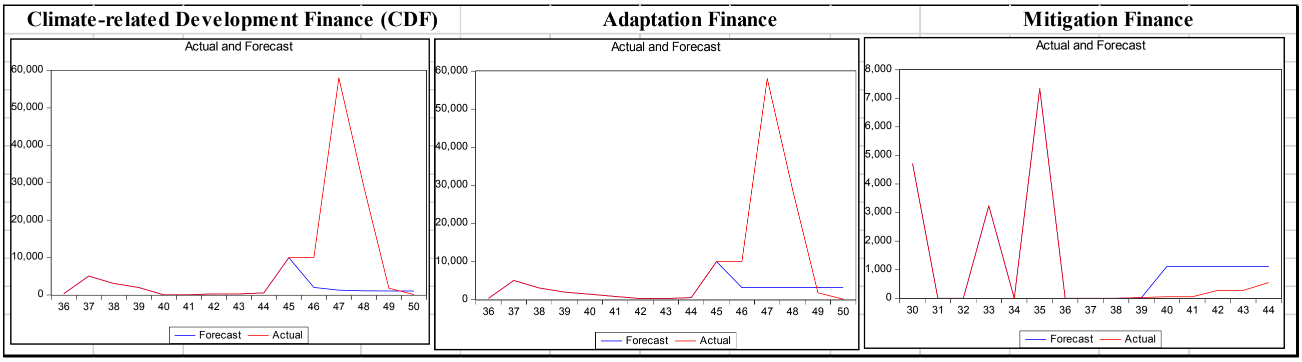


Fig. 12: Graph of Actual Values vs Predicted Values of Climate Finance (Sample 3)

To further analyze the forecast accuracy of the modeling, the probability of overvaluation and undervaluation was computed. It is evident from the results that undervaluation was more likely than overvaluation, implying that climate funding was lower than the expected amounts. Out of the 647 CDF observations of sample 2 used for forecasting, 610 (about 94%) were below the expected value. Similarly, out of the 240 observations of sample 1, only six (2.5%) were overvalued, whereas the remaining 97.5% (about 234) were undervalued, indicating the extent to which climate finance is unpredictable.

Table 9: Forecast Accuracy

	Sample 1			Sample 2			Sample 3		
	CDF	ADF	MDF	CDF	ADF	MDF	CDF	ADF	MDF
Undervaluation	234	216	236	610	593	619	1	2	5
%	97.50	94.74	98.33	94.28	93.53	98.57	20	40	100
Overvaluation	6	12	4	37	41	9	4	3	0
%	2.50	5.26	1.67	5.72	6.47	1.43	80	60	-
Total	240	228	240	647	634	628	5	5	5

Discussion and policy implications

Based on the forecasts obtained, it was apparent that the current climate finance figures were much lower than predicted, as the forecast values deviated from actual values. This implied that climate-related funding was not predictable as shown by the empirical evidence and in line with previous reports and studies (Bendandi and Pauw (2016); Samuwai and Hills (2018); Bracking and Leffel (2021); Afful-Koomson (2015); Wanner, Grosjean et al. (2006); Schalatek and Bird (2012); Fenton, Wright et al. (2014); Khan, Robinson et al. (2020)).

Predictability is very crucial for climate financing, described by Schalatek and Bird (2012) as funding that "is known and secure over a multi-year, medium-term funding cycle".[6] According to Report Progress Plan Delivery Finance (October, 2022), "there is a need to provide clarity and predictability on the pathway to 2025 for adaptation finance."[7] Although international treaties and agreements (UNFCCC[8], Art.4.3; Bali Action Plan[9], Art. 1[e][i]; the Cancun Agreements[10], paragraph 97) on climate change continuously stipulate the importance of predictable funds for achieving climate targets, the data suggest that climate finance is still unpredictable. If climate-related funding becomes more predictable, governments will be able to devise programs to meet climate change targets.[11] Predictability would also help the private sector to make profitable investment decisions.

On the other side, developing countries need to improve their transparency and accountability. According to Katherine Browne of the Stockholm Environment Institute (2022), *"transparency can help improve accountability over the type of funding that countries count as climate finance."*[12] There are new requirements for international accounting and reporting standards. Climate-related disclosures are developed by two standard-setting boards, the International Accounting Standards Board (IASB) and International Sustainability Standards. The new requirements ask *"countries to distinguish between mitigation, and adaptation funding, and between grants, loans, and private finance"*.

6. https://us.boell.org/sites/default/files/uploads/2016/11/cff1_2016_normativeframework_english.pdf
7. https://www.auswaertiges-amt.de/blob/2560806/8cc5034f86da07811f8cb6adacba1130/neuer-inhalt--1--data.pdf
8. "Adequacy and predictability in the flow of funds and the importance of appropriate burden sharing among the developed country Parties" (UNFCCC, Art. 4.3.).
9. "Stipulates that funding must be adequate, predictable, sustainable, as well as new and additional (Bali Action Plan, Art. 1(e)(i)).
10. Paragraph 97 on long-term finance states that "scaled up, new and additional, predictable and adequate funding shall be provided to developing country Parties."
11. https://www.auswaertiges-amt.de/blob/2560806/8cc5034f86da07811f8cb6adacba1130/neuer-inhalt--1--data.pdf
12. https://www.sei.org/perspectives/accountability-climate-finance/

Climate finance recipients need to understand these disclosure requirements. According to Browne, these new reporting requirements could improve the predictability of climate finance, which is "a major concern for recipient countries who need information in advance in order to plan climate programs and integrate them into domestic budget and policy processes". Recipient countries perceive wealthy nations' tendency to announce ad hoc financial commitments as public relations, rather than as genuine assistance.[13] Multilateral funds require complicated application provisions and assessment benchmarks, demanding capacity that many LDCs and LMICs do not possess. In order for the LDCs such as Somalia to access more climate-related funds, the capacity of the institutions working in climate-related programs need to be enhanced. Similarly, the federal government should improve its financial governance by improving the accounting and reporting standards of climate-related funds.

Conclusion

This study examined the adequacy and predictability of climate finance in LDCs. The study employed ARIMA modelling to identify the predictability of the flow of climate finance to the LDCs in general and to Somali in particular.

After thorough analysis, the study found that climate finance is inadequate and unpredictable which affects the fight against climate change in LDCs in general and in Somalia in particular. Equally, the findings pointed out that the amount of funding received by Somalia for climate-related programs is inadequate, suggesting the climate financing targets of Somalia ($48.5 billion for adaptation and $6.96 billion for mitigation) will not be realized. This implies that the Somali government (and other governments in the region) are incapable of developing programs that have long-term impacts to achieve their climate change targets.

The adverse multiplier impacts of climate change are already pushing many rural communities in Somalia to migrate to the big cities, causing unplanned urbanization which leads to informal settlements that lack basic infrastructure or services and contribute to hazard creation. Such climate migration is creating pressure on host communities and causing potential conflict between the hosts and the hosted. This will exacerbate climate-related conflicts and increase the risk of violent armed conflict.

Climate finance providers should ensure that financing is adequate and predictable to help LDCs accomplish their climate adaptation and mitigation targets. Governments in LDCs should improve the capacity of their environmental institutions and improve their accounting and reporting standards to attract more climate financing, which will assist them in achieving their climate adaptation and mitigation goals.

13. https://www.sei.org/perspectives/accountability-climate-finance/

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Climate Impacts Associated with Modern Technology: Telecoms and Energy Sectors

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Abstract

The telecoms industry accounts for about 1.4% of global greenhouse gas emissions, which is predicted to increase to 14% of global greenhouse gas emissions by 2040. Each smartphone consumes about 35 kilograms of raw materials and produces 55 kilograms of carbon dioxide (CO2), on average, during its lifetime. In Somalia, mobile phone towers rely on diesel generators and electricity from the grid when available. Telecommunications and data centres are the primary utility industries that support the operation and connectivity of the Somali economy. However, Somalia's energy and telecoms industries have lagged behind other sectors in responding to the expanding environmental concerns of their clientele. Telecoms companies should review their business operations, considering both economic and environmental sustainability. This study examines the potential for the energy and telecom sectors to implement energy management solutions. This study focused on the sizing and simulation of small-scale distribution generation systems (SSDGs) with solar photovoltaic (PV) and wind power in island mode using MATLAB Simulink software and CST for antenna radiation. The results showed that the proposed solar PV system is more suitable for small-scale islands than wind power.

Keywords: climate change, telecom services, energy sectors, carbon emissions, climate action

Introduction

Over the course of centuries, human activity has raised the atmospheric CO2 content from 280 parts per million (ppm) to over 480 ppm and still continues to rise. The earth's surface temperature has risen by 0.74 degrees Celsius on average over the last century. By the end of this century, temperatures are predicted to increase by an additional 3.4 degrees Celsius if carbon dioxide emissions are left unchecked. A climate shift of that size could result in a rise in sea levels, as well as droughts, floods, severe storms, forest fires, and a shortage of water. Irreversible climate change could include widespread melting of polar ice, the devastation of the Amazon rainforest and the warming and acidity of the oceans. Despite rising evidence of the risks posed by climate change, attempts to reduce carbon emissions are still too few, ineffective or nonexistent in the majority of countries. Scientific data suggests that humankind must reduce overall CO2 emissions by at least 80% by the year 2050, based on present trends (Abdallah & El-Shennawy, 2013). Similar research by the authors was published by the KTH Royal Institute of Technology in 2010–2015 using data from several European Standards (Malmodin et al., 2018)

There has been growing emphasis on the energy usage of telecommunication (TC) networks in light of growing public awareness about sustainability and climate change and the digitalization of society, which requires access to both fixed and mobile connectivity (Lundén et al, 2022). The amount of mobile and data traffic is only expected to increase dramatically in the coming years. Networks will have to be extended to cope with rising demands as well as changes in consumer behavior. Though the information and communication technology (ICT) industry still only accounts for a small portion of the world's electricity consumption and carbon emissions (Andrae, 2022), the use of mobile services and apps will continue to grow and data centers will play a bigger role in the delivery of ITC services.

Telecom and energy industries have taken longer than other businesses to respond to the growing environmental concerns of their consumer bases. However, energy consumption has become a crucial economic concern for network operators since energy costs account for a sizeable portion of their operating expenses. As public concern over climate change grows, the industry is in a good position to act to seize opportunities to mitigate its own impact, increase energy efficiency at a network level and help customers to minimise their own environmental footprints, as reported in this reference (Altice Portugal, 2019).

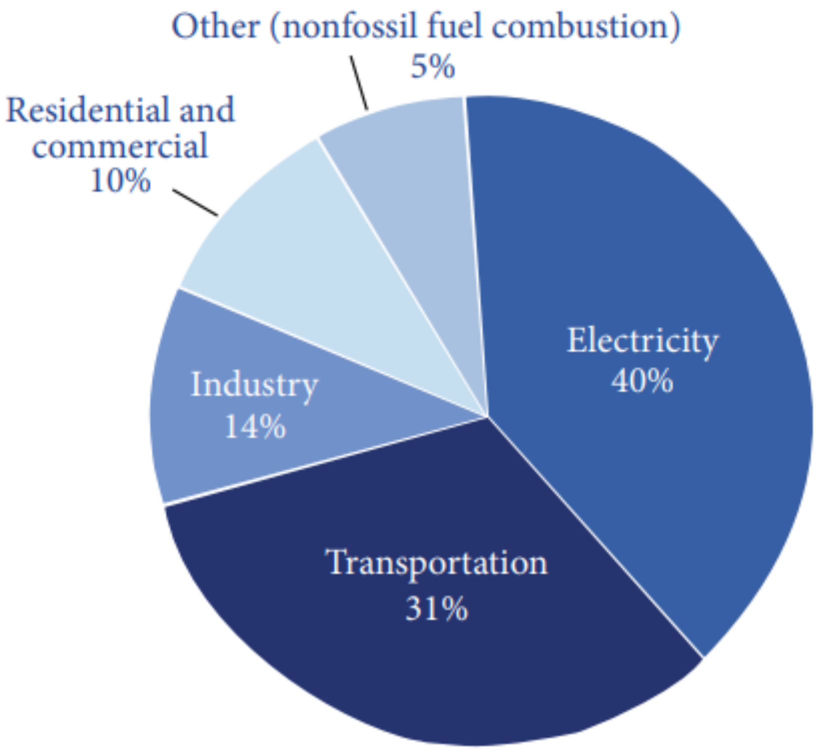

Figure 1. Sources of CO2 emissions by sector (adopted from Abdallah & El-Shennawy, 2013)

The electricity sector is responsible for approximately 40% of total global CO2 emissions worldwide (see Figure 1). This paper will focus on how to decrease the quantities of CO2 emitted from the electricity sector using the Smart Electric Grid (Abdallah & El-Shennawy, 2013). This data is considered to be more accurate than any modeled estimates that are based on fewer parameters (Networks and Services; International Telecommunication Union: Geneva, Switzerland, 2014). The study is structured as follows: section 1 introduces the background of the study, definitions and data sources; section 2 presents the previous studies; section 3 describes the proposed method of this study; section 4 presents the results and the discussion; and section 5 offers the conclusion.

Literature review

Numerous papers on network energy consumption and potential improvements have been released recently, with a focus on energy efficiency in light of rising traffic demand and the growing importance of internet and broadband access. The telecommunications and data center industries depend on networks of international supply chains which provide clients with sophisticated services. Due to the complexity of the network, climate changes that affect a section of the supply chain in one region may also affect supply chain segments in other regions of the world (Lange et al., 2010).

This study calculates the energy usage of the operator of a universal telecoms network delivering broadband services. A related quantity structure of network elements is designed and evolved across the examined timeframe based on expected traffic volume and subscriber number developments for certain broadband network services. An overall energy consumption forecast for the network is produced by providing power consumption estimates and operation times for the network components. Data sheets, vendor information and in-house laboratory measurements were used to compile the power consumption values for the numerous network components. We calculate the operational electricity consumption and the associated greenhouse gas emissions measured in CO2 equivalents (referred to as carbon emissions despite considering all greenhouse gas emissions) of a subset of European operators. The publicly stated values for the various operators were gathered and compared one-by-one at an aggregate level to the data set used in this study to validate the data for electricity consumption and the use of renewable energy sources (origin-guaranteed products offered by operators locally). It covers all varieties of renewable electricity purchase contracts between operators and utilities. Depending on the nation and location, different power requirements and definitions of "renewable" apply.

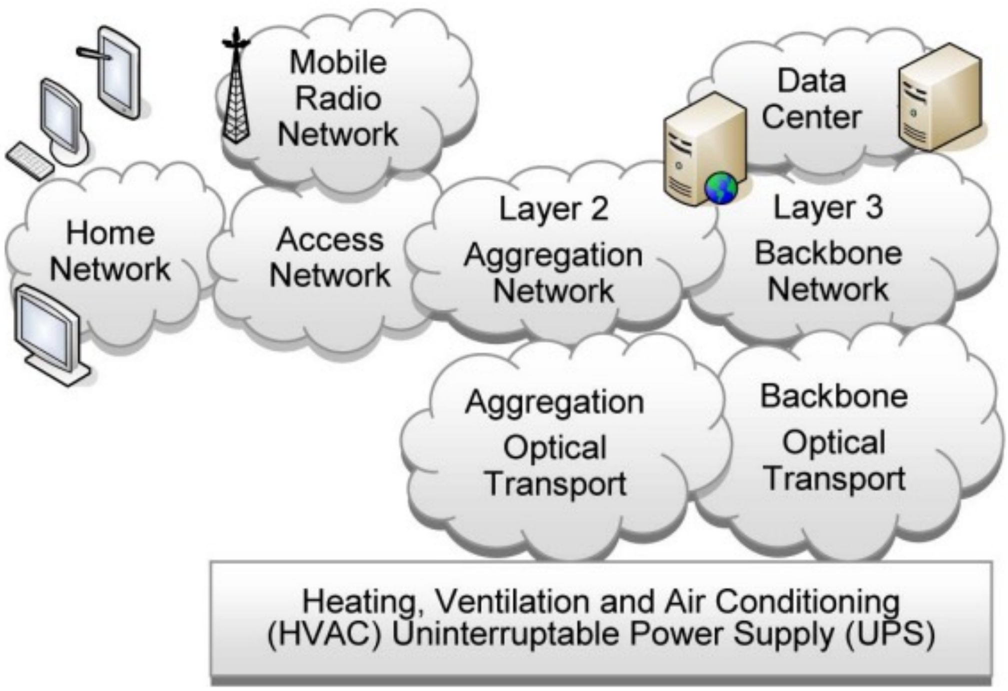

Figure 2. Overall broadband telecommunications network (Lange, C., et al., 2010)

Energy and environmental aspects of mobile communication systems

Due to growing expenditures on renewable energy and the need to maximize resources, planning for electrical transmission lines has recently been a prominent topic of discussion across the globe. Determining reliable and pertinent plans for the system's growth is essential since planning outcomes directly influence the price of power for end users. With a focus on energy interconnections, routing studies and tower-spotting optimization approaches have been effectively applied to a number of challenges related to transmission line expansion planning. These methods are used to provide information to planning procedures that will help analysts pursue specific objectives. The current work suggests a dynamic programming-based way to get the best transmission-spotting towers, considering both the engineering (minimum distance between the electric conductor and ground and tensions supported by each tower type) and environmental (land use, slope and geotechnical class of the terrain) aspects of the issue. Two independent case studies, including a genuine transmission line project with a 39-kilometer extension, were used to test the methodology. When compared to the actual transmission line project, the data demonstrated that the recommended strategy saved about 3.8% of costs. The study also pointed out that it is possible to confirm a strong correlation between the tower arrangements specified in the actual project and the best decisions produced by the suggested approach, highlighting its usefulness as a tool to support decision making in the early stages of investment planning and over the long term. Variable separations between towers were also taken into account, and the best tower placement along the topographic profile was determined, in addition to testing the constructions that were most suitable for the project.

An overview of the analysis procedure used in this study is shown in Figure 3, along with representations of the input data, the tower allocation mechanism and the output data. By analyzing various tower combinations, optimization strategies used for transmission tower allocation frequently aimed to reduce deployment costs. In addition to the expenditures associated with these characteristics and the topographic profile of the route, this allocation is based on land use, site deflection in the route, foundation type, tower type and height. Future research that examines the impact of profile resolution, topography and height growth in the process of telecoms tower allocation is made possible by the remaining uncertainties. In order to provide more precise information about the costs of the projects for the electric planning that determines which buses of the system should be interconnected, future works may investigate the application of the methodology to other TL traces as well as the joint consideration of the methodology in transmission planning processes (Lange et al., 2010).

Smart grids for electricity, which provide more distributed and renewable energy sources, are probably going to be used for power generating. Many renewables like wind farms are small-scale and suitable for interfacing at the distribution level. However, some wind farms are large-scale and interface with transmission networks. The grid's design must be altered substantially, and unique interfaces are required. It combines distributed (or local) power like solar, wind and biogas/biomass, which will be supplemented by battery storage and quick-starting production sources. Hydropower, solar and wind energy are examples of renewable energy sources that are good for the environment. However, they aren't accessible everywhere. Solar energy requires sufficient irradiation intensities, while hydropower is bound to dams. A consistent, unidirectional wind speed is necessary for wind energy. When solar and wind energy are insufficient, they are typically combined with a conventional diesel or gas generator to provide power. When connecting these sources to the grid, specific technical issues occur (Abdallah, 2013).

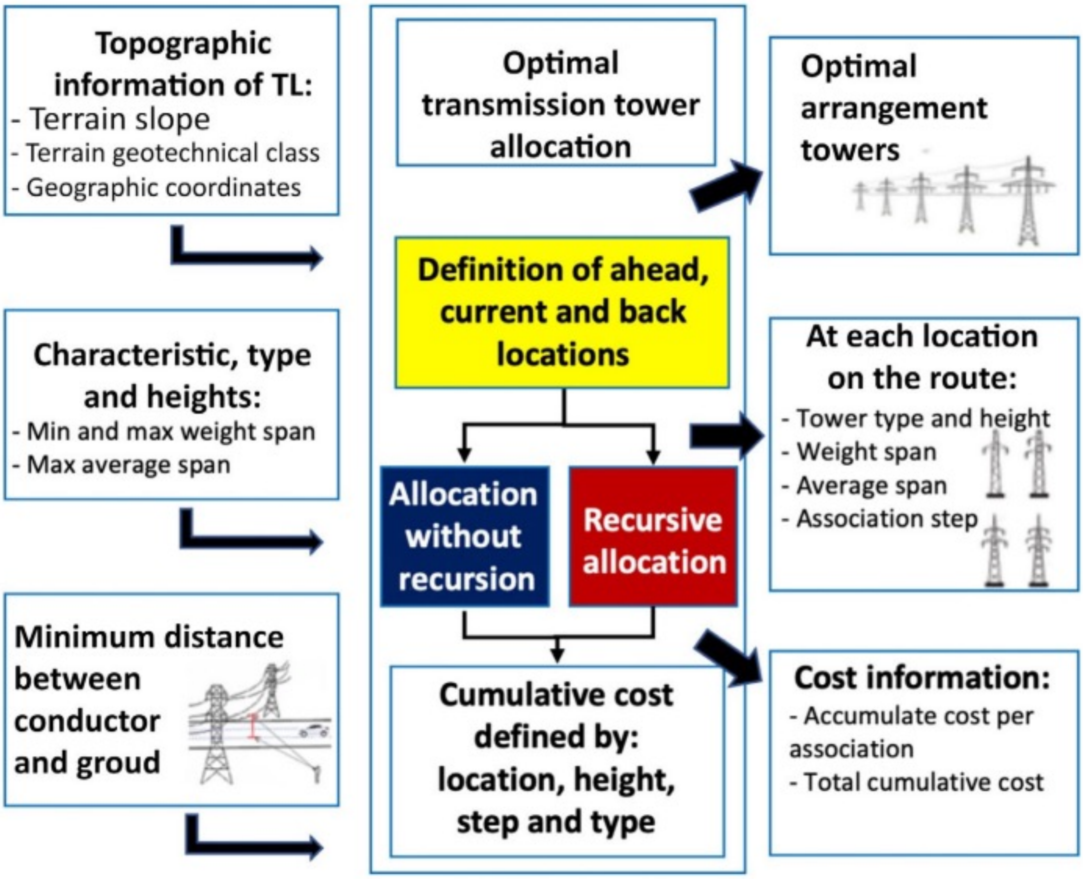

Figure 3: Overview of the proposed methodology for optimal transmission tower allocation (adopting from Lange et al., 2010).

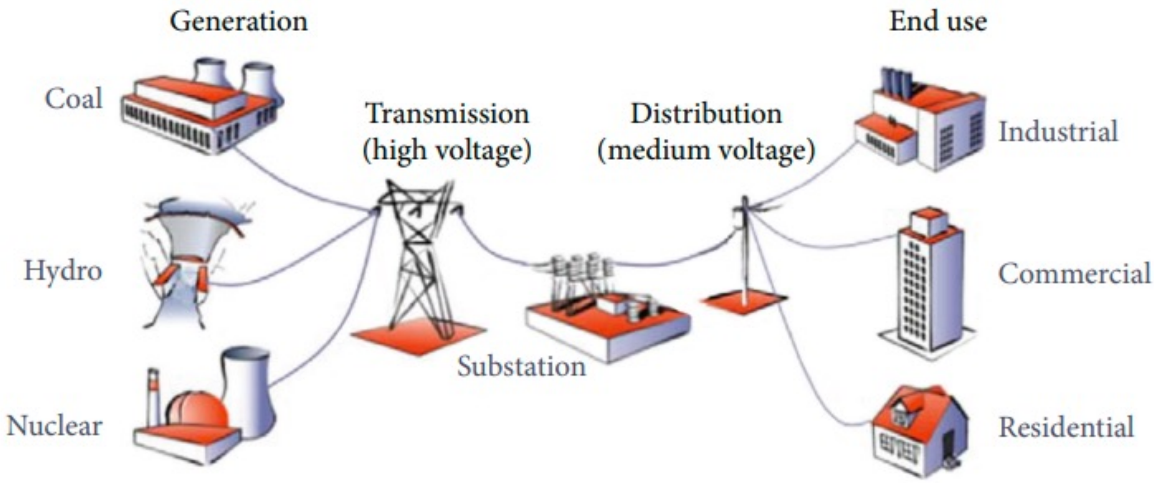

Figure 4. Interval elements of electrical power grid (adopted from Abdallah, 2013).

Table 1: Climate impacts associated with the telecommunications sector.

Temperature

• As temperatures rise and heat waves become more frequent, intense and lasting, it becomes harder for base stations and exchanges to keep their equipment cool, which leads to greater failure rates.

• If the operational temperature of network equipment exceeds design limits, mean temperature increases may cause malfunction or premature failure.

• Elevated temperatures can harm telecommunications infrastructure and equipment, shortening their lifespan.

• Workers at telecommunications facilities and supplier locations may be more at risk for heat-related health and safety issues when temperatures rise.

• Power outages during heat waves may be caused by increased energy consumption, which may interfere with the delivery of telecommunications services. These interruptions may raise the price of energy supplies.

• Higher winter temperatures may result in lower space heating costs for assets (like exchanges), providing a chance to save money.

• Over time, rising temperatures may make it less necessary to deal with difficulties caused by snow melt water surges (floods), but in the short term, melting snow will make flooding problems worse.

Table 2: Summary of major climate variables and their associated impacts on the power sector (adapted)

Sample 1	Sample 1	Sample 1	Sample 1
Increased air temperatures	• Lower generation efficiency • Decreased coal-to-gas conversion efficiency • Decreased combined cycle gas turbine efficiency • Decreased solar PV efficiency	Generation	• Implement air chillers or more efficient chillers • Site new generation in cooler locations
	• Reduced carrying capacity of lines and transformers • Increased losses in lines and transformers	Delivery-transmission & distribution	• Underground hardware • Use more heat-resistant materials • Implement more effective cooling for transformer
	• Increased peak demand and total energy demand for cooling	Demand-end use	• Energy efficiency • Building thermal efficiency • Peak load shifting
Increase in precipitation	• Reduced combustion efficiency due to increased moisture content of coal	Generation	• Protect coal stockpiles • Switch to fuel that is more moisture resistant (e.g., natural gas)
	• Damaged power lines from snow and ice • Flooding of underground infrastructure • Damaged towers due to erosion	Delivery-transmission & distribution	• Improved flood protection for equipment at ground level • Use covered and/or insulated conductors
Decrease in precipitation	• Damaged infrastructure • Disrupted supply chains and offshore activity • Damage to facilities related to soil erosion	Generation	• Switch to recirculating or dry cooling • Switch to more water-efficient fuels (e.g., natural gas, wind, solar)

Proposed method

Energy Sectors: The proposed micro grid is completely electronically interfaced and is operated in grid-connected mode. Figure 5 shows the proposed small scale DGs while Figure 6 shows the follow chart. Since most of the micro/mini-grids are based on the distributed generation source such as solar PV and wind, these sources are very intermittent and unpredictable, hence their optimum utilization is very much necessary to tackle the energy issues for a residential community. One of the major challenges of a micro-grid protection system is that it must respond to both island and grid connected faults. To deal with these crucial issues of power and energy, the more appropriate solution is the SSDGs which can optimally and intelligently manage the load and distributed generation resources so that there is maximum utilization of the renewable energy resources with a lower installed renewable energy capacity.

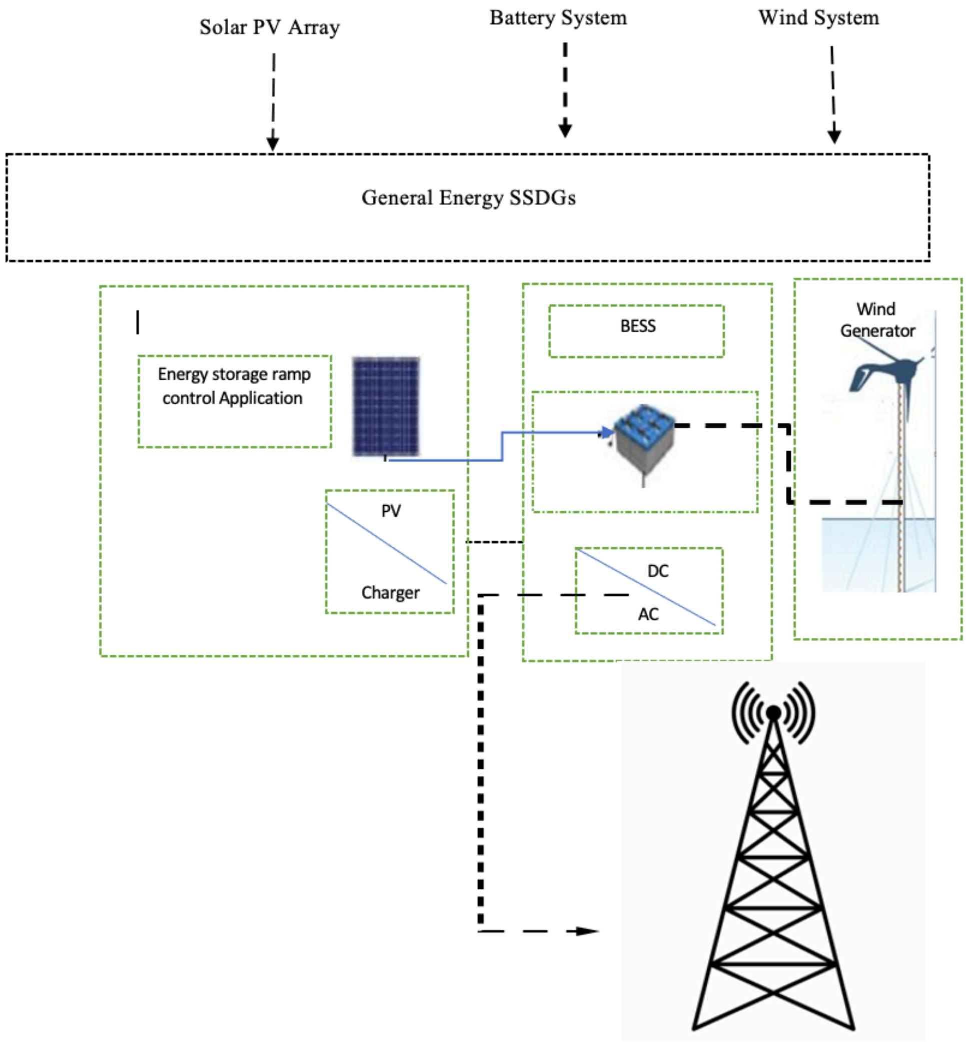

Figure 5. Proposed small-scale distribution generation system (SSDGs)

System Components: The grid-connected micro grid consists of a solar PV generator, charge controller circuit, battery energy storage system (BESS) supplying power to the load, inverter (convert module) and load. An energy of a micro grid model which employs a novel "mix-mode" operating strategy to operate the grid-connected micro grid with PV and wind is presented.

Main Parts of PV: Photovoltaic panels consist of various devices including an inverter, charge controller and batteries. In this renewable energy system, the energy produced through a photovoltaic cell is stored in the batteries. Furthermore, Energy will be supplied to the system, which commonly happensat nights, on cloudy days and on days that require higher electrical demands. Deep-cycle batteries are the most common type of battery. They are a lead-acid battery with a wide range of uses and benefits. Nickel-cadmium batteries are very costly but the electricity stored can be discharged at a higher level and they are more durable.

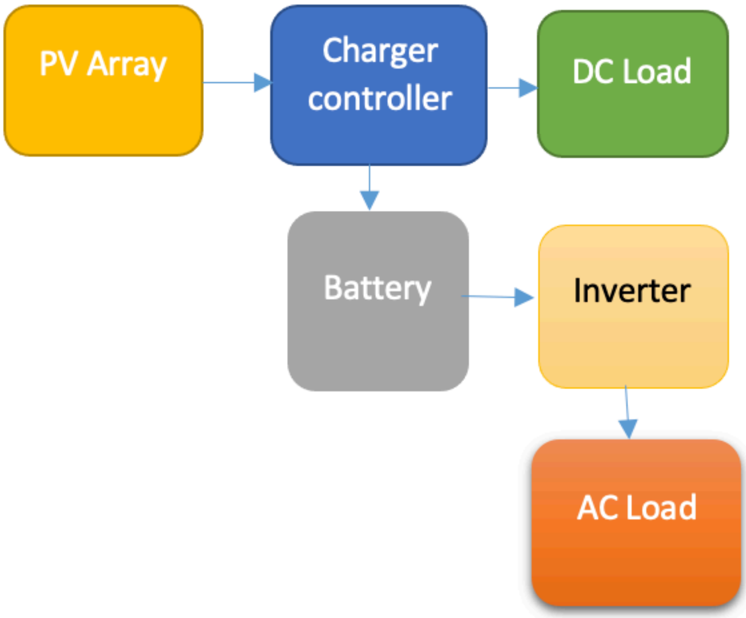

Figure 6. Block diagram of a typical solar PV system

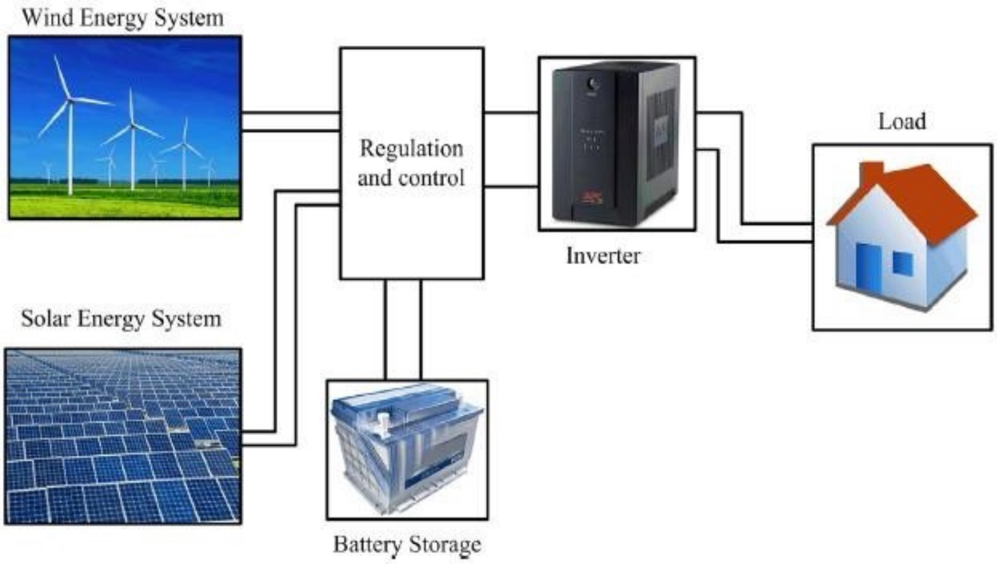

Figure 7. Model components

PV Array and MPPT Model: Two series modules each rated 150 W are used in SIMULINK to model the 300 W PV array. The array-rated outputs at the maximum power point are 36 V and 8.5 A. The boost converter is designed to boost the input voltage to 250 V, where the inductor and capacitor values are designed based on equations.

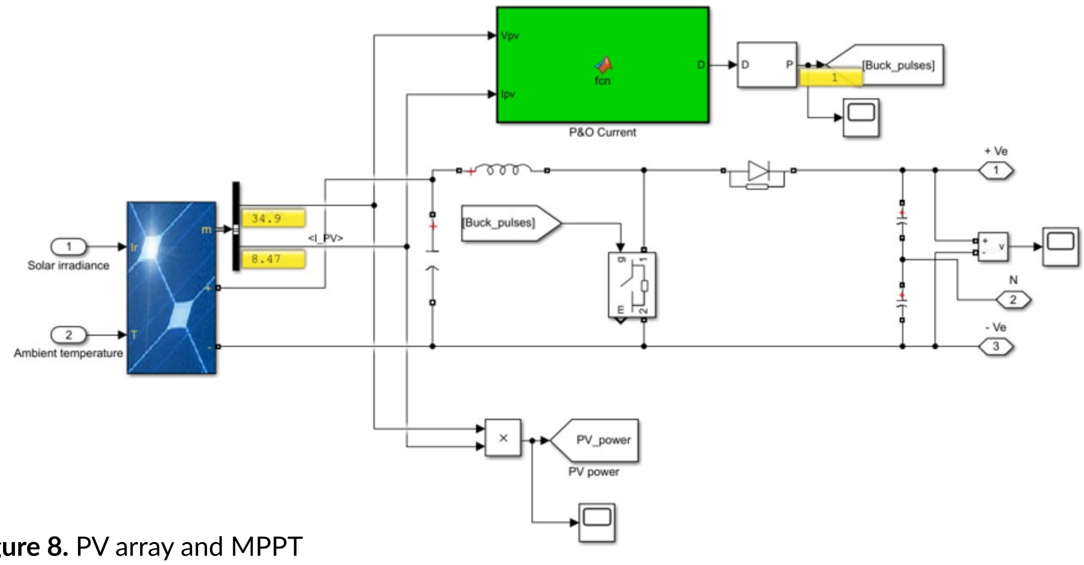

Figure 8. PV array and MPPT

Battery Storage Model: The battery model implemented uses a 12 V battery with 100 Ah capacity and an initial state of charge of 90%. The battery is controlled using a bi-directional boost converter that controls the charging/discharging of the battery based on the SOC. The converter also boosts the battery voltage to 250 to match the DC link voltage set point. The bi-directional converter is also designed based on equations 1, 2 and 3. The selected values for the inductor and the capacitor are 1.5e-7 H and 0.05 F. Two PI controllers are implemented to control the operation of the converter switches. The first PI controller compares the battery cell voltage to the battery nominal voltage to detect if the SOC has decreased significantly or not. Based on the difference, the controller specifies the current required for charging/discharging. The specified current is considered as the reference current and compared with the actual battery current where the error is used with another PI controller to get the switching signals of the two switches.

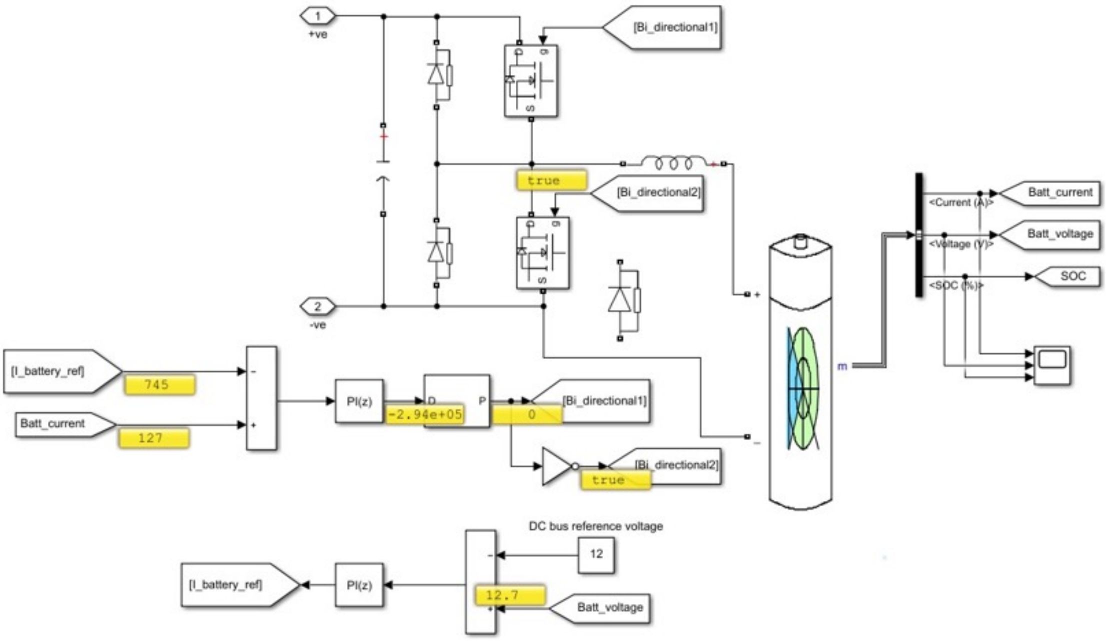

Figure 9. Battery system and controller

PV Array and Battery Voltage Source Converter: The VSC applies the control of the DC link voltage and the DC/AC conversion process. The VSC is also connected to a step-up transformer to match the VSC voltage with the grid voltage. The first part of the block implements the abc to dq frame transformation of the grid voltage and current waveforms so the control using PI controllers can be developed. DQ frame signals are then used with the phase looked loop block to maintain the frequency of the VSC output AC waveforms as the grid specifications, 50 Hz. The current compensators block utilizes the dq frame voltage and current values with PI controller to evaluate the switching signals of the VSC converter. The reference values for the current waveforms are estimated using another PI controller where its input is the difference of the DC link voltage set point and the measured DC link voltage.

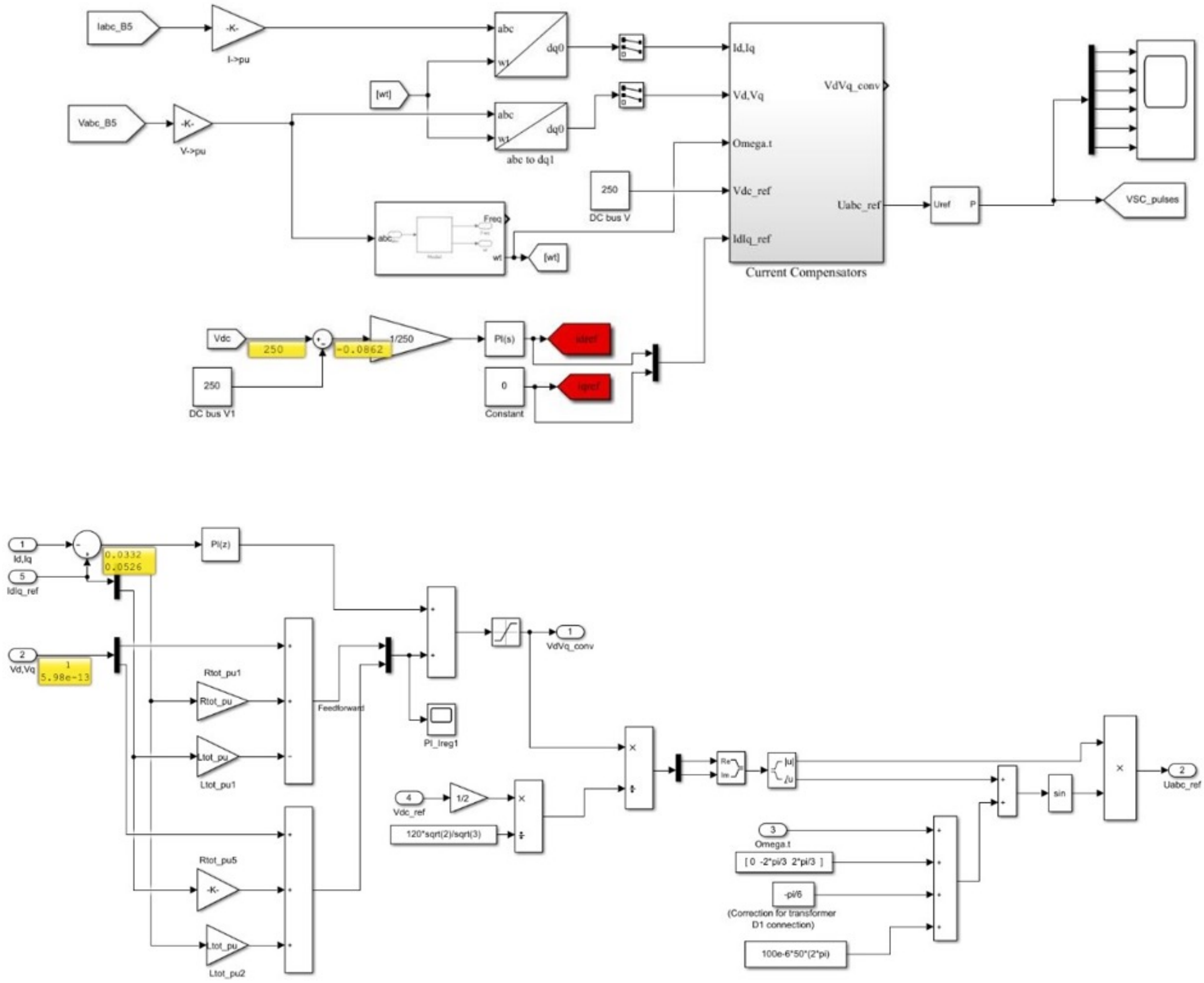

Figure 10. Control of VSC

Wind Turbine System: The wind turbine system is composed of a maximum power point tracker that controls the pitch angle with respect to the available wind speed to extract the maximum power. Based on the optimum pitch angle, the model estimates the mechanical torque and mechanical power required for the synchronous generator. The output AC waveforms are converted to DC signal by means of an AC/DC rectifier. The boost converter aim is to control the speed of the synchronous machine by means of current control. Then DC/AC conversion is applied by the VSC of the wind system. A reactive power filter is also developed with the model to maintain the voltage level of the VSC output side and supply the machine requirements of the reactive power for starting operation. The machine voltage is selected to be 737 Vph-ph, machine rated power is 5 kW that is also set to be the turbine nominal power.

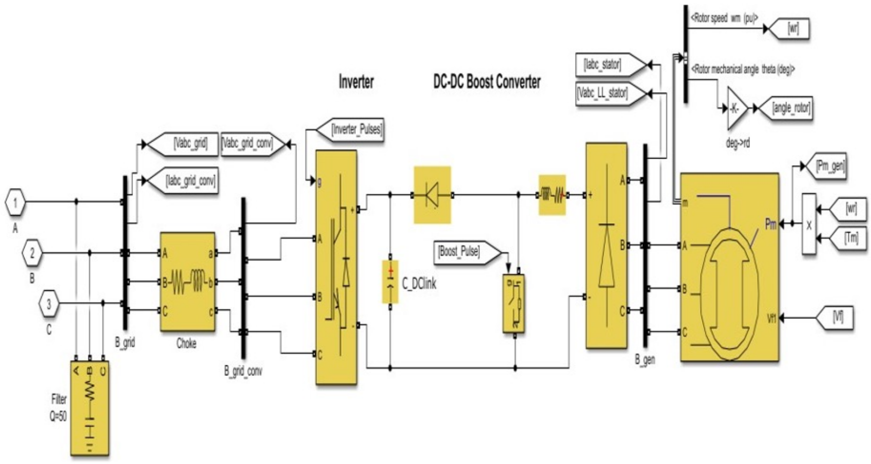

Figure 11. Wind turbine

Results and discussion

The small-scale distribution system with PV and wind is analysed using SIMULINK. First, the performance of the PV array is analysed in terms of the MPPT efficiency. Figure 12 shows the output power of the PV modules. MPPT successfully tracks the array rated power to be 298 W where the efficiency of the algorithm is 99%. The figure also shows a perturbation on the power waveforms due to the selected algorithm of the MPPT, the perturb and observe, where changes in the duty cycle perturb the PV output power. To minimize the power perturbations as much as possible and not affect the simulation time, the change in duty is selected to be 1e- 4 so that the change in power is as shown in Figure 12 PV array power is injected to VSC at the constant DC link voltage that effectively oscillates around 250 V by VSC control algorithm.

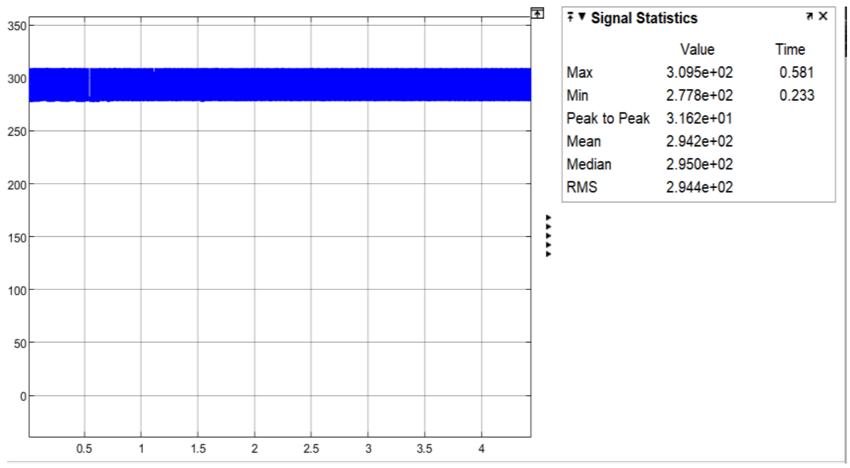

Figure 12. MPPT results – PV modules output power

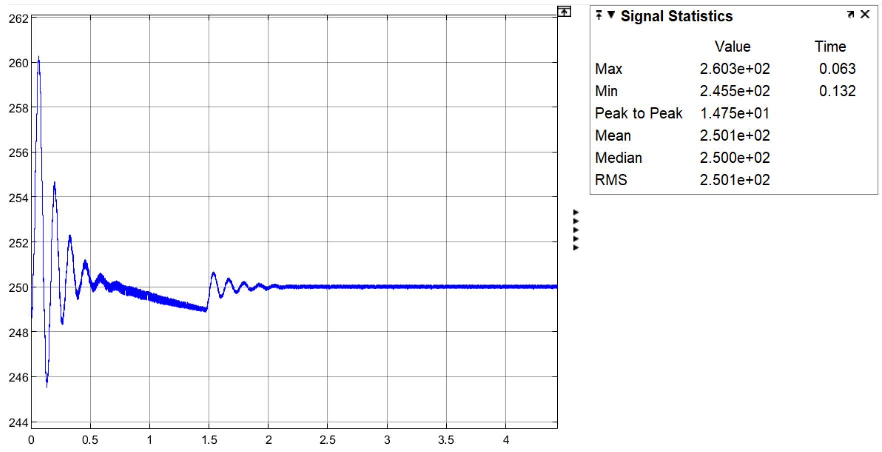

Figure 13. DC link voltage

Figure 14 shows the DC link voltage waveforms, where the control target is achieved. In addition, the battery system was analysed with an initial SOC of 90%. The battery waveforms represent the current withdrawn from the battery, the terminal voltage of the battery and battery SOC.

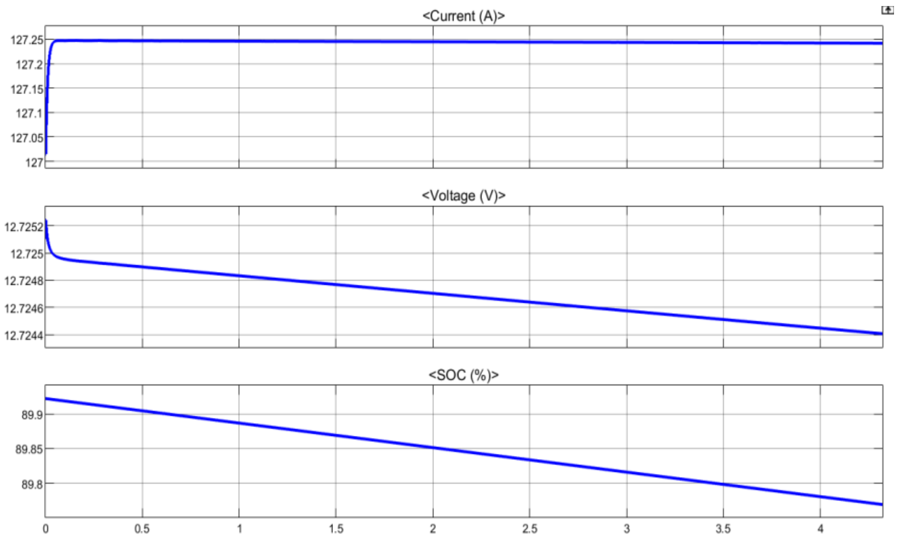

Figure 14. Battery waveforms

Figure 15 shows that the battery is discharged at a constant current, since the current is positive, and battery energy is injected into the grid. Plot two of Figure 15 shows the decrease in the battery voltage during discharging. The battery voltage started at approximately 12.725 V and during four seconds of simulation decreased to 12.724 V. The decrease in battery voltage is reflected on the SOC where it decreased from 90% to 89.75% as shown in the third plot of the figure. Figure 15 shows the grid-injected current and the grid voltage, where the design requirements are met such that the grid phase voltage peak value is 311 V with a frequency of 50 Hz.

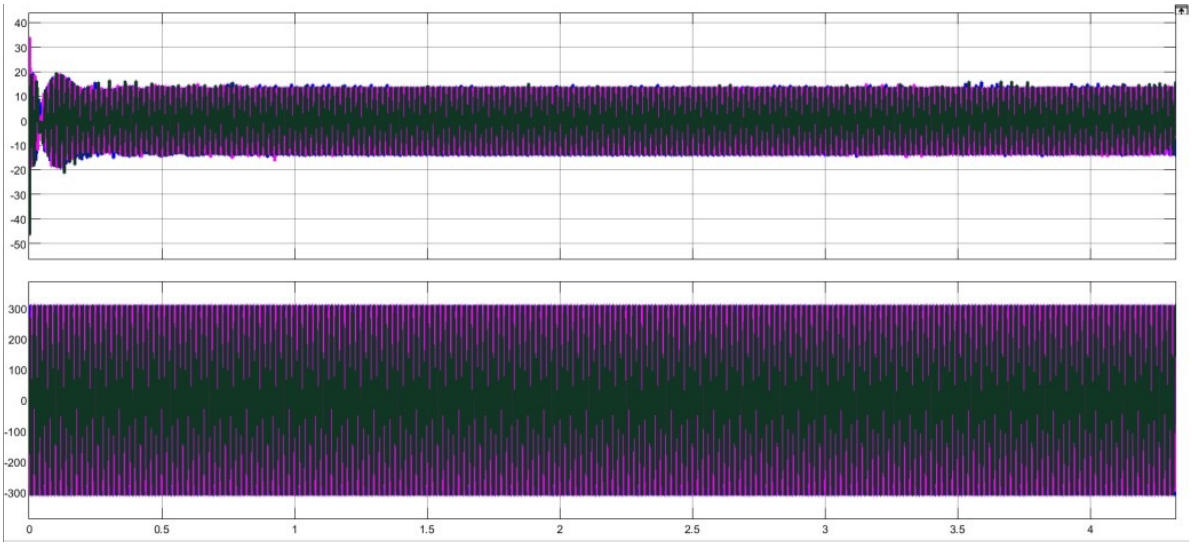

Figure 15. Grid-injected current and voltage

Figure 16 shows that the battery is discharged at a constant current, since the current is positive, and battery energy is injected into the grid. Plot two of Figure 16 shows the decrease in the battery voltage during discharging. The battery voltage started at approximately 12.725 V and during four seconds of simulation decreased to 12.724 V. The decrease in battery voltage is reflected on the SOC where it decreased from 90% to 89.75% as shown in the third plot of the figure. Figure 16 shows the grid-injected current and the grid voltage, where the design requirements are met such that the grid phase voltage peak value is 311 V with a frequency of 50 Hz. A detailed analysis is presented in Figure 16 where the injected current peak value is approximately 13 A which satisfies the relation between the injected power and grid voltage.

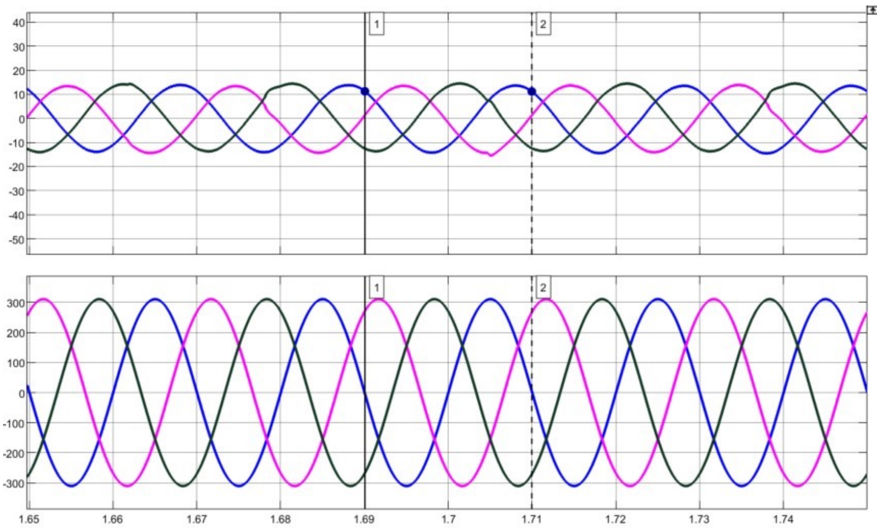

Figure 16. Grid injected current and voltage

The wind system waveforms are analyzed in Figure 17. The first plot of the figure shows the per unit voltage of the grid at the point of common coupling of the grid and the wind turbine system. The maximum value of the voltage is one per unit as obvious in the figure as the nominal voltage defined is the phase voltage of 311. The second plot shows the injected current of the wind turbine systems to the grid in per unit, the value of the current start to be about 1.7 pu at the beginning of the simulation but then converging to 1 pu during the rest of the simulation time. Plot three of the figure shows the active output power of the wind turbine system, approximately 4.0 kW. The decrease in the output power below the rated value for design is due to model non idealist due to the addition of resistance elements with the system filters.

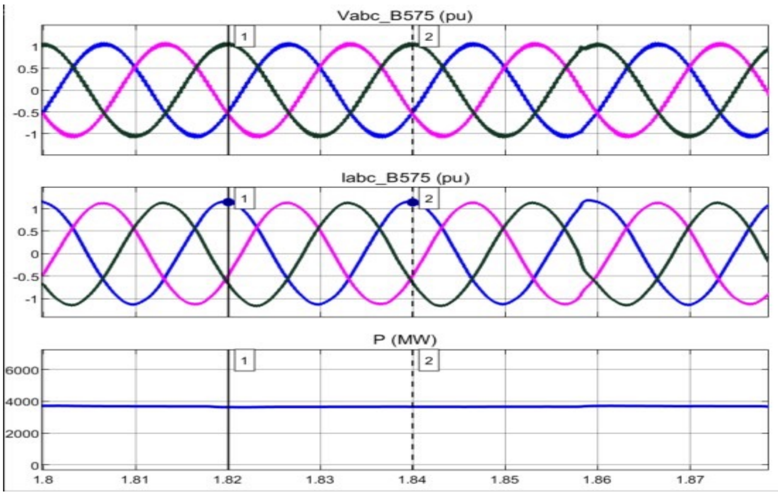

Figure 17. Wind turbine voltage and current frequency

A detailed analysis of Figure 18 shows that the frequency of the waveforms is also 50 Hz, matching the grid requirements of the frequency since the time of each cycle is 0.02. The peak value for the voltage and current waveforms is 1 pu. The total harmonic distortion of the injected current to the grid is also analyzed for each phase. It was found that for phase one the THD was 4.1 %; for phase two 3.8 %; and for phase three 3.75%. Overall, the THD was below 5% which satisfied the grid requirements.

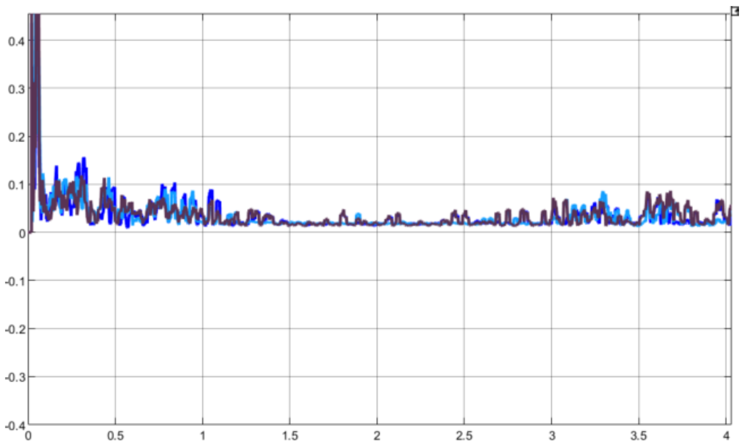

Figure 18. Grid current THD

Formulating a suitable structure for the antenna took up significant attention, since the design is to be depicted on the proposed substrate with minor errors. Different samples of UWB antenna structures have been developed and studied using CST MWS. The evaluation of Specific Absorption Rate (SAR) was achieved using the developed arm model and values have been compared with SAR standards. The radiation pattern of the proposed antenna at far-field was simulated in a 2D plot mode (Figure 19). The plot indicated that the gain increased as the frequency increased. The direction of the radiation tended to be intense at the front upper region of the antenna as the frequency got higher. It was observed that the radiation pattern had a maximum gain of 2.74 dB at 3.0 GHz surrounding the antenna. The antenna also had a maximum gain of 4.17 dB and 4.07 dB at 7.0 GHz and 9.0 GHz respectively at the upper region of the antenna (phi~ 10°-180°, theta~10°-150°). The radiation pattern also indicated the behavior of the resulting operating frequency. It can be seen that the shape of the pattern of frequencies 3 GHz and 9 GHz took a ring-like plot (the red region that surrounds the light green region), which is the characteristic of monopole antennas. From this, it can be concluded that antenna had an omni-directional radiation pattern, where the gain was high around the antenna and low at the top and bottom sides, given that the strip-line points towards z-axis minimum.

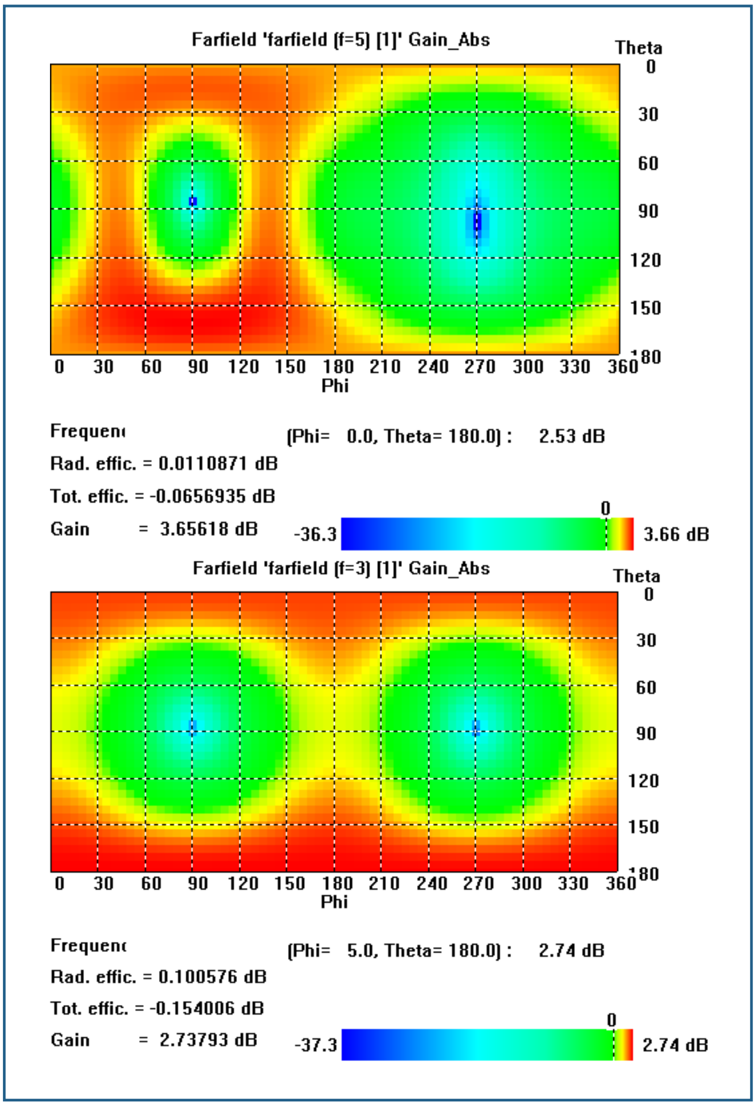

Figure 19. Simulated 2D radiation pattern for the proposed antenna at free space for frequencies 3 GHz and 5 GHz.

Solutions to climate change and climate change action

There are several recurrent themes in the literature on the types of climatic hazards that affect both data centres and telecommunications. Both industries have intricate relationships with climate change that present challenges as well as opportunities for response. The greatest solution is to quit using fossil fuels and to switch renewable energy as our primary energy source. Renewable energy sources include innovations in geothermal, wave, wave, tidal, and wind energy.

Table 3: Summary of impact, policy law and climate change action

Rising Temperatures
• Due to increased energy consumption during heat waves, power disruptions have a negative impact on the energy and telecommunications sectors.
Changes in Precipitation
• Floods due to more frequent precipitation cause damage to telecommunication wires and other infrastructure.
Extreme Weather
• Due to severe wind, lightning, floods and other extreme weather occurrences, new technology service delivery may be disrupted. • The capacity of the system is being strained due to an increase in emergency communications as extreme weather events become more frequent and intense. • During extreme events and possibly life-threatening catastrophes, populations in underserved areas, especially in isolated rural areas with only one type of service, may find it challenging to report outages.

Actions

Planning

Maintain backup supplies of poles and wires so that you can quickly replace any that are damaged, and have emergency restoration teams ready before the storm hits to prevent disruptions.

Management Practices

- Relocate central offices that contain communications infrastructure away from floodplains, especially in coastal regions that are being put at increased risk from coastal storm surges and sea level rises.
- Make the backbone network redundant for the majority, if not all, of service locations and weather-resistant.
- As much as feasible, disentangle the electrical grid from the communication infrastructure, and increase the robustness and resilience of both.
- Trim trees near power and communication wires to prevent disruptions.
- Whenever it is technically and financially possible, bury telecommunications cables.

Technology

- Provide backup power for cell towers using generators, solar-powered battery banks, and "cells on wheels" that can replace broken towers to reduce the impact of power outages on communications services.
- Ensure there is an adequate supply of fuel and dependable backup power for prolonged grid outages. Replace the wired network's weather-sensitive areas (such as customer drop wires) with low-power wireless alternatives.
- Create a standardized charging interface that enables any phone to be recharged by any charger and establish additional backup cell phone charging choices for customers, such as automobile chargers.
- If alternative telecommunications technologies appear to increase redundancy and/or reliability, they should be evaluated, developed and expanded. Examples include free-space optics, which use light rather than physical connections to transmit data, and power line communications, which use electrical current satellite phones, ham radio and transmission through electric power lines to send data.
- Boost redundancy and variety in vulnerable distant locations, provide high-speed broadband and wireless services in low-density rural areas.

Policies / Laws
Re-evaluate industry performance standards together with suitable, more consistent regulation for all forms of telecommunication services, and consistently implement legislation, such as making outage reporting to regulatory authorities required rather than only optional.
Research / Monitoring
Create databases that are easily visible for use in extreme weather events to quickly assess damage, loss and consequences in potential hazard and damage zones. These databases should show the location and elevations of installed telecommunication facilities and lifelines as well as their operational capacity. Create consistent, easily accessible information about service disruptions and anticipated restoration periods for the general public.
Invest In Renewable Energy
Changing our main energy sources to clean and renewable energy is the best way to stop using fossil fuels. This includes technologies like solar, wind, wave, tidal and geothermal power.

Conclusion

This research attempted to reduce power consumption in every part of the power system from generation and transmission to distribution by making each component smarter or more intelligent. The environment will benefit when electricity is produced from renewable energy sources instead of from conventional thermal power plants, because fewer greenhouse gases (particularly CO2) will be emitted. By implementing smart grid technology, Somalia and other nations can profit greatly on the technical and environmental fronts, particularly in the area of enhanced electricity production from renewable energy sources like solar and wind as well as from activation. More efforts are required to educate consumers about energy conservation and its benefits for protecting the environment, as well as programs to present the smart grid's possibilities to decision makers for quick funding and planning decisions.

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