

Enhancing Agricultural Sustainability and Food Security in Somalia: Addressing Climate Change Challenges

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Abstract—The agriculture industry in Somalia employs a large portion of the country's workforce. Somalia has been known for its production and notable agriculture for many years, the key sector that fuels the country's economy. Due to decades of civil conflict, poor administration, neglect, and a string of natural calamities, the Somali agricultural industry has suffered significant damage. The irrigation systems in Juba and Shabelle, the two major rivers, have failed and deteriorated. Crop output has decreased because of ongoing drought, poor agricultural techniques, desertification, and the exodus of rural people to neighboring nations. With pandemic levels of hunger and malnutrition brought on by climate change, Somalia has become one of the world's most food-insecure countries. Additionally, there is strong evidence that climate change, particularly in Somalia and other East African nations, has exacerbated civil wars across Africa. The El Nino/Southern Oscillation, which results in drier and warmer weather in tropical regions, may have contributed to numerous civil wars. Additionally, an increase in temperature is believed to raise the risk of internal armed conflict in sub-Saharan African nations. This paper examines Somalia's present extension programs, lists the challenges the nation's agricultural industry faces, and discusses the effects of climate change. Improvement measures are advised based on the analysis presented in the paper. This article's major goals are to highlight the serious challenges that Somali farmers face and to offer potential solutions for achieving sustainable agriculture and food security through the worst of climate change. Farmers, legislators, decision-makers, and academics may find the material in this article useful in developing credible plans, and policies, and in establishing research and extension programs. With improved extension systems, management, encouraging public investments, and an enabling climate, Somalia's agricultural industry can increase its resilience, the quality of life for its population, and the safety and added value of its goods. Offshore and coastal fisheries can contribute more to sector growth and return to and surpass their amazing pre-war output and export levels.

Keywords—Sustainable agriculture, innovation, land use, climate change, farm management, drought management, resilience, agribusiness, agri-extension, farmer field schools, agricultural development.

I. INTRODUCTION

SOMALIA is located in the "Horn of Africa" region, including Ethiopia and Djibouti. The easternmost African country is Somalia, whose 637,660 km² land area is slightly larger than France. With a coastline that stretches 3,025 km from the Gulf of Aden in the north to the Indian Ocean in the east and south, with shores that are around 1,000 km and 2,000 km long, respectively, Somalia has the longest coastline in

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Africa. Kenya, Ethiopia, and Djibouti border Somalia on its western side [1]. The nation spans 1,095 km from west to east between longitudes 41°00' and 51°21'E and about 1,550 km from north to south between latitudes 12°00'N and 1°37'S. Most of Somalia is flat, with a few hundred meters of elevation gain in the southern and central regions along the Ethiopian border. Along the northern shore, where mountains rise to a height of about 2,000 meters, is where the country is highest [2]. The highest mountain in the nation is Shimer Berris, located in the Sanaag area (2,407 m). In 2002, 1071000 ha were under cultivation, of which 1045000 ha were arable land and 26000 ha were used for permanent crops. The remaining 43000000 ha were used for permanent pastures (Table I).

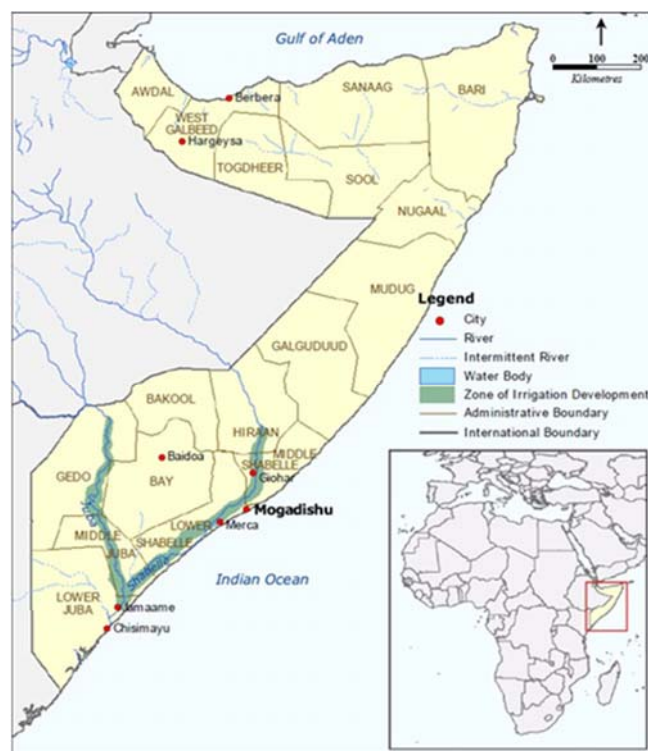


Fig. 1 Somalia map [2]

II. AGRICULTURE

About Somalia, the agricultural industry continues to be the foundation of the Somali economy, contributing over 75% of

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GDP and 93% of all export earnings, respectively [3], [4]. However, a variety of challenges, including political, economic, and environmental constraints, are impeding the development of a strong agriculture industry. Indeed, environmental concerns, particularly climate change, constitute the most critical problem, as indicated by the Center for Global Development's ranking of Somalia as one of the world's most vulnerable countries to climate change [5]-[7]. Furthermore, taking into account the importance of agriculture to the country's economic development and fight against poverty, the National Adaptation Program of Action (NAPA) of Somalia identified four climate threats, including recurrent droughts, rising temperatures, rising flood levels, and strong winds [8].

TABLE I
 BASIC STATISTICS AND POPULATION

Physical areas			
Area of the country	2002	63 766 000	ha
Cultivated area (arable land and area under permanent crops)	2002	1 071 000	ha
• As % of the total area of the country	2002	2	%
• Arable land (annual crops + temp fallow + temp. meadows)	2002	1 045 000	ha
• Area under permanent crops	2002	26 000	ha
Population			
Total population **	2004	10 312 000	inhabitants
Rural	2004	65	%
Population density	2004	16	inhabitants/km ²
Economically active population	2004	4 368 000	inhabitants
- as % of the total population	2004	42	%
- female	2004	43	%
- male	2004	57	%
Population economically active in agriculture	2004	3 028 000	inhabitants
- as % of the total economically active population	2004	69	%
- female	2004	50	%
- male	2004	50	%
Economy and development			
Gross Domestic Product (GDP) (current US\$)	2001	806	million US\$/year
• Value added in agriculture (% of GDP)	2001	60	%
• GDP per capita	-	-	US\$/year
Human Development Index (highest = 1)	-	-	-
Access to improved drinking water sources			
Total population	2002	29	%
Urban population	2002	32	%
Rural population	2002	27	%

**Somalia's population is estimated at 6.8 million, of which 66% are rural [1].

A. Agricultural Production

Somalia's per capita food output has been steadily declining. Between 1970 and 1974, food aid made up 20% of total food imports, and between 1980 and 1984, it made up 5%. The "food gap"—the difference between total food produced and total food consumed went from being 5% in excess to being almost 30% in deficit. Despite significant foreign expenditures in the rural sector, this fall in food self-sufficiency occurred between 1960 and 1990 [9]. One of the causes of this drop was:

- In the 1980s, population expansion outpaced advances in food production.
- Rapid urbanization, which keeps an increasing portion of the population away from food production in pastoral or agricultural settings.
- A shift in the food preferences of urbanized Somalis, who favor pasta, wheat, and rice over locally produced maize and sorghum.
- Inappropriate price limits and government policies in the 1970s discouraged farmers from growing grain crops.
- Unintended consequences of the yearly, widespread, and frequently inefficient distribution of food aid, which lowers prices and forces farmers out of the agricultural sector.
- The use of some of the most productive irrigated land in the nation to grow bananas for export rather than grains.

In Somalia, agriculture continues to be the second-most significant production system. In the past, agriculture generated up to 19% of the GDP and about 20% of jobs [7], [10]. The most productive soils in Somalia are found in the country's southern alluvial plains, which combined with the Bay inter-riverine region once provided about 90% of the nation's agricultural output. However, because of the unrest, crop yields and planted areas decreased, but the livestock industry did not suffer as much [11]. Though 18.7% of the arable land, or about 2% of the total land surface, is suitable for irrigated agriculture [10]. In regions with an annual rainfall of more than 450 mm, the principal crops produced using rainwater are maize and sorghum, with cow peas being planted in dryer regions. Poor management methods on rain-fed farmed and fallowed land are causing reduced levels of soil fertility and soil erosion, which has a knock-on effect on residents' productivity and degree of suffering. Rain-fed agriculture is becoming increasingly prevalent in riskier regions because cultivation is a desirable alternative for development, enhancing lives, and rural economic growth. This may be suitable as an opportunistic production technique to generate a crop if the rains are excellent or additional feed if the rains are inadequate. However, this is a risky tactic if the crops are the only source of income. By removing vital, frequent dry season grazing and browsing resources from the much wider pastoral land use system, expanding rain-fed crops increases the risk to the entire land use system [12].

B. Land and Land Use

The geography of Somalia is mostly made up of plateaus, plains, and mountains. But in the extreme north, the rough east-west Karkaar Mountain ranges are located at various distances from the shore of the Gulf of Aden. Somalia is a land with little physical difference. A marine plain that varies in width from around 12 km runs parallel to the Gulf of Aden shoreline toward the north, as little as 2 kilometers in the west, toward the east. This plain, known as the Cuban (scrub land), which is covered in scrub, semi-arid, and typically gloomy, is traversed by broad, shallow watercourses that are beds of dry sand unless during the rainy seasons [13]. When it rains, the vegetation, which is made up of low shrubs and grassy patches, quickly regenerates, giving livestock temporary grazing space in the guban. The

plain climbs inland from the gulf coast to the steep, northward-facing cliffs of the divided highlands. These make up the rough Karkaar mountain ranges, which stretch from the Horn of Africa's easternmost point to its northwest border with Ethiopia. At Caseyr, they come to an abrupt halt with precipitous cliffs.

South of the coastal city of Berbera, the overall height along the crest of these mountains is around 1,800 meters above sea level, and it continues eastward at 1,800 to 2,100 meters almost to Caseyr. Shimer Berris (2,407 m), the highest peak in the nation, is situated close to Erigavo [14].

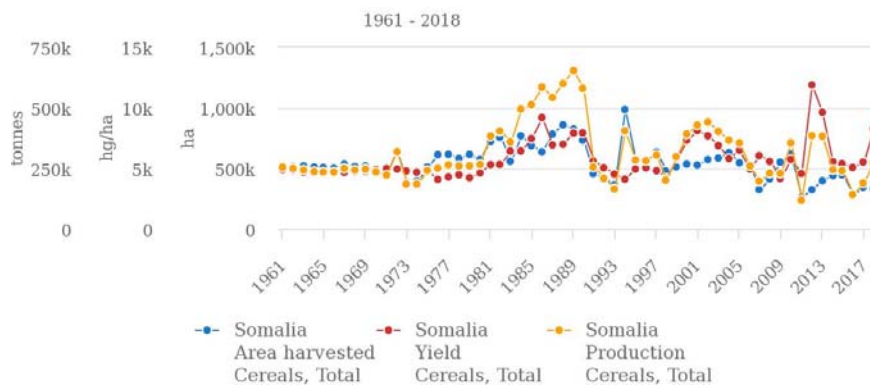


Fig. 2 Cereals, total production

The mountains fall to a high plateau devoid of perennial rivers as they move south, frequently in the form of scarred ledges. The Ogo is an area of fragmented mountains, shallow plateau valleys, and mostly dry waterways. The plateau, which is divided into many isolated mountain ranges and gradually falls into the Indian Ocean in the Ogo's particularly parched eastern region, forms the Mudug plain in central Somalia. The long and broad Nugaal valley, with its large network of intermittent seasonal watercourses, is a prominent feature of this eastern part [15].

Numerous small valleys and dry watercourses cut across the western portion of the Ogo plateau. There are flat regions of agricultural land, and the annual rainfall is higher than in the east. The primarily nomadic population uses the permanent wells in the western region during the dry seasons. Despite receiving no considerable rainfall for more than half of the year, the western plateau slowly dips southward and merges into the Haud, a large, undulating region that provides some of the greatest grazing pastures for Somali nomads. The natural depressions that become transient lakes and ponds during rainy spells add to the Haud's value. The huge Somali Plateau, which sits between the northern Somali mountains and the highlands of southeast Ethiopia, stretches south and eastward across Ethiopia into central and southwest Somalia. The Haud zone continues for more than sixty kilometers farther into Ethiopia [16], [17].

The Jubba and the Shabelle, the only two permanent rivers in Somalia, dominate the southwest of the region. The Somali plateau has extensive valleys carved into it as it descends toward the sea by these rivers, which have their origins in the Ethiopian highlands. The plateau's height drops off quickly in this region. The neighboring coastal zone, which stretches from the Mudug plain to the Kenyan border and includes the lower sections of the rivers, has an average width of 180 meters over the sea level. At Gobweyn of Kismayo, the Jubba River empties into the Indian Ocean. Though it once reached the sea close to

Merca, the Shabelle River's route has shifted since prehistoric times. Near Balcad, the Shabelle now swings southwest and travels along the shore for more than 85 kilometers [18], [19].

Only a small portion of the river, southwest of Mogadishu, remains perennial. After that, the river is made up of dry and marshy stretches until disappears entirely in the sand east of Jilib, not far from the Jubba River. The Shabelle River may overflow during the flood seasons to a location close to Jilib, and on rare occasions, it may even cross over to the Jubba River farther south. The country's greatest sedentary population is concentrated in the riverine region, which is also a fruitful agricultural area because of favorable rainfall and soil conditions [19], [20].

The Jubba and Shabelle river valleys have the richest soils, which are often calcareous. These are the "black cotton soils," or deep vertosols, that serve as the foundation for irrigated agriculture. These soils are also excellent for opportunistic rain-fed agriculture, as are the dark grey and brown calcareous of the inter-riverine zones. There are some alluvial plains in the northwest of the nation, where the soils can be suited for rain-fed agriculture. Rich alluvial soils are present in several of the seasonal rivers. The majority of the country's drier regions have thin, generally infertile desert soils [11], [18].

C. Agriculture and Rangelands

Approximately 46% to 56% of Somalia is classified as permanent pasture, which includes savannah woods and is dominated by natural flora. Some regions of the nation are impacted by rangeland degradation, notably those that are adjacent to metropolitan centers and places like the Sol plateau. Long-lasting droughts, instability, and the trade in charcoal, which results in localized degradation, make this worse. According to a report, Somalia's northern ranges are the most severely (up to 50%) degraded because of its steep topography, big populations of cattle, and closeness to ports for exporting livestock [21], [22]. Much of the country has deteriorated regions around water sources and wells. People are forced to

demand ever-increasing quantities from their rangelands, wood, and forest lands, due to the loss of traditional grazing areas to private livestock enclosures, particularly those adjacent to urban centers, as well as a rise in livestock numbers and a lack of law enforcement make enclosures contentious topic. On the one hand, it is a component of the traditional Somali pastoralist approach to managing natural resources, which included grazing reserves during dry and wet seasons as well as wet and dry season grazing regions. Even though they were not walled, community grazing grounds existed in the past and were widely valued. However, this is no longer the case, as many individuals now construct their own private, frequently large enclosures, which restricts access to pasture and restricts the movement of

pastoralists during periodic migrations. In Somaliland, where the government and elders characterize them as a constant source of conflict and instability, this has become a particularly pressing issue [23], [24].

In terms of potential land usage, arable land (rain-fed and irrigated) is thought to make up 13% of the nation, even though 20,000 to 30,000 Ha are irrigated. In drier increasingly dryer environments, more amounts of land are farmed opportunistically, which may produce crops but also serve to supply pasture for cattle. People in the Bay region do rely more on rain-fed agriculture for livelihood, which is cause for worry [25]-[27].

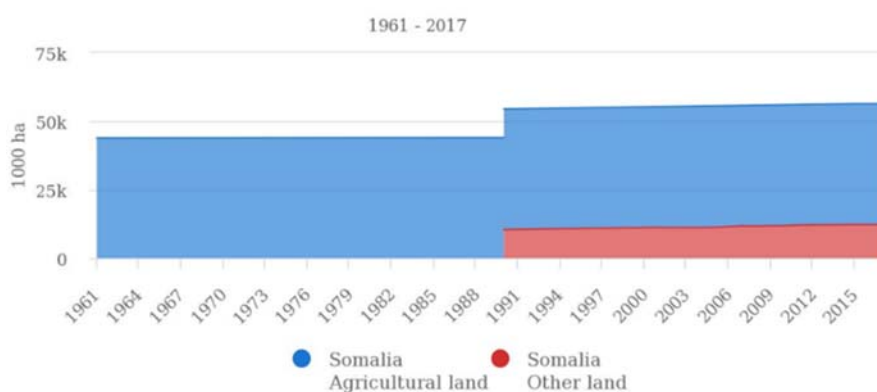


Fig. 3 Land Use

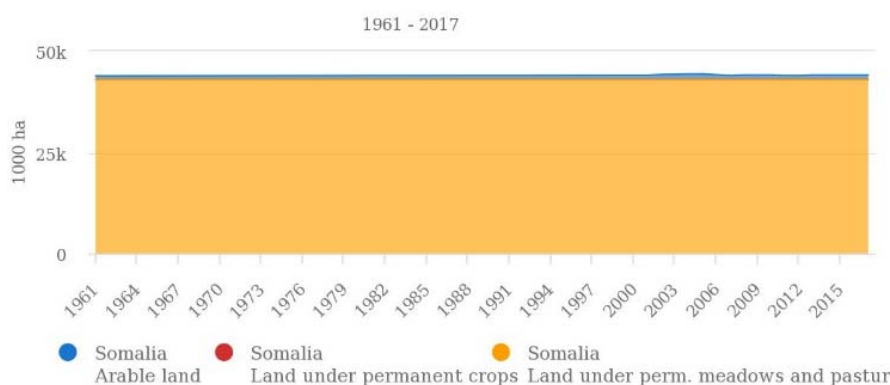


Fig. 4 Agricultural Area

D. Food Consumption and Poverty

In Somalia, the need for food at the household level is rapidly changing. A devastating twenty-year civil war is ending in a country in the horn of Africa. Estimated demand elasticities for Somalia are taken into consideration when accounting for changes in household type, local conflict, and international remittances. Household food consumption is highly sensitive to income shocks as assessed by spending, owning, and cross-price resistances, notably for animal goods like meat and milk, which are important sources of protein. The shock caused by extremely low income has an influence on household budgets and food expenses, which is likely to have an impact on a balanced diet that is less diversified due to a higher intake of grains, particularly among Somali nomadic households. The

negative macronutrient consequences appear to have an impact on malnutrition levels. Increased food security is therefore necessary for Somalia's future economic development and toughness [28]-[30].

The severity of Somalia's economic resilience and the shocks brought on by repeated severe droughts or violent conflict make the need for establishing policies aimed at combating poverty in the nation even more pressing. To assess the degree of the severe drought in Somalia's effects on poverty, hunger, and consumption, two microdata waves of the High-Frequency Survey in Somalia were undertaken. To study the consequences of the drought, data collecting should take into account the variability of drought exposure. The drought significantly affects poverty and hunger, especially in rural areas, among

agricultural households, and among those who lack access to basic amenities. A new drought shock might cause poverty to increase by 9% points. This shows how important investments in rural resilience are, especially for agricultural households [31], [32].

i. Pest, Grain-Eating Birds, and Diseases

Pests and illnesses significantly affect agricultural productivity in Somalia, as well as crop preservation and storage. The future potential to resume agricultural productivity may be constrained by some ailments. Additionally, agriculture in Somalia is also being decimated by a new disease that harms the tuber crop and may jeopardize food security. Cassava Brown Streak Virus is the name of the disease, which is connected to Cassava Mosaic Disease [33].

Even though farm pests are rarely discussed in the literature, they can seriously harm agricultural livelihoods in emergency scenarios. Birds, army worms, stem borer, and sorghum smut were all seen during field trips and conversations with farmers. Farmers complained that the birds bothered them throughout the Deyr seasons even though *Quelea quelea* birds are typically only sighted in the Gu season. Crop establishment in the Baidoa area was also being hampered by a mole cricket infestation. An invasion of mole crickets happens around every 15 to 20 years. Insect pests are by far the most difficult problem on irrigated fields, especially during the Deyr season. A fresh generation of desert locusts that are attacking farmlands has recently made insect pests a more major problem during the Gu season, even though dryness is the production constraint on rain-fed Deyr fields that is most usually noted [34].

ii. Poor Crop and Varietals Diversity

There is a paucity of varietal variety within each of the many crops farmed in Somalia, and the restricted options of crops and varieties imply that farmers are not adequately buffered against biotic and abiotic stressors, increasing their risk of crop loss. In addition, in the last two decades, a new vegetative material has been introduced in Somalia. As a result, Somalia has gained little from global agriculture research advancements in the last three decades [35].

E. Lack of Agricultural Research and Limited Access to Information

Since the fall of Mohamed Siad Barre's administration in 1991, the country has lacked national agricultural research institutes and systems. As a result, links to agricultural research groups outside the country are minimal, and access to knowledge about new technology is severely constrained. Finally, the recent improvements in the worldwide agricultural research agenda, like a greater emphasis on marginal regions such as dry lands and markets, have yet to be implemented in Somalia [36]. However, the second Agricultural Extension Project in Somalia seeks to promote agricultural research and extension to boost agricultural output by providing technical assistance, cars, staff housing, operational expenditures, and renovations to headquarters facilities to create a research directorate, a dryland research station at Bonka, and a fund for more adaptable research improving extension and research

capacities, as well as their influence on agricultural output and farmer incomes, are predicted to yield benefits under the proposed initiative [37].

F. Food Security and COVID-19

The general trend of Somalia's food security, particularly in pastoral areas, has drastically declined throughout the COVID-19 outbreak. Declining tendencies were noted in research on Somalia's food security that was published in 2021 by the Famine Early Warning Systems Network (FEWS NET). Many underprivileged pastoral families struggled to fulfill their basic nutritional and non-nutritional needs. In the central pastoral livelihood zones of Somalia, where animal stocks are low among pastoralists due to rising agricultural output relative to other pastoral zones, households are in distress. COVID-19 saw a decline in cattle sales because of restrictions on the domestic and international markets. The Hajj, an annual pilgrimage to Mecca for Muslims that takes place around the holiday of Eid al-Adha and involves the sacrifice of several animals as offerings, was postponed, which had an impact on Somalia's exports of livestock in June 2020. The decline in export income among wealthier households resulted in a decrease in labor demand across the whole livestock value chain, especially for those who are paid to feed, water, and sell livestock [38]. The impacts of COVID-19 also reduced the social and financial assistance provided to pastoralists. More wealthy pastoralist homes in Somalia receive remittances and give them to numerous poor urban, pastoral, and IDP households that are unable to provide for their basic food needs. By 2020, it is expected that Somalia will get 25 to 30% less money from outside [39]. The COVID-19 control measures reduced the amount of social assistance provided to poorer homes by medium and better-off households. These factors caused the Global Acute Malnutrition (GAM) score in the central Hawd Pastoral livelihood zone to increase from serious (10–14.99%) to critical (15–9.99%) [40], [41].

G. Food Security and Nutrition

Somalia has faced food shortages for decades, with famines declared in 1992 and 2011, widespread drought in 2016 and 2017, and the possibility of famine in 2017 and 2018. Since then, the situation has changed, and Somalia now has a government that is both functioning and unstable [42]. In 2017, 3.1 million population of Somalis required immediate humanitarian assistance and were experiencing food insecurity emergencies, with famine looming in some parts of the country [43]. The nutrition situation became perilous due to acute and widespread food shortages as well as several other issues, including increasing morbidity, relocation, restricted access to health care, and the spread of cholera and measles. According to nutrition surveys, global acute malnutrition in Somalia is at dangerously high levels, with prevalence rates exceeding 15% in all affected areas and 30% in the areas with the most severe effects [44]. 388,000 children under five were predicted to be acutely malnourished that same year, with 87,000 of them experiencing severe acute malnutrition [45]. Children under the age of five are regarded as a high-priority vulnerable group in

food crises due to their increased nutritional demands from quick growth and development in early infancy, as well as higher incidence of illness and mortality [46].

i. Vulnerability and Resilience

Droughts and wars have become more common in Somalia in recent years. Between 2011 and 2016, the relationship between vulnerability and resilience, as well as the role of international humanitarian actors in resilience building, were investigated to give data on how distinct demographic groups responded to and survived repeated shocks; the prevalent drivers of marginalization and exclusion, and the methods by which these are sustained; as well as the importance of external stakeholders. Kismayo, Baidoa, and Beledweyne were chosen as research locations complimented by more information from the Somali diaspora community. There is an intertwined relationship between vulnerability, war, and catastrophes, with the most vulnerable Somalis' main issue being uncertainty about the future. Depending on their resource endowments, Somali households evolved various coping methods, including social and organizational one's diversification of revenue-generating and food production tactics, divesting of non-essential domestic assets, and coping strategies. As a result, diverse demographic groupings were able to weather the storms thanks to social ties, which combined with the successful use of remittances to build a stable economy method for risk sharing. Regardless, parties with the support of more powerful clans appeared to have an advantage over those that did not [47].

ii. Drought and Food Security

The Somali populace found it extremely difficult to cope with 2011 since it was the driest year in decades. The drought caused a severe food crisis in the country when extreme food insecurity emerged in many regions in South Somalian districts. The United Nations classified Lower Shabelle and Bakool to be in a condition of famine on July 20 [48]. By the beginning of August, 12.4 million people, more than twice as many as at the start of the year needed urgent food assistance in east African including Somalia. The Afgooye corridor refugee camp, various areas of Middle Shabelle, and the internally displaced people in Mogadishu all experienced famine in Somalia during July and August. The worst humanitarian crisis is in Somalia, where one-fourth of the population is now displaced, and huge regions of the country only have spotty access to supplies. Strong effects on the population were caused by the environmental condition in Somalia, which, in our opinion, were somewhat anticipated. Civilians did not receive national support and assistance because of Somalia's lack of environmental regulations and disaster risk reduction policies, which can be attributed to the country's extremely tumultuous political environment and the absence of a national government since Siad Barre's dictatorship ended in 1991. However, all attempts to fill the country of Somalia's policy void and deal with its administrative shortcomings were futile. The creation of Somalia's Transitional Federal Government (TFG) in 2004 heightened expectations, but the many warring factions have failed to bring about peace, security, and safety. Conflict

between the forces of the TFG and the African Union Mission to Somalia (AMISOM) that has been mostly centered in the South of Somalia since 2009. Al-Shabaab is one such Islamist group that has further complicated the political situation. The Somali population has not been subject to effective and unifying national institutions' sovereignty, which has prevented the country from managing its challenges effectively. As a result, in an area that is already regarded as the poorest in the world, residents are left even more vulnerable following each catastrophe [49].

There are now regional attempts to reduce the effects of desertification and drought. Six nations in the Horn of Africa decided to establish the Intergovernmental Authority on Development (IGAD) in 1996 to prevent famine and malnutrition in the area by fostering development and drought management and developing strategies to deal with disasters in the future. Some nations in the Horn of Africa were able to successfully establish preventative programs, for instance, countries like Kenya and Ethiopia which depended on humanitarian help were able to forecast their future requirements and crisis management. The failure of the project in Somalia may be partially explained by the absence of solid political structures in the nation. The demographic shifts the nation has seen over the past few decades, together with the absence of advancements in food production, are further significant factors explaining the vulnerability of the Somali community. Somalia's population has more than quadrupled since 1970, but the country's food supply has not grown to keep up with the demand. Due to the high cost of the conflict, Somalia's development efforts to improve sustainable agriculture in response to the country's expanding requirements were hampered. Vulnerabilities are significantly increased by both the lack of agricultural economic prospects and food shortages. Somalia's rural population depends heavily on the agricultural industry for its living, yet it lacks basic equipment to boost output like appropriate pesticides, fertilizers, machines, etc. The Horn of Africa's land aridity has never been addressed, which explains why farmers there have a hard time producing adequate crops to feed the people. Farmers are unable to create enough reserves, even in good years, to avert potential crises in the future.

Therefore, it is hard to comprehend the effects of the 2011 drought without taking into account the connections between the famine and earlier socio-economic trends. Environmental factors severely damage Somali pastoral societies, which confront grave dangers to their way of life in addition to farmers. Nomadic pastoralists, who make up most of the Somali people, lost their cattle because of the drought conditions that were present in 2009 and 2010 together with significant rainfall intervals. The pastoralist community lacked the resources to both mitigate the consequences of the 2011 drought and adapt to the new environment [49].

H. Irrigated and Rainfed Farming Systems

According to the World Bank's collection of development indicators, Somalia recorded a development rate of 70.34 percent in 2018 [3]. Sorghum, millet, beans, cassava, maize,

groundnuts, cowpeas, mung, and other minor crops are cultivated twice a year during the Gu and Deyr seasons as part of rainfed agriculture. Along the Shabelle and Jubba River valleys, there are also small-scale irrigated fields that grow maize, sesame, fruit trees, and vegetables. Large-scale plantations are home to lemon, mango, sugar cane, bananas, guava, and papaya. Vegetables are frequently grown during flood recessions in natural depressions called Desheks in the floodplain of the Jubba River. The agricultural products usually grown in these areas are beans, maize, sesame, peas, vegetables, groundnuts, and watermelons [50]. Attempts to introduce innovative approaches as well as traditional agroforestry techniques in Somalia have been a priority because they affect physical, social, and political limitations. In most parts of the Horn of Africa, nomadic pastoralism with shifting crops is practiced. In some regions, the live fence is planted by settled communities. Near the two main rivers, the Jubba and the Shabelle, is where you will find most of the agroforestry. Trees are kept in dispersed formation on rain-fed terrain, most typically *Dobera glabra*. These mostly serve as shelter for the farmer and his cattle; however, they also offer some fodder, fruit, and poles during the dry season. Keeping the bush planted helps to preserve soil fertility and reduce soil erosion. A common practice on irrigated land is to grow crops next to young fruit trees until the shade is too much. Other methods include cultivating crops beside date palms and in established coconut farms. Shelterbelts made primarily of *Casuarina equisetifolia* surround and protect large banana farms [51].

Agricultural water shortage in Somalia and the broader sub-Saharan region is more correlated with rainfall unpredictability and significant non-productive losses than with the overall yearly rainfall during the growing season. 'Green' productive transpiration accounts for less than 15% of terrestrial rainfall. Therefore, technologies for rainwater harvesting and management (RWHM) show a lot of promise for enhancing the effectiveness of rainwater usage and maintaining rainfed agriculture in the area. Currently, rainwater irrigation methods from macro-catchment systems are less widespread than those from micro-catchment and in situ systems. Applying the right in situ and micro-catchment techniques might increase the soil water content of the rooting zone by up to 30%, depending on rainfall patterns and local soil properties. By combining the use of fertilizers and rainwater harvesting, crop yields can be increased by up to six times when compared to conventional methods. In addition to lowering the danger of total crop failure due to dry spells, supplemental irrigation of rainfed agriculture by rainwater harvesting also significantly increases water and agricultural yield [52].

III. CHALLENGES FOR SUSTAINABLE AGRICULTURE IN SOMALIA

A. Land Degradation

According to SWALIM's assessments, the most common kinds of land degradation in Somalia from 1980 to 2009 were loss of vegetation, topsoil loss, and a decrease in soil moisture. Loss of vegetation included loss of cover as well as composition (species) of the vegetation. The studies [4] revealed that the loss

of vegetative cover is particularly severe in Somalia's central and northeastern regions. Between 1982 and 2008, these regions saw a net cover loss of 37% or around 1.4% per year. At an average rate of 0.6% per year, other regions were losing their vegetative cover. North-west and south Somalia, as well as the region along the Indian Ocean coast, were the most affected in terms of species loss.

B. Effects of Climate Change on Agricultural Growth

A nation that currently experiences severe levels of economic, social, and environmental fragility faces an uncertain future because of changes in air and sea temperatures and rainfall patterns connected to climate change. After adjusting for coping capabilities, the Center for Global Development ranks Somalia first among the 167 nations for total climate change risk. The sustainability of conventional agricultural livelihoods is already in jeopardy due to increasing unpredictable rainfall and extended periods of extreme drought and flooding. Numerous Somalis have also resorted to unsustainable resource exploitation due to a lack of other options, increasing the nation's susceptibility and vulnerability to upcoming climatic shocks [53].

More so than in almost any other nation, Somalia exhibits the interconnections between climatic variability and climate change, environmental degradation and the loss of natural resources, conflict, food insecurity, and poverty. Although extensively studied and documented, these processes are poorly understood. Understanding these connections and how climate change is expected to impact agriculture in the future decades will be crucial as the nation goes forward to solidify peace dividends and advantages from increased security. Decision-makers may use this information to find the optimal investments and policies to promote Somalia's strong and resilient sector growth, reduction of poverty, and sustained economic growth.

The World Bank commissioned a background study to evaluate the effects of climate change on Somalia's agriculture industry to fill this information vacuum. The report [3], which was prepared by the Horn of Africa Regional Environment Centre and Network (HoAREC&N), reviews the literature on current weather patterns and projections of climatic change and discusses the risks these phenomena pose to the nation's natural resource base (soils, rangelands, water, and forests) as well as its traditional ways of life.

C. Agriculture Risks

Analyzing the sector's most recent performance can assist in discovering the causes of its poor performance and highlight patterns. Fig. 5 shows a history of some of the most significant risk occurrences that threatened agricultural livelihoods and had an impact on grain output between 1980 and 2017. The impacts of broad-scale climate events are far more visible than the impacts of conflict. Between 1980 and 2017, eight major weather events affected cereal production (in 1982–83, 1991–92, 1994–95, 1997–98, 2002–03, 2006–07, 2009–11, and 2015–17) [54]. The biggest threat to Somalia's agriculture still comes from recurring droughts, although the opposite extreme

may also severely harm agricultural and livestock productivity. Extreme El Nino Southern Oscillation (ENSO) changes are frequently accompanied by prolonged periods of heavy rain and extensive floods, which create the perfect environment for the mosquito-borne virus that causes Rift Valley Fever to proliferate. Middle Eastern nations restricted cattle exports from the Horn of Africa in response to epidemics (in 1998–99

and 2000–02), resulting in losses of \$109 million and \$326 million, respectively [55], [56]. The purchasing power of pastoral households was severely reduced by declining cattle prices, declining terms of trade, and the sharp devaluation of the Somali shilling (which was mostly brought on by the abrupt decline in export tax income) [57].

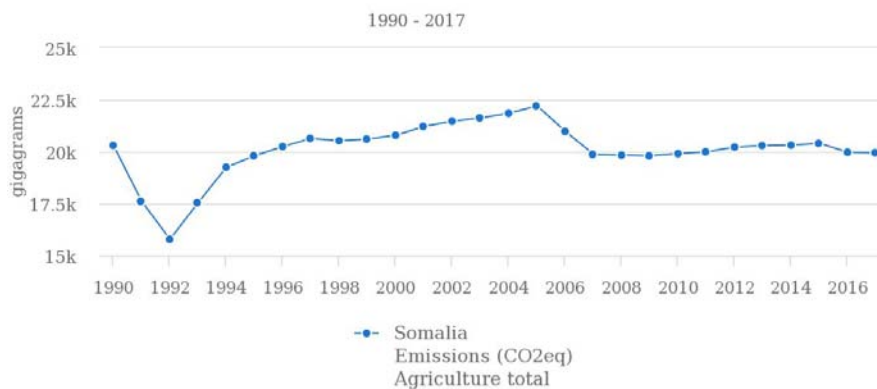


Fig. 5 Emissions (CO₂ Equivalent), Agriculture total

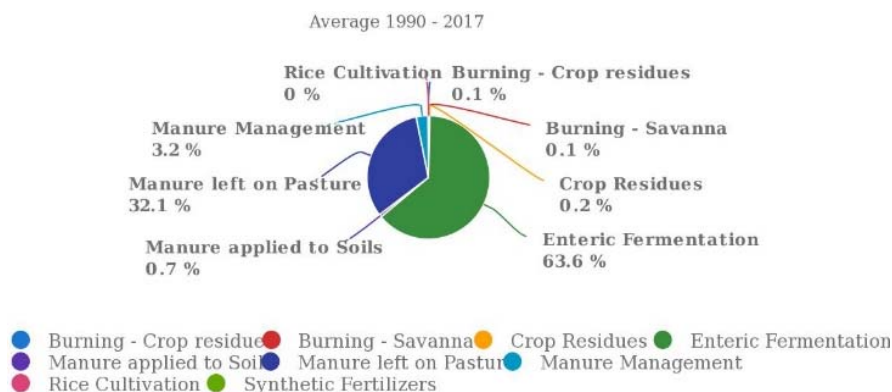


Fig. 6 Emissions by Sector (CO₂ Equivalent)

D. Rural to Urban Migration

Although the Somali population is primarily rural, there are noticeable trends of rural-urban migration. This trend was temporarily reversed during the conflict when people abandoned the towns for the homelands of their tribes. Consequently, when people left fighting in Mogadishu, the Lower Jubba, and the inter-riverine territories, the population of once minor regional towns like Belet Weyne, Galkaayo, Baidoa, and Bosasso significantly increased. According to FAO report [4], the recent consensus shows that urban movement is at its peak exacerbated by returnees from the diaspora, especially in Puntland, Somaliland, Juba Land, and the capital Mogadishu, the division of rural to urban population from 1990-2018 is increasing.

Due to significant displacement caused by the 2019 drought, about 45000 people fled from rural regions to urban centers, making it the second largest rural-to-urban migration in Somalia. As a result, the situation about food security is rapidly getting worse. 2.2 million people are predicted to experience extreme food insecurity between July and September 2019

based on the findings of the most recent multi-agency assessment [58].

To halt or at least reduce rural-to-urban migration and make sure rural people stay in their Indigenous environment and play their role in keeping the country more productive, there is a need to focus on teaching them new skills, improving their resilience capacity, and putting durable solutions in place.

E. Threats, Challenges, and Opportunities by the Agricultural Sector of Somalia

The agriculture sector faces many constraints and challenges. These can be broadly classified as natural, institutional, technological, political, and socio-economic. A detailed discussion of the categories is presented below.

iii. Inadequate Rainfall

The scarcity of water for agriculture remains one of the biggest bottlenecks to agricultural development in most parts of Somalia. This scarcity is a direct result of inadequate, unreliable, and poorly distributed rainfall, in addition to poor

endowment with surface waters such as streams and springs. This could be offset by exploiting available ground water harvesting rainwater and flush floods. Concentration of fodder

production for livestock, which requires less water than many food crops, will be a good option to encourage more livestock production with better quality for export [59].

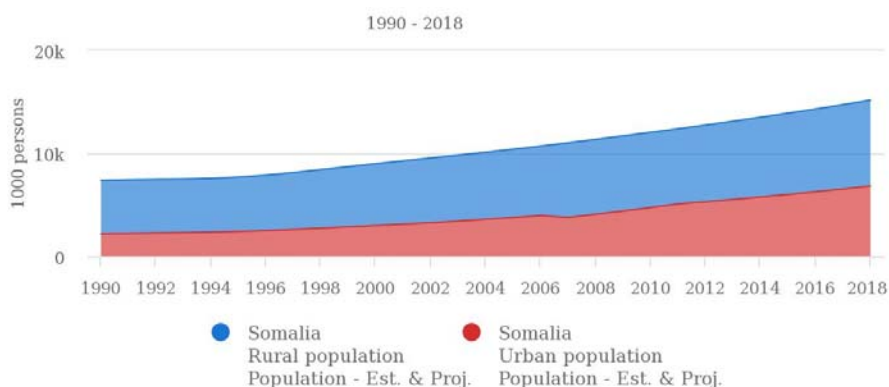


Fig. 7 Rural-urban population

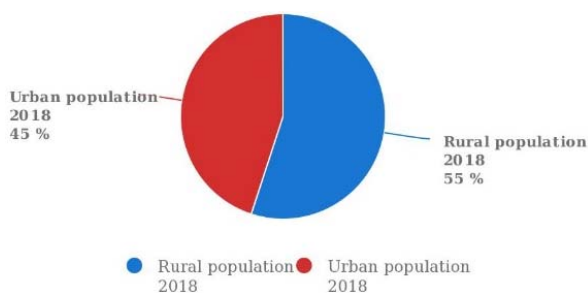


Fig. 8 Rural and Urban Population

iv. Agricultural Land Degradation Brought on by Soil Erosion

Most of the soils are sandy loam with little organic matter. Due to poor farming techniques and soil erosion, the majority of Somalia's agricultural land has been transformed into hills and mountains made of dunes. A mixture of indiscriminate de-vegetation, sporadic intense downpours, and overgrazing have made this issue worse. To stop this land deterioration, urgent action must be taken to implement soil conservation and sound farming methods [60].

v. Institutional Constraints

These problems relate to the institutional arrangement for agricultural development and the human resource capacity of the government institutions to provide adequate services to the agriculture sector.

vi. Poor National Policy Framework

Since the collapse of the central government of Somalia, there has been a shortage of the required policies and legislations to develop the sector and to set out development goals, strategies, and regulatory mechanisms to guide the development of the federal and state ministries of agriculture. This lack of sector legislation has impacted negatively on sector development because currently, interventions in the sector are at best on an *ad-hoc* basis.

vii. Human Resource Capacity

The efficacy of service delivery in the sector exhibits a positive association with the quality of the human resources available. Key responsibilities in the delivery and coordination of agricultural support services are played by the federal ministry of agriculture and state ministries. The devastation of the educational system and the infrastructure for education and training, such as agricultural schools, veterinary colleges, and universities during the Somalian civil war, is what led to the Ministries' current insufficient technical human resource basis. The following can help the Somali agriculture sector's technical human resource performance:

1. Improve the capacity, knowledge, and skills of the sector staff to guide and coordinate agricultural development activities
2. Provision of appropriate guidelines for sector human resource development
3. Provide structured training programs, agricultural knowledge, and skills for agricultural professionals to reduce the technological gap between Somalia and the neighboring countries
4. Encourage trained professionals who left the country during the civil war to comeback home and participate in agricultural development programs in the country.
5. Regain available agricultural professionals who are employed by international agencies and local and international NGOs, sometimes in non-agricultural fields, by giving them incentives and competitive salaries.
6. Train tertiary training institutions to train fresh agricultural professionals.

viii. Agricultural Technologies

The Somali agriculture sector is still subsistence to a large extent and often relies on outdated technologies that impact agricultural productivity and sector performance. Although theoretically technological innovations developed elsewhere are being introduced to the farmers through projects by development agencies, the uptake is low due to the low levels

of knowledge and un-affordability by the farmers. There is a need to identify and domesticate appropriate technologies that are environmentally, economically, and socially adaptable to ensure sustainable agricultural production. These technological packages should be anchored on demand-driven capacity building of the farmers [61].

ix. Inadequate Marketing Services and Infrastructure

Agriculture productivity and farm households' income levels have been impacted by poor marketing. Due to limited market intelligence, rivalry for the local market with neighboring nations, and a lack of agro-processing capacity, this notably impacts the horticulture sub-sector. Poor feeder roads, a lack of marketing organizations, and a lack of growth Agricultural technical committees from all interested stake holders are further concerns [62].

x. Resource Use and Sustainability

It might be challenging to prescribe for sustainable use since what is unsustainable under one set of circumstances could be sustainable under another. While population is one factor contributing to unsustainable consumption, most of the population expansion is concentrated in metropolitan areas, which have their own unique set of requirements (charcoal and products for the urban market). Therefore, what was formerly sustainable under more conventional management settings for 30 years may no longer be so owing to population growth, which is expected to be 2.85% annually [63], [64]. To encourage the use of natural resources in a way that is environmentally sustainable and locally advantageous, it is essential to understand what constitutes or may be considered sustainable usage and to use the requisite management techniques. All urban centers' landscapes and catchments are a major area of attention for sustainable usage, as well as how sustainably managed sources may provide the urban market with natural resource-based goods. Village-based and urban environmental and land use planning is one aspect of this because there is little actual data on the catch size of a marine species as a basis for an improved fishery (net size, number of boats, nets), or a local ban on certain areas of fishing to allow all the fish stocks to increase in number and size. Additionally, it must be combined with adaptive management concepts when a more accurate evaluation of the issue is necessary. This would involve designating specific areas for restoration, enacting local restoration regulations in response to a decline in the natural regeneration of particular tree species, and utilizing village planning to implement a river catchment approach in response to an increased, whether real or perceived, drying up of riverbeds to restore the catchment functions [63].

It is challenging to set requirements because there are so many factors that affect what constitutes sustainable usage, including species, land use, climate, soil types, and current levels of use. The implementation of and policy backing for adaptive management concepts (either broadly or/and more species-specific) are required at the local level. It may be necessary to reserve some areas for sustainable usage to allow the reservoir of species and seeds to grow and allow for

restoration. This might be one need for the creation of conservation areas when such areas are based on both local resource use demands and biodiversity and conservation needs. Examples of this integration include marine protected areas and dry season forage and browse reserves, which are both based on community management, benefits, and control yet might be considered conservation areas.

xi. Some Potential Policies and Procedures that Might Contribute to the Development of Sustainable Agriculture [65], [66]

- It is becoming more and more crucial to use compost for land reclamation to increase the amount of land that can be plowed.
- The use of reclaimed irrigation water on reclaimed lands is justified by its ability to sustainably manage water resources, reduce the demand on freshwater supplies, and support agricultural productivity while mitigating environmental impacts.
- Implementing organic farming in Forster can be a strategic move to enhance agricultural exports by meeting the growing global demand for organic products and improving market access.
- Reducing the use of chemical pesticides and fertilizers can improve agricultural output while benefiting the environment by minimizing soil and water contamination and promoting healthier ecosystems.
- By setting quality standards for agricultural goods, one can prevent contamination of the environment.
- Increasing the production of fodder can help replace imported feedstuffs, reducing dependency on external sources and enhancing local agricultural sustainability.
- Employing cutting-edge information and communication methods can significantly benefit the agriculture industry by enhancing data management, improving access to market information, and facilitating better decision-making.
- Creating agricultural markets, marketing infrastructure, and services for small farmers can enhance their access to buyers, improve market efficiency, and boost their overall profitability.
- Developing procedures for enhancing the quality of agricultural goods and commodities both before and after harvest can improve product standards, reduce losses, and increase market value.
- Establishing a specialized unit to manage agricultural risks by employing cutting-edge methods for tracking, evaluating, and forecasting technical and marketing hazards can significantly enhance risk mitigation and decision-making in the agriculture sector.
- Establishing marketing routes and procedures to connect farmers, especially small farmers, with markets can improve their access to buyers, increase their sales opportunities, and enhance their economic stability.
- Increasing government oversight of quality standards for both inputs and outputs, outlawing monopolies and adulteration, and enhancing consumer protection can

ensure fair practices, improve product quality, and safeguard consumer interests.

- Strengthening institutional and organizational structures to enhance connections between local and international marketing can improve market access, expand opportunities, and increase competitiveness for local producers.
- Taking proactive measures to cut losses along the value chain can enhance efficiency, reduce waste, and improve overall profitability.
- Given the higher export potential of horticulture crops, more study should be done on them.
- Developing pest-resistant, environment-tolerant, and water-efficient plant cultivars can improve crop resilience, reduce dependency on pesticides, and enhance resource use efficiency.
- Conducting more genetic and biotechnological research can lead to the development of crop types with desired features, enhancing productivity and resilience in agriculture
- Initiating research field experiments with the support of relevant government agencies and national research facilities can advance agricultural knowledge and innovation.

IV. AGRICULTURAL EXTENSION SERVICE IN SOMALIA

In 1954, the Bonka Research Station launched the first agricultural advising service for Somalian farmers as part of an Italian/Somali Government initiative. The building of three extension facilities at Lower Juba, Janale, and Hargesa followed in the 1960s. They were primarily focused on promoting cash crops, notably citrus and banana, and as a result, had little interaction with the smallholder sector, which was mostly comprised of subsistence farmers [67].

The expansion of the irrigation infrastructure was the focus of the government's agricultural development program during the 1970s. Extension efforts got little attention, and Ministry of Agriculture (MOA) employees essentially created a body of local rural administrators with no technical training. Four-fifths of anticipated investments in agriculture were committed to the sector. Meetings in villages and chats with farmers were the primary means of communication with farmers as part of a campaign called "Agraria Propaganda." There have been attempts to add animal traction and to encourage the use of inputs like better fertilizer and seed. Older extension agents, however, recall that this program was mostly a PR stunt with little fieldwork or actual training [68].

The following causes for the lack of extension efficacy in the nation were enumerated in the 1981 Agricultural Sector Review (ASR) of the World Bank:

- Limited agents and displays at the farm level.
- Inadequate instruction
- Insufficient preparation and oversight
- Scant information from the Agricultural Research Institute.
- The absence of credit and inputs
- Low employee motivation

At this moment all those obstacles were doubled due to the lack of functional government and civil wars that dismantled all the extension facilities, according to the current federal Ministry of Agriculture's strategic plan and policies they mentioned the urgent demand for effective extension services to be put in place to tackle climate change implications and to improve the livelihood and food security of the country.

The education sector particularly Universities, schools and business enterprises have a major role to play in providing extension technologies and qualifications that can fill the void of the government, The Somali Ministry of Agriculture should engage in training local farmers, and students in the field of agriculture both public and private. Universities have a major role in setting curriculums of extensions and other intensive courses plus researching the farmer's needs as they are well prepared to carry out field-based research programs and training to enhance the knowledge and skills of both farmers and students and also increase the country's Agricultural productivity [69].

A. Challenges Associated with Agricultural Extension in Somalia

After the collapse of the central government of Somalia, the extension sector fragmented and collapsed with the other government institutions but since then there have been private companies alongside international organizations committed to rebuilding the country's extension services which unfortunately did not work. Some federal member states including Puntland and Somaliland are having the remaining portion of the former services but it is functionally handicapped, although most of the challenges are linked with the lack of functional government other obstacles weaken the performance of the sector partly [70]. The main weaknesses of the extension service include:

- Few qualified extension staff to undertake extension activities effectively and efficiently
- The modern enhancements of old extension services to new systems
- Uncoordinated extension services because available extension workers are not answerable to the relevant government institutions
- Extension service struggling with inducing behavioral changes in farmers to adopt modern farming technologies.
- Inadequate technical know-how due to limited training and on-the-job skills development that become prime challenges to help farmers learn new agricultural practices from them.
- Few universities offering agricultural extension qualifications, reducing the number of qualified staff in the sector
- Lack of financial and logistical capacity of the country to provide effective extension services.

This coupled with inadequate incentives and limited career development opportunities has resulted in demoralized public sector extension personnel.

To correct all these constraints better facilities, suitable rewards, achievable targets, sector prioritization, and increased budgets are needed to improve the sector productivity and

provide qualified extension personnel in the areas where there is a shortage.

B. Strategies to Improve the Effectiveness of National Extension Services

i. Adopting a Participatory Approach

By preserving and distributing the advantages of local activity within the community and so creating new chances for growth, participatory techniques may assist in correcting inequities. Participation may also boost managerial and economic effectiveness in three different ways. First, by removing choices from the control of foreigners or unaccountable locals and giving them to the local inhabitants who pay the price for the absence of effective extension service. By integrating local knowledge, values, and ambitions in project design, implementation, administration, and assessment; second, by lowering administrative and management transaction costs via the proximity of local participants; and third, by utilizing local knowledge, values, and aspirations. Participatory methods can be used as a conflict management technique [71].

ii. Community-Based Extension Approach

To support agricultural innovation and developments, CBEA offers a potentially low-cost and extensive alternative. This strategy also appears sustainable when communities support their extensionists; community extensionists and links with research and extension bodies are maintained; this strategy has the potential to offer solutions to some of the issues found in Africa's communal lands, where the majority of people live. It centers on the devolution of power from central governments and the empowerment of communities who in most cases form groups called user groups. The approach involves the management and development of the sector that holds the potential to address some of the challenges faced in the rural areas of Africa that live on communal land that is next to them and that they depend on it for their livelihood [72].

iii. Establishment of a National Extension Research Centre

The Extension research centers that existed before the civil war in Somalia were either looted or destroyed. Currently, the ministry has limited qualified technical personnel to carry out research activities based on the needs of the Somali farmers. There is a pressing need to re-establish the National Agricultural Research Centre (NARC), Agricultural Secondary School (ASS), and Extension centers to effectively address the current and emerging technological needs of the agricultural extension sector [59].

iv. Improved Access to Agricultural Inputs

The major inputs for agriculture production are farm machinery, seeds, fertilizers, pesticides, and technical and financial support for the farmers. It is imperative to have a successful agricultural sector, inputs for agricultural production must not only be readily available but must also be of the right quality and affordable price. An enabling environment can be created for farmers by ensuring easy access to affordable agricultural inputs through Public-Private partnerships and

establishing regulatory mechanisms for quality control [73].

v. Financing for Extension Sector Development

Perfect extension services require high capital investment and most of the agencies responsible in the sector do not have sufficient cash to maintain and improve the sector. The unavailability of credit facilities limits the expansion and commercialization of the agriculture industry. Agricultural production and marketing in general are constrained by inappropriate funding mechanisms and inadequate financing. Public sector investment in extension is still missing. Access to financial services to support the extension sector is limited since returns to investment on agriculture projects take a long time. The government's intervention in this sector will mainly be in the form of support for viable and sustainable solutions to the difficulties faced by financial institutions in providing credit and savings where there is a general lack of collateral. To increase accessibility to financial resources that will be invested in the extension sector to ensure increased agricultural production will be viable [74], [75].

vi. Capacity-Building Programs to Develop the Professional Skills of Extension Staff and Farmers

One of the essential elements for any extension service is the availability of well-trained, competent, and confident agents, managers, producers, and processors who can adopt appropriate practices and technologies. The role of training is to develop, implement, coordinate, monitor, and maintain human resource development for extension activities. The capacity-building programs for the extension workers will bring new trained and informed agents in the sector as well as refresh and retrain the existing ones to meet the new demand. There will also be a need for improvement of training facilities and re-orientation of the training staff to effectively address these needs. While working with training institutes and agricultural technical schools, universities, and other research institutions to improve the quality of education, it is also very crucial to link students with commercial farms and agricultural industries for internships [76].

The technical and communication abilities of extension personnel must be urgently improved for them to assist farmers in learning new agricultural methods and increase the efficiency of the extension team. The sector productivity will increase by creating a program to enhance capacity that targets both farmers and extension agents. In this matter extension staff should have job descriptions and be held responsible for their duties which will help them stay focused on their responsibilities. Such activities prevent mismanagement and assigning unfamiliar personnel to certain tasks resulting in the loss of money, time, and resources [77].

vii. Using Electronic Media (Radio, Telephone Messages, and Social Media)

A short message both audio and visual that mainly targets Somali farmers broadcasting in their local language who have a strong oral tradition will help convey message contents and reach out to the target audiences. The message will incorporate docu-dramas with segments of role play, songs, expert talks,

poetry, and varied historical background pictures depicting various states of the country. Capturing videos that fully represent the diversity of the natural environment in the regions of Somalia will teach them a lesson in understanding the different extension services of the country, exchanging ideas, and sharing experiences from region to region. This will be used to produce short messages centered on topical themes such as proper seed selection with germination tests to ensure viability, use of improved seed varieties, planting in rows, regular plant spacing, early planting, weeding, use of insecticide, and integrated pest management [78].

viii. Capacity building through Farmers Field School

There is also another approach to teaching small-scale farmers integrated agricultural techniques known as farmers' field school (FFS) which enables extension workers to interact with local farmers and participate during the entire crop production season, there is a great possibility that FFS can enhance the productivity by improving agricultural practices and farm management in Somalia [79].

ix. Mobile Vans: An Effective Approach to Delivering Extension Messages in Remote Areas

Approximately, 46% to 56% of Somalia is considered permanent pasture dominated by natural vegetation and includes the savannah woodlands while 55% of the Somali people are living in rural areas and mobile extension services are very crucial to reach and disseminate messages to those living in remote areas of the country [3]. A well-equipped vehicle and trained extension workers equipped with TV, video, and microphones to raise awareness and educate farmers in the most applicable and relevant agricultural techniques and provide ample information on cultivation, planting, land preparation, crop management, harvesting, and weeding in easy and understandable language [3], [21].

x. Establishment of a Regulatory Framework for Extension Sector

For proper functioning, the extension sector requires a legal and regulatory framework within which the sector players will operate to ensure adherence to set standards that protect public interests and those of stakeholders. The relevant government institutions must establish legal and regulatory frameworks with adequate incentives to facilitate sector stakeholders to engage in productive and profitable sectoral activities while at the same time ensuring that the interests and well-being of the public are adequately protected. To operationalize the legal and regulatory frameworks there will be a need for well-trained and competent personnel and adequate infrastructure, equipment, and logistical support [80].

xi. Gender Participation in the Extension Sector

Gender equality considerations and mainstreaming into agriculture production processes have become increasingly important in recent years. In Somalia, men are traditionally considered as heads of households and therefore have control over production resources such as land and other services like extension but women extensively participate in almost all

farming operations. There is a need for women to play a bigger role in both agricultural production and as extension workers and in decision-making on utilization of agricultural products. Although women play an essential role in the labor force and their significant contributions, they unfortunately suffer the most due to poor health, illiteracy, cultural bias, poor nutrition, high birth rate, and many other challenges. Women's empowerment and ensuring equitable access to the sector resources and services as well as full participation in the decision-making process extremely essential to ensure sustainable agricultural production. Similarly, rural youth need to be encouraged to participate more in agricultural and rural development enterprises. These issues need to be taken into account when planning at the national and regional levels, and the process may be started right away by using proactive planning methods and gender-positive budgeting [81], [82].

V. CLIMATE CHANGE

Long-term changes in temperature and weather patterns are referred to as climate change. Even if some of these changes could be due to natural causes, human activity has been the primary cause of climate change since the 1800s. The primary cause of this is the burning of fossil fuels like coal, oil, and other gases that cause global warming [83].

The problem of climate change has become crucial for both developed and developing economies. Since the agricultural sector is more vulnerable to climate change and extreme weather changes like temperature shifts, unpredictable rain patterns, and an increase in the frequency of floods and droughts than other sectors, the impact of climate change on many economic areas, particularly the agricultural sector, has already been felt by many countries.

Even though world leaders, non-governmental organizations (NGOs), and international organizations have focused on addressing the issues of climate change globally in recent years, the effects of climate change have been more pronounced in underdeveloped and developing countries, particularly in countries with an agriculture-based economy. This could be explained by the developed economies' capacity to react promptly to climate-related disasters and lessen their detrimental impacts and in contrast, emerging nations, like Somalia, heavily rely on the agricultural sector since it greatly raises their GDP, export revenues, and jobs. Developing and underdeveloped nations are particularly susceptible to the effects of climate change due to their heavy reliance on the agricultural sector and the absence of adaptation strategies. Given that it produces over 75% of the country's GDP and 93% of all export revenue, respectively, the agricultural sector is still the foundation of the Somali economy [3], [7], [84]-[86].

A. Climate of Somalia

The Inter Tropical Convergence Zone affects the climate, which spans from tropical to subtropical and from arid to semi-arid (ITCZ). Except for higher elevations in the north, the majority of Somalia has a semi-arid to desert climate, which is hot and dry all year long and has irregular and low precipitation. Every two to three years, there are droughts, which are

frequently followed by disastrous floods. The time and amount of rainfall are significant elements affecting the sufficiency of grazing in Somalia, where the climate is the fundamental predictor of life.

Somalis distinguish between two wet (Gu and Deyr) and two dry seasons (Jiilaal and Haggaa). The Gu rains, which start in April and extend through June, are the primary rains and account for more than 60% of all rainfall. The brief Deyr rains follow this, which is followed by the Haggaa dry season (July to September) (October-November). The Jiilaal season, which lasts from December to March, is the most challenging for pastoralists and their herds. Most of the nation receives less than 500 millimeters of precipitation yearly, while a sizable region including much of northern Somalia and the northeast receives as little as 50 to 150 mm. Some coastal locations and certain higher places in the north both record more than 500 mm annually [87]. 330 to 500 mm are delivered to the southwest. The average daily maximum temperature is between 30 and 40 °C, except for higher altitudes and the Indian Ocean shore. The range of the mean daily low temperature is 20 °C to above 30 °C. The highest temperature variances may be seen in northern Somalia. Southerly temperatures are more moderate, hovering between 20 °C and 40 °C. February through April are the warmest months, while the coast is typically 5 to 10 degrees cooler than the interior. Even during the dry seasons, the relative humidity in the coastal zone often stays about 70% [88].

B. Climate Change and Drought

One of the worst droughts the nation has ever experienced occurred in the summer of 2011. As a result, there were lower agricultural yields, greater rates of animal death, and higher food prices. All of East Africa's nations were impacted by the drought and the ensuing losses in agricultural output, but in Somalia, the drought resulted in famine. Ten million people had acute food shortages, which led to tens of thousands of deaths from hunger. Huge environmental effects resulted from the drought of 2016–2017 where 68% of the natural standing vegetation, 18% of the country's landmass, was destroyed during this period. Overall, the ecosystem suffered losses and damages from this drought totaling about USD 564.8 million. Due to the decline of traditional livelihoods caused by the drought, excessive resource exploitation has also occurred [3], [89]. Naturally occurring droughts can be intensified by anthropogenic and environmental factors. In addition, drought frequency and severity have increased due to climate change. This is a result of shifting climate patterns, an increase in the population, poor institutional capacity, civil unrest, and a high level of poverty in the country [90]-[92].

C. Desertification in Somalia

Somalia, like most African nations, experiences environmental degradation and desertification. The nation also faces environmental problems caused by both natural and human-made factors. Soil erosion and desertification are brought on by excessive grazing and deforestation. The destruction of productive land by irrigation. There is an increasing population in the country, and many of them depend

on agriculture as well as livestock for a living. Extremely high levels of evaporation and very little rainfall, together with severe droughts followed by flash floods, all contribute to the environmental degradation that threatens the sustainability of the environment. In Somalia, trees are cut down for firewood and to make charcoal for sale.

The primary contributors to desertification include the production of charcoal, the clearing of land for agriculture, the overgrazing on already diminishing green areas, the poor management of land, and the felling of trees to produce timber for sale and building purposes. Additionally, the region's ongoing drought has made these extremely harmful practices even worse. Loss of biodiversity and frequently increased soil erosion are both results of the drought. The future of the nation is threatened by several behaviors that have persisted for years. Desertification and poverty have started to coexist in the region. Because it is difficult to grow food due to land degradation, desertification has increased poverty in the area. In Somalia, clearing land along rivers has been going on for decades to alter the direction of the river flow so that more land may be used for agriculture, which causes soil to erode.

As important as the charcoal industry is to the Somali people's ability to exist, it also serves as their primary source of energy because access to electricity is still limited and expensive. Acacia trees, which mostly grow in plateau regions and have a very slow natural regeneration process, are the source of this energy. Deforestation has emerged as the most obvious issue in Somalia as a whole runs out of trees due to the increasing rate of desertification [93]-[95].

D. Biodiversity Loss

Somalia is divided into four ecological areas: The Ethiopian Xeric grasslands and shrublands, the Northern Zanzibar-Inhambane Coastal Forest, the Mosaic Somali Montane Xeric Woodlands, and the East African mangroves. These habitats are a component of the Horn of Africa biodiversity hotspot, one of the 36 locations with the greatest biodiversity on earth. Due to overgrazing, charcoal burning, and poor management, it is also severely degraded, with just 5% of the natural ecosystem left. Hyenas, foxes, leopards, lions, warthogs, ostriches, small antelopes, and a wide range of birds are among the wildlife species found in Somalia. Due to substantial land degradation, the northern region of the country has a limited number of animal species.

The main threats to Somalia's biodiversity species include numerous droughts brought on by climate change, increased land degradation, a lack of security, an unstable government, a lack of law enforcement in the management of national parks, the production of illegal charcoal, pressure on remaining wildlife due to hunting and illegal fishing, unsustainable mangrove harvesting, coastal mining, and the dumping of hazardous waste. In Somalia, many plant and animal species are endemic. approximately 25% of the 3,165 plantations are Indigenous, for instance. High percentages of endemic conditions. Besides freshwater fish, mammals (18%), reptiles (35%) and amphibians (14%) have been recorded. Although Somalia has a diverse range of species, little is known about

them. The most recent research on biodiversity was released in the 1990s, mostly because of pervasive insecurity. In the previous 25 years, no new biodiversity research has been carried out. As a result, there is a substantial information vacuum regarding the biodiversity state of the nation and the patterns of species distribution. According to fragmented data, the nation is home to 3,165 species of higher plants and 1,340 kinds of animals that have evolved to survive in its biological environment. All these have an impact on the food security of the country [96]-[98].

E. Climate Change, Cyclones, and Flooding in Somalia

Climate change, which increases the frequency and intensity of extreme weather events and results in damaging cyclones, strong winds, and flooding, is the most existential danger to Somalia. Due to Somalia losing 30% of its forest cover in less than 40 years, riverbank stability has been compromised, and the effect of floods has increased. In 2018, tropical storm Sagar drove over 230,000 people to evacuate floods, while in 2019, heavy seasonal rains prompted over 400,000 people to flee flooding. However, drinking more water may have unforeseen negative health effects. Most recent occurrences of cholera in Somalia have occurred in flood-affected regions, with standing water contributing to malaria epidemics and damage to water treatment systems causing outbreaks of water-borne diseases, including cholera. Additionally, with ever-more-frequent and intense cyclones flooding coastal and riparian areas and increasing insect infestations like locusts, the Indian Ocean continues to be the fastest-warming tropical ocean. Given the fall in production of fundamental food essentials like grains [99], [100].

Additionally, long-term droughts and desertification are anticipated to be interspersed with an increase in the frequency of catastrophic storms. A lack of water and an abundance of water are connected phenomena that can occur in most areas of the country at the same time. For example, soil that has been dried up by years of drought cannot absorb water effectively, making heavy showers become flash floods readily [101], [102]. Political upheaval and violence followed 24% of the 92 significant flooding disasters studied globally between 2015 and 2018, which enhanced the danger in ethnically fractionalized Somalia [103]-[105].

F. Water Resource

97% of Somalia's 6 cubic kilometers of renewable water resources are used for agriculture and raising cattle. Three percent is allocated for home and urban usage. More than 26% of the population has access to clean water to drink [106]. Numerous immediate and long-term effects of climate change are being felt on water resources in Somalia. These include flooding, drought, sea-level rise in estuaries, river drying and becoming salty, and poor water quality in surface and groundwater systems. The continued existence of many places in Somalia is threatened by these effects, which when combined have devastating effects on ecosystems, agriculture, and communities. These implications range from economic and social effects to health and food shortages [107].

The effects of climate change on aquifers are immediate effects on shallow aquifers that are directly recharged by rainfall and delayed effects on aquifers that recharge slowly or cannot be recharged. Groundwater level changes can be observed almost immediately after a precipitation event in shallow aquifers that are in alluvial pockets above the rock foundations as well as in sandy riverbeds. Deep aquifers that, if at all, replenish from both slowly percolating surface water and groundwater movements are typically embedded in cracked or porous rock formations. In each case, the effects of climate change on these deep groundwater resources are significantly more delayed, and they may also be impacted by changes on a larger aquifer size as opposed to those on a surface basin scale. Due to rising population and livestock numbers, reactions of aquifers must be regarded as a mixed signal of reduced recharge as well as partially strongly enhanced abstraction. The current behavior of groundwater levels, driven by climate trends, directly impacts food insecurity and agricultural output [108].

G. Climate Change and Conflicts

Somalia has had significant issues with climate change because of a protracted conflict and an incompetent administration. The loss of property and livelihoods, deaths from migration, disputes over resources, and several other catastrophes are constantly related to the climate extremes of today, including floods, droughts, and coastal marine severe systems, among others. The IPCC has shown that climate change is a reality and that it is crucial to comprehend local future climate change scenarios [109].

The country's long-running violent conflicts have seriously harmed both the physical and emotional health of its men and women. As a result, women had to assume tasks that were previously filled by men, such as being the household's major breadwinner. This creates tension in families who are negatively impacted by climate change. Women must labor to support their families, but they have little or no control over how resources are accessed, owned, and used in their homes and communities. This limits their ability to engage in social and economic life in their neighborhoods [47].

The conflict has been exacerbated by climate change, which has also diminished the resilience and adaptive capability of governmental structures. This dispute highlights the incapability of the institutions, particularly in conditions of significant climate change producing lower agricultural productivity, since it intensifies competition for finite resources and leads to increased ethnic tension and mistrust [110].

H. Charcoal Production: "Black Gold" in Somalia

Due to the revenue, it produces, charcoal, the main source of energy for cooking in millions of Somalian homes, has been dubbed "black gold." Studies show that between 1993/95 and 2014, the amount of forest cover decreased by 50% and the amount, of wood decreased by 17%. It is also noted that the 4700 km² region along the Juba River in southern Somalia has an average production of 24,000 tons of charcoal and 2.7% tree loss over the two years based solely on the locations detected in 2013. Additionally, it was discovered that producing charcoal

was a maladaptive reaction to climate changes [111], [112]. Furthermore, Al-Shabaab, a militant terrorist organization, receives funding in part from the illegal production and selling of charcoal, which turns Somalia's trees into "black gold." It is challenging to estimate how many trees are cut down to support the violent Shabab's objective because sections of the country under the group's control are inaccessible to researchers [113].

Using multitemporal extremely high-resolution satellite images and field investigation, tree-cutting rates over five years in a very dry bush region in northeastern Somalia with major charcoal-producing activities have been assessed. It was feasible to build baseline tree density layers for the two years of observation and to estimate the tree-cutting rates for the years 2001 to 2006 by using a traditional area frame sampling approach, eye interpretation of the samples, and a semi-automatic tree detection system. The 2.8% average yearly tree loss and the complete lack of recovery over 5 years show the detrimental ecological effects of tree cutting for charcoal on bush vegetation. By highlighting regional and temporal trends in the cutting areas, it is obvious how deforestation in Northern Somalia's sensitive rangeland ecosystem has both ecological and human dimensions, aggravating the nation's food crisis. The entire region might one day be completely deforested if deforestation continues as usual [114], [115].

I. Energy and Emissions

Due to its detrimental effects on people's health, the economy, and society, environmental degradation mitigation is a global goal for all countries. However, little is known about the elements that the least developed countries' environmental pollution can be reduced through. More precisely, there is very little empirical research on the relationship between environmental deterioration, institutional quality, and renewables in Somalia in the literature currently. The results over the long term show that institutional quality and renewable energy improve environmental quality. Population increase and economic development worsen environmental quality whereas capital expansion slows down environmental degradation and low agricultural produce [116]. After a protracted period of political turbulence and civil unrest, Somalia is now beginning to recover. The urbanized population is expanding at a previously unheard-of rate, which eventually increases the need for energy. Urbanization is shown to hinder energy consumption, although economic and population expansion result in long-term increases in energy demand [117]. Generally, for a very long time, Somalia's energy requirements were met by importing oil, wood for burning, and charcoal. There are around 80 oil-dependent "state-owned" diesel and oil-powered facilities in the nation. Decentralized power generation by the private sector has become standard practice. Although detailed information on emissions is scarce, it is estimated that carbon dioxide emissions are relatively low, with annual emissions of less than 1 ton per person, considering population density and power consumption. In 1995, 3.085 million tons of non-CO₂ air pollutants, including carbon monoxide, nitrogen monoxide, and sulfur dioxide, were released into the atmosphere, accounting for 0.25% of total

emissions [5]. Renewable energy is naturally abundant in Somalia thanks to the country's rivers, sun, and wind. The vibrant private sector in Somalia, which has a generation capacity of about 106 megawatts (MW), provides all the country's electricity of this, 100 MW comes from diesel generators and 6 MW from solar and wind energy. Potential sources of worldwide emissions include shipping oil from the Middle East and the usage of diesel generators to produce energy. In research by the African Development Bank, Somalia was found to have the largest resource potential of any African country for onshore wind power, with a capacity to produce between 30,000 and 45,000 MW, and solar electricity, with a capacity to produce more than 2,000 kWh/m² [70]. Hence, there is a growing interest in hybrid systems that draw on solar and wind energy resources. This provides immense opportunities to exploit this potential for sustainable green growth. However, lack of investment and purchasing power hinders worsening food insecurity and agricultural food output [118], [119].

J. Climate Change Adaptation and Resilience

Humanity is faced with immense difficulties, such as food shortages, global pandemics, and climate change, which call for durable and long-term solutions. Somalia, a country where environmental hazards brought on by a rapidly changing climate coexist with violence and insecurity, is at the vanguard of climate change. Food security issues are a primary priority in Somalia since the country warms more quickly than the rest of the world due to destructive climatic changes. Increased frequency of droughts and floods puts more households at risk of food insecurity. Future food security will face a new problem due to climate change and no adaptation or resilience mechanisms are in place. Due to climate change, there will be alternating droughts and floods. The need for a comprehensive approach to sustainable crop types is highlighted by the production ecosystem perspective. Reduced external inputs, integrated crop protection, low soil fertility, and flooding are some of the production concerns. The implementation of policies for disaster risk management and mitigation designed to address the consequences of climate change and boost the resilience of communities and families is still significantly lacking. Along with weak governance structures and a lack of essential services, the local community lacks the financial, technical, and informational resources needed to build food insecurity resilience. The humanitarian crisis in Somalia is one of the world's most complex and protracted situations [120]. In Somalia, wars and droughts have increased recently, peaking in 2011 and 2016. Uncertainty about the future is the biggest challenge the most vulnerable Somalis are experiencing, according to a study [41] that discovered an unbreakable relationship between vulnerability, war, and catastrophes. Depending on their resource endowments, Somali households used a variety of coping mechanisms, such as social and organizational coping mechanisms, selling non-essential domestic possessions, and diversifying their methods for generating income and producing food. As a result, distinct demographic groups were able to survive the shocks thanks to their social connections, which combined with effective

remittance utilization to produce reliable mechanisms for risk sharing [47].

VI. CONCLUSION

According to FAO [3], agriculture is the main driver of the Somali economy. In 2001, the GDP for Somalia was projected to be approximately US\$ 806 million, but the GNP is greater due to remittances from Somalis living abroad, known as the Somalia diaspora, which amount to US\$ 300-400 million. Agriculture is anticipated to provide 60% of the GDP among all sectors. However, the existing challenges and limitations of the sector like climate change, instability, old farming methods shortage of enough water to cultivate crops, population growth, and rural-to-urban migration made the sector fragile and less productive.

The goal is to advance the agricultural extension sector to bridge the gap between farmers' practices and available technology by providing comprehensive technical advice, information, and training. Farmers' capacity to embrace new technology to boost crop productivity and incomes would be constrained in the absence of adequate agricultural extension services. An efficient and effective agricultural extension service is one of the most important services for increasing agricultural productivity. Public extension and extension by sector development organizations serve as the primary information sources for Somalia's majority of small-scale and resource-poor farmers seeking to adopt better husbandry techniques. Additionally, they give access to additional chances for agricultural growth via connections to education, sources of input supplies, bettering water resources, including women and young people in agriculture, and maybe markets. The aim is to develop a public extension service that leverages technologies and services provided by research institutions, development agencies, and NGOs to create an integrated agricultural extension system that effectively meets the diverse needs of farmers.

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DECLARATION

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