DOI: https://doi.org/10.59983/s2025030108
AgroEnvironmental Sustainability, 2025, 3(1), 64-76

REVIEW

Impact of Rainfall Variations on the Production of Major Crops: Sorghum (*Sorghum bicolor*) and Maize (*Zea mays*) in Burao District, Somaliland

Sharmake Mohamed Ahmed [1, *], Abdullahi Ali Ibrahim [2], Fathi Abdirahman Farah [3] and Abdiaziz Hassan Nur [2]

[1] Department of Agronomy, Hajee Mohammad Danesh Science and Technology University, Dinajpur 5200, Bangladesh
[2] Department of Agricultural Extension, Hajee Mohammad Danesh Science and Technology University, Dinajpur 5200, Bangladesh
[3] Department of Entomology, Hajee Mohammad Danesh Science and Technology University, Dinajpur 5200, Bangladesh
[*] Author responsible for correspondence; Email: dabmagawshe12@gmail.com.

ARTICLE HISTORY
Received: 20 February 2025
Revised: 05 March 2025
Accepted: 12 March 2025
Published: 15 March 2025

KEYWORDS
agricultural productivity
constraints
major crops
rainfall variations

EDITOR
Pankaj Kumar

eISSN 2583-942X

Abstract

This study examines the impact of rainfall variability on the production of major crops sorghum and maize in Burao District, Somaliland. Given that agriculture in the region is predominantly rainfed, fluctuations in rainfall patterns significantly affect crop yields and food security. The study reviews existing literature and data to assess trends in rainfall variations and their consequences for agricultural productivity. Findings indicate that inconsistent rainfall, prolonged dry spells, and drought conditions have led to decreased crop yields, affecting both food availability and farmer livelihoods. Additionally, farmers in the region face multiple constraints, including limited access to irrigation, financial resources, and modern agricultural techniques. The study highlights the necessity of climate adaptation strategies, such as drought-resistant crop varieties, improved water management, and policy interventions, to mitigate the impacts of climate variability. Strengthening agricultural extension services and adopting climate-smart farming practices are crucial to ensuring sustainable crop production in Burao District.

Citation: Ahmed, S. M., Ibrahim, A. A., Farah, F. A., & Nur, A. H. (2025). Impact of Rainfall Variations on the Production of Major Crops: Sorghum (*Sorghum bicolor*) and Maize (*Zea mays*) in Burao District, Somaliland. *AgroEnvironmental Sustainability*, 3(1), 64-76. https://doi.org/10.59983/s2025030108

Statement of Sustainability: This study presents a comprehensive analysis of how rainfall variability impacts the production of sorghum and maize in Somaliland's Burao District. It aligns with Sustainable Development Goals (SDGs), particularly SDG 13 (Climate Action) by highlighting the need for climate adaptation strategies, and SDG 2 (Zero Hunger) by addressing food security concerns. The research suggests practical solutions to enhance agricultural resilience and ensure sustainable crop yields in vulnerable, rain-fed regions affected by climate variability. These solutions include the adoption of drought-resistant crop varieties, improved water management practices, and policy interventions. Such strategies are crucial for regions like Somaliland, where climate variability poses significant challenges to food security and livelihoods.

1. Introduction

Agriculture plays a crucial role in Somaliland's economy, providing livelihoods for the majority of the population. The sector is primarily rain-fed, making it highly vulnerable to climate variability and water scarcity. Historically, rain-fed agriculture has been a dominant practice since the colonial era, but climate change has significantly reduced its viability (Sharmake et al., 2022). Despite its challenges, the agricultural sector remains a key source of food security and economic stability, with crops like sorghum and maize being the most widely cultivated. Sorghum and maize are staple crops in Burao District, serving as the primary sources of food and income for smallholder farmers. These crops are well-adapted to semi-arid conditions, yet they remain highly sensitive to changes in rainfall patterns. Studies indicate that prolonged droughts and erratic rainfall significantly reduce sorghum yields, particularly in regions that rely on traditional rain-fed farming methods (Abukar, 2023). Additionally, maize production has shown vulnerability to extreme weather

fluctuations, which directly impact food availability and economic sustainability in the district (Ahmed, 2023). Burao District, like many areas in Somaliland, experiences high rainfall variability, with fluctuating seasonal patterns affecting agricultural productivity. Studies show a long-term decline in precipitation trends, exacerbating the frequency of droughts and extreme weather events (Samatar, 2024). Between 1985 and 2015, annual rainfall in some parts of Somaliland decreased at a rate of approximately 1.4 mm per season, impacting the length and intensity of the rainy seasons (Sharmake et al., 2022). The increasing unpredictability of rainfall has led to shifts in planting seasons and reduced crop yields, necessitating adaptive farming techniques such as drought-resistant seed varieties and irrigation systems.

Agriculture is a fundamental sector in Somaliland, contributing significantly to food security and the economy. However, agricultural productivity in the region is highly dependent on climatic conditions, particularly rainfall. Rainfed agriculture is the primary mode of farming in Somaliland, making crop production highly vulnerable to variations in rainfall patterns. Sorghum and maize are among the most cultivated crops in the country, providing staple food for the population. Nevertheless, the impact of rainfall variability on their production remains a critical concern for farmers and policymakers (Abdisa et al., 2022). Rainfall variability has been identified as one of the most influential climatic factors affecting crop yields in arid and semi-arid regions. The dependence of sorghum and maize on rainfall patterns means that any fluctuations in precipitation levels can significantly affect their growth, development, and yield. Studies indicate that both maize and sorghum yields are highly sensitive to changes in rainfall amount, intensity, and distribution (Lawrence & Elisha, 2022). The Burao district, located in the semiarid regions of Somaliland, experiences significant rainfall variations, which pose challenges to consistent agricultural output. The unpredictability of rainfall in the Burao district has led to fluctuating crop yields, adversely affecting food security and livelihoods. Erratic rainfall, prolonged dry spells, and drought conditions have become common, leading to decreased productivity of staple crops like sorghum and maize. Research suggests that inadequate rainfall during critical growing periods can lead to severe yield reductions (Ahmed, 2023). Conversely, excessive rainfall, particularly during certain growth phases, can also negatively impact crop health and productivity (Ali, 1975). Therefore, understanding the extent to which rainfall variability affects sorghum and maize production is crucial for developing strategies to mitigate its impact. Sorghum and maize are particularly susceptible to water stress during critical growth stages such as germination, flowering, and grain filling. Studies have shown that delayed rainfall or prolonged dry periods during these stages can lead to stunted growth and poor grain formation (Dennett et al., 1981). Additionally, heavy rainfall during harvesting periods can result in post-harvest losses due to mold growth and spoilage, further reducing available food supplies. Farmers in the Burao district have historically relied on traditional knowledge and adaptive strategies to cope with rainfall variability. These strategies include altering planting dates, selecting drought-tolerant crop varieties, and adopting water conservation techniques such as mulching and contour farming. However, the increasing frequency and intensity of climate variability necessitate more systematic and scientific interventions to support local farmers (Msongaleli et al., 2017).

Climate models predict that future rainfall patterns in Somaliland will become increasingly erratic due to global climate change. Rising temperatures and shifting precipitation trends may exacerbate existing agricultural challenges, making it imperative to implement climate-smart agricultural practices. These practices include integrating irrigation systems, improving soil fertility management, and investing in early warning systems for better preparedness (Tolosa et al., 2023). Government policies and international support play a crucial role in mitigating the impact of rainfall variability on agriculture. Strengthening agricultural extension services, providing access to improved seed varieties, and promoting sustainable land management practices can significantly enhance the resilience of farmers in the Burao district. To find long-lasting solutions to the problems caused by climate change in agriculture, researchers, policymakers, and local communities must work together (Abdisa et al., 2022). Rainfall variability plays a crucial role in determining the success of cereal crop production in semiarid regions such as Burao, and Somaliland. Agriculture in Burao is predominantly rainfed, making it highly vulnerable to the effects of fluctuating rainfall patterns, which directly influence crop yields and food security (FAO, 2020). Because of climate change, it rains less consistently, with later starts, shaky distribution, and long dry spells. This makes the already fragile agricultural sector in the region even worse (World Bank, 2018; IFPRI, 2021).

Cereal crops, including sorghum and maize, are staple foods in Somaliland and form the backbone of rural livelihoods. However, unpredictable rainfall patterns have led to increased incidences of drought and soil degradation, further reducing productivity (FSNAU, 2021; FAO SWALIM, 2019). Studies show that less rain and uneven distribution

during key growth stages greatly reduce grain yields, which affects farmers' ability to get food and their ability to make money (UNDP, 2022; CGIAR, 2020). Moreover, the increasing frequency of extreme weather events, such as flash floods and prolonged droughts, has intensified the vulnerability of cereal crops (IPCC, 2019; WFP, 2013). Drought conditions reduce soil moisture availability and lead to a decline in pasture quality, impacting livestock production, which is often integrated with crop farming in Somaliland (FAO, 2016). Farmers in Burao face difficulties in adapting to these changes due to limited access to irrigation, financial resources, and technological innovations (IFAD, 2021; World Bank, 2019). Addressing these challenges requires a multi-faceted approach, including the promotion of drought-resistant seed varieties, improved soil and water conservation techniques, and investment in sustainable irrigation infrastructure (FAO, 2017; AWF, 2014). Additionally, strengthening early warning systems and providing climate information services can help farmers make informed decisions regarding planting and harvesting periods (WFP, 2023; UNEP, 2021). Enhancing the resilience of smallholder farmers through policy interventions and capacity-building initiatives is also essential for sustaining cereal crop production in Burao (FAO, 2016).

In this article, we will discuss the previous discussions, findings, and information and aim to address the following objectives: 1) to explore the impact of rainfall variations on production of major crops sorghum and maize in Burao district and 2) to appraise the constraints faced by the major crop farmers in Burao district.

2. Literature Review

2.1. Climate of Somaliland

Somaliland's climate is predominantly arid to semi-arid, influenced by its geographical location and topography. The region experiences significant seasonal variations in temperature and precipitation, which shape its agricultural activities and water availability. Rainfall is low and highly variable, often leading to drought conditions that impact livelihoods, especially in rural areas dependent on rain-fed farming and pastoralism. The combination of hot temperatures, irregular rainfall, and prolonged dry seasons makes water scarcity a recurring challenge, affecting both crop yields and livestock productivity (Figure 1 and Table 1).

2.1.1. Rainfall

Somaliland experiences a bimodal rainfall distribution, with two primary rainy seasons: Gu (April–June) and Deyr (August–November). The Gu season contributes approximately 60% of the total annual rainfall, while the Deyr season provides additional but lesser precipitation. Between these wet periods, two dry seasons occur: Jilaal (December–March), which is the most severe, and Hagga (July–August), a shorter dry spell characterized by high temperatures and arid conditions. Rainfall across Somaliland is low and erratic, with regional variations influencing agricultural productivity. Higher rainfall levels are recorded in Hargeisa, Sheikh, and Borama (500–600 mm per year), while Ceerigaabo receives up to 400 mm annually. In contrast, the northern coastal areas receive less than 100 mm, and most of Somaliland, including Burao District, typically receives 200–300 mm annually. However, due to unpredictable rainfall patterns, Burao experiences frequent droughts, significantly impacting the production of major crops such as sorghum and maize, which rely on seasonal precipitation. The dependence on rainfall for crop cultivation means that any deviation in seasonal rains—either delayed onset, early cessation, or overall reduction—can lead to substantial yield losses, threatening food security in the region.

2.1.2. Temperature

In the higher altitudes of the mountains and plateau areas temperatures vary considerably with the seasons, with a mean annual temperature of 20-24°C, while the coastal region has mean annual temperatures of 28-32°C. The hottest weather is experienced between June and September and temperatures get cooler in December, January, and February. The highest long-term mean maximum value that has been recorded is 42°C in June and July at Berbera. The lowest can reach 5-10 in Ceerigaabo Hargeisa and Borama.

2.2. Cereal Crop Production in Somaliland

Agriculture in Somaliland is predominantly rain-fed, with sorghum and maize being the major cereal crops. These crops are mainly cultivated in the Awdal, Waqooyi Galbeed, and Togdheer regions, where rainfall is relatively higher. According to FAO-FSNAU data, the average annual cereal production (sorghum and maize) in Somaliland is approximately 25,362 metric tons (MT), covering an area of about 35,087 hectares.

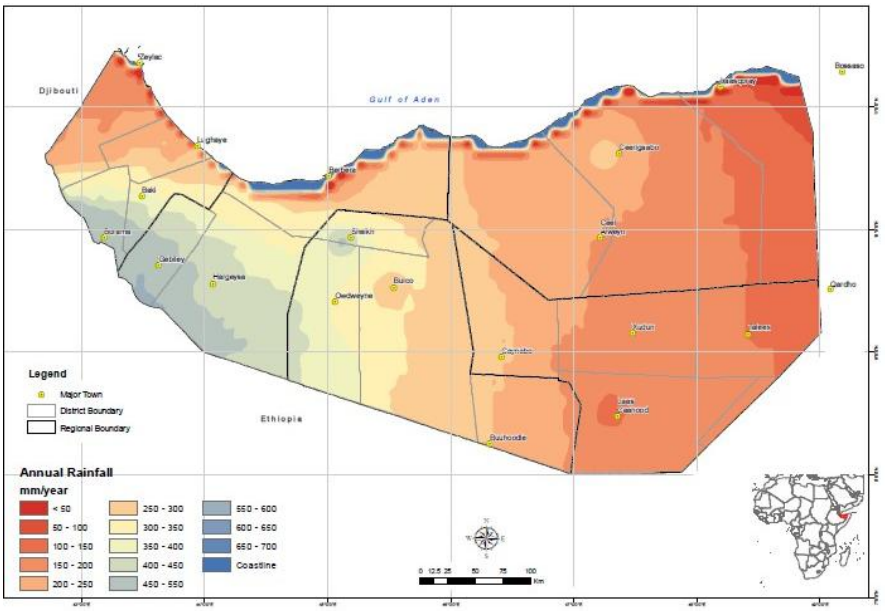

Figure 1. Map of rainfall in Somaliland (Data source: FAO-SWALIM).

Table 1. Sorghum and maize production statistics (2005–2010).

Year	W. Galbeed		Awdal		Tog Dheer		Total	
	Area (HA)	Production (MT)	Area (HA)	Production (MT)	Area (HA)	Production (MT)	Area (HA)	Production (MT)
2005	32,640	19,767	8,380	5,004	1,660	944	42,680	25,715
2006	27,596	19,821	6,380	4,578	1,064	602	35,040	25,001
2007	27,786	20,260	6,655	4,008	1,573	968	36,014	25,236
2008	22,350	15,080	3,300	1,565	1,780	907	27,430	17,552
2009	20,000	9,667	2,360	884	585	205	22,945	10,766
2010	37,100	40,441	5,700	4,086	3,540	3,377	46,410	47,904
Average	27,912	20,841	5,474	3,354	1,700	1,167	35,087	25,362

Source: FAO-FSNAU.

2.3. Steps Adopted in Literature Survey

- Step 1: Formulation of Research Objectives
- Step 2: Search Strategy Development
- Step 3: Data Source Identification
- Step 4: Data Collection
- Step 5: Screening and Selection Process
- Step 6: Data Extraction and Compilation
- Step 7: Data Synthesis and Presentation
- Step 8: Review and Refinement

This paper is based on secondary data. To fulfill the objectives of this paper, a variety of published and unpublished research articles, papers, books, and the latest reports by some international organizations such as FAO, etc., on the impact of rainfall variations on the production of major crops sorghum and maize in Burao district, Somaliland were collected from different databases, Google Scholar, and Scopus. The searches included a combination of keywords and phrases such as "Impact of rainfall variations on production of major crops," "Constraints faced by the major crop farmers," "Climate change," "Agricultural productivity in Somaliland," "Sorghum and maize production," "Rainfall and crop yield," "Rainfall dependency in farming," "Impacts of climate change on agriculture," and "Impact of drought on crop production." The review was conducted from January 2024 to February 2025 and included relevant sources published between 2000 and 2024. A total of 113 published and unpublished papers were gathered from all of the

searches. To review the work, only 34 published and unpublished papers were taken into consideration. Based on the review topic's suitability, recentness, and relevance, as well as the data type, specific research was either included or excluded. The review compiled and presented evidence and information using figures and tables obtained from reliable sources and calculated by the authors themselves.

3. Results and Discussion

This study examines how changes in rainfall affect the production of maize and sorghum in Burao District, Somaliland, is presented in this part. To understand these results and explore their implications for regional food security and agricultural resilience, it also incorporates pertinent literature. The findings shed important light on the difficulties faced by farmers in rain-fed regions, especially in light of climate variability. Based on these results, workable ways to mitigate the negative consequences of climate change and improve agricultural output are suggested. A thorough examination of the findings is given in the ensuing subsections, which also place them in the larger framework of comparable environmental and agricultural patterns seen in other areas.

4.1. Impact of Rainfall Variations on Production of Major Crops

4.1.1. Average Rainfall Trends in Burao

Rainfall patterns in Burao have shown significant variability over the past decade, directly influencing agricultural productivity. The fluctuations in annual rainfall impact soil moisture levels, crop growth, and overall yields. Periods of lower rainfall often correspond with declines in cereal production, underscoring the challenges faced by farmers. The figure below illustrates the annual rainfall trends in Burao from 2015 to 2024, providing insight into these climatic variations (Figure 2).

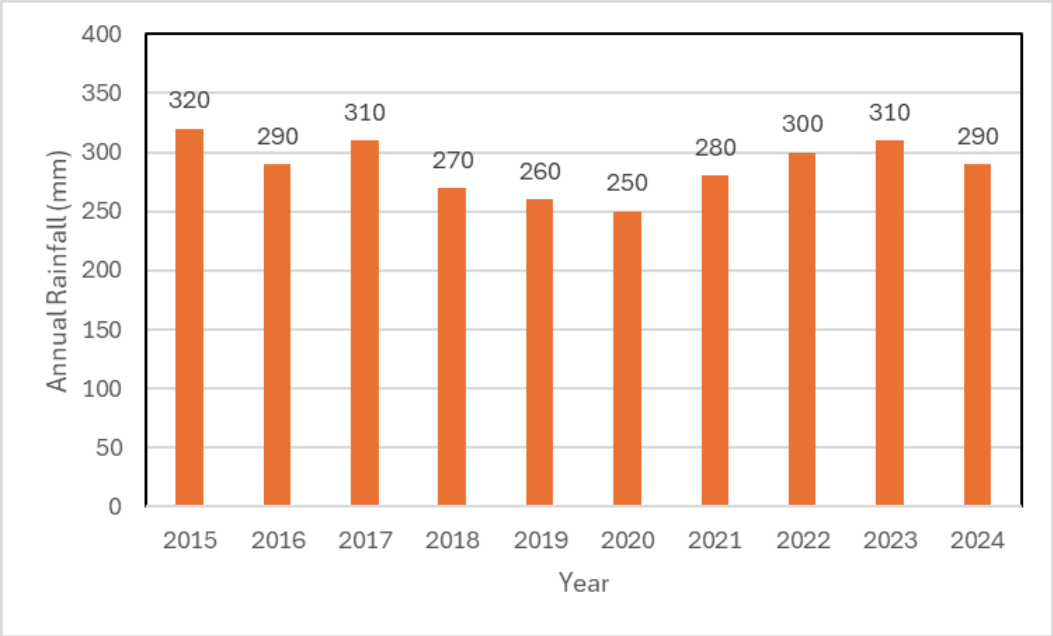

Figure 2. Average Rainfall Trends in Burao (Ogallo et al., 2017; World Bank, 2020).

This figure presents the annual rainfall data for Burao over ten years. The values show a fluctuating pattern, with rainfall declining in some years and slightly recovering in others. The overall trend indicates variability in precipitation, which directly affects agricultural activities. For example, the lowest recorded rainfall occurred in 2020 (250 mm), which likely contributed to lower crop yields.

4.1.2. Impact of Rainfall Variability on Cereal Crop Yields in Burao

Variability in rainfall substantially influences cereal crop yields in Burao, impacting both sorghum and maize productivity over time. Variations in annual precipitation led to yield volatility, particularly evident during arid intervals. Comprehending these trends is essential for formulating ways to bolster agricultural resilience. The subsequent table displays sorghum and maize yields from 2015 to 2024, emphasizing the impact of fluctuating rainfall patterns (Table 2).

Table 2. Impact of rainfall variability on cereal crop yields in Burao.

Year	Sorghum Yield (tons)	Maize Yield (tons)
2015	2.1	1.8
2016	1.9	1.6
2017	2.0	1.7
2018	1.5	1.3
2019	1.4	1.2
2020	1.2	1.0
2021	1.6	1.4
2022	1.8	1.6
2023	1.9	1.7
2024	1.7	1.5

Source: FEWS NET (2020); IFAD (2021)

This table illustrates the relationship between annual rainfall levels and cereal crop yields (sorghum and maize). It shows a decline in crop production during years of lower rainfall, such as 2018-2020, when sorghum and maize yields dropped significantly. Conversely, yields improved slightly in years with more rainfall (2022-2023). This data highlights the strong dependency of cereal crops on sufficient and timely rainfall.

4.1.3. Farmers' Perception of Rainfall Variability and Crop Production

Farmers in Burao have observed significant changes in rainfall patterns, which have directly affected their agricultural practices and crop yields. Many report experiencing more frequent droughts, shorter rainy seasons, and unpredictable rainfall, making farming increasingly challenging. Reduced soil moisture and higher crop failure rates further highlight the difficulties faced by local farmers. The following figure presents farmers' perceptions of rainfall variability and its impact on crop production, reflecting their firsthand experiences with climate change (Figure 3).

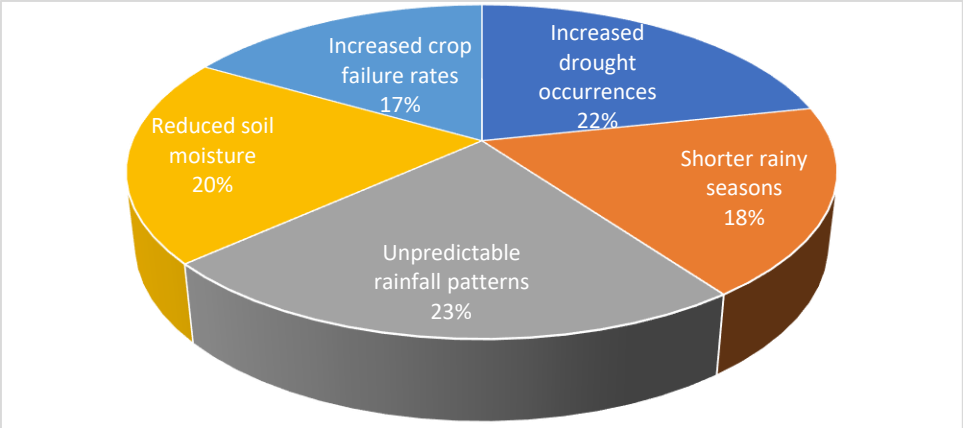

Figure 3. Percentage of farmers' perceptions of rainfall changes (Source: FAO, 2021).

This figure summarizes the views of farmers regarding changes in rainfall patterns and their effects on farming. The majority (70%) reported unpredictable rainfall patterns, while 65% observed an increase in drought occurrences. Additionally, 60% linked rainfall changes to reduced soil moisture, which in turn impacts crop health. These perceptions align with the observed decline in crop yields during dry years.

4.2. Constraints Faced by the Major Crop Farmers in Burao District

While specific studies focusing exclusively on the constraints faced by major crop farmers in Burao District, Somaliland are limited, research from the broader Togdheer region, which includes Burao, provides valuable insights. Below is a summary of key challenges identified. Farmers in the Burao district face numerous challenges that hinder their productivity and sustainability. These constraints include environmental, economic, technological, and infrastructural factors that significantly affect crop production and food security (Table 3).

4.2.1. Environmental Constraints

One of the most significant challenges faced by farmers in Burao is the harsh climatic conditions, characterized by low and erratic rainfall. The increasing frequency of droughts has led to soil degradation, loss of soil fertility, and decreased agricultural productivity (FAO, 2020). Additionally, desertification and land degradation are major concerns,

exacerbated by deforestation, overgrazing, and poor land management practices (UNEP, 2021). Extreme weather events such as floods and prolonged dry spells further impact crop yields (IPCC, 2019).

Table 3. Constraints faced by the major crop farmers in Burao District.

Constraint Category	Specific Constraints	Source
Agricultural Constraints	Pest and disease outbreaks in crop fields Declining soil fertility Crop damage due to natural calamities such as drought	Ali et al. (2023)
Economic Constraints	High cost and scarcity of agricultural inputs (fertilizers, pesticides) Limited access to credit and financial support	Abdi-Soojeede (2018)
Infrastructure Constraints	Poor irrigation facilities Inadequate storage and transport facilities for crops	The Pharo Foundation (2023)
Social Constraints	Lack of agricultural extension services and training Inadequate farming practices and policies to address climate change	World Vision Australia (2019)
Environmental Constraints	Unpredictable and erratic rainfall patterns affecting rainfed agriculture Degraded natural environment impacting agricultural productivity.	Relief Web (2023)
Historical Constraints	Presence of landmines in agricultural lands due to past conflicts, posing risks to farming activities	Ikpe and Njeri (2021)

- **Low and Erratic Rainfall:** The arid climate in Burao is characterized by low and inconsistent rainfall, making water scarcity a primary challenge for farmers. Research on semi-arid regions shows that reduced precipitation, coupled with rising temperatures, leads to declining surface and groundwater availability, reducing crop yields by up to 11% under extreme climate scenarios (Aliyari et al., 2021). In Burao, where agriculture relies heavily on rain-fed systems, the unpredictability of rainfall disrupts planting cycles and diminishes crop productivity. Additionally, temperature increases of 2.7–3.2°C under future climate scenarios will exacerbate water stress and reduce maize water productivity (Waqas et al., 2020).
- **Drought and Soil Degradation:** The increasing frequency and intensity of droughts accelerate soil degradation and reduce soil fertility. In arid regions, drought decreases crop biomass production and shortens growing seasons, resulting in significant yield reductions (Becker et al., 2020). In Burao, drought-related soil degradation leads to nutrient depletion, making it harder for farmers to maintain soil health and sustain crop yields. A study on Iranian arid regions found that wheat yields could decrease by approximately 59.95% under severe drought conditions. These findings highlight the severe impact droughts have on agricultural systems similar to Burao's.
- **Desertification and Land Degradation:** Desertification is a growing concern in Burao, driven by deforestation, overgrazing, and poor land management practices. Land-use changes in semi-arid regions, including the conversion of shrubland to bare land, accelerate soil erosion and reduce arable land (Eze, 2023). Overgrazing strips vegetation cover, exposing the soil to wind and water erosion, which leads to loss of soil fertility. In addition, decreased rainfall further compounds land degradation by limiting the regeneration of natural vegetation.
- **Extreme Weather Events:** Extreme weather events, including floods and prolonged dry spells, pose additional risks to Burao's agricultural sector. Sudden floods wash away fertile topsoil, while prolonged dry spells reduce soil moisture, affecting seed germination and crop growth. Evidence from Central Asia shows that increasing drought frequency leads to a reduction in net ecosystem productivity and aggravates desertification (Zhang et al., 2021). Such patterns mirror the environmental challenges faced by Burao's farmers, where both floods and dry spells disrupt agricultural productivity and long-term soil health.

4.2.2 Economic Constraints

Farmers in Burao face significant economic challenges that hinder agricultural development. These constraints include limited access to financial resources and credit facilities is another major barrier to agricultural development in Burao. Smallholder farmers often lack the capital required to invest in quality seeds, fertilizers, and modern farming equipment (IFAD, 2021). High costs of inputs and lack of financial support programs restrict farmers from adopting improved agricultural techniques (World Bank, 2023). Additionally, market access challenges, including inadequate infrastructure and price volatility, make it difficult for farmers to sell their produce profitably (FAO, 2016).

- **Limited Access to Financial Resources and Credit Facilities:** A major economic constraint in Burao is the lack of access to financial resources and affordable credit. Smallholder farmers often struggle to obtain capital to purchase quality seeds, fertilizers, and modern farming equipment. Studies highlight that inadequate financial support prevents farmers from adopting new technologies and improving agricultural productivity. For instance, research on arid regions indicates that poor economic conditions and a lack of credit facilities limit farmers' ability to invest in agricultural improvements (Kumawat et al., 2011). Institutional constraints also play a role in limiting access to financial resources. In semi-arid regions, structural issues such as inadequate credit, weak legal frameworks, and insufficient extension services make it difficult for farmers to benefit from financial aid. This has been observed in African agricultural systems where financial constraints and lack of supportive institutions prevent technology adoption (Thomson et al., 1987).
- **High Costs of Inputs and Lack of Financial Support Programs:** The high cost of essential agricultural inputs, such as fertilizers and irrigation systems, poses another significant economic barrier. In many arid regions, production costs represent a substantial portion of farmers' total expenses. For example, a study in Algeria found that production costs, including harvesting and irrigation, accounted for nearly 70% of total agricultural expenses (Sarni et al., 2024). Farmers are further constrained by limited access to government support programs. Policies focused on economic-environmental planning in arid regions highlight the need for financial incentives and optimized resource management to support sustainable agricultural practices (Zhang et al., 2002). Without financial assistance, farmers are unable to afford advanced technologies that improve productivity and mitigate the effects of environmental stress.
- **Market Access Challenges and Price Volatility:** Inadequate infrastructure and market access further restrict agricultural profitability in Burao. Poor transportation systems and limited market facilities prevent farmers from selling their produce efficiently, leading to post-harvest losses and reduced incomes. Studies in Rajasthan reveal that low prices for agricultural produce and lack of market facilities are among the primary concerns for farmers in arid regions (Singh et al., 2018). Moreover, market price volatility adds to the economic uncertainty. Farmers operating in arid and semi-arid regions are particularly vulnerable to fluctuating prices due to irregular yields and limited bargaining power. This uncertainty discourages investment in agricultural innovations and perpetuates cycles of low productivity and poverty (Chander et al., 2013).

4.2.3 Technological and Infrastructural Constraints

Farmers in Burao face substantial technological and infrastructural challenges that hinder agricultural productivity. Limited access to modern farming techniques, inadequate irrigation systems, and poor storage facilities exacerbate the difficulties faced in sustaining and improving agricultural yields. The lack of access to modern farming technologies significantly hinders productivity. Farmers in Burao primarily rely on traditional farming methods, which are less efficient in optimizing yields under unpredictable climate conditions (CGIAR, 2020). Limited availability of mechanized farming equipment, poor irrigation facilities, and lack of storage facilities lead to high post-harvest losses (Rees et al., 1991). Improved agricultural extension services and knowledge transfer are necessary to enhance productivity and resilience (GIZ, 2019).

- **Limited Access to Modern Farming Technologies:** A significant barrier to agricultural productivity in Burao is the reliance on traditional farming methods. These methods are less efficient in optimizing yields under unpredictable climatic conditions. In semi-arid regions, the absence of mechanized farming equipment and modern techniques reduces productivity and prevents adaptation to climate variability (Sanders et al., 1997). Studies on technology development in Sub-Saharan Africa emphasize the need for integrated solutions such as improved water retention methods combined with modern agricultural technologies to enhance soil fertility and water efficiency (Sanders & Vitale, 1998). Farmers often lack financial resources and institutional support to access advanced farming tools. Institutional constraints, including weak agricultural policies and limited extension services, prevent the successful adoption of modern technologies (Thomson et al., 1987). This gap in knowledge transfer further restricts the implementation of sustainable agricultural practices in arid regions.
- **Inadequate Irrigation and Water Management:** Poor irrigation infrastructure is another major technological constraint. In arid regions like Burao, water scarcity is a significant challenge, and the lack of efficient irrigation systems exacerbates the problem. Research on semi-arid agricultural systems reveals that improved irrigation technology, such as surface irrigation systems and drip irrigation, can significantly enhance water efficiency and

crop yields (Ivanov et al., 2019). Moreover, research from Central Asia indicates that inadequate irrigation infrastructure can cause water and soil resources to become unbalanced, leading to environmental degradation and lower productivity (Zheng et al., 2022). This suggests that enhancing irrigation systems in Burao through investment in sustainable water management practices is crucial to improving agricultural outcomes.

- **Poor Storage Facilities and Post-Harvest Losses:** The lack of proper storage infrastructure leads to high post-harvest losses, further reducing the profitability of farming in Burao. Farmers in arid regions struggle with inadequate post-harvest handling facilities, which increases food wastage and diminishes economic returns. Studies highlight the importance of improving storage systems to reduce post-harvest losses and maintain food security (Kumar et al., 2019). In semi-arid environments, improved storage technologies, including better drying systems and temperature-controlled storage, can reduce food losses and enhance farmers' incomes. However, the adoption of these technologies requires investments and technical training, which are currently limited in Burao (Singh et al., 2018).
- **Need for Agricultural Extension Services and Knowledge Transfer:** A critical component of overcoming technological barriers is improving agricultural extension services. Effective knowledge transfer is vital for enabling farmers to adopt new technologies and sustainable practices. Research in arid regions emphasizes the role of participatory extension programs and community engagement in successfully disseminating agricultural innovations. Additionally, enhancing farmers' technical capacity through tailored training programs can facilitate the adoption of advanced agricultural techniques. Without effective extension services, farmers remain reliant on outdated methods, which limits productivity and resilience to climate change (Ryan and Spencer, 2001).

4.2.4 Policy and Institutional Constraints

Policy and institutional challenges present significant obstacles to agricultural development in Burao. Weak institutional support, ineffective policies, and limited government intervention hinder farmers' ability to adopt sustainable practices and improve productivity. Weak institutional support and limited government intervention in the agricultural sector pose additional challenges. Farmers often struggle with inadequate extension services, weak land tenure policies, and minimal investment in rural development programs. The absence of effective agricultural policies to promote climate resilience and sustainable farming practices further exacerbates the situation (WFP, 2013).

- **Weak Institutional Support and Limited Government Intervention:** Farmers in arid regions like Burao often lack sufficient institutional support to address agricultural challenges. Research indicates that weak agricultural institutions, combined with inadequate funding and poor coordination, impede the adoption of new technologies and best practices (Thomson et al., 1987). Without effective agricultural extension services, farmers remain dependent on traditional methods, reducing their resilience to climate change and limiting productivity improvements. In Iran's Fars Agricultural Organization, institutional weaknesses in drought adaptation policies were identified as a significant barrier to agricultural sustainability. This case highlighted the need for a stronger organizational culture, improved human resources, and clearer strategic planning to effectively implement drought management practices (Keshavarz and Karami, 2013). Similar issues in Burao hinder the implementation of adaptive agricultural measures that could mitigate the impact of climate change.
- **Inadequate Land Tenure Policies:** Weak land tenure policies present a major constraint to sustainable agricultural development. Secure land ownership is crucial for encouraging investment in long-term agricultural improvements such as soil conservation and irrigation infrastructure. In many semi-arid regions, unclear or unenforced land tenure policies discourage farmers from adopting sustainable practices due to uncertainty about their long-term rights (Al-Kilani, 2024). A study on agricultural adaptation measures in arid regions underscores the importance of clear land tenure and legal frameworks to facilitate climate change adaptation. Without these frameworks, farmers face barriers to adopting practices such as conservation agriculture and rainwater harvesting (Al-Kilani, 2024).
- **Minimal Investment in Rural Development Programs:** Limited government investment in rural development programs compounds the challenges faced by farmers. Effective agricultural development relies on funding for infrastructure, training programs, and market access. However, evidence from arid regions suggests that underinvestment in these areas leads to poor productivity and increased vulnerability to environmental stress (Xu et al., 2018). Community-based integrated watershed management (IWM) programs have shown promise in improving agricultural productivity and resource conservation. However, such programs require sustained

institutional support and funding to be effective (Reddy et al., 2007). In Burao, the absence of similar initiatives limits farmers' capacity to implement sustainable agricultural practices.

- **Lack of Climate-Resilient Agricultural Policies:** Agricultural policies that promote climate resilience are essential in arid regions like Burao. However, existing policies often fail to address the specific needs of smallholder farmers or to provide incentives for adopting climate-smart practices. Research emphasizes the need for policies that support both organic and inorganic inputs, especially in water-scarce environments (Sanders et al., 1998). Policy frameworks that encourage the rapid adoption of drought-resistant crops and efficient water management strategies are crucial for long-term agricultural sustainability. Without these measures, farmers in Burao remain vulnerable to environmental and economic shocks (Sanders et al., 1997).

5. Conclusion

Rainfall variability in Burao has significantly affected sorghum and maize production, with lower yields recorded during drier years. The fluctuating precipitation patterns have led to inconsistent soil moisture, impacting crop growth and overall productivity. Farmers have reported increased droughts and unpredictable rainy seasons, further complicating agricultural activities. The strong dependency of crops on rainfall highlights the need for climate adaptation strategies to enhance resilience. Implementing sustainable water management and drought-resistant farming techniques is crucial for ensuring food security in the region. Farmers in Burao District face numerous challenges that threaten their productivity and long-term sustainability. Environmental constraints, such as erratic rainfall and soil degradation, coupled with economic barriers like limited financial access, significantly impact agricultural output. Additionally, inadequate infrastructure, reliance on traditional farming methods, and weak institutional support further hinder progress. Addressing these issues requires a multi-faceted approach, including investment in modern farming techniques, better financial support, and improved policies to enhance resilience. By tackling these constraints, Burao's agricultural sector can move towards a more sustainable and productive future.

Author Contributions: Conceptualization: Sharmake Mohamed Ahmed, Abdullahi Ali Ibrahim; Data curation: Abdullahi Ali Ibrahim, Sharmake Mohamed Ahmed, Fathi Abdirahman Farah; Methodology: Sharmake Mohamed Ahmed, Abdullahi Ali Ibrahim, Fathi Abdirahman Farah; Supervision: Abdullahi Ali Ibrahim, Abdiaziz Hassan Nur; Writing – original draft: Sharmake Mohamed Ahmed, Abdullahi Ali Ibrahim; Writing – review & editing: Sharmake Mohamed Ahmed, Abdullahi Ali Ibrahim, Fathi Abdirahman Farah, Abdiaziz Hassan Nur. All authors have read and agreed to the published version of the manuscript.

Funding: The authors did not receive any funding during and after the completion of the study.

Acknowledgment: The authors thank the Department of Agricultural Extension, Hajee Mohammad Danesh Science and Technology University, Dinajpur for their support in this research.

Conflicts of Interest: No potential conflict of interest was reported by the author(s).

Institutional/Ethical Approval: Not applicable.

Data Availability/Sharing: Data will be made available on request to the corresponding author.

Supplementary Information Availability: Not applicable.

References

Abdisa, T., Diga, G., & Tolessa, A. (2022). Impact of climate variability on rain-fed maize and sorghum yield among smallholder farmers. *Cogent Food & Agriculture*, 8, 1-10. https://doi.org/10.1080/23311932.2022.2057656.

Abdi-Soojeede, M. I. (2018). Crop production challenges faced by farmers in Somalia: A case study of Afgoye district farmers. *Agricultural Sciences*, 9(8), 1032-1046. https://doi.org/10.4236/as.2018.98071

Abukar, H. M. (2023). Hudur district, Bokool region of Somalia: Impact of drought on sorghum production. *African Multidisciplinary Journal of Development*, 12(3), 185-193. https://doi.org/10.59568/AMJD-2023-12-3-16

Ahmed, A. (2023). Effects of Rainfall Variability on Maize Production in Afgooye District, Lower Shebelle Region, Somalia. *Asian Journal of Research in Crop Science*, 8(3), 167. https://doi.org/10.9734/ajrcs/2023/v8i3167

Ali, F. (1975). Effects of Rainfall on Yield of Grain Sorghum in the Sudan. *Experimental Agriculture*, 11, 167-171. https://doi.org/10.1017/S0014479700006669

Ali, M. A., Karim, M. R., & Osman, M. A. (2023). Constraints faced by the small-scale farmers in the production of major crops sorghum and maize in Awdal Region, Somaliland. *Asian Journal of Research in Crop Science*, 8(2), 1-10. https://doi.org/10.9734/AJRCS/2023/v8i2159

Aliyari, F., Bailey, R., & Arabi, M. (2021). Appraising climate change impacts on future water resources and agricultural productivity in agro-urban river basins. *Science of the Total Environment*, 788, 147717. https://doi.org/10.1016/j.scitotenv.2021.147717

Al-Kilani, M. (2024). Agricultural land measures for climate change adaptation in arid regions: Can the farmers do it alone?. *Journal of Aridland Agriculture*, 10, 82-93. https://doi.org/10.25081/jaa.2024.v10.7945

AWF (2014). Somaliland Water Resources Management and Investment Plan. Available online: https://www.africanwaterfacility.org/en/projects/somaliland-water-resources-management-and-investment-plan (accessed on 10 January, 2025).

Becker, R., Schulz, S., Merz, R., aus der Beek, T., & Schüth, C. (2020). Effects of temperature and water stress on agricultural productivity in a semi-arid irrigation system under changing climate, EGU General Assembly 2020, Online, 4–8 May 2020, EGU2020-8144, https://doi.org/10.5194/egusphere-egu2020-8144

Chander, G., Wani, S., Maheshwer, D., Hemalatha, P., Sahrawat, K., Krishnappa, K., Sawargaonkar, G., Anantha, K., Sudi, R., Jangawad, L., Rao, C., Pardhasaradhi, G., & Jat, R. (2013). Managing soil fertility constraints in market-led shift to high value agriculture for benefiting smallholders in the semi-arid tropics. *Journal of SAT Agricultural Research*, 11, 1-11.

Dennett, M., Elston, J., & Speed, C. (1981). Rainfall and crop yields in seasonally arid West Africa. *Geoforum*, 12, 203-209. https://doi.org/10.1016/0016-7185(81)90021-X

Eze, J. (2023). Impact of Land use and land cover change on Agricultural Productivity in Semi-Arid Region of Nigeria. *BADEGGI Journal of Agricultural Research and Environment*. https://doi.org/10.35849/bjare202303/149

FAO (2016). Boosting Resilience and Adaptation to Climate Change. Available online: https://www.fao.org/geospatial/projects/detail/en/c/1651391/ (accessed on 10 January, 2025).

FAO (2020). Improving sustainable livelihoods in dryland areas. Available online: https://www.fao.org/family-farming/detail/en/c/1620553/ (accessed on 10 January, 2025).

FAO-FSNAU (2022). Agricultural production statistics 2000–2022. FAO

FAO-SWALIM. (2024). Somalia Rainfall Forecast – Issued 22 November 2024. FAO-SWALIM. Available online: https://www.faoswalim.org/content/somalia-rainfall-forecast-%E2%80%93-issued-22-november-2024 (accessed on 10 January, 2025).

FSNAU (2021). Somalia Food Security Outlook. Available online: https://fsnau.org/downloads/Somalia-Food-Security-Outlook-October-2020.pdf (accessed on 10 January, 2025).

IFAD (2021). Rural Development Report 2021. Available online: https://www.ifad.org/en/w/publications/rural-development-report-2021 (accessed on 10 January, 2025).

IFPRI (2021). 2021 Global food policy report: Transforming food systems after COVID-19: Synopsis. Available online: https://ebrary.ifpri.org/digital/collection/p15738coll2/id/134344/ (accessed on 10 January 2025).

Ikpe, E., & Njeri, S. (2021). Landmine Clearance and Peacebuilding: Evidence from Somaliland. *Journal of Peacebuilding and Development*, 17(1), 91-107.

IPCC (2019). Climate Change and Land. Retrieved: https://www.ipcc.ch/srccl/ (accessed on 10 January 2025).

Ivanov, O., Utenkov, G., & Ivanova, T. (2019). Mechanical and technological support the efficiency of arid farming. *Agricultural Machinery and Technologies*, 12(1), 1-10. https://doi.org/10.22314/2073-7599-2018-13-1-34-40

Keshavarz, M., & Karami, E. (2013). Institutional adaptation to drought: the case of Fars Agricultural Organization. *Journal of Environmental Management*, 127, 61-80. https://doi.org/10.1016/j.jenvman.2013.04.032

Kumar, S., Craufurd, P., Haileslassie, A., Ramilan, T., Rathore, A., & Whitbread, A. (2019). Farm typology analysis and technology assessment: An application in an arid region of South Asia. *Land Use Policy*, 88, 1-10. https://doi.org/10.1016/J.LANDUSEPOL.2019.104149

Kumawat, S. R., Reager, M. L., & Deora, N. S. (2011). A study on Constraints responsible for adoption of the arid fruits cultivation. *Journal of Progressive Agriculture*, 2(1), 15-18.

Msongaleli, B., Tumbo, S., Kihupi, N., & Rwehumbiza, F. (2017). Performance of Sorghum Varieties under Variable Rainfall in Central Tanzania. *International Scholarly Research Notices*, 2017, 2506946. https://doi.org/10.1155/2017/2506946

Ogallo, L. A., Ouma, G., & Omondi, P. (2017). Changes in rainfall and surface temperature over lower Jubba, Somalia. Journal of Climate, 1(2), 1-10.

Reddy, V., Shiferaw, B., Bantilan, M., Wani, S., & Sreedevi, T. (2007). Collective Action for Integrated Watershed Management in Semi-Arid India: Strategic Policy and Institutional Options. Strategic Assessments and Development Pathways for Agriculture in the Semi-Arid Tropics. Monograph. Available online: http://oar.icrisat.org/id/eprint/3895 (accessed on 10 January 2025).

Rees, D. J., Omar, A. M., & Rodol, O. (1991). Implications of the rainfall climate of southern Somalia for semi-mechanized rain-fed crop production. *Agricultural and forest meteorology*, 56(1-2), 21-33.

ReliefWeb (2023). Somaliland: Enhancing resilience and food security through sustainable agricultural solutions. Available online: https://reliefweb.int/report/somalia/somaliland-enhancing-resilience-and-food-security-through-sustainable-agricultural-solutions (accessed on 10 January, 2025).

Ryan, J. G., & Spencer, D. C. (2001). Future challenges and opportunities for agricultural R&D in the semi-arid tropics. International Crops Research Institute for the Semi-Arid Tropics. Monograph. Available online: http://oar.icrisat.org/id/eprint/1107 (accessed on 10 January 2025).

Samatar, E. H. (2024). The influence of climate change on crop production: Evidence from Somalia. *Edelweiss Applied Science and Technology*, 8(4), 1428-1447.

Sanders, J., & Vitale, J. (1998). Developing Technology For Agriculture In Sub-Saharan Africa: Evolution Of Ideas And Some Critical Questions. Conference Proceeding. http://doi.org/10.22004/ag.econ.187676

Sanders, J., Ramaswamy, S., & Shapiro, B. (1997). Technology Development for Semi-Arid Sub-Saharan Africa: Theory, Performance and Constraints. Occasional Paper Series No. 7 198203, International Association of Agricultural Economists.

Sanders, J., Shapiro, B., & Ramaswamy, S. (1998). A Strategy for Technology Development for Semi-Arid Sub-Saharan Africa. *Outlook on Agriculture*, 27, 157-161. https://doi.org/10.1177/003072709802700305

Sarni, C., Zoubeidi, M., Faci, M., & Bencherif, S. (2024). Technical and economic evaluation of the olive oil value chain in the semi-arid zones: the case of the Tiaret region (western Algeria). *New Medit, Mediterranean Journal of Economics, Agriculture, Environment and Food,* 2, 111. https://doi.org/10.30682/nm2402h

Sharmake, M. A., Sultan, K., Zaman, Q. U., Rehman, R., & Hussain, A. (2022). Decadal impacts of climate change on rainfed agriculture community in Western Somaliland, Africa. *Sustainability*, 15(1), 421.

Singh, R., Dogra, A., Sarker, A., Saxena, A., & Singh, B. (2018). Technology gap, constraint analysis and improved production technologies for yield enhancement of barley (*Hordeum vulgare*) and chickpea (*Cicer arietinum*) under arid conditions of Rajasthan. *The Indian Journal of Agricultural Sciences*, 88(2), 1-10. https://doi.org/10.56093/ijas.v88i2.79207

The Pharo Foundation, (2023). Somaliland Agriculture Productivity Enhancement Programme. Available online: https://www.pharofoundation.org/somaliland-agriculture-productivity-enhancement-programme (accessed on 10 January, 2025).

Thomson, J. T., Waldstein, A. S., & Wiese, K. (1987). Institutional constraints on the transfer of agricultural and complementary resource-conservation technologies appropriate for semi-arid Africa (No. PB-89-107346/XAB). Associates in Rural Development, Inc., Burlington, VT (USA).

Tolosa, A. A., Dadi, D. K., Mirkena, L. W., Erena, Z. B., & Liban, F. M. (2023). Impacts of climate variability and change on sorghum crop yield in the babile district of eastern Ethiopia. *Climate*, 11(5), 99. https://doi.org/10.3390/cli11050099

UNDP (2022). Resilience and Climate Change. Available online: https://www.undp.org/somalia/our-focus/resilience-and-climate-change (accessed on 10 January, 2025).

UNEP (2021). Helping farmers beat the climate crisis in Central America's Dry Corridor. Available online: https://www.unep.org/news-and-stories/story/helping-farmers-beat-climate-crisis-central-americas-dry-corridor (accessed on 10 January, 2025).

USAID (2013). Horn of Africa Joint Planning Cell Annual Report. Available online: https://20172020.usaid.gov/sites/default/files/documents/1860/Horn_of_Africa_JPC_Annual_Report_2013_1.pdf (accessed on 10 January, 2025).

Waqas, M. M., Shah, S. H. H., Awan, U. K., Waseem, M., Ahmad, I., Fahad, M., ... & Ali, S. (2020). Evaluating the impact of climate change on water productivity of maize in the semi-arid environment of Punjab, Pakistan. *Sustainability*, 12(9), 3905. https://doi.org/10.3390/su12093905

WFP (2023). *Changing Lives – Climate*. Retrieved from: https://www.wfp.org/publications/changing-lives-climate (accessed on 10 January, 2025).

World Bank (2018). Climate-Smart Agriculture. Available online: https://www.worldbank.org/en/topic/climate-smart-agriculture (accessed on 10 January, 2025).

World Bank (2023). World Investing in People for Climate Adaptation and Resilience. Available online: https://blogs.worldbank.org/en/investinpeople/investing-in-people-for-climate-adaptation-and-resilience (accessed on 10 January, 2025).

World Vision Australia (2018). *Shock proof: Building community resilience to recurrent crises*. Available online: https://www.worldvision.com.au/docs/default-source/publications/emergency-and-humanitarian-affairs/8825_multi_resilience_policy_final.pdf (accessed on 10 January, 2025).

Xu, D., Liu, Y., Li, T., Wu, P., Chen, Y., & Runa, A. (2018). Pattern of agricultural and pastoral development under water resource constraints in semi-arid areas: A case study of Tongliao, Inner Mongolia. *IOP Conference Series: Earth and Environmental Science*, 191. https://doi.org/10.1088/1755-1315/191/1/012097

Zhang, J., Hao, X., Hao, H., Fan, X., & Li, Y. (2021). Climate change decreased net ecosystem productivity in the arid region of central Asia. *Remote Sensing*, 13(21), 4449. https://doi.org/10.3390/rs13214449

Zhang, Z., Guo, H., Chen, B., & Zhang, N. (2002). Economic-Environmental System Planning for Arid Regions in China. *Acta Ecologica Sinica*, 22, 1018-1027.

Zheng, H., Sang, Z., Wang, K., Xu, Y., & Cai, Z. (2022). Distribution of irrigated and rainfed agricultural land in a semi-arid sandy area. *Land*, 11(10), 1621. https://doi.org/10.3390/land11101621