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REVIEW

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Systematic review of government strategies for sustainable crop production in Botswana: navigating climate change challenges

Boitshwarelo Lorato Masocha[1*], Paidamwoyo Mhangara[1], Botlhe Matlhodi[2], Daniel Mmereki[3] and Oagile Dikinya[4]

Abstract

Changing climate patterns are a major contributing factor in the failure of government initiatives and sustainable crop production, particularly for subsistence smallholder farming systems in Botswana. These challenges faced by small-scale farmers require more than just programs and policy implementation; continuous assessment is essential to achieve their mandate. Moreover, there is limited research in Botswana to provide an understanding of issues related to policy implementation and the progression of crop production after the implementation of these policies. Therefore, this systematic review aims to evaluate government-implemented programs and policies for promoting sustainable crop production in Botswana, examining their successes, failures and providing recommendations for sustainable crop production. PRISMA guidelines were followed for systematic review via the Google Scholar database, and inclusion and exclusion criteria were observed for the eligibility of the assessed articles. The major findings indicate that several programs and national policies for sustainable crop production have been implemented in Botswana over the past decades. However, crop production continues to decline despite governmental efforts. The increasing adverse effects of climate change have contributed to the failure of government efforts. To advance sustainable crop production and resilience to climate change, the following adaptation approaches are recommended: efficient and sustainable use of water resources in agriculture, policy reformation, capacity building, regional collaboration, and climate-smart agriculture. Moreover, extensive evaluations are necessary for policies and implemented programs. This includes timely adjustments to policies on the basis of feedback from monitoring and evaluating specific, measurable indicators of ongoing policies and programs. Furthermore, engaging relevant stakeholders and local community members in the monitoring and evaluation process can enhance the relevance and accuracy of implemented government policies or programs.

Keywords Botswana, Climate change, Crop production, Government initiatives, Smallholder farming systems, Sustainable

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Introduction

The increasing human population along with climate change challenges, has confronted agriculture with unprecedented challenges [1]. Agriculture plays a significant role in poverty reduction, with 75% of the world's poor living in rural areas and working in farming [2, 3]. In recent years, the issues of climate change and its impact on food security have been increasingly recognized in different parts of the world, including Africa [4], this which is evident from the growing global discourse on the linkages between global climate change and food security [5]. Hence, there is a need for sustainable agriculture. Agricultural sustainability is a multi-dimensional issue, in which economic, social and environmental aspects must be equally considered. An appropriate tool for a multi-dimensional assessment is to develop a suitable set of indicators for measuring agricultural sustainability so that the key problems impeding sustainable agriculture can be identified [6]. Sustainable agriculture emerged as a key solution to address challenges in Africa's diverse agricultural landscape [7].

Crop production is clearly critical to human life and is closely linked to sustainable development goals (SDGs) [8]. According to the United Nations, sustainability '… calls for a decent standard of living for everyone today without compromising the needs of future generations'. Sustainable crop production refers to agricultural production in such a way that it does not impose any harm to the environment, biodiversity, or quality of agricultural crops [9]. This underscores the need for coordinated efforts at the global level to address climate change and promote sustainable agriculture. On the basis of this definition of 'sustainability', most of the world's crop production systems cannot be considered sustainable simply as a result of the wide range of impacts—both onsite and offsite—associated with crop production [10]. Sustainable crop production is an important need for food security, livelihoods, and economic development worldwide. Producing crops sustainably increases the ability of the system to maintain stable levels of food production and quality for the long term without increasing the demand and requirements of agricultural chemical inputs to control the system [9]. There is a pressing need to redesign agriculture to achieve sustainability [1]. In addressing sustainable crop production, increased involvement in research projects by other disciplines must become routine [10].

Crop production performance in Botswana

In Botswana, crop production is limited to a small area of approximately 2500–3000 square kilometers on the eastern and northern margins of the country [11]. A study by [12] reported that only 3% of the country's land is arable, particularly in the northeast, where rainfall is highest. Although environmental problems were observed as early as 1983, the cultivated areas in Botswana were 330 and 600 ha, greater than those in recent years. The decline in agricultural performance in Botswana in the last 30 years (1979–2012) has occurred even during the implementation of a variety of policy measures as well as the introduction of new technologies designed to improve that performance [13]. The annual growth rate in national output declined from 7.5% from 1980–1990 to approximately 3.8% in 2015 [14]. The performance of the agricultural sector has remained below 5% in recent years, which is unsustainable and leads to a decline in farm income [14]. Figure 1 shows the decline in crop yield based on the area planted and the area harvested for the years 2008–2019. The figure clearly shows a decrease in production indicators, i.e., the area planted, and the area harvested. Compared with the 2017 cropping season, the 2019 cropping season included 13.2% of the area planted. Additionally, the smaller areas harvested indicate poor crop production; according to [15], poor crop performance is attributed to poor rainfall recorded during the 2018/2019 cropping season.

For the period 1985–2008 agricultural production in Botswana was estimated to have declined by 0.14% per annum compared with the average growth of 0.92% per annum for Sub-Saharan Africa (SSA). Table 1 shows the indicators of the traditional sector/ arable farming for the years 2017 and 2019 reported by the agricultural statistics Botswana [15]. Table 1 clearly indicates that the area of fallow land has increased recently (2019) compared with that in the previous year (2017), which may be due to inadequate rainfall and severe soil constraints. Moreover, total land indicators (planted, harvested, etc.) were lower for the year 2019. This indicates that the possibility of having increased yields in recent years is lower because of the already experienced environmental issues, such as climate change. Other challenges faced by the agricultural systems in Botswana are presented in Table 2.

Despite all the evidence highlighted above concerning the continuous decline in crop yields in Botswana, there is limited research [16, 17] and evaluation of Botswana's government initiatives and climate change challenges, which play a major role in sustainable crop production. [18] examined smallholder farmers' perceptions of climate change and variability in semiarid Palapye, eastern Botswana and concluded that there is a need to codevelop resilient farming systems with farmers and extension workers; however, evaluation of the program that follow still needs to be addressed. Retrofitting current farming systems to be climate resilient was recommended as the first step toward climate-proofing smallholder farmers' livelihoods [16]. [19] also reported that climate change

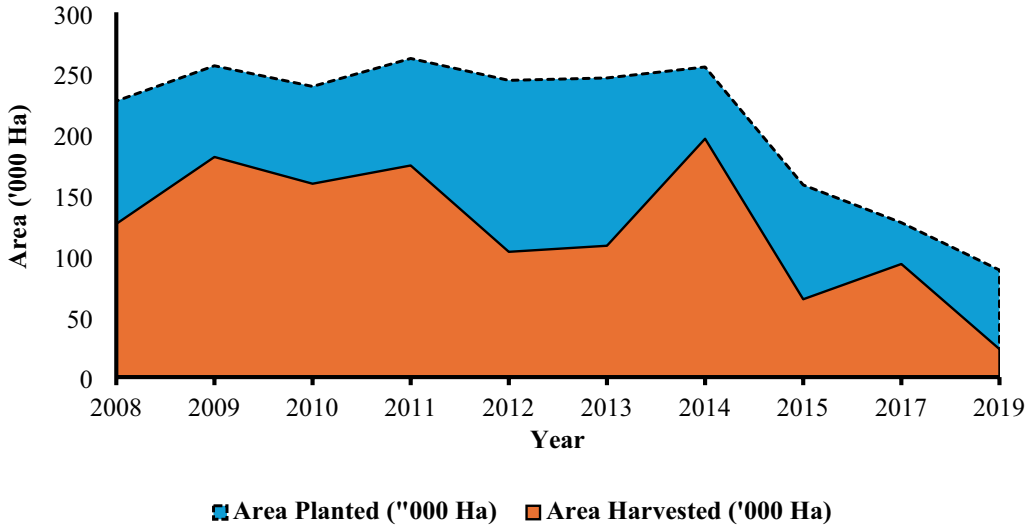


Fig. 1 Area planted versus area harvested trends from 2008 to 2019. *Source:* Modified from Statistics Botswana Annual Agricultural Survey Report 2019 [15]

Table 1 Indicators of the traditional sector in Botswana for the years 2017–2019

Indicators	2017	2019
Land holdings	35,173	30,212
Holdings planted	33,399	24,396
Holdings harvested	28,585	10,956
Total land area (ha)	135,315	117,416
Total area planted (ha)	126,821	88,288
Total area harvested (ha)	92,942	22,866
Fallow land area (ha)	8494	29,128
Land area not planted (%)	6.3	24.8

Source: Modified from an agricultural statistics report [15]

is a major challenge for the arable sector despite large resource inputs and subsidies; however, the effectiveness of these programs has not been explored. [5] differed from the findings of [19] who emphasized the need for a greater understanding of the political economic constraints that influence smallholder farming livelihoods and rural food security in Botswana. The findings of [5] revealed minimal direct impacts of climate change on food security. However, that is not convincing enough, as the study was based on surveys and interviews, which could be affected by the respondent bias. A survey to provide an overview of the chances of advancing sustainable agriculture in Botswana findings show that only half of

Table 2 Climate change challenges and possible solutions in arable farming systems

Challenges in arable farming systems	Possible solutions
Physiological droughts [44]	Use of best management practices related to plant genotype, soil, etc. [45]
Irregular rainfall patterns and catastrophic floods [46, 47]	Develop genetically modified and drought-tolerant crops that can effectively respond to climate change [48]
Significant soil moisture depletion during the arid seasons [49] Excessive dryness or moisture prior to the scheduled planting period [39]	Usage of highly hydrophilic superabsorbent polymers which are believed to function as a reservoir for both nutrients and water [50]
Exceedingly high temperatures [51]	Amendments of organic fertilizers in the soil, the organic fertilizers have the capacity to retain soil moisture that helps to reduce water stress when temperatures are high and rainfall is limited [52]
Accumulation of soil salts [51, 53]	Phytoremediation approach which involves plant-based strategies for reclaiming degraded soils [54]

Batswana (51%) have heard of climate change [20], which indicates that climate change issues are not efficiently addressed during the implementation of programs for sustainable crop production. [21] study reported that the El Niño southern oscillation (ENSO) is the most dominant factor influencing the local climate across Botswana accounting for 85% and 78% of the variation in maize and sorghum yields, respectively, indicating that revising agricultural policies and programs is crucial.

Although there are still different views and findings from different studies, the international policies are still advised for sustainable agriculture on the basis of the adverse effects of climate change [22]. Therefore, expanded efforts to respond to climate change in Botswana are needed immediately to ensure sustainable crop production and food security. Hence, this review aims to assess the current state of crop production in Botswana in the context of changing climate patterns and environmental challenges. Moreover, this review aims to analyze the how effective government programs and policies have contributed to promoting sustainable crop production in Botswana, identify successes and shortcomings, challenges and barriers to sustainable crop production; and propose adaptation approaches and future directions. The novelty of this review is the evaluation of crop production in the context of climate change in Botswana, the analysis of the effectiveness of government initiatives and the emphasis of continuous assessment aimed at promoting sustainable crop production in Botswana. Moreover, the review sheds light on the successes and failures of government initiatives and programs, emphasizing the involvement of stakeholders, particularly small-scale farmers, in efforts to ensure future food security in Botswana.

Overview of Botswana's agricultural landscape

The agricultural landscape in Botswana is characterized by predominantly arid to semiarid conditions and is prone to drought, with highly erratic rainfall ranging from 250 mm in the southwest to approximately 650 mm in the north, making it inherently vulnerable to climate variability and change [5, 11, 23–26] with high atmospheric pressure and being landlocked [11, 25]. The majority of districts in Botswana face unpredictable and inconsistent yearly precipitation (Fig. 2), ranging from 250 mm/annum in the southwest to 650 mm/annum in the north (average of 425 mm) [27, 28]. Among the four downscaled global climate models that have been used in Botswana (IPCC Fourth Assessment Report, Commonwealth Scientific & Industrial Research Organization and Model for Interdisciplinary Research on Climate), most predict a 50–100 mm decline in rainfall in the southern and southeastern parts of the country and an increase in the annual maximum temperature from 1.5 to 2.5°C [5]. Different climate change scenarios make varying predictions for the 2000–2050 period.

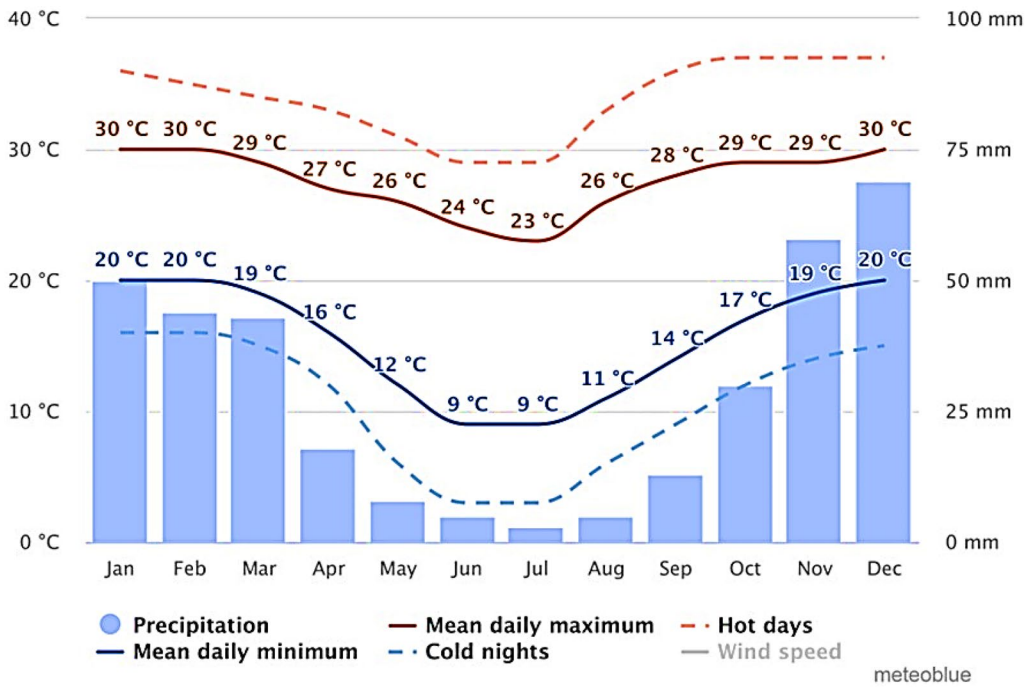


Fig. 2 Yearly climate profile of Botswana. *Source*: Adapted from [35]

Botswana is also susceptible to prolonged periods of drought, which are characterized by extremely dry conditions and elevated temperatures from October to April [12, 17, 29] as shown in Fig. 2. The average minimum temperature demonstrated a rising trend, increasing by 14.7°C from the reported value of 12.6°C from 1971 to 2016. During the 2016/2017 season, exceptionally high temperatures were recorded in Ghanzi, Shakawe, Tsabong, and Tshane, with values of 41.4, 41.6, 40.7, and 41.0°C, respectively, surpassing typical conditions [30]. Botswana is likely to suffer greatly from climate change because of its climatic conditions. Intergovernmental Panel on Climate Change (IPCC) data indicate that Botswana experienced an average temperature increase of 1–2°C between 1970 and 2004 [31]. Moreover, the country is projected to experience a temperature increase of 1–3°C, making it one of the hottest places in Sub-Saharan Africa. As reported by Botswana's Communication to the United Nations Framework Convention on Climate Change (UNFCCC), Botswana intends to achieve an overall emission reduction of 15% by 2030, taking 2010 as the base year [17, 32, 33]. The increasing frequency of extreme weather conditions, such as heatwaves, drought and flooding, dramatically negatively affects agricultural productivity [34].

Challenges facing crop production in Botswana

The challenges of adverse weather conditions including climate-related factors (Table 2), greatly hinder the advancement of sustainable crop production in Botswana [13, 36–39]. Moreover, low levels of adoption of improved technologies [13] contribute to poor agricultural performance. Arable farming remains dominant among resource-limited smallholder farmers in Botswana [14, 23, 30, 40–42]. Approximately 70% of the population in rural area heavily depends on arable farming for their livelihoods [27]. As a result, obtaining sustainable crop production is challenging because of the susceptibility of arable farming to droughts and its vulnerability to climate change [38] and constraints related to funding, infrastructure, knowledge dissemination and market access. Furthermore, inappropriate policies and poor planning, coupled with hostile climatic conditions such as floods and droughts, have had a significant impact on arable farming and the sector's contribution to GDP [43].

Despite the extreme weather conditions, the agricultural sector, particularly arable farming still plays a significant role in Botswana's economy, especially at the subsistence level [31]. However, the reliance on rainfall poses a significant challenge for ensuring food security and sustainable crop production in Botswana in the face of climate change. For the past three decades, Botswana has experienced stagnant agricultural productivity due to a variety of socioeconomic, environmental, and technological factors [5, 38]. Moreover, real wages in agriculture have also fallen compared with those in other sectors, such as manufacturing and services [13]. The other obstacles that have negatively impacted crop productivity include a lack of infrastructure, support services, and education, as well as limited access to financing [55].

As more challenges were experienced in the crop production sector, a considerable decline in the agricultural contribution to gross domestic product (GDP) was noted. The decline in the agriculture sector's share of GDP is another factor that indicates poor agricultural performance in Botswana. Historical data show that the agricultural of share to GDP has declined from 43.6% in 1960 to 1.74% in 2022 (Fig. 3). However, the sector increased by 0.1 percent in real value added during the fourth

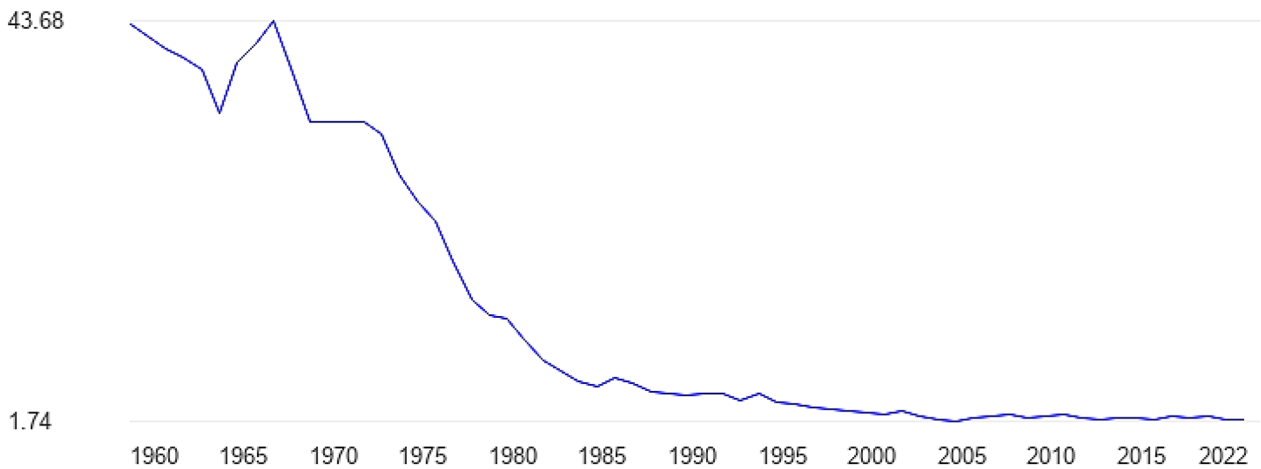


Fig. 3 Historical chart of Botswana: GDP share of agriculture. *Source:* [57]

quarter (Q4) of 2023, relative to a decrease of 0.6 percent registered in the same quarter of 2022 [56]. Although, a slight increase was observed in 2023 Q4, with a decrease of approximately 40% to 1.72% in GDP in 2023, the second quarter was shown [5, 14, 25, 38] in comparison with the earlier contribution since Botswana gained independence in 1966 [41]. Although the agricultural sector's contribution to GDP has been relatively small in recent years, it is still essential for the livelihoods of subsistence farmers in Botswana [13, 38].

The impact of climate change on crop production

Climate change has become a mandatory agenda item in most twenty-first-century national, regional, and international forums [58]. It is a unique but important exogenous determinant of crop productivity [59]. Climate change manifests through rising temperatures, erratic precipitation patterns [23], more frequent droughts and floods, and an increased incidence of storms affecting agriculture across Africa [24]. The key global climate indicators of surface temperature, precipitation, ocean heat content, atmospheric carbon dioxide, ocean acidification, sea level, and Arctic and Antarctic sea ice contents all provide an unfavorable trajectory of the global climate situation [58]. Smallholder farmers in Sub-Saharan Africa are particularly vulnerable to the impacts of climate change on crop productivity [60]. The vulnerability of African countries, including Botswana, to climate change is compounded by a strong dependence on rainfed agriculture [61] and natural resources, high levels of poverty, low levels of human capital, low levels of preparedness for climate events, and poor infrastructure in rural areas [17].

Projections also point toward a decrease in rainfall (5–15% per century) coupled with hotter climates (a temperature increase from 2 to 5°C by 2050), specifically within southern Africa [27]. Southern Africa is projected to experience longer dry seasons and increased rainfall uncertainty [31], leading to adverse consequences such as flooding, famine, and drought [5]. [62] has reported that these trends could lead tropical areas to lose up to two hundred suitable plant growing days annually by the year 2100. Higher temperatures and increasing rainfall variability are expected to reduce crop production capacity by approximately 50% [27]. According to the IPCC sixth assessment report, temperature increases will continue in most African regions because global warming leads to decreases in crop yields, increases in rainfall variability and unpredictability [58]. Global warming could harm agriculture across various countries studied [43]. Changes in precipitation affect crop revenue elasticity, but can have negative effects beyond a certain threshold [43].

The detrimental effects of climate change are particularly evident in its impact on food security, agricultural productivity, and rural development and are among the most significant emerging challenges to household livelihoods in Africa [17, 30, 31, 37, 61]. Scientific reports indicate that crops are already being damaged globally due to climate change, with undeveloped nations bearing the brunt of this phenomenon [17, 46, 62, 63]. A study conducted by [64] demonstrated significant reductions in yield for staple crops such as maize, sorghum and sunflower, with sorghum showing a comparatively lower reduction than maize followed by sunflower. [42] reported that maize yield is expected to decrease by an average of 18% in southern Africa. According to a study by [64], simulated decreases in yield for maize, sorghum, and sunflower were observed under various climate change scenarios. Notably, warm and dry conditions resulted in the greatest reduction in yield based on the basis of the Soil Moisture Accounting and Crop Simulation (SMACS) model for assessing the risk, resilience, and reliability of rain-fed agriculture [64]. Reference [37] further highlighted an estimated decline (2.9% in 2030 and 5.1% in 2050) and roots and tubers (1% in 2030 and 1.7% in 2050). Potential substantial reductions anticipated across all crop types ranged from 10 to 50% by the year 2050 [24].

Climate change poses a significant threat to crop production in Botswana, as it does in other regions of the world. There is an increased likelihood of increasing aridity and drought stress and higher temperatures in the country, leading to reduced crop yields [65] as stated above. The impacts of climate change also include constrained agricultural production, increased food insecurity and negative effects on the economic well-being of communities, which will worsen with time, as projected [24], given that much of the country's agriculture relies on rainfall for irrigation [5], similar to other African countries. The implications of climate change for agriculture are significant, compounding the already challenging conditions confronting farmers in this area [23]. Additionally, human-induced negative effects related to climate change are anticipated to have far-reaching consequences for biodiversity and ecosystem services, as traditional water and food supply systems face strain due to population growth [31].

Moreover, marginalized communities tend to excessively exploit the environment through intensive farming and deforestation, which ultimately results in soil degradation and the loss of essential nutrients. The alterations occurring within the soil significantly affect its physical and chemical properties, ultimately contributing to poor plant growth and reduced crop yields. If these climate change challenges are not addressed, the difficulties

associated with climate change in the Botswana crop production industry will exacerbate the ongoing decline in crop yields, particularly in arable farming. Therefore, it is imperative that efforts to address agriculture in the context of food security and rural development consider climate change. In the absence of interventions, agricultural yields in Botswana could decrease by as much as 30% by 2050 [17]. Despite the different challenges that have been identified in Botswana's crop production industry, it is important to acknowledge the efforts made by the government to address these issues. Through the implementation of institutions, the government has helped increase crop production and improve food security in the country.

Botswana agricultural institutional support for sustainable crop production

Government initiatives and adaptation efforts are crucial in advancing sustainable crop production in Botswana, especially amidst the challenges posed by climate change. Despite substantial government support, arable development continues to underperform, and its contribution to the economy is declining; thus, the country is facing a situation of food insecurity [13, 61]. In response to these challenges, the Botswanan government has provided significant public assistance to promote sustainable crop production in Botswana, achieve food security at both the household and national levels [41], and promote a business-oriented approach to farming [55]. To support these objectives, the Ministry of Agriculture Development and Food Security and established parastatals such as the Botswana Agricultural Marketing Board (BAMB), the Botswana Institute for Technology Research and Innovation (BITRI), and the Botswana University of Agriculture and Natural Resources (BUAN) have been set up [55].

In addition to institutions, the government has implemented various initiatives to address issues related to agricultural failures in Botswana; however, their goals have not been met [66]. Therefore, advancing sustainable agriculture is still highly important for improving the welfare of the rural population and promoting economic diversification in Botswana. In addition to the adverse weather conditions faced by smallholder farmers, other challenges include the effective adoption and implementation of government programs or initiatives designed to improve crop productivity and policy integrations to ensure sustainable crop production in Botswana [41]. Moreover, there is limited research on why these programs continue to fail despite government efforts and implementation strategies. Hence, this review aims to assess the implemented government programs and policies in promoting sustainable crop production in Botswana and provide recommendations for advancing sustainable crop production in Botswana.

Methodology

This systematic review adhered to the Preferred Reporting Items and Meta-Analysis for Systematic Reviews (PRISMA) guidelines to investigate government strategies for sustainable crop production in Botswana amid climate change challenges. Such reviews enable the identification and exploration of the best available evidence, contradictory findings, and gaps in the literature. To be considered systematic, a review must aim to answer a specific research question, follow a predefined protocol, and comprehensively examine all relevant information. The PRISMA framework was utilized to ensure the synthesis of literature while maintaining high levels of scientific integrity, transparency, and reproducibility of the findings.

Data collection

A desktop research methodology was employed, drawing upon Google Scholar databases to collect data on government policies and programs. This involved reviewing published, peer-reviewed journal articles as well as relevant reports issued by governmental authorities.

Search strategy

The literature search was conducted via Harzing's Publish or Perish software (Windows GUI Edition_8.12.4612.8838) to source relevant information from the Google Scholar database. These keywords, including other databases "Botswana AND Climate change AND Crop production AND Government initiatives AND Smallholder farming systems AND Sustainable", were used to retrieve information aligned with the research objectives. The search was then expanded to include all years, to capture the limited available research in this field. This broader search query generated 260 papers, which were subsequently filtered to remove duplicates and select only those relevant articles on the basis of country, title, abstract, and full text.

Data screening

Inclusion and exclusion criteria

The search results from Google Scholar were exported to Excel and underwent a multistep screening process. Only studies directly relevant to the review's objectives were included in the analysis. Initially, duplicates were removed, followed by the exclusion of studies (192) that did not align with the review's geographic scope, ensuring the research's relevance and focus. A second round of screening (68 articles) based on the title and abstracts further excluded 48 articles, and finally, full text

screening excluded (6 articles) primarily because of the lack of information on government strategies for sustainable crop production. Articles were also excluded if their titles and abstracts did not mention key terms such as "agricultural sustainability", "advancing sustainable crop production", "crop production in Botswana", "Botswana initiatives for improving crop production", "sustainable agriculture", "effect of climate change on crop production", "Botswana climate change", and "climate mitigation strategies".

Data analysis

The third step involved a thorough examination of each article, extracting key information based on Botswana agricultural government's efforts for sustainable crop production. Each included reviewed article focused on sections addressing the government's policy or program for promoting sustainable agriculture.

Findings

The overall screening process is presented in Fig. 4. Among the 260 identified papers, 14 covered topics related to policies and programs that were implemented in Botswana for sustainable crop production.

Agricultural policy support by Botswana's government for sustainable crop production

In addition to institutional development, the government of Botswana has introduced and implemented a variety of policies since the mid-1980s [14]. A summary of the implemented agricultural policies is presented in Table 3. Various strategies and initiatives have been implemented under different policies to successfully achieve the aims and objectives of these policies. Botswana adhered to a policy of food self-sufficiency in the first few decades following independence. In the early 1980s, however, Botswana transitioned from a policy of food self-sufficiency to one of food security in 1991 [5, 11, 58]. Drought is the

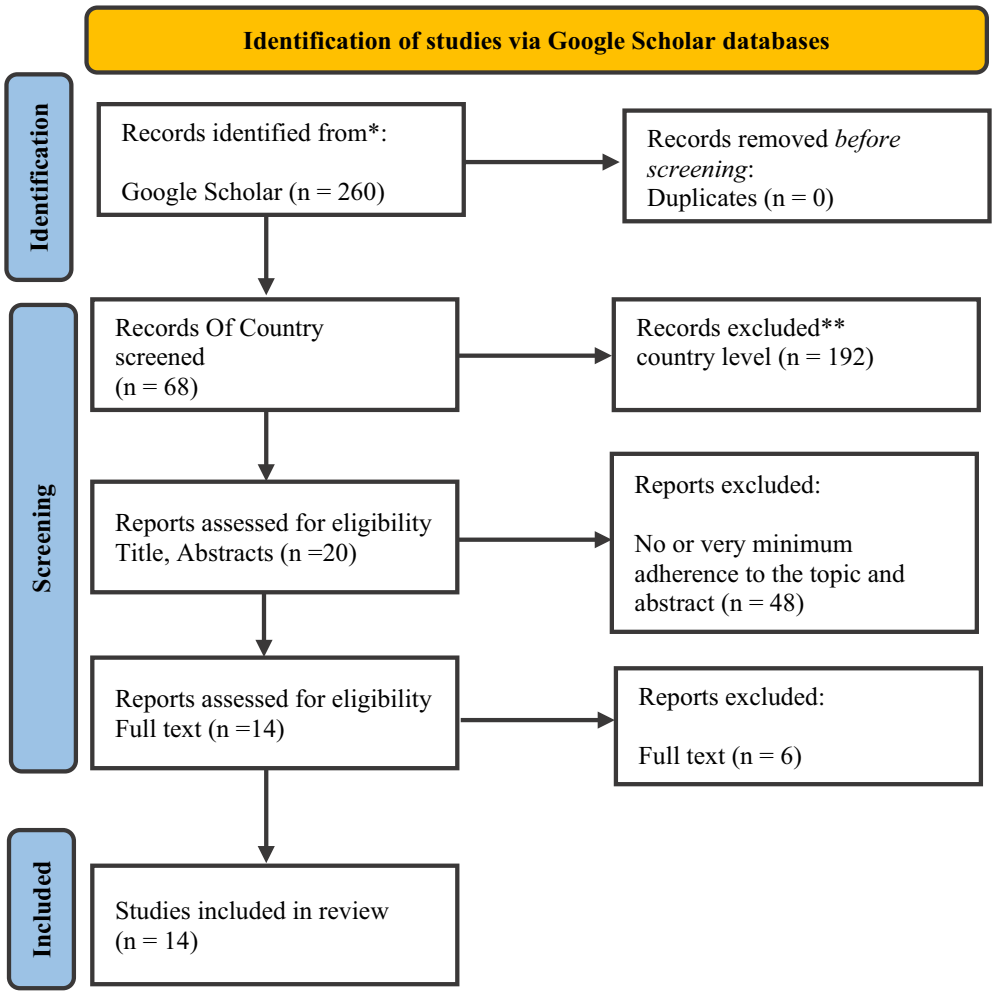


Fig. 4 Systematic review flowchart (PRISMA diagram)

Table 3 Agricultural policy support by the government of Botswana for sustainable crop production

Policy	Year	Objective	Challenges	References
National Food Strategy (NFS)	1985	To reduce dependence of the nation on foreign sources of food supplies; food sufficiency, and conserve agricultural land and reduction of dependence of households on government and others to make up food deficits which cannot be produced by themselves.	Had a weak link to climatic factors which significantly contribute to crop production	[67, 72]
National Policy on Agricultural Development	1991	To improve agricultural production through provision of secure and productive environment for agricultural producers. Revised to improve food security and nutrition by improving access to productive resources such as land, finance, inputs, infrastructure, and information.	Did not discuss or consider the significant influence of climate change and adaptation, which are crucial factors impacting the success or failure of crop production.	[26, 32, 73, 74]
National Adaptation Plan (NAP) and Action Plan Climate Change Response Policy		Aim is to bring sustainability and climate change resilience issues into the mainstream policy discourse, addressing development planning with the intention of enhancing Botswana's resilience and capacity to respond to existing and projected climate change impacts.	Insufficient resources, limited public knowledge, and ineffective communication may impede the successful implementation of the policy.	[33, 58, 71, 74]
National Committee on Climate Change (NCCC)	Revised in 2014	To become a society that is climate resilient; to provide, among other things, guidance on development areas; to facilitate national research programs concerning global warming and climate change; and to advise government	Disparities in resource access impair the capacity of individuals, households, and communities to effectively respond to disruptive events and pressures, such as climate change	[17, 70]

predominant climate-related stress that has necessitated government intervention [67]. The policies were focused on encouraging sustainable crop production practices and aimed at guiding, enhancing, and advancing the production and productivity of agricultural subsectors since gaining independence in 1966. The primary objectives of agricultural policy are to ensure adequate and secure livelihoods for those involved in agriculture, increase productivity, achieve food sufficiency, and conserve agricultural land [13, 68]. The government approved a white paper on the National Food Strategy in 1985 to facilitate the realization of some of these objectives [68]. With the introduction of the National Policy on Agricultural Development in 1991, a food security strategy focused on ensuring that households had access to sufficient food [13].

Other objectives of Nation Food are to achieve broad-base recovery in arable production after the drought period, achieve national self-sufficiency in the main staple crops of maize and sorghum for both food and seed as soon as possible, ensure at least a minimum acceptable diet for all Botswana people and build up and maintain the national capacity to address drought and other emergencies (national strategic grain reserves) [68]. However, the outcomes of these policies have not met expectations since there has been a continuous decline in the crop yields of major cereals (sorghum, maize and millet) in Botswana [41, 41, 68] and inconsistencies in policies [14]. The possible reason for these policy failures may be that the packages offered have concentrated mainly on providing input subsidies rather than extension services and equipping farmers with improved management skills [13]. Moreover, the initiatives seem not to have aligned with challenges of climate change in previous years, as climate effects were still manageable in the country as indicated by higher yields that were received by farmers. Nonetheless, an empirical model used by [13] showed positive output growth during the policy periods although it was relatively small at an average annual rate of 0.072%, which was attributed to increased input use. Overall, the climate change mitigation strategies developed in previous years does not seem to be well adopted by farmers; hence, sustainable crop production is still a concern in Botswana.

In 2020, the Botswana government developed a National Adaptation Plan (NAP) and Action Plan in response to the dire climate change situation [58]. The framework has several guidelines for ensuring inclusive climate change adaptation, which highlight all the priority areas, including climate-smart agriculture, which include techniques such as low to zero tillage and multicropping to increase mulching, which reduces evapotranspiration and soil erosion [22].

In addition to the National Adaptation Program, the Government of Botswana drafted a climate change response policy [58]. The policy includes a range of adaptation strategies, categorized into agriculture and food security, biodiversity and ecosystems, human health, water, infrastructure, disaster risk reduction, forest management, land use and land allocation, and human settlement [69]. Botswana's established national policies indicate the country's commitment to both climate change adaptation and mitigation. The National Committee on Climate Change (NCCC) in 1999, which was reconstituted in 2012, was developed for the country to become a society that is climate resilient [70]. Additionally, the National Agricultural Policy was formulated to improve food security at both the household and national levels [17]. Climate change strategies and policies for mitigation and adaptation include the National Climate Change Strategy 2018 and action plan, Draft Botswana Climate Change Response and 3rd communication to UNFCC (2019) [69, 71]. There is still an urgent need to propose a systematic evaluation framework so that more appropriate policies can be released to facilitate sustainable crop production [8]. However, further research is needed to verify the success of these measures and to scale up climate-smart innovations through policy support, capacity building, and effective dissemination of information. Agricultural policies in Botswana have faced little uptake, and practices have usually been discontinued after subsidies have been removed [61].

Botswana is also a signatory to the Kyoto Protocol seeking to limit greenhouse gas emissions and the United Nations Framework Convention on Climate Change [20, 32]. The global community has recognized the urgency of addressing climate change and promoting sustainable development. World leaders at the SDG Summit 2023 adopted a sweeping political declaration reaffirming their commitment to the 2030 Agenda for Sustainable Development [2]. Despite national policies and specific initiatives to enhance sustainable crop production, world leaders, including Botswana in 2015, established 17 global sustainability development goals (SDGs) as a universal agenda for 2030. Among the set SDGs, SDG 2 (zero hunger) aims to eradicate hunger, ensure food security, improve nutrition, and encourage sustainable agriculture [75]; however, this goal is still a challenge due to the continued adverse impacts of climate change. Therefore, efforts must be put into the agricultural crop production sector to achieve this goal, which can only occur if government policies are well implemented in line with current situations with the involvement of all stakeholders.

Integrating adaptation to climate change into economic principles is essential for building resilience and protecting vulnerable sectors such as agriculture. The

Table 4 Agricultural programs for sustainable crop production in Botswana

Programs	Year	Objective	Challenge	Reference
Arable Lands Development programs (ALDEP)	1977	To assist in improving farming practices and food production, and with the sole aim of achieving self-sufficiency in staple food production	Top-down approach, weak link to climatic factors, and less skills development in conservation tillage; no additional manpower to implement and monitor	[32, 41, 67]
Accelerated Rain-fed Agriculture Programme (ARAP)	1985	To assist arable farmers to de-stump ten hectares, provide seed and fertilizer, and subsidize land preparation and planting	The government terminated the program upon Dryland Crop Production in Botswana after realizing that farmers were now relying solely on the government for all their inputs	[32, 41, 67]
National Master Plan for Agricultural Development (NAMPAAD)	2002	To transform traditional to commercial farming activity. It aimed to improve crop yields and productivity and to create viable business opportunities for farmers	The manpower, expertise, and infrastructure required to implement is limited, and climatic issues are not adequately factored in.	[14, 66, 67]
Integrated Support for Arable Agricultural Production (ISPAAD)	2008	To increase grain production, promote food security at the household and national levels, commercialize agriculture through mechanization, facilitate access to farm inputs and credit, and improve extension outreach	ISPAAD initiative failed to recognize the agroecology of the country as a semiarid area including issuing non-suitable crops and varieties for the prevailing climate.	[14, 41, 59, 61, 66, 77]

Botswanan government's initiatives are commendable, but more work is necessary to ensure the long-term viability of agricultural production in Botswana in the face of climate change. Given the significance of the agricultural sector and the ongoing decline in crop productivity despite government interventions, developing effective policies is essential. Botswana's agricultural sector policy focuses on addressing the impact of climate change, promoting backyard gardening as an adaptation strategy to support poor populations, and providing safety nets to poor urban and rural residents. Therefore, Botswana has transitioned from a policy emphasizing food self-sufficiency to a focus on food security, which incorporates increasing imports.

By aligning with global sustainability targets and local action, adopting adaptive approaches, and integrating policies, Botswana can enhance its agricultural resilience and contribute to sustainable development goals while increasing crop production and enhancing food stability. Although there are set and implemented policies, it is essential to offer integrated and coherent policies that promote sustainable growth and benefit the poor. Providing targeted support for small farmers, particularly women, who cultivate a significant portion of farmland and deliver a substantial harvest [5]. Moreover, policies should effectively address issues such as soil degradation and low crop yields to advance to sustainable crop production. Understanding the potential impacts of climate change on crop production is key for formulating and establishing policies for sustainable crop production and improved food security in Botswana. Furthermore, integrating policies across sectors such as agriculture, water resource management, and climate change adaptation is crucial for sustainable food security in Botswana.

Agricultural programs for sustainable crop production in Botswana

Since 1980, the government has allocated funds for agricultural programs that amount to approximately 40% of agricultural GDP, surpassing the Sub-Saharan African average of 25–29% [13]. Moreover, the Botswana government has been supported by introducing programs tailored for farmers (producers) [66]. Table 4 presents a summary of programs implemented by the Botswana government for sustainable crop production. These programs include the Arable Lands Development Programme (ALDEP), the Accelerated Rainfed Arable Programme (ARAP), the Irrigation and Water Development Project, Dairy Improvement and other ventures funded under the Financial Assistance Policy (FAP) [13, 66]. Furthermore, conservation agriculture (CA) has been introduced as a strategy to increase crop production in drylands; however, smallholder systems continue to experience low crop yields of less than one ton per hectare [41]. The Arable Land Development Program (ALDEP), launched in 1979 to assist small-scale farmers (representing almost 70–75% of traditional arable farmers), did not produce satisfactory outcomes as stated by Morapedi (2016). There are constraints linked to the implementation of competing programs in the same sector, in addition to problems of climate variability [67].

The implementation of the Accelerated Rainfed Arable Programme (ARAP) in 1985 was subsequently introduced as an inclusive initiative supporting farmers involved in rain-fed arable agriculture. ARAP helped with grants for ploughing, access to improved seeds and fertilizers, and water development initiatives, which led to notable increases in cultivated area, output, and yields of 27, 120 and 74%, respectively, according to [14] findings. However, the ARAP initiative was discontinued in 1990 and was only reintroduced in a modified format in 1993 as Drought Relief to Arable Farmers (DRAF) [13]. Both ALDEP and ARAP provided complimentary capital and operating inputs to farmers with the goals of promoting technology adoption and enhancing rain-fed arable agriculture productivity, as documented in the study by [13]. The initiatives survived only for as long as there was a government subsidy.

In 2008, ALDEP was rebranded the Integrated Arable Agriculture Development Support Program (ISPAAD) because of its failure to achieve its goals amid a continuous decline in crop production [13, 76]. ISPAAD aimed to supply farmers with free inputs and equipment, and provides financing at low interest rates [14, 77]. The implementation of the ISPAAD program in 2008 led to an improvement in arable farming, reflected by a slight increase in the total cultivated area between 2010 and 2011 (220,059 ha and 261,967 ha, respectively). In 2010, 64.2% of the total area was harvested, whereas in 2011 the total harvested area was 66.4% (Botswana, 2008). However, there was a subsequent reduction in the total cultivated area during 2017 and 2019 compared with that in the previous year [14, 15]. Despite overall improvements in agricultural efficiency, both the total planted and harvested areas have considerably declined recently. The low crop yields during the ISPAAD program period given the free input support to farmers suggest that the current adaptation practices used in rain-fed crop production were inadequate [59]. Consequently, despite substantial investment in ISPAAD, Botswana's agricultural productivity levels have not significantly increased relative to those of other countries within Sub-Saharan Africa [13]. The findings of [59] suggested that current adaptations were inadequate and that the implementation of the ISPAAD program required fine-tuning to be more effective; hence, the program was unsuccessful.

On the basis of the findings of a study by [13], the stochastic frontier approach model was employed to examine literature related to ALDEP, ARAP and ISPAAD outcomes. The results indicate that only ISPAAD is statistically significant and has a positive effect, suggesting that the program contributed to agricultural output growth from 2009 to 2012. Records from the ISPAAD show an increase in the number of beneficiaries impacted compared to previous programs, as well as an expansion in cultivated area since its introduction in 2008. However, crop production yields have been lower than expected with increased fallow land, which clearly indicates that there are external factors contributing to the failure of these programs, with climate change being among them, as has been observed around the world.

Botswana suffers from endemic droughts that are becoming more frequent and severe due to climate change [61]. Recently, in 2023, Botswana's government declared the year 2022/2023 a severe drought period for agriculture due to significantly low rainfall levels, extremely elevated temperatures, and prolonged dry spells. A government press release on drought and household food security relief measures for the 2023/2024 season dated 20 June 2024 indicates that the declaration of the drought season was based on the reported outcomes of drought and household food security vulnerability and analysis exercise. Some outcomes of the report were as follows: (1) the rainy season (October 2023–March 2024) exceptionally dry with below average rainfall throughout the entire country; (2) the February month was harsh, experiencing the driest conditions since 1980; (3) water levels in dams and rivers across the country significantly declined, with some dams at critically low levels (below 30% capacity), with major rivers (Thamalakane & Chobe) experiencing the lowest water levels in a decade; (4) currently, a moderate hydrological drought is in effect, necessitating close monitoring of water usage; (5) delayed rains and extended dry spells severely impacted crops (wilting & failed early in the season; and (6) deterioration of the grazing areas.

Owing to these challenges, a drought relief program for 2022/2023 was initiated with measures and support during the drought period because of Botswana's rural context, that of a "dual society", i.e., a large number of smallholder farmers using low technology and dependent on drought relief [61]. However, it is still to be understood whether this initiative aligns with the current experienced situation of climate change in the crop production sector. Furthermore, Temo Letlotlo was implemented to improve food security at the household and national levels, with the main intention of the program being to help farmers achieve commercial operation. The chances that these programs will be effective for sustainable agricultural productivity are unknown; therefore, it is highly recommended that these new initiatives be consistently evaluated due to climate change challenges otherwise the same results from past initiatives may be experienced. Investment in sustainable crop production practices is essential not only for food security, but also for economic development and poverty alleviation. For Botswana to achieve sustainable growth while benefiting its impoverished population, it is crucial to implement integrated and reliable policies addressing the multifaceted challenges posed by climate change, water scarcity, and agricultural waste management [5]. The lack of comprehensive studies exploring the effectiveness of government programs aimed at promoting sustainable crop production in arable farming underscores the need for additional research in this area. Considering the pressing need to address climate change and its impact on sustainable crop production, it is essential to evaluate initiatives and implement effective mitigation strategies. In the following section, we explore various approaches that can help overcome these challenges.

Approach strategies for sustainable crop production amidst climate change

Advancing sustainable crop production in Botswana requires a multifaceted approach that includes government initiatives, international cooperation, and adaptation efforts to mitigate the impacts of climate change on agriculture. Mitigating the impact of climate change is crucial in southern Africa, particularly in Botswana, which is affected by frequent and prolonged droughts as high temperatures [64]. Inventive techniques and adaptable strategies are necessary to reduce susceptibility and promote resilience in rain-fed agricultural systems to maintain food security. For instance:

- **Policy reforms:** By harmonizing policies and strategies across sectors, Botswana can effectively address the intersection of climate change, crop production, and national initiatives aimed at increasing crop yields. The current national policy on agricultural development should be evaluated to assess its alignment with and potential for climate-smart agriculture [17], investment priorities, and research priorities, for example, considering CO_2 fertilization to potentially mitigate the adverse effects of climate change through adaptation [42].
- **Conservation agriculture:** Practices should be adopted to increase soil health and fertility while minimizing erosion. Enhancing soil water productivity through conservation agriculture practices such as reduced tillage, retaining crop residues, and on-farm

water conservation has been suggested as a means of mitigating climate change effects [64].

- **Genetic diversity** in crops is also essential for enabling adaptation to changing environmental conditions. The use of drought-resistant crop varieties can improve crop production despite changing climatic conditions [17]. The use of improved crop varieties [78, 79] alongside better management practices with suitable fertilizers also aids in enhancing yields amidst changing climates [80].
- **Indigenous and emerging plant resources** that have been overlooked by policymakers, researchers, and consumers are promising for addressing food security, income generation and climate change impacts [81].
- **The adoption of sustainable irrigation methods** may involve advocating for the efficient and sustainable use of water resources in agriculture, and the creation of viable irrigation systems.
- **Implementing climate-smart agriculture:** Includes beneficial climate information, such as accurate weather forecasts, enabling smallholder farmers to make informed decisions regarding their crops. Furthermore, implementing early warning systems helps alert farmers about impending weather events, allowing them sufficient time to safeguard their crops against potential damage [82–84].
- **Adequate capacity-building initiatives** for further advancing sustainable crop production in Botswana amidst climate change involving training smallholder farmers on climate-resilient agricultural practices play an important role in facilitating their adaptation efforts amidst evolving climatic conditions [85–87].
- **Regional collaboration** helps smallholder farmers, establish institutional frameworks that promote collaboration among different stakeholders. This approach is essential for effective climate change mitigation across Southern Africa; modeling approaches can serve as decision support tools when assessing rain-fed farming systems interventions against climate impacts involving smallholder farmers [64].

Conclusion

Advancing sustainable crop production amidst climate change challenges is urgent worldwide. This review assessed crop production sustainability in Botswana based on government initiatives and policies. The findings of the review highlighted that the government has been providing input subsidies through different agricultural policies since independence. However, a significant decline in crop productivity has occurred in recent decades despite the government's efforts to improve food security. Climate change, with erratic rainfall and higher temperatures, a lack of a skilled workforce, inconsistent policies and low adoption of agricultural technologies, may have contributed to the failure of these initiatives. Recently, 2022/2023 was declared a drought year, indicating the need for advanced strategies for sustainable crop production in Botswana. Additionally, this implies that Botswana is likely to continue importing cereals from other neighboring countries soon. To address this situation, comprehensive and inclusive approaches are urgently needed for sustainable crop production. For instance, emphasizing adaptation, collaboration, and stakeholder commitment can ensure sustainable crop production and future food security in Botswana. This review's main limitation was the reliance on limited data, and there is limited information on the subject matter in Botswana. Hence, future research focusing more on surveys and field visits, and engaging relevant stakeholders in government institutions to understand the reasons behind government initiative failures is highly recommended. Reassessing initiatives before implementation is also highly important.

Abbreviations

ALDEP	Arable Lands Development Programme
ARAP	Accelerated Rainfed Arable Programme
BAMB	Botswana Agricultural Marketing Board
BITRI	Botswana Institute for Technology Research and Innovation
BUAN	Botswana University of Agriculture and Natural Resources
CA	Conservation Agriculture
DRAF	Drought Relief to Arable Farmers
ENSO	El Niño southern oscillation
FAP	Financial Assistance Policy
GDP	Gross domestic product
IPCC	Intergovernmental Panel on Climate Change
ISPAAD	Integrated Arable Agriculture Development Support Program
NAMPAAD	National Master Plan for Agricultural Development
NAP	National Adaptation Plan
NCCC	National Committee on Climate Change
NFS	National Food Strategy
PRISMA	Preferred Reporting Items and Meta-Analysis for Systematic Reviews
SDGs	Sustainable Development Goals
SMACS	Soil Moisture Accounting and Crop Simulation
SSA	Sub-Saharan Africa
UNFCCC	United Nations Framework Convention on Climate Change

Author contributions

BLM and BM conceived and designed the structure of the review manuscript. All the authors contributed to the review's conception and design. BLM drafted the original manuscript draft, and all the authors contributed equally to the reading, critical revision and approval of the final draft of this manuscript.

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