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Contribution of smallholder farmers to food security and opportunities for resilient farming systems

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Climate change poses challenges that negatively affect smallholder farmers' contribution to food security in sub-Saharan Africa. Consequently, countries from this region have the responsibility to reduce green gas emissions and adapt to the changing climate in the agricultural sector through such measures as climate-smart agriculture (CSA). This systematic review provides an overview of the CSA adoption challenges faced by smallholder farmers towards ensuring food security as well as recommendations to upscale CSA practices uptake. The review focuses on smallholder farmers of sub-Saharan Africa. Data collection for formal systematic reviews followed the Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines. Information was gathered from peer-reviewed articles with no limit to the year of publication. A total of 58 papers from the Web of Science and Scopus databases were included in the analysis. Results reveal that more research efforts need to be exerted towards the very vulnerable Southern Africa. The adoption of innovative agricultural practices should focus on rainwater harvesting and mulching while other CSA practices such as crop diversification and crop rotation show a high number of practices. However, major challenges facing smallholder farmers are financial availability, access to information and farm size. These hinder stallholder farmers' ability to contribute to food security. As such, authors have recommended policy intervention, knowledge dissemination and capacity building as possible measures to get smallholder farmers on the right path to sustainable food production and CSA practices uptake.

KEYWORDS

smallholder, food security, indigenous crops, irrigation, climate smart technologies

1. Introduction

Food availability depends primarily on the performance of the agricultural sector, as well as a country's capabilities and competencies in processing, importing, storing, and distributing food. In addition to domestic production, food imports are directed by consumer consumption patterns. In contrast to most southern African countries, South Africa (SA) is food secure at the national level (with increasing imports of key crops such as wheat) but has severe food access barriers at the household level. According to estimates, 20% of South African households do not have enough or very limited access to food (Statistics South Africa, 2014). In South Africa's Limpopo Province, 52% of rural households were deemed to be extremely food insecure in 2013 (De Cock et al., 2013), up from an estimated 10.6% of adults and 12.2% of children who were projected to be occasionally or always hungry in 2007 (Jacobs, 2009).

The need to improve the agriculture value chain through modern and innovative technologies and attract the youth to the sector is huge, particularly considering the challenges of unemployment in this age group. This will lead to employment creation and enhance food security and climate change resilience and adaptation among smallholder farmers (Denison et al., 2016). Unfortunately, the likelihood of attracting the youth to the sector has generally remained low as rainfed agriculture continues dominating the sector in southern Africa (Denison et al., 2016). Currently, rainfed agriculture ranks third in importance among rural communities' income sources (Denison et al., 2016). The vulnerability of rural communities to the vagaries of climate change is compounded by the reliance on natural systems for their climate-sensitive livelihoods.

The adoption of innovative technologies in the agriculture sector provides the benefits of transforming the sector into a viable economic impetus and a means of propelling rural development. Thus, agriculture has a significant role in ensuring food security, promoting employment, enhancing rural livelihoods, and achieving the aims of the South Africa 2030 Roadmap 2030 National Development Plan (NDP) and Sustainable Development Goals (SDG) 2. South African agriculture is made up of a subsistence agricultural sector (which includes smallholder farms and homestead gardens) and a commercial sector. Smallholder farming is a longstanding practice in SA, particularly in rural households. Literature shows that most smallholder farmers produce for consumption although there is a small faction that is market-oriented (Rapsomanikis, 2015).

As already alluded to, one of the main strategic areas for employment and rural development is agriculture, yet there is not much uptake of modern technologies by smallholder farmers who form the majority of rural communities, contributing the most to the agricultural Gross Domestic Product (GDP) (Rapsomanikis, 2015). The challenges of low productivity and poor uptake of technologies by smallholder farmers are being exacerbated by that they are cut off from the larger economy and key agricultural value chains by a poorly functioning rural economy with underdeveloped infrastructure, tenuous market ties, and inadequate agricultural support services (ILO, 2008). Compounded by factors such as loss of agricultural land and water to activities such as mining, access to irrigation water and food production remains a challenge to smallholder farmers. Furthermore, National Food and Nutrition Security (NFNS) indicates that the state has the responsibility of promoting food supply through a variety of techniques, such as deliberate legislation, policies, practices, and programs that promote the production of sustainable foods, the advancement of technology, and studies into the production, processing, storage, and safety of food (NFNS, 2017).

Smallholder farms often use family labor particularly women, children, and elders in their management (Galhena et al., 2013). For smallholder farmers to contribute and ensure food security nationally, they must (1) contribute to food production, therefore, increasing availability, (2) provide income and livelihood, (3) be able to contribute towards diverse diets, and (4) be able to be used as a buffer to market-related shocks (HLPE, 2013). As such, smallholder farms play a significant role in improving the food security status of many households and offer different benefits. Self-sufficiency in food is essential for a home safety net and as protection against unforeseen economic circumstances and smallholder farms provide that especially at household levels. Even so, obstacles such as climate change, gender disparity and discrimination related to land and water ownership and many more pose a serious threat to smallholder farms' ability to produce enough food (Chikazunga, 2013). The production of food by smallholder farmers has the potential to influence the nutrition of members of their households, either through direct consumption or by generating income that allows them to buy food locally (Waage et al., 2013).

The high rate of malnutrition in rural communities is a harsh reminder that the connection between agriculture and nutrition is broken (Duncan et al., 2022). The value chain between seed and plate and where farmers and poor households purchase most of their fresh produce is not clear. Given the high unemployment rate in rural communities, many families suffer from hunger and poverty daily and this impacts the early development of the children (Duncan et al., 2022). Although some of these families receive some form of government grant and help from a school feeding scheme, they are not food secure and do not have sustainable livelihoods (Devereux et al., 2018). Furthermore, malnutrition negatively affects all aspects of an individual's life and households suffer long-term effects and irreversible changes because of poor nutrition in early life. Globally, there is a growing interest in strengthening and intensifying local food production initiatives to mitigate the effects of food price shocks (Devereux et al., 2018).

The United Nations Commission on Sustainable Development (CSD) and other major international organizations now recognize the significance of smallholder farmers in ensuring food security and a global sufficient supply of food (Denison et al., 2016). Smallholder farm production is viewed as a viable means for household food security and nutrition-enhances the local food system. Furthermore, smallholder farming plays a key role in contributing to the food security status of poor households in developing countries, including South Africa. However, the abovementioned constraints lead to the need to adopt effective water irrigation use at the household level for food production increase, which may guarantee an adequate supply and open selling opportunities of any surplus, thus allowing the poor to enter the agricultural value chain and earn an income. Therefore, considering climate change's negative impacts on the water supply. There is a lot of work being done to get crops to use less water and yield "more crop per drop." Some of the responsive measures include adopting irrigation development, precision agriculture and climate-smart technologies in smallholder farming.

Small-scale irrigation is a process other than natural rainfall that supplies water to grasses, orchards, and crops (Mnkeni et al., 2010). Small-scale irrigation is defined as the management of water supply to crops initiated, organized and managed by landowners at the extent not exceeding 10 ha per family and can be formal or informal (Fanadzo and Ncube, 2018). Small-scale irrigation systems include farmers who utilize individual or shared water sources that have one common characteristic, i.e., farmers own small parcels that are sometimes fragmented, for instance, plot sizes range from 0.36 ha to 0.86 ha, 600 m^2 to 10 ha, and a plot size of 0.45 ha in Zimbabwe, South Africa, and Ethiopia, respectively (Maepa et al., 2014).

Therefore, this article broadly looks at the challenges faced by smallholder farmers in their adoption of climate-smart agriculture (CSA) practices to contribute towards food and nutrition security, CSA benefits to smallholder farmers and some solutions that could be adopted in enhancing the resilience of smallholder farms. The study achieved the latter by providing pathways for improving smallholder crop yield, water uses efficiency and agricultural solutions that enhance climate change resilience and adaptation to the most vulnerable communities. This was achieved through a systematic review of the literature on innovative smart technologies developed in the context of smallholder farmers.

2. Methods

This article intended to conduct a systematic review of studies that evaluated the climate-smart technologies adoption challenges faced by smallholder farmers in sub-Saharan Africa. The Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines were followed to produce this review (Albeha et al., 2020). PRISMA provides a guideline checklist that is peer accepted and thus will be followed in this paper. The review is structured into two sections answering the following questions: (a) What are the challenges hindering the contribution of smallholder farmers to food and nutritional security? and (b) How can productivity be enhanced at the smallholder farming scale going forward? The literature search and analysis were conducted in four stages to address these sections. These stages describe the article selection criteria and search strategy, eligibility selection criteria, data extraction and data analysis procedures. The search was conducted with no imitation of a particular year, and although the initial intent was to limit the scope to Southern Africa, it was extended to sub-Saharan Africa to expand the data.

2.1. Stage 1: literature search

Two electronic databases; Scopus and Web of Science were used for a systematic search with no limitations to the year of publication. The keywords combination used to obtain data across SCOPUS and Web of Science databases were searched using these search strings; ("smallholder farm*" OR "smallholder farming" OR "smallholder agriculture" OR "small scale farm*" OR "small scale agriculture") AND ("food security" OR "food production") AND ("climate-smart" OR "resilient farming").

2.2. Stage 2: screening and eligibility criteria

The articles eligible for the analysis had to meet the following criteria:

1. Peer-reviewed articles in accredited journals.
2. Studies that are written in English.
3. Studies on sub-Saharan Africa.
4. Studies based on Smallholder Farmers' adoption of CSA technologies.

The bibliographic information of the articles was retrieved and compiled on Mendeley desktop for screening preparations.

A total number of 126 and 95 articles were retrieved from Web of Science and Scopus, respectively. Titles and abstracts were reviewed using the abovementioned criteria to determine the study's eligibility to be included in the study. The first screening process comprised the removal of duplicates, resulting in a total number of 167. Thereafter irrelevant articles were removed ($n = 100$) including review articles, resulting in a total of 67 articles. Included articles were recorded as per PRISMA and meta-analysis statement (Figure 1). All studies that were unavailable in portable document format (pdf) were excluded resulting in 58 studies. Full-length articles of the selected articles were then downloaded, and the number of retained articles after the screening was recorded at 58. Thereafter, a Microsoft Excel spreadsheet was created to capture each study's details and was used for quantitative assessment.

2.3. Stage 3: data extraction

Bibliometric information of the selected articles such as the author's names, the title of the article, year of publication, keywords, and the abstract, uniform resource locator (URL) was exported from Mendeley to a Microsoft Excel spreadsheet. Furthermore, information on the study was conducted (country), climate-smart adoption practices, challenges experienced by farmers, recommendations, identified responsible representatives, and what the study addressed were also captured after going through each article. The categorical data were then converted into numerical variables of zeros (No) and ones (Yes) to prepare for data analysis.

2.4. Stage 4: data analysis

Graphs were created using Microsoft Excel for each recorded study's characteristics and are reported in the results section. The review was then divided into two sections, which serve the purpose of the study. The first section outlines the identified CSA practices in literature and the challenges faced by smallholder farmers in adopting them. The final stage outlines and discusses the recommendations in literature and the way forward associated with knowledge generation and takeaways from the available literature that can assist in upscaling the adoption of CSA practices. Both stages considered literature search characteristics, CSA practices, farmers' challenges, and authors' recommendations in the discussion. Considering that not only frequencies were assessed in this study, but biases tests were also not conducted.

3. Results

3.1. The publication trends in the contribution and challenges of smallholder farmers to food and nutritional security

Overall, 14 countries (Figure 2A) in sub-Saharan Africa have been studied in association with identifying challenges that sub-Saharan Africa smallholder farmers face in adopting CSA practices whilst

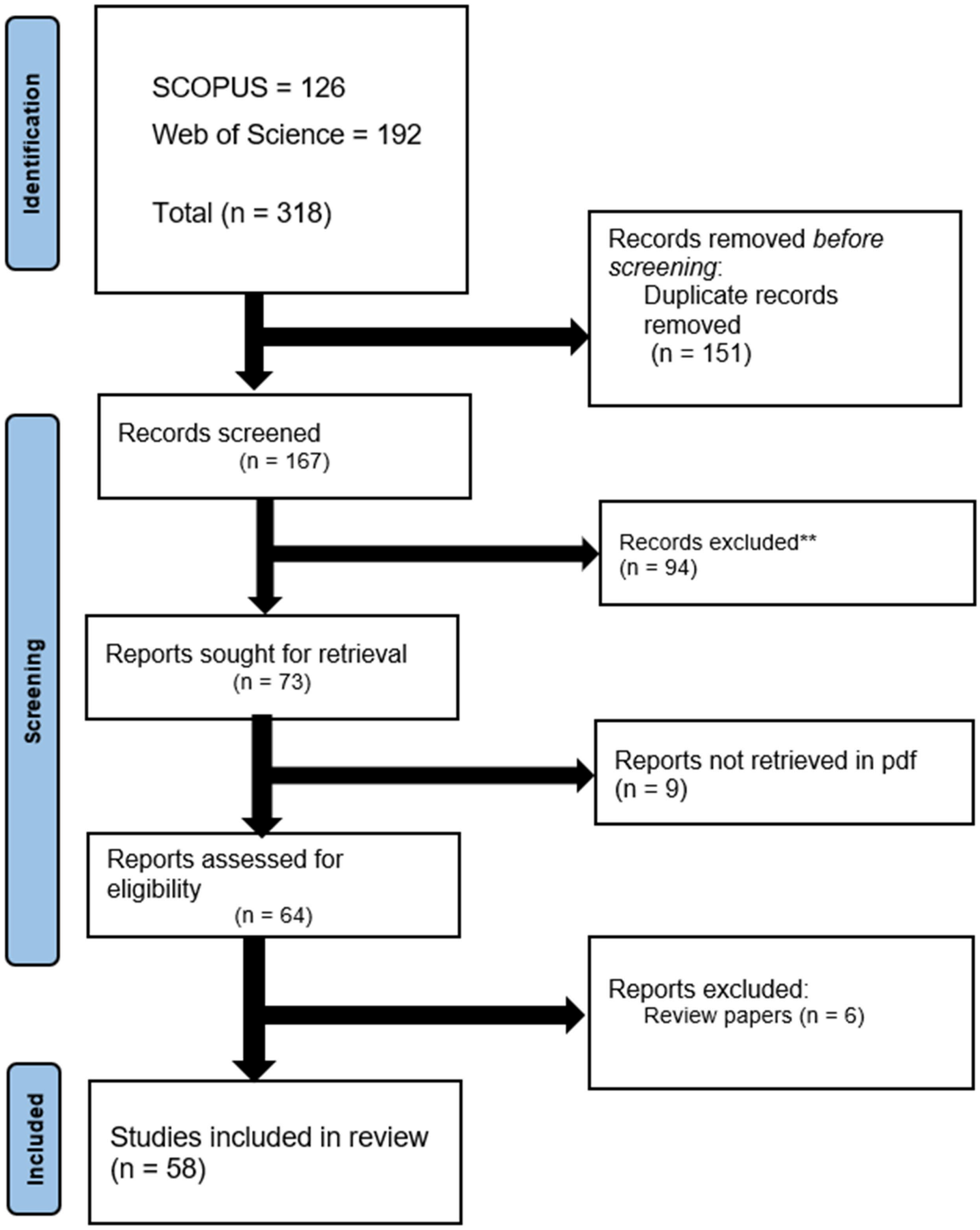

FIGURE 1
Results and filtering process of articles that comply with the search keywords used.

providing possible remedy actions required as well as responsible authorities who can action them. With regards to the spatial distribution of the studies, Kenya (18.03%) and Ethiopia (18.03%) are leading, followed by South Africa (16.39%) (Figure 2A). Despite efforts done in South Africa, Zimbabwe (6.56%), Malawi (9.84%) and Zambia (3.28%), fewer research efforts are observed in Southern Africa, generally. The same can be observed in central and West Africa (Figure 2A). However, results show there has been a considerable increase in the number of publications throughout the years since 2015. The earliest publications began in 2015, since then there has been an increase in publications to date, especially from 2020 with a spike in 2022 (Figure 2B). This reveals a growing interest in smallholder adoption of CSA technologies in recent years.

3.2. The adopted CSA technologies to aid the contribution of smallholder farmers towards food and nutritional security and associated challenges

Results show that 17 different CSA practices have been adopted by smallholder farmers in sub-Saharan Africa (Figure 3A). Specifically,

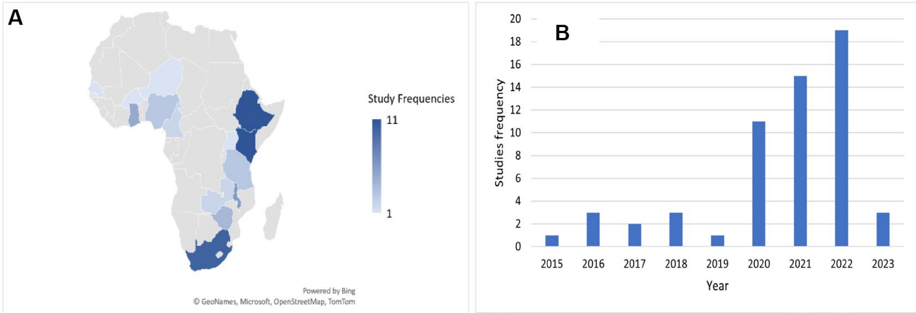

FIGURE 2
Spatial distribution of studies that focused on smallholder adoption of CSA practices **(A)** and the number of studies that focused on smallholder adoption of CSA practices **(B)** in sub-Saharan Africa.

organic manure accounts for 10.26% of the identified CSA practices, thus it is the most adopted CSA practice. Followed by other practices such as agroforestry (9.62%), crop rotation (9.62%), crop diversification (8.33%), and irrigation (7.69%), in that order. However, more smallholder farmers need to consider significant CSA practices such as rainwater harvesting (2.56%), mixed cropping (3.21%) and cover cropping (3.21%), among others (Figure 3A). Meanwhile, Figure 3B shows variables that affect the adoption of CSA practices identified in the literature. Results reveal that the availability of finance (15.90%) is a significantly prominent variable prohibiting or/and enabling the adoption of CSA practices by smallholder farmers. Smallholder farmers' access to information (9.74%) is identified as the second most influential variable in the adoption of CSA by smallholder farmers. Furthermore, farmer's proactiveness (1.54%), labor required (2.05%) in the adoption of CSA practices, direct impacts of changing weather patterns (2.05%), and training (2.05%) required by farmers should be further explored as the possible enablers and/or hinders of adopting CSA technologies (Figure 3B).

3.3. Identified possible measures to enhance productivity at the smallholder farming scale

In light of the identified challenges that continue to cripple the smallholder farmer's ability and success to adopt the CSA practices, several authors have outlined recommendations for further assistance (Figure 4A). Three of the highly recommended interventions by authors include policy intervention (26.04%), followed by knowledge dissemination (19.79%) and capacity building (17.71%). Astonishingly, irrigation adoption (1.04%) and learning material written in native languages (1.04%) fall among the least frequently recommended solutions to smallholder farmers' challenges (Figure 4A). Both information material that is available in a familiar language to farmers and irrigation are relevant to smallholder farmers with rainfed agriculture in a changing climate and who may also not be familiar with science jargon. Nonetheless, authors have attempted to identify and comprehend challenges faced by smallholder farmers to be able to influence evidence-driven solutions. As such, most authors have investigated the adoption challenges (38.46%) that smallholder farmers are faced with. Secondly, results show that the effectiveness of CSA in climatically vulnerable areas (16.92%) has also caught researchers' attention. However, it is rather surprising that issues relating to women empowerment (3.08%) and the financial gains (3.08%) from CSA practices fall in the two least focus areas for researchers. Nonetheless, this presents a research gap in these areas and more research efforts should be exerted.

4. Discussion

4.1. Climate-smart agriculture practices identified in the literature

Results reveal that most adopted CSA practices (Figure 3A) by smallholder farmers are those easy and less costly to apply and implement. Such practices include the use of organic manure (Kruger et al., 2021; Mthethwa et al., 2022), and agroforestry (Arslan et al., 2015; Nyang'au et al., 2021). Abegunde et al. (2020) state that the use of organic manure and crop rotation were highly accepted by smallholder farmers of the KwaZulu-Natal province in SA because they found them easy to adapt and implement. This could be attributed to the fact that smallholder farmers in developing countries reside close to or have livestock kraals that provides them with quick access to animal dung for garden fertilization (Wenhold et al., 2007). Other practices such as agroforestry have been adopted by smallholder farmers because it is less laborious than the monocropping system (Kassa, 2015; Chavula and Turyasingura, 2022). This is concurrent with the findings in Figure 3B where practices' labor requirements are found in the literature to be one of the influential variables in the adoption of the CSA practice. Moreover, in their study, Senyolo et al. (2018) found that smallholder farmers were reluctant and avoided practices and technologies that they found costly to acquire and implement. Whilst Kruger et al. (2021) found that despite the farmers' initial hesitation to produce crops that they do not know and do not often use, they adopted mixed cropping and crop diversification because they are very simple techniques to implement into the smallholder farming process. Also, Smale and Mason (2014) found that smallholder farmers adopted practices that are physically easy to use. Other practices such as mulching (Mutsamba et al., 2020; Nyirenda and Balaka, 2021), crop rotation (Gashure and Wana, 2022), and crop diversification (Beshir et al., 2022) are easy to practice and, as such, showed a high level of CSA practiced (Figure 3A).

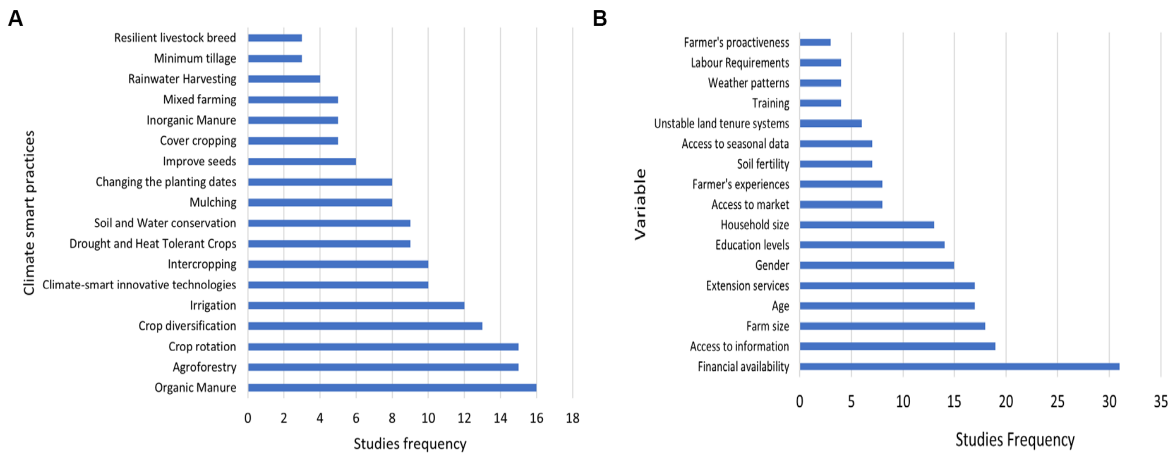

FIGURE 3
CSA adopted by smallholder farmers in sub-Saharan Africa **(A)**, and variables affecting the adoption of CSA practices **(B)**.

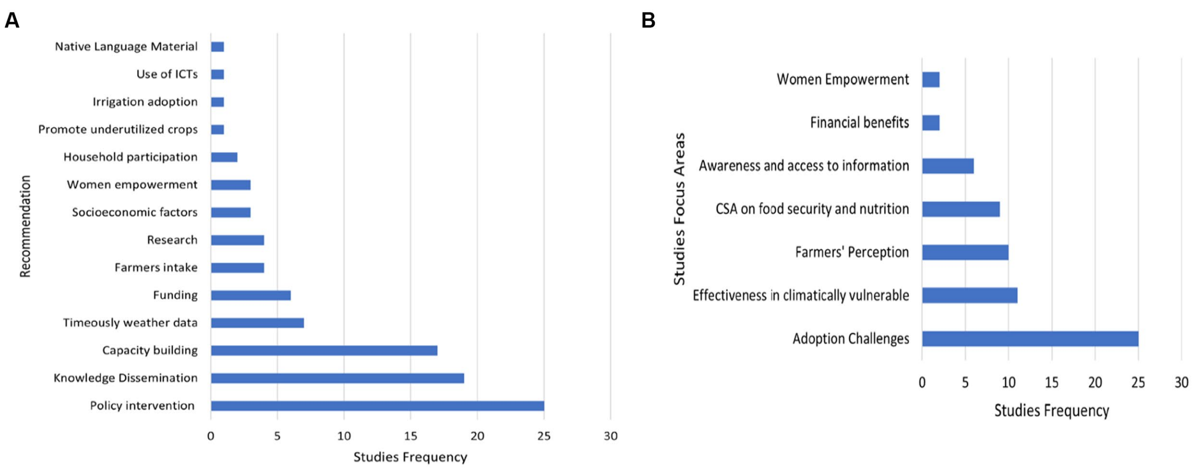

FIGURE 4
Authors' recommendations **(A)** to CSA adoption challenges and researchers' study focus areas **(B)**.

Perhaps one other common feature among these practices is that they have low capital and labor requirements, which is an advantage to smallholder farmers that do not have enough financial resources to adopt expensive practices. The lack of financial resources by smallholder farmers has been revealed in the results as a hindrance to smallholder farmers' improvement (Figure 3B). For instance, Mulwa et al. (2017) found that the major determinant of practice adoption was influenced by access to credit. Smallholder farmers may struggle to cover the expenses of adaptation due to resource constraints, and occasionally they are unable to exploit CSA practices information to their advantage (Kandlikar and Risbey, 2000). Results reveal that such practices as resilient livestock breed, improved seeds and inorganic manure are some of the least adopted practices (Figure 3A). In fact, in their study, Mulwa et al. (2017) found that lack of access to credit led to less likely adoption of pests and disease varieties and drought-tolerant crops. Some practices require the use of finances such as purchasing new adaptive seeds, thus, in the absence of funds, smallholder farmers may find it challenging and often abandon the adoption of practices even when provided with information on climate change. This is also attributed to the fact that smallholder farmers may resort to alternative off-farm income. As such, Mulwa et al. (2017) and Velandia et al. (2009) found that smallholders that had off-farm income were less likely to adopt practices such as drought-tolerant crops and changing to early planting days.

Results reveal that the issue of training has been identified as an influential variable generally (Figure 3A), and this could be achieved through capacity building, knowledge dissemination and providing information material that is written in their language of understanding (Figure 4A). Aheibam et al. (2017) found that farmers are likely to adapt to a CSA strategy when they have received training and are familiar with the strategy. Also, Legesse et al. (2013) discovered that farmers' perceptions and manner of adaption are also influenced by the frequency of extension contact and training. In addition, Mapanje et al. (2023) found that not only does training increase adoption it also increases smallholder farmers' productivity. Training smallholder farmers is significant in raising awareness to farmers so they are aware of the CSA practices that they could adopt and also, to capacitate them with relevant skills thus improving their productivity.

4.2. Factors influencing the adoption of climate-smart agriculture, or the lack thereof

A combination of private and public financing approaches to assist and contribute to the needs of resource-poor farmers, particularly in suitable areas can assist to promote the adoption of underutilized crops, improve irrigation development, and equip smallholder farmers with all resources they need to adopt CSA practices. Unfortunately, in southern Africa, promoted CSA practices are those promoted by funding agencies and such practices have low adoption levels since they may generally not respond to the unique challenges that farmers face (Mazibuko et al., 2023). Mixed funding from donors or prudent government subsidy programs, carefully designed not to distort the market and based on CSA practices and socio-economic status, allows small-scale investment in areas with high suitability, thus improving farmers' access to practices such as irrigation (Kafle et al., 2022). However, since most smallholder farmers have no collateral, private sector financial services are generally unavailable to them and their inability to use the land they farm as collateral precludes them from access to funds from commercial banks. This is because smallholder irrigation farmers are frequently cut off from equipment suppliers and support services (FAO, 2013). As recommended by the authors, funding (Figure 4A), is crucial to smallholder farmers' empowerment, particularly because financial availability is one of the factors affecting farmers' ability to adopt CSA practices (Figure 3B). Collaborative funding towards irrigation development of smallholder farmers, for example, can improve farmers' productivity which can then benefit them financially and improve their time invested in on-farm activities. In fact, when (Machethe et al., 2004) found that the withdrawal of the government from support service provision in the Limpopo province led to low productivity and food insecurity, they recommended that access to support services should be improved through public and private sector partnerships. More work has to be done by government and non-governmental organizations (Figure 4A) to assist smallholder farmers attain financial support.

Results reveal that policy intervention is required going forward in an attempt to encourage and ensure that smallholder farmers adopt CSA practices. A lack of institutional and governmental support prevents smallholder farmers and rural economies from thriving (Kamara et al., 2019). Mainly because of such reasons where there's a frequent underestimation or overlook of women's contribution to agricultural production in national policy, especially regarding aspects of the production dominated by women, i.e., storage at home, smaller scale manufacturing and food production (Beuchelt and Badstue, 2013; Nchanji and Lutomia, 2021). Implementing CSA aspects should help the household's greater output and income since farming is frequently their primary or even only source of income. As a result, several policy incentives are essential for improving smallholdings' environmental performance (Mizik, 2021). In reverse, comprehending the smallholder's perception of climate change challenges such as drought can inform policy formulation (Ogundeji and Okolie, 2022). Results also reveal that a fair number of studies has focused on studying farmers' perception (Figure 4B), however for evidence-informed policy, more still has to be done in this regard.

Women empowerment is yet another aspect that is recommended by authors (Figure 4A) to benefit the adoption of CSA practices, this aligns with the findings that the gender of the farmer's head (Figure 3B) affects the adoption of CSA practice. Both men and women work in agricultural production, marketing, and post-harvest processing to earn a living, women and girls are typically in charge of providing for the nutritional needs of the family (Wenhold et al., 2007). Perhaps a gender-sensitive approach will consider the role of men and women in agriculture and the role of women and men in households as recommended by the authors (Figure 4A). In their study, Chitja et al. (2015) found that young single women, *Makoti*s (newly married), and divorcees, frequently had to submit to male in-laws, and were shown to have less autonomy in their decision-making than middle-aged and elderly married women and widows. Women have less time to pursue their agricultural interests due to the triple burden of carrying out reproductive tasks, productive jobs, and communal responsibilities. Assets that a woman controls because of her domestic obligations (such as water tanks, tools, fencing, and outbuildings) increase her negotiating power on the homestead. Women's empowerment, in particular, the empowerment of female smallholder farmers through agriculture, is a highly pertinent issue in agricultural development – especially in light of the high growth potential of the agriculture sector in Africa and the high involvement of smallholder farmers (Chitja et al., 2015). Rural farming women play an important role in agricultural production and processing.

Perhaps, sustainable rural productivity is dependent on the capacity of women, as the principal users of the land. However, in their study, Oladele and Mudhara (2016) found that women who had access to land, livestock and machinery lack off-farm skills and are not literate. These include skills such as operations management, business, financial knowledge and marketing skills. However, they found that off-farm training provided to the women in KwaZulu-Natal and North-West province met their expectations and had the potential to improve their livelihoods. Similarly, Nesamvuni (2022) found that there was a low level of education for women in Vhembe district, of Limpopo province, even so, their results reaffirmed that women are essential to agriculture and agricultural enterprises. Results reveal that the issue of training has been identified as an influential variable generally (Figure 3A), and this could be achieved through capacity building, knowledge dissemination and providing information material that is written in their language of understanding (Figure 4A). It is therefore no surprise that these have been recommended by authors and can be built on to capacitate smallholder farmers.

Capacitating smallholder farmers is crucial since agriculture is also seen as one of the most important strategic opportunities for employment and rural development, yet smallholder farmers face daunting challenges. Fanadzo and Ncube (2018) identified capacity building as one of the "missing links" in the development of smallholder irrigation. Lack of adequate farmers and extension staff because smallholder farmers generally lack technical expertise in irrigated crop management. Farmers' literacy levels also affect how effectively they used written information, their capacity to keep important records and their ability to share information and transfer skills. Farmers are more likely to successfully embrace CSA practices if they have practical practice expertise or exposure to CSA training, whether official or informal. Therefore, it is imperative to train farmers and their collectives. Even in areas for which appropriate modern technologies exist, the technologies do not always reach smallholder farmers because of poor extension services and inadequate use of communication and dissemination tools (Figure 3B).

4.3. Adoption of climate-smart agriculture methods by smallholder farmers to contribute to food and nutrition

Climate variability and extremes, and economic slowdowns and downturns are two of the major drivers behind recent changes in food security and nutrition identified by the Food Agricultural Organization (FAO), which are exacerbated by the fundamental causes of poverty and very high and ongoing levels of inequality (WHO, 2021). According to demographic estimates, between 720 and 811 million people worldwide experienced hunger in 2020 (WHO, 2021). This could be worse for most South African households who find it challenging to buy enough food to feed their entire household due to the high degree of poverty in the country (Chakona and Shackleton, 2019). Fortunately, CSA has been identified as a significant instrument for overcoming the climate change challenges to agricultural systems and better-integrating agriculture into international climate negotiations (Gatien et al., 2020). According to the FAO, CSA is agriculture that enhances resilience, sustainably increases production and contributes to the achievement of national food security and development goals (FAO, 2013). Challenges in the smallholder farming sector hinder their ability and potential to contribute towards food security and nutrition amidst the changing climate.

Such practices that are beneficial to smallholder farmers include mulching a strategy often discussed strategy in climate-resilient agriculture that reduces evaporation, lowers soil temperature, and, to some extent, enhances soil fertility and soil health (Peera et al., 2020). Also, mulches are typically more effective at retaining moisture during periods of higher rainfall, dryness, and sparse canopy cover, such as during the vegetative stages of crop growth (Peera et al., 2020). Despite the clear advantages, smallholders are widely aware of this strategy but do not frequently put it into effect. Results reveal that mulching was fairly adopted by smallholder farmers because of a fairly low frequency of studies focused on it (Figure 3A). The two main causes, according to smallholders, are an increase in insect and disease occurrence as well as difficulty in locating mulching materials. In fact, Kruger et al. (2021) state that only 32% of smallholder farmers that are introduced to the mulching practice continue to use it in their gardens. Nonetheless, because of the abovementioned benefits, the use of mulching provides a conducive environment that assists smallholder farmers in increasing crop production.

One other CSA strategy that improves crop production is crop rotation. Results revealed that crop rotation is among the most studied CSA practices (Figure 3A). This was evident in the study conducted by Mutsamba et al. (2020) where they found that maize-groundnut rotation had higher maize grain yield compared to intercropping and sole systems. As a consequence, practices such as intercropping were less frequently studied compared to crop rotation and diversification (Figure 3A). Even though crop rotation has been found to result in more crop produce than intercropping in areas of Zimbabwe and Malawi (Thierfelder et al., 2012; Nyagumbo et al., 2016) for instance, intercropping has been the smallholder farmers choice to those with land constraints because they think the overall yield penalty and loss of agricultural land dedicated to maize are minimal (Thierfelder et al., 2012). Also, Arslan et al. (2015) found that crop rotation and cover crops improved cereal yields by 116%. Because of such benefits, results reveal cover crops as one of the considered CSA practices by smallholder farmers (Figure 3A). Suffice to state that these practices have been proven in the literature to assist smallholder farmers contribute towards food security by increasing their production, meaning an increase in food availability.

In addition, crop diversification enables communities to address their nutritional issues more independently. In addition to being easy to implement, crop diversification also offers the chance to have a sufficient diet as opposed to monocultures. The goal in crop diversification is to have as many different types of crops (including medicinal, pest repellent, and multi-purpose plants) as possible in vegetable and fruit production systems throughout the year to ensure a healthy food supply, improve pest, disease, and weed management, and reduce the risk of crop failure shortages (Makate et al., 2016; Kruger et al., 2021). As such, crop diversification falls among the most studied CSA practices (Figure 3A). Due to economic restrictions associated with poverty, achieving dietary diversity is challenging for low-income households. Major obstacles have been cited as affordability and availability, particularly concerning the consumption of fruits and vegetables (Wenhold et al., 2007). Through this method, farmers can spread the risk of crop failure and productivity loss due to weather events by diversifying their crops, which helps to reduce the impact of these events on consumer demand (FAO, 2018). Additionally, some believe that crop diversification mitigates the consequences of climate change since native flora can hold more carbon than monocultures can, resulting in lower carbon dioxide emissions (FAO, 2018). This practice provides an opportunity for the introduction of novel crops, the promotion of traditional food crops that are currently underutilized, and home gardens, the availability of a wider variety of healthy meals can be expanded at the community and family level.

4.4. Future considerations in promoting smallholder farmers' adoption of climate-smart agriculture practices

Declining available water has posed a significant threat to agricultural production in countries such as South Africa, a water-stressed country with about 90% of it being classified as arid to semi-arid (Republic of South Africa (RSA), 1998; Department of Water Affairs and Forestry (DWAF), 2006). In addition, drought is a common phenomenon, especially in rural South Africa where the majority of the population resides. The poor rural population of Sub-Saharan Africa (SSA) subsists primarily on climate-sensitive rain-fed agriculture (Mango et al., 2018). Therefore, under these conditions, water is the main factor limiting agricultural production. In fact, Serdeczny et al. (2017) stated that rainfall in West Africa and East Africa has increased by 2 and 7%, respectively, while Southern Africa appears to have experienced a decline of roughly 4 percent on average. This makes it a challenge for many African nations especially southern African countries to reduce poverty and improve food security. Therefore, due

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to its limited flexibility and reliance on rainfed agriculture, Southern Africa is the region most susceptible to the effects of climate change (Mutengwa et al., 2023). Unfortunately, results reveal that only four countries in Southern Africa (Figure 2A); South Africa, Zimbabwe, Zambia and Malawi, have devoted research on the adoption challenges faced by smallholder farmers. This could be attributed to funding available to support research work in these countries.

What is needed is a transformation in the sub-sector and complementing unreliable rainfed agriculture through an irrigation system that enhances crop-water productivity. Even though results reveal that irrigation is among the five most adopted CSA practices (Figure 3A), it is also among the least recommended focus areas by researchers (Figure 4A). This only reveals that small-scale irrigation presently has a limited role in African agriculture (Mango et al., 2018). This could be attributed to the fact that research has already developed tools to guide this transformation. Literature reveals that access to irrigation has a positive effect on agricultural production and reduces poverty among farmers. Akudugu et al. (2021) in their study found that the immediate and direct impact of irrigation on livelihoods and transformation of smallholder agriculture is through output levels in Ghana. Mudima (2000) investigated the livelihood impacts of five irrigation schemes in Zimbabwe. The findings of the study indicated that, for participants and their neighbors, irrigation schemes were a source of food security. Increased productivity, stable production and incomes have contributed to the main livelihood contributions of irrigation schemes. Moreover, the study revealed that compared with those relying on rainfed crops, irrigation scheme members did not run out of food. Access to irrigation provides farmers with a reliable source of water at critical times in the crop life cycle and eliminates the dependence and inherent uncertainty of rain-fed and lake-based farming systems in arid and semi-arid regions, minimizes unexpected production losses, especially in relation to bad weather.

Improving agricultural production and promoting year-round production ultimately leads to improved livelihoods through higher food availability and income levels (Denison et al., 2016). For Ethiopians, this was indicated by the increase in livestock compared to farmers with no irrigation resources since they have limited access to water. Small-scale irrigation in Ethiopia is not only used to improve livestock and crop production for farmers, but also provides employment opportunities for some families, especially the wives and children of irrigation users, and day laborers working on irrigated farms of irrigation users (Gidey, 2020). Kafle et al. (2022) state that even though there is a high potential for irrigation development, there are factors limiting or hindering this development, namely, a lack of enabling environment and adequate resources. Recently, small-scale irrigation has been regarded as crucial for the expansion of higher agricultural productivity and irrigated agriculture, as such, donors, governments and development organizations have since given the concept considerable attention. The significance of irrigation adoption by small-scale farmers cannot be overstressed. For instance, irrigation development in sub-Saharan Africa could result in annual revenues of 14–22 billion USD and provide a better life to 113–329 million rural population (Xie et al., 2014).

Most Southern African countries must make concessions to mitigate the effects of climate change and GHG emissions (Abegunde et al., 2022) through agriculture. However, nutritionists and agriculturalists continue to face difficulties in identifying appropriate and practical practices to lower the prevalence of malnutrition in Africa, including South Africa (Wenhold et al., 2007). As such, presently, the most effective strategy for tackling both the causes and effects of climate change is being widely pushed as CSA (Mnkeni et al., 2019). Agriculture has primarily focused on developing conventional cereal and horticultural crops since the 1960s, and as a result, these foods have become more popular and have replaced many locally produced crops, leaving indigenous crops' development and cultivation severely undervalued (Akinola et al., 2020). This transition has swept the world so thoroughly that indigenous crops, which were once widely used, have been replaced with lower-nutrient foods, increasing health-related problems. This is also compounded by the limited influence of smallholder rural farmers, who are the custodians of underutilized indigenous and traditional crops (Mabhaudhi et al., 2019). Results reveal that promoting underutilized crops falls among the least recommended practices (Figure 4A), perhaps more attention needs to be given to the introduction or/and reintroduction of indigenous crops into food systems since they can improve the food and nutrient security of the most vulnerable groups.

To remedy the low agricultural yields challenge facing smallholder farmers, some of the recommended approaches for increasing the resilience of smallholder farmers are; promoting crop diversification which also enables communities to address their nutritional issues more independently (Wenhold et al., 2007); mainstreaming of indigenous crops, most of which are nutrient-dense and well adapted to harsh environmental conditions; adopting farmer-led irrigation, through the IDAWM framework which aims to provide resilience and empower rural communities in the advent of increasing climatic shocks and associated negative agricultural production impacts. Improving access to a combination of private and public financing to resource-poor farmers to assist improve irrigation development in these areas and benefit the livelihoods of these communities. The use adoption of CSA practices also helps strengthen resilience by facilitating a transition to agricultural production systems that are more productive, use inputs more efficiently, have less variability and greater stability in their outputs, and are more resilient to risks, shocks, and long-term climate variability required to enhance food security while contributing to the mitigation of climate change and preserving the natural resource base and vital ecosystem services (Kruger et al., 2021). Farmer training and the provision of ongoing extension support are important in the adoption of any technology.

Some of the African indigenous crops include leafy vegetables such as Chinese cabbage (*Brassica rapa*), cowpea leaves (*Vigna unguiculata*), pumpkin leaves (*Cucurbita* spp.), and spider flower (*Cleome gynandra*). These crops can help alleviate malnutrition because they are high in vitamins (Mabhaudhi et al., 2019). Furthermore, their ability to withstand environmental shocks makes them a viable option for reducing farmer vulnerability. These advantages would be appealing to smallholder farmers who are increasingly vulnerable to climate change events. Modi and Mabhaudhi (2016) developed a research agenda for mainstreaming indigenous crops, it proposes that research, development and innovation for underutilized crops should in the future support and develop value chains for underutilized crops. This will open new employment opportunities for women, youths and previously disadvantaged communities through participatory action research and formulation of priorities.

5. Conclusion

As the most vulnerable region in Africa, more research efforts addressing smallholder challenges in adopting CSA needs to be excited in Southern Africa. Although results show there is a significant increase in studies focusing on smallholder farmers' adoption of the CSA practices in sub-Saharan Africa, more research efforts need to be exerted in Southern Africa. The research work should focus on but not be limited to food and nutrition aspects while considering mainstreaming indigenous crops, and irrigation development for smallholder farmers, among other things. There is also an urgent need to improve the agriculture value chain model and improve access to food for all. The adoption of innovative technologies in the agriculture sector is important in transforming the sector since it improves productivity in the midst of changing climate. It is increasingly clear that agriculture has a significant role in ensuring food security and nutrition, therefore, enhancing rural livelihoods and thus can achieve the aims of the South Africa 2030 National Development Plan (NDP) and SDGs. Smallholder farms play a significant role in improving the food security status of many households and offer a wide range of benefits: The production of food by smallholder farmers has the potential to influence the nutrition of members of their households, generating income that allows them to buy food locally. It is evident from the results that in an attempt to aid smallholder farmers and encourage the adoption of CSA practices, timeously weather data needs to be available to them, training should be provided, and any information relating to CSA practices needs to be available to smallholder farmers who have low literacy levels, preferably in their mother tongue.

Author contributions

MK and SH-G drafted the manuscript with support from LN and SM. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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