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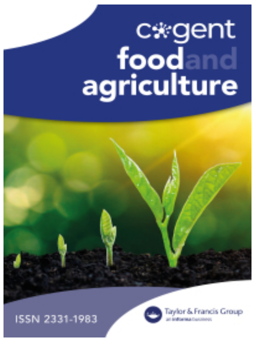

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Effects of systemic challenges on agricultural development systems: a systematic review of perspectives

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ABSTRACT

Achieving measurably reduced greenhouse gas emissions by 2030 as a key sustainable development goal has often been overshadowed by systemic challenges in the agricultural agribusiness system. Although many studies have examined sustainable agriculture extension services, few have considered the effects of the war in Ukraine, the Israeli-Palestinian conflict, climate change, debt burdens, and the ongoing impact of COVID-19. To address this gap, a systematic literature review of literature from 2019 to 2023 was undertaken to analyze the effects of climate change, COVID-19, debt burdens, and the conflict in Ukraine on sustainable agriculture development and extension services. The Russian conflicts have significantly disrupted the global agricultural landscape, impacting food supplies, production, and consumption due to distribution constraints. The loss of agricultural and health workers through COVID-19 has compounded the challenges. Studies also highlight rising inflation rates in many nations, driving communities further into debt, hunger, and poverty, with a noted 5.6% increase in worldwide debt due to COVID-19 alone, and an estimated 9.2% of the world going hungry in 2022. These disruptions have worsened existing agricultural challenges in developing countries such as a decline of 61% in pollinator numbers due to temperature rises caused by climate change, and a loss of 4.1 million hectares of tropical primary forest in 2022, releasing 2.7 gigatonnes of carbon dioxide. In response to these complex challenges, leadership that fosters collaboration among stakeholders through private and public dialogue is crucial. This study examines sustainable agricultural development and resilient extension services amid global systemic challenges.

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1. Introduction

In achieving the world 2030 sustainable development goals (SDG), the aspiration of measurably reducing greenhouse gas emissions by 2030 directly relates to number 13, climate action (United Nations, 2023), which in turn has a direct link on several other SDGs such as number 1, no poverty; number 2, zero hunger; number 15, life on land; and number 12, responsible consumption and production. In addressing the SDGs, the agricultural sector has made significant advancements in innovations and technology in its pursuit of overcoming numerous systemic issues faced (Cerami, 2013) that hinder its ability to feed over 10 billion global inhabitants. Interconnected

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disruptions and stresses have persistently emerged, hindering the development of sustainable agricultural extension to support agricultural progress. International organizations and many countries are engaged in discussions to find lasting solutions to the challenges posed by climate change, the aftermath of COVID-19, and the burden of debt (Reardon & Swinnen, 2020). These efforts are underway and are beginning to have some concerted effects on agricultural development and growth (Reardon & Swinnen, 2020).

Despite the challenges facing the agriculture and extension delivery systems, the aspiration to meet and end poverty and hunger by 2030 (SDG nos. 1 and 2) remains alive and active. For example, recent challenges like COVID-19, which emerged in China, have continued to challenge the status quo, and render the achievement of global sustainable goals unattainable (Laborde et al., 2023). In a chain reaction, COVID-19 gave way to the Russian-Ukraine conflict, initially underrated by many Western countries, who failed to recognize its potential trickle-down effects on numerous other nations (Fasil, 2023; Laborde et al., 2023). Recent studies have shown that developing countries in Africa and Asia were already experiencing the effects of the combined long-term impact of COVID-19 and the Russian-Ukraine war creating high inflation, rendering their economies unstable and underperforming (Chenarides et al., 2024; FAO and WFP, 2022). This situation has caused both political and economic instability (FAO & WFP, 2023). Additionally, studies have indicated that climate change, COVID-19, the conflict in Ukraine, and the burden of debt have had a significant impact on agriculture and extension service delivery systems, particularly on global production and consumption patterns (Natalia et al., 2023; Siankwilimba, Mumba, et al., 2023).

Research consistently demonstrates that poverty and hunger disproportionately affect women and children globally, with these challenges on the rise (Georgieva, 2022; Siankwilimba, Hiddlestone-Mumford, et al., 2023). Despite the vital role of agricultural extensions in educating smallholder farmers, their effectiveness is limited due to various complex factors such as climate change, poor funding and limited skills and competency levels (Khan et al., 2022; Yap & Lee, 2023; Zeufack et al., 2022). Further analysis shows that women and youths are the primary victims of international disruptions, and in 2020, over 70 million more people fell into extreme poverty, predominantly rural residents and agricultural workers (Alvi et al., 2021; Siankwilimba, Hiddlestone-Mumford, et al., 2023). While the agricultural sector in emerging economies helps alleviate poverty, interconnected disruptions, especially affecting women and youth, hinder progress (Alvi et al., 2021). Despite the significance of agricultural extensions, their inefficacy persists, posing barriers to development. Research has revealed that many of these factors are natural, while others are human-induced occurrences (Siankwilimba, 2019).

To what extent have information sharing and production affected women, youth, and, most importantly, the elderly in sustaining their agricultural production systems? This question remains complex due to the interrelated nature of these disruptions, with each reinforcing the other. Many scholars advocating for systems thinking, argue that traditional linear models fail to address systemic issues in agriculture as they focus on symptomatic solutions, ignoring root causes (Jones & Bowes, 2017; Mumba et al., 2017; Sterman & Sweeney, 2007; Sweeney & Sterman, 2000). These scholars have applied systems thinking to understand various challenges in agricultural business spheres. However, they have not explored the impacts of recent global events such as the Russia-Ukraine conflict, debt burden, climate change, and the aftermath of COVID-19 on agriculture and extension service delivery (Fasil, 2023). Behind the minds of systems thinkers lies the understanding that the agricultural sector plays a dual role for the less fortunate in society: it helps the impoverished overcome poverty while also providing food. Therefore, this study aims to critically review the sustainability of agricultural development amidst the multiple systemic challenges faced, including the conflict in Ukraine, the aftermath of COVID-19, ongoing climate change, and debt burdens. These challenges significantly affect agriculture and global consumption patterns in developing countries and the ability of agricultural extension services to support food production whilst focusing on reducing greenhouse gases. To address these challenges, the research question is: What effect does systemic challenges have on agricultural development systems?

2. Methodology

To conduct a comprehensive review, the study begins by exploring the theoretical perspectives of agricultural extension services and agriculture market systems amid complex disruptors. Subsequently, it delves into extension services, climate change, and debt burden. The escalation of poverty and hunger due to climate change, in the aftermath of COVID-19, and the Russia-Ukraine war is then examined (Fasil, 2023). The discussion progresses to topics such as access to affordable finance and credit facilities, adaptation and mitigation intervention strategies, and challenges to mitigation and adaptation intervention strategies.

The databases examined, techniques employed to source relevant material, inclusion and exclusion criteria, and methods for searching these databases are outlined in the following sections. Preferred Reporting Items for Systematic Reviews and MetaAnalysis (PRISMA) diagram conformance was maintained by the techniques used for this analysis (Figure 1).

2.1. Eligibility criteria

Published research papers and data that evaluated and investigated the effects of systemic challenges on agricultural development systems were included in the study. Due to the difference in the use of the official language, only articles written in English were considered.

2.2. Literature identification and data extraction

Two authors, as researchers, independently identified relevant literature and extracting the associated data. Where there was disagreement, a third party was consulted to determine the article's eligibility. This review involved an examination of recently published literature related to key words of 'agriculture and extension services', 'agriculture and debt burden', 'climate change', 'war in Ukraine', 'COVID-19', OR 'coronaviruses', and 'systemic challenges' and 'factors affecting agriculture' from reputable scientific journals and websites.

The titles of each article were used to identify and extract information. After reviewing the title and determining that the content appeared to discuss effects of systemic challenges indicators on agricultural development systems on a global level and developing countries, the associated articles were retained. The article's full reference included the author, year, title, and abstract were recorded for further evaluation. The focus was on literature from 2019 to 2023, emphasizing global or regional contexts. While not exhaustive, the search prioritized the most recent publications, ensuring a pertinent overview of the subject matter.

2.3. Process of gathering data and potential for bias

Data was gathered using Mendeley referencing manager, using the Rayyan program designed for systematic evaluations. To ensure no errors were made throughout the extraction process, the two researchers jointly evaluated the data. The two researcher each carried out an independent full-text evaluation of possibly eligible studies. To ensure all pertinent

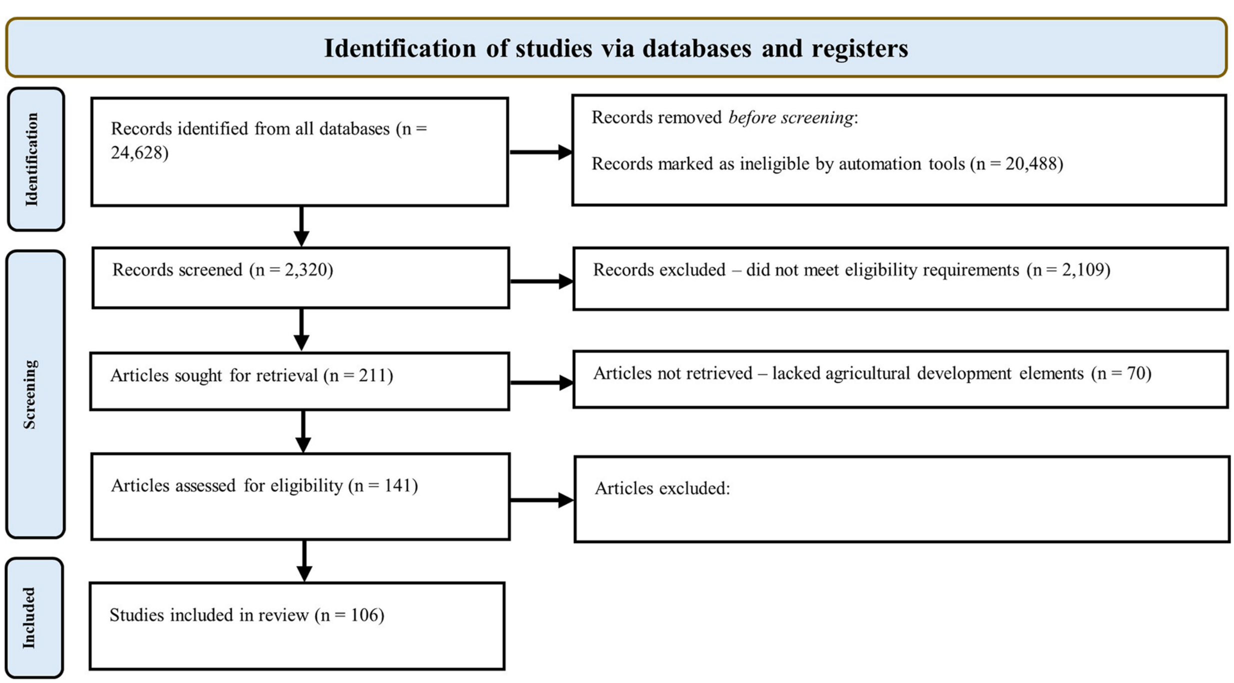

Figure 1. PRISMA flow diagram of literature identification, selection and screening of articles for the systematic review.

data was retrieved, the two researchers then compared their results and discussed any disagreements. In cases where the two researchers could not agree, a third researcher was consulted before a conclusion was made. The study design and sample size were among the primary study features extracted. Included were survey location, duration, participant recruitment strategy, and demographic breakdown. To enhance data management, all extracted references were stored in the Mendeley referencing manager, which was then utilized to transfer the data into a Microsoft Excel sheet and eliminate article duplication.

2.4. Quality assessment

The quality of the studies drawn from the literature was assessed using the Critical Appraisal Skills program (2018). The authors assessed the quality of the studies, which included inclusion and exclusion criteria, and a clear statement of the objective. The studies were identified as eligible or omitted based on their titles and abstracts. The checklist used had 11 items to assess the: (i) validity of results, (ii) methodological quality, (iii) design approach that addressed the objective, (iv) recruitment strategy, (v) data collected in a way that addresses the research outcome, (vi) relationship between researcher and participants, (vii) ethical issues, (viii) data analysis, and (iix) value of the research. Answers such as yes, can't tell, or no were used. The 'yes' response was marked with a green, the 'no' response was marked with a red, and the 'unclear' response was marked with a grey.

2.5. Data collection results – electronic/manual search

The search was conducted on widely recognized platforms such as PubMed, ResearchGate, Google, Scopus, Google Scholar, Web of Science, and PMC open-access articles, collectively feeding into Web of Science and Scopus. The focus was on literature from 2019 to 2023, emphasizing global or regional contexts. While not exhaustive, the review of literature prioritized the most recent publications, ensuring a pertinent overview of the subject matter.

The systematic review of the Scopus, Web of Science, and Google Scholar Advanced Search databases generated a total of 24,628 articles. A total of 20,488 records were removed by automation tools, and 1,820 records were removed for reasons of covering unspecified years and/or systematic challenges not being in agriculture, retaining 2,320. From of which 753 were Scopus, 827 from Web of Science, and 740 from Google Scholar. Further evaluation was undertaken, and 2,109 were eliminated because they did not meet the eligibility requirements as they did not study effects of systemic challenges in agriculture development systems. A total of 211 articles were requested for retrieval, of which, 70 were not recovered because they lacked agricultural development elements. The final articles that passed the title and abstract screening (n = 141) were subjected to a full screening by researchers, which resulted in the exclusion of a further 35 reports representing difference categories of variables not under discussion. After the full-text screening, 106 (n = 106 articles) were included. However, 24 articles from grey literature, being reports from such organizations as FAO, World Bank, and IMF Governments, were included to enhance further discussion bringing the total to 130 as shown in Figure 1.

3. Results

3.1. Theoretical perspectives of agricultural extension service and agriculture market systems within the face of complex disruptors

The worldwide expansion of agriculture relies on essential supporting activities, such as infrastructure development as depicted in Figure 2, encompassing road networks, diverse extension services like farmer training centers and digital channels, and input (i.e. feeds and fertilizers) and output market systems growth (Hasimuna et al., 2019; Muhala, Rumieque, et al., 2021; Rahmandad & Sterman, 2022). Government initiatives, along with contributions from corporate agribusinesses and lobbying groups, drive these efforts to grow the sector (Rahmandad & Sterman, 2022). Additionally, the regulatory framework governing the agricultural market's enabling environment is pivotal. The demand and supply sides, crucial for agricultural sector growth, are central to these supporting roles to avoid solutions based on silos (Sinkovics & Reuber, 2021).

Despite these efforts, agriculture faces persistent systemic challenges, especially in rural areas of emerging nations (Todaro & Smith, 2015). The concept of 'gender-based markets' emerges as a strategy to empower women and young individuals in challenging marketplaces. Research reveals that despite their significant contributions to rural agricultural industries, women often lack opportunities like market expansion through extension services and information exchange (Bayar et al., 2023; Global Hunger

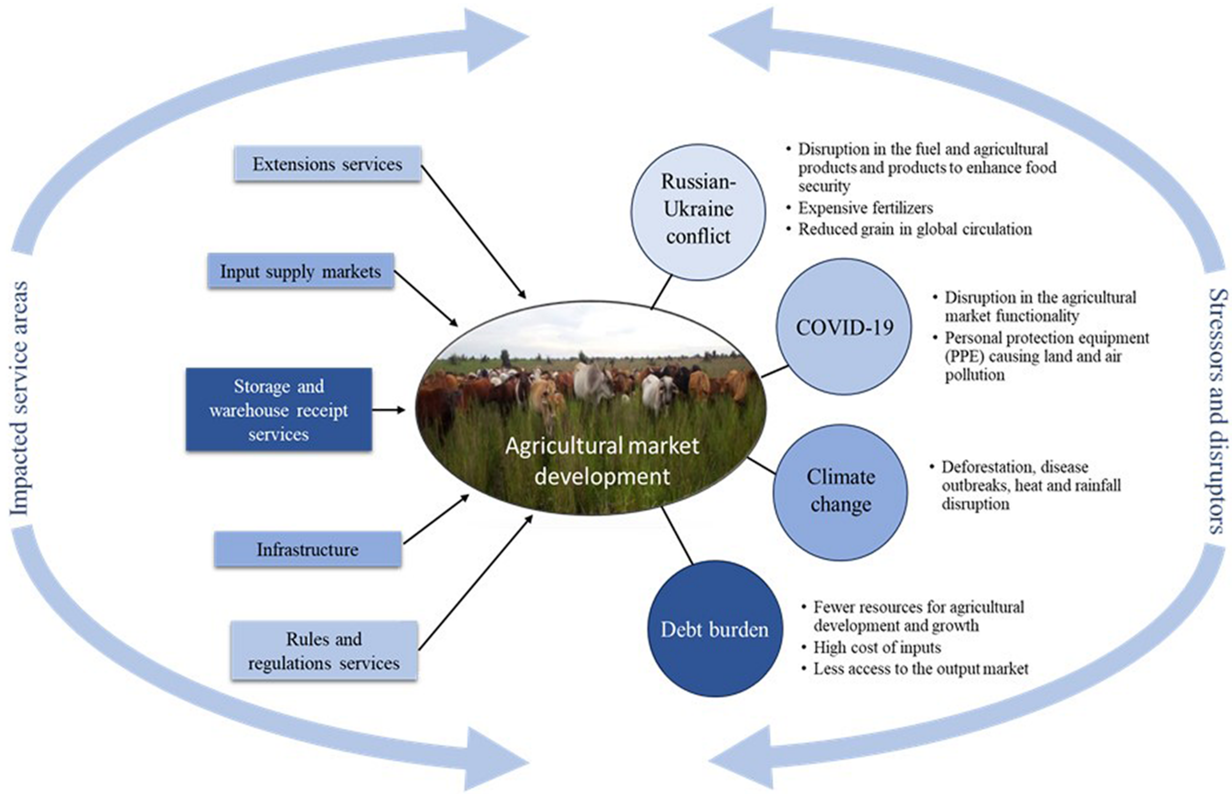

Figure 2. Effects of the Russia-Ukraine conflict, COVID-19, climate change, and debt burden on the growth of the agricultural sector and their effects on extension services provisions, creating a wicked reinforcing loop connection (source: Authors' computation.

Index Report, 2021; Mphande et al., 2023; Siankwilimba, Hiddlestone-Mumford, et al., 2023). Ongoing challenges such as the aftermath of COVID-19, climate change, debt obligations, and the crisis in Russia and Ukraine continue to hinder the engagement of women, young people, and individuals with disabilities in agricultural and extension markets (Alvi et al., 2021; Siankwilimba, Hiddlestone-Mumford, et al., 2023).

Globally, these pressures and disruptions exert both positive and negative impacts on agriculture and extension services (Mwiinde et al., 2022; Siankwilimba et al., 2022). For example, on the negative front, Khan et al. (2022) and Zeufack et al. (2022) indicated that systemic issues derail the fight against hunger and food security due to increased production costs. Studies on the effects of COVID-19, climate change, and debt burdens all take up both financial and human resources that were meant to drive the planned developmental projects (Mwiinde et al., 2022; Pyburn et al., 2023; Siankwilimba, Hiddlestone-Mumford, et al., 2023; Siankwilimba, Mumba, et al., 2023). Additionally, Pyburn et al. (2023) argue that systemic issues promote persistence gender gaps in value chains that continue to exist despite differences depending on the kind and node of the chain. Over the past 10 years, Pyburn et al. (2023) reported that, with an increasing emphasis on analyzing the intersectional dimensions of power inequalities and gender inequality for women and youth, the gap has continued to widen as women participate in agrifood chains. In their 2023 study, Pyburn et al. reviewed literature on gender participation patterns, engagement returns, and power dynamics in agrifood value chains since the first FAO State of Food and Agriculture (SoFA) report on Gender and Agriculture in 2010/2011. The study centered around the critical question: What progress has been made since 2010 in the area of gender equality in agrifood value chains? What evidence exists that women's empowerment and gender equality have improved, and under what specific conditions? The review employed qualitative methods to identify the body of knowledge regarding women's empowerment and gender equality in agrifood value chains. Given the study's objective to describe the current status, incorporate a wide range of studies, and provide an overall summary with interpretation and critique, this methodology was appropriate. This paper aligns with Pyburn et al.'s review, which utilized a conceptual framework to conduct the literature review and achieve better results from authoritative databases.

However, Lybbert et al. (2024) submitted that the green agricultural revolution is the mother of innovation and development to mitigate the effects of complex systemic challenges faced by the world. Their study determined the impact of input and output market support on farmers' adoption and production of pulses by assessing two related experiments. The first two project years' worth of primary support activities included a total of six cropping seasons based on traditional and modern technologies. Lybbert's stylized model encapsulates the main idea of the pulse assistance program, which was that farmers could greatly increase their output using pulses in comparison to conventional production methods if they had access to high-quality seeds, new varieties, enhanced inputs, and improved agronomy. At the heart of this straightforward Lybbert's approach, scaling up was embodied by a transition from traditional to 'modern' pulse production processes.

Lybbert's study found that previous observational studies, particularly in Northeastern Indian states, identified lack of extension and underdeveloped local markets as barriers to pulse production. These studies also suggested that removing these barriers could lead to higher pulse yields and production. According to Lybbert's research findings, even in situations where smallholder farmers have access to high-quality inputs and a marketable product, extension is not enough to persuade them to plant pulses on their land. Input subsidies have an immediate impact, but as incentives run out, these effects diminish. Even in complex situation, Lybbert indicated that the farmers who had received treatment seem to reexamine their reasons for favoring other crops while relegating pulses. It is against this background that we argue that these findings imply that pulses would never be able to completely replace rival crops given current costs and technologies, not even with the best short-term adoption incentives, comprehensive training, and commercial assistance. In market systems, one solution is not enough to solve all the systemic issues, which are interconnected in nature.

The systemic interactions among these challenges create complex systems, necessitating multifaceted interventions to mitigate their adverse effects on agricultural growth (Rahmandad & Sterman, 2022). The systemic interactions among these challenges create complex systems, necessitating multifaceted interventions to mitigate their adverse effects on agricultural growth (Lin et al., 2023). Sustainable agriculture, as shown in Figure 2, represents the sustainable management of debts, sustainable management and mitigation of climate change effects and impacts, sustainable conflict control and management, and more importantly, the management and control of diseases to reduce their outbreaks and impacts, while support systems such as input and output markets should be in place, sustainable green infrastructure for agriculture, and sustainable storage and warehousing receipt systems (Janzen et al., 2024). More importantly, the rules and regulations should mesh well with the informal sector to create harmony and sustainable extension for agriculture development.

3.2. Extension services and the impact of climate change on sustainable agriculture

The relationship between extension service delivery systems and climate change is complex and influenced by various systemic risk factors (Thalheimer et al., 2023). To understand the complexity of climate change impact and agriculture sustainability, Thalheimer et al. (2023) employed a systemic risk impact pathway (SRIP) model on food security in Somalia. The research used publicly available data records from the EM-DAT Emergency Events Database regarding weather-related and climate-related calamities. Disasters related to climate, weather, and hydrology, as well as related impact events, were gathered between 1983 and 2022. Droughts were classified as 'climatological' disasters in the database, floods as 'hydrological', and storms as 'meteorological' catastrophe categories. The related disaster impacts are documented after every disaster in relation with food security and extension provision service. Through reports and estimates from UN agencies, non-governmental organizations, insurance firms, and other sources, EM-DAT obtained this precise information at the local level. In order to separate out the intricacies of disasters, including climatological reasons, the study choose related disaster impacts from the database. Results show that the EM-DAT disaster data displayed the distribution of famine and food insecurity events across time, and additionally indicated that a sizable section of the populace is impacted by drought and recurrent floods. It should be noted that data on food insecurity and extreme weather was applied to internally displaced populations between 2011 and 2019. The study was able to identify various components of vulnerability and demonstrate how they interact with systemic risk drivers. Figure 3 shows how the systemic risks (interconnected and non-linear process risks) interact in an agricultural ecosystem.

Climate change, characterized by extreme weather events such as changes in rainfall, floods, droughts, forest fires, and global warming, has severe implications, especially for smallholder farmers, who are the weaker in the agricultural market system (Maulu, Hasimuna, Haambiya, et al., 2021; Muhala, Chicombo, et al., 2021). These effects impact population dynamics and access to basic human needs like food and water and pose serious risks to crops and animals, hindering the provision of extension services for agricultural sustainable development (Muhala, Chicombo, et al., 2021). Climate change has been noted to put pressure on extensions to designed information to mitigate its impacts amid traditional and cultural rules and regulations holding back rural people from innovation. For example, the processing of developing climate-smart crop varieties that mitigate the effects of climate change is expensive and is worsened by the fact that farmers' adoption of new varieties is low in most cases. Not being willing to adopt suitable technologies compromises research and innovation and consequently fosters the growth of the impact of climate change on food production. Therefore, Thalheimer et al. (2023) postulated that extreme weather and compound economic risk events are having an increasing impact on extension delivery, which consequently highlights the vulnerabilities of women and youth regarding food security. Ringsmuth et al. (2022) revealed that the result of several factors acting in concert rather than just one is a compound systemic event that manifests climate change, which on the one hand increases the commercial farmers' ability to adapt and increases the chance of food security while increasing food insecurity for smallholder farmers, especially when the farmer extension ratio remains unacceptably higher.

Shifting patterns in extension services with climate change are mediated by risk factors such as diet, pollution, microplastics, and the microbiota-gut-brain axis which increase pressure on extension delivery information service (Gössling et al., 2021). While recent extensions have promoted the use of plastic waste as mulch, it has been found to contribute to greenhouse gas emissions (Shen et al., 2020), affecting human and animal health and further exacerbating climate change. To mitigate these challenges, the adoption of climate-smart products, which minimize greenhouse gas production, is encouraged. However, these solutions face criticism for reducing yields in the initial years of adoption (Dunkerley, 2021). Breaking the cycle of climate change-causing elements requires that extension staff provide information for farmers to adjust at the individual, community, and national policy levels, focusing on prevention and mitigation (Dunkerley, 2021). It is also important to consider adopting more sustainable agrifood production systems for example integrated agriculture aquaculture (IAA) and other diversified food production systems (Hasimuna et al.,

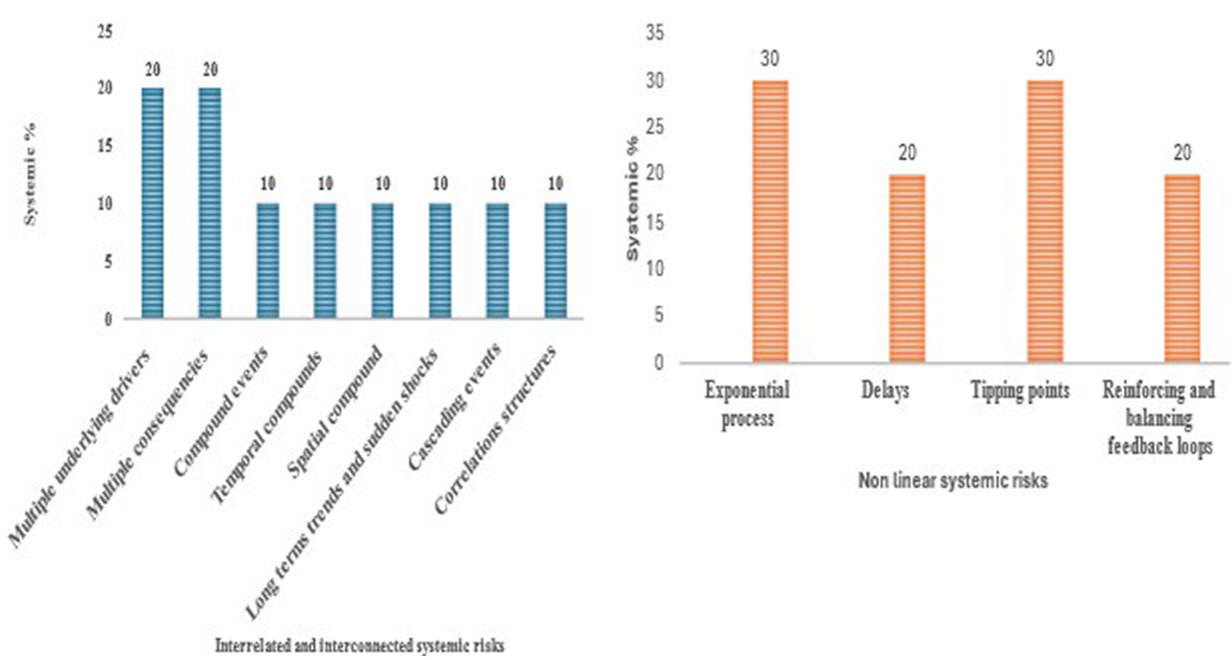

Figure 3. The interaction of critical observed interconnected and non-linear processes risks in agricultural ecosystems.

2023). To arrive at interconnected results, Hasimuna et al. (2023) conducted a review study based on authorized databases such as Scopus, Web of Science, PubMed, Google Scholar, and government reports. However, this study did not employ a systematic review and also did not use market systems or market development to guide its findings. The study findings play a vital role in guiding the policy direction for the private and public sectors to enhance aquaculture sustainable development. Raising awareness and promoting sustainable agricultural practices fall largely on the shoulders of extension workers, who often lack adequate support and specialization in climate communication in many developing countries (Maulu, Hasimuna, Mutale, et al., 2021; Moser, 2010; Sinkovics & Reuber, 2021).

The urgency of addressing climate change is underscored by alarming statistics. In 2022, the world lost 4.1 million hectares of tropical primary forest, equivalent to 11 football fields' worth of forest being lost every minute, causing further global climate change effects (World Resource Institute, 2023) in the face of limited extension outreach systems. This significant forest loss released 2.7 gigatonnes of carbon dioxide, highlighting the pressing nature of the problem of low forest mitigation conservation and preservation messages. Moreover, the recorded forest loss in 2022 increased by 10% compared to the previous year, intensifying concerns (Schlüter et al., 2023; World Resource Institute, 2023). Therefore, in this regard, sustainability should be based on its genuineness, reliability, tangible value, and capacity to meet the needs of its target agricultural players, currently and in the future, by preserving and conserving the natural resource stock (Schlüter et al., 2023). Achieving excellence in function, value and form is also crucial according to Almutawa and Alfraih (2023), as show in Figure 3.

3.3. Increasing the intensity of poverty and hunger based on climate change, the aftermath of COVID-19, and the Russia-Ukraine war

It is disheartening to note that despite progress made over many years, poverty and hunger are on the rise both globally and across the world (FAO and WFP, 2022). The global food system has been severely impacted by multiple factors such as supply chain disruptions, climate change, throughout and during the aftermath of the COVID-19 pandemic, financial constraints due to rising interest rates, and conflicts like the war in Ukraine and the recent Israeli-Palestinian conflict (Lin et al., 2023; World Bank, 2023). These challenges have hit the most vulnerable members of society the hardest. Specifically, Russia's war in Ukraine has significantly disrupted global agricultural trade, leading to food shortages in numerous nations, especially in developing countries (Natalia et al., 2023). According to Natalia et al. (2023), this conflict exposed the fragility and unreliability of the globalized neoliberal agricultural paradigm, which struggled to promptly respond and adapt to disruptions in the agrifood value chain. Further analysis shows that particularly susceptible to the recent global price shocks are staple foods such as rice, wheat, corn, milk powder, cooking oil, and chicken (Almutawa & Alfraih, 2023). Additionally, Almutawa and Alfraih (2023) indicated that climate change is causing rising temperatures, warming oceans, more frequent and severe droughts, biodiversity losses, increased health risks, and a reduction in global food production. Almutawa and Alfraih (2023)'s study was forecasted using three scenarios coupled with the Geophysical Fluid Dynamics Laboratory of the US National Oceanic and Atmospheric Administration (GFDL's CM 2.1). It is anticipated that in the tropics, the Southern Ocean, the North Atlantic, the Northeast Pacific coast, and semi-enclosed seas like the Mediterranean, Red Sea, and Arabian Gulf, local extinctions will occur often. It was predicated that in one scenario, the distribution range boundaries of species are predicted to shift poleward by a median of 291 km (25th to 75th percentiles = 61 – 747 km) between 2001–2005 and 2040–2060, with 887 species exhibiting a positive poleward shift.

Researchers like Mumba et al. (2017) and Siankwilimba, Mumba, et al. (2023) have emphasized the importance of building resilience in the agriculture and extension service food systems to withstand global shocks such as debt burdens, pandemics of the scale and intensity of COVID-19, climate change, and conflicts like the one in Ukraine (Lin et al., 2023). Their work highlights the need for adaptation strategies to address these challenges effectively. For instance, Almutawa and Alfraih (2023) reported that Kuwait's lack of a comprehensive adaptive strategy that outlines action plans and targets for the short- and long-term to address challenges brought about by COVID-19 and difficulties related to climate change intensifies the burden already placed on the agricultural business ecosystem. The inability of several actors to assume their roles in the agricultural sector has a significant impact on agriculture, according to Mumba et al. (2017) system dynamic analysis, conducted before the commencement of COVID-19. The study covered the districts of Lundazi and Monze in

Zambia and was based on a qualitative research approach. But according to Siankwilimba et al. (2024) the introduction of COVID-19 made matters worse. The combination of COVID-19, climate change, and conflicts, including those in Ukraine-Russia and Israel-Palestine, has significantly worsened global food insecurity (Lin et al., 2023). Despite past advancements, hunger levels in developing countries have stagnated or increased due to the pandemic, fluctuating prices, and reliance on imports (FAO, 2022b; Otsuka & Fan, 2021). Recent conflicts, like the Israel-Palestine conflict, and natural disasters, such as the devastating floods in Mozambique and Malawi caused by Cyclones Idai and Freddy respectively, have escalated the crisis, causing loss of life, displacement, and infrastructure destruction (Department of Disaster Management Affairs, 2023; Limuwa et al., 2018; Muhala, Chicombo, et al., 2021; World Bank, 2023).

These challenges have led to the emergence of 'hunger hotspots', affecting 24 nations, notably 16 in Africa, where severe food shortages persist (FAO and WFP, 2022). Agricultural solutions have been hindered by disruptions in food supplies and extension services, particularly in conflict zones (Farmery et al., 2021; Siankwilimba, Mumba, et al., 2023). The alleged weaponization of food and fuel supplies by Russia further complicates the global food crisis.

Amid these challenges, approximately 349 million people across 79 countries face severe food insecurity, compounded by double-digit food inflation that hampers market access for vulnerable populations (Mphande et al., 2023; Mthembu et al., 2022; Voegele, 2023). The World Bank estimated that in 2022, 9.2% of the global population would be hungry, up from 7.9% in 2019 (FAO and WFP, 2022; Natalia et al., 2023). With hunger and food insecurity on the rise, it's more important than ever to boost agricultural output to meet consumption demand. As a result, one of the key motivating reasons is the rising desire for increased agricultural output while minimizing the environmental impact. These circumstances emphasize the urgent need for international cooperation and innovative solutions to address the escalating crisis of hunger and food insecurity worldwide according to the World Bank (2023). Earlier research by Voegele (2023), indicate that societies residing in violent or conflict-affected areas are especially susceptible to the effects of climate change, which results in multiple risks that promote hunger and feminine violence. These effects have also been shown to escalate forced displacement and conflicts over rangeland management land, coupled with the high costs of fighting disease induced by climate change, which eventually act as a catalyst for conflict and war (Tambo et al., 2023; World Bank, 2023). Kruczkiewicz et al. (2021) deduced that the consequences of catastrophe systemic risk reduction are raised by the increasing extension and agriculture awareness of compound events, susceptibility, and systemic risk. Kruczkiewicz et al. (2021) findings are in line with Table 1 results.

3.4. Effects of COVID-19 and resultant debt burden on agricultural development and extension provision

Before COVID-19, scientists and development organizations were dedicated to integrating women and youth into economic development strategies. However, several countries had already accrued significant debt due to their economic challenges, as depicted in Figure 4 (Hemida & Ba Abduallah, 2020; Rennie et al., 2021; World Health Organisation, 2021). The onset of the pandemic further exacerbated the situation, leading to decreased agricultural productivity and increased debt burdens in most developing countries. The worldwide economic challenges triggered by the COVID-19 pandemic caused a significant surge in the total debt stock of low- and middle-income countries. Specifically, the total debt increased by 5.6% from US$8.6 trillion in 2020 to US$9 trillion in 2021 (Bayar et al., 2023). In response to the emerging challenges, various nations and international organizations devised economic recovery stimulus and relief packages specifically addressing the impact of COVID-19.

Although initially regarded primarily as a health threat, the aftermath of COVID-19 has significantly affected the agricultural and livestock sectors, especially for smallholder farmers in countries burdened by heavy debts, such as Zambia, Chad, and Ghana (Gilbert et al., 2020; Ministry of Finance & National Planning, 2022; Ragasa et al., 2022). The World Bank projected that by June 2023, 20 African nations could

Table 1. The extent of calamity due to the Israeli-Palestine conflict.

Statistics	Gaza	West Bank
Number of Palestinians	3,478 killed	136 killed
Injured	12,065 injured	1,300 injured
Estimated displaced	1 million people	–
Non-functioning hospitals	11%	66%
Closed primary healthcare clinics	64% UNRWA, 64% MoH	64% UNRWA, 64% MoH
Litres of water available per person per day	3	–

Source: World Health Organization (2023).

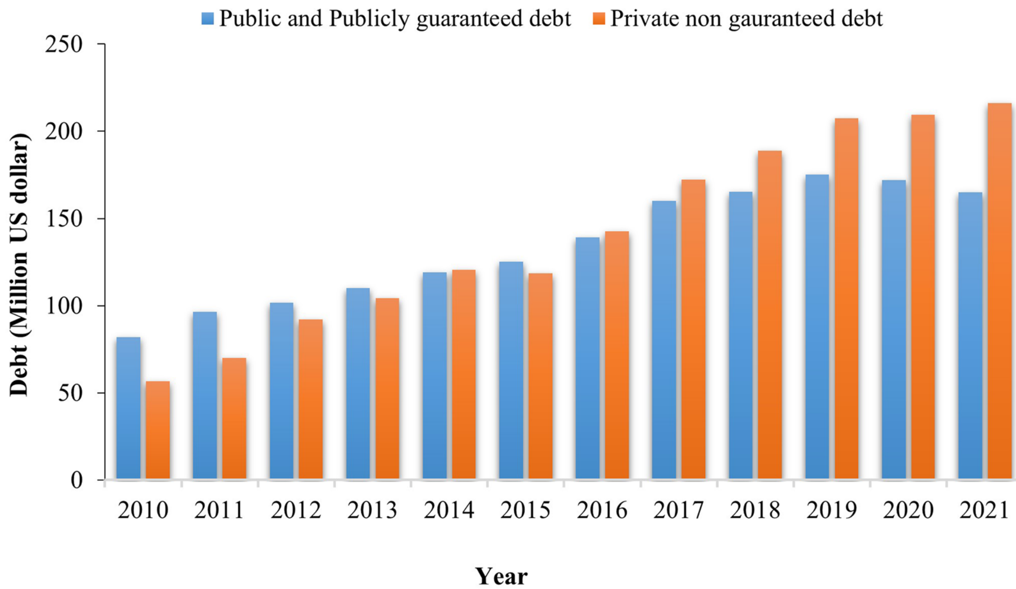

Figure 4. Long-term private creditor obligations of sub-Saharan African countries, 2010–2021 (source: IDS; World Bank, 2022).

face default or be on the brink of it, with Chad, Ghana, and Zambia already in this predicament. Despite a liquidity crisis being prevalent rather than insolvency, these countries are hindered by high-interest rates and lack access to credit markets, preventing them from reducing their high debt/GDP ratios. In 2022, the region allocated 31% of its government revenue to debt servicing, funds that could have been utilized for public goods like agriculture, extension services, healthcare, and infrastructure. Extension services were already underfunded even before COVID-19, making the situation worse. Further, Resnick et al. (2020) revealed that many sub-Saharan countries failed to meet the recommended 10% budget allocation for the agriculture sector.

The economic shocks resulting from the pandemic compelled nations to formulate policy responses (World Bank, 2023). However, these measures, while necessary, proved unsustainable and detrimental to national debt levels. Bayar et al. (2023) highlighted significant regional and national variations in debt, disproportionately affecting women and older individuals. Although foreign debt decreased for some economies, vulnerability escalated for others. Behind regional and group statistics, individual countries grappled with deteriorating debt outlooks, directly impacting extension services and technical information delivery systems.

Figure 5 illustrates that in 2021, South Asia, Latin America and the Caribbean, and East Asia and the Pacific (primarily due to China) experienced an increase in debt compared to the previous year before the onset of COVID-19. In contrast, sub-Saharan Africa, the MENA region, and Europe/Central Asia had slower rates of external debt accumulation. Europe/Central Asia's decline was mainly due to Turkey's reduction in short-term debt.

However, recent studies indicate a concerning trend in developing countries like Zambia, Malawi, and Nigeria (Laborde et al., 2023). The price of fertilizer has doubled due to factors such as the COVID-19 outbreak, the war in Ukraine, debt accumulation, and the strengthening US currency (Laborde et al., 2023; Natalia et al., 2023). This situation has heightened food instability and hunger, especially in anticipation of challenging weather conditions from the el niño season. Some countries and agronomists are advocating for a switch to organic fertilizer methods. However, the adoption of organic farming methods is slow due to the time it takes for yields to recover to levels achieved with commercial fertilizers before the shortage and replacement (Stewart et al., 2020).

Moreover, climate change has impacted the population of useful insects, particularly pollinators. Studies show that insect pollinator numbers can decline by 61% due to temperature rises caused by climate change, especially in regions where extension services are not proactive in educating rural communities (Harvey et al., 2023; Kharuk et al., 2017). Around 35% of the world's food crops, including coffee and chocolate, rely on these pollinators (Zandersen et al., 2021). Tropical locations face the greatest risk of crop loss, as insects in these areas are already operating close to their thermal thresholds. During December 2019 and January 2020, farm level surveys were conducted on 213 smallholder livestock

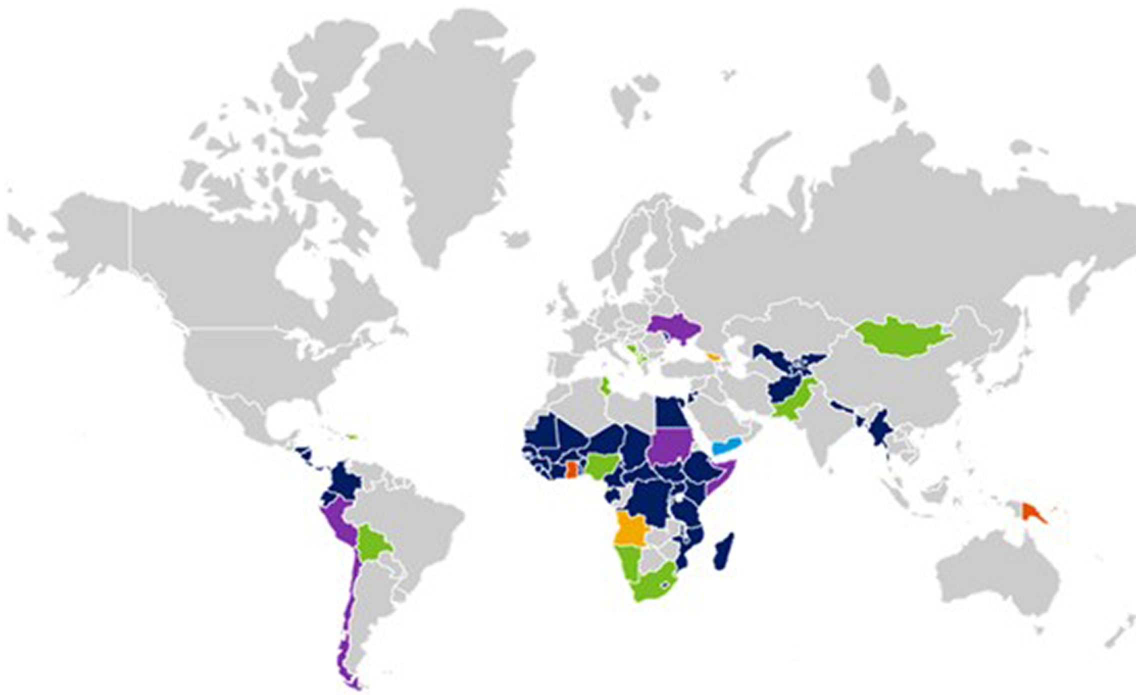

Figure 5. Financial assistance totaling SDR 84,918.82 million (US$117,639.14 million) has been provided to 87 countries through debt relief and assistance from the IMF (International Monetary Fund, 2021).

producers' farms to gather socioeconomic data, including data from 2819 paddocks (Castro-Nunez et al., 2024). Castro-Nunez et al. (2024) study was conducted in four municipalities in the Caquetá department: Albania (71 farms with 878 paddocks), Belén de los Andaquíes (55 farms with 943 paddocks), Morelia (55 farms with 697 paddocks), and San José del Fragua (32 farms with 301 paddocks). The head of the household was interviewed for the majority of the cases. The person in charge of the farm's agricultural operations was interviewed in the event that the head of the household was not present. The survey recorded socioeconomic information on households and farms, as well as technical and financial livestock farming indicators, the number of paddocks and paddock practices, and the circumstances and motivations for farmers' use of SPS measures. Castro-Nunez et al. (2024) results show women have greater motivation for environmental conservation. Female-run, smaller-sized cattle paddocks with a higher number of SPS-related projects exhibit a medium- to high-SPS adoption trend. Moreover, the correlation that exists between loan availability and the adoption of SPS highlights the need of financial resources specifically designed for SPS initiatives. Improved gender roles, easier access to financing for land usage, and SPS system training programs can all help Colombia produce cattle with lower emissions. The importance of using a variety of management techniques and interacting with farmers who are not participating in SPS initiatives is emphasized in this research report. Investments in the production of low-emission livestock are emphasized, particularly for female heads of families. This strategy encourages the partition of paddocks and the use of SPS by acknowledging its wider benefits beyond productivity and financial gains.

3.5. Access to affordable finance and credit facilities

Calice's (2023) study reveals that access to finance poses a significant hurdle for small and medium-sized businesses, especially women, in countries burdened by debt, fragility, and conflict. The research suggests that a favorable credit information environment, reduction in informality, and a secure banking system enhance financial inclusion for farmers when economic shocks are managed effectively. With COVID-19 increasing indebtedness among countries and smallholders, Calice (2023) recommends narrowing the gap by creating an enabling environment, particularly in debt-burdened nations. Calice's study is reliable with its use of World Bank Enterprise Surveys (WBES) data to describe small and medium enterprises' (SMEs) funding in countries with fragile and conflict-affected situations (FCS). WBES is a firm-level survey of a typical sample of the private sector in an economy. The surveys address a wide range of issues related to the business environment, such as competition, infrastructure, corruption, and financial access, as well as other company performance metrics. WBES are accessible to both major companies and SMEs, and each country normally surveys every four years, albeit there are still certain gaps in the total coverage. The study pays particular attention to WBES data that, according to the most recent WBES accessible in a nation, is relevant to SME access to and use of financing. The final sample, which spans the years 2006–2020, is a cross-section of 153 nations worldwide, comprising both developed and emerging economies as well as developing nations.

Enabling environments, particularly in debt-burdened nations, can be achieved through strategies such as deepening financial markets, reducing public sector borrowing, and enhancing competition in the banking sector. Figure 5 illustrates the vital role of public intervention in managing debt and fostering agricultural sector growth post-economic stress.

Additionally, the International Monetary Fund (IMF) (2021) has been providing financial assistance and debt service relief to member countries impacted by COVID-19 since late March 2020. The IMF offered approximately US$250 billion, a quarter of its US$1 trillion lending capacity, to member countries. Despite implementing governance mechanisms to ensure responsible and transparent resource utilization, developing countries have faced challenges. Reports of misused COVID-19 relief funds have emerged, disproportionately affecting vulnerable groups like women and youth. Furthermore, stringent measures have made it difficult for deserving yet vulnerable farmers to access these funds at both organizational and individual levels.

From the provided IMF global map, it is evident that Sub-Sahara Africa is heavily reliant on financial and debt relief packages from the IMF, indicating the economic challenges faced by the region. However, despite these interventions, Sub-Sahara Africa struggles with low agricultural productivity and production, further exacerbated by inadequate extension and advisory services. Calice (2023) notes that interventions in Sub-Sahara Africa led to a decline in the rate of debt creation from 5.6% in 2020 to 2% in 2021. This decrease provided these countries with an opportunity to enhance food security. Notably, South Africa's reduction in private debt by 6% in 2021 significantly contributed to slowing down the expansion of foreign debt across Sub-Sahara African countries that year (Calice, 2023). The discovery of vaccines and the implementation of safety protocols such as masking, social distancing, and digital extension systems have brought hope in managing the COVID-19 pandemic (Chung et al., 2021; Pan et al., 2021) over the long term. These measures, recommended by the World Health Organization (Chakraborty & Maity, 2020; Chatterjee, 2020), have prevented a catastrophic scenario. Although virus mutations remain a concern, the situation is considerably better than before the introduction of vaccines, particularly benefiting women and youth involved in agricultural production. Countries heavily reliant on agriculture and facing unstable situations should implement comprehensive macro-financial and institutional measures to promote financial inclusion for small and medium-sized enterprises and downstream farmers (Calice, 2023; Islam et al., 2021). Managing inflation becomes crucial during these times. When inflation is low, countries can reduce interest rates or acquire assets to alleviate financial stress and stimulate agricultural markets (Zeufack et al., 2022). However, developing countries' central banks face complex challenges in balancing financial and price stability. Governments have taken measures to normalize their economies, reducing extraordinary financial aid and consequently decreasing public debt and deficits (Caselli et al., 2023) (Figure 6). The rebound in nominal GDP, combined with unexpected inflation increases, has aided several countries in improving their public finances. Positive market access, especially for women and youth, has been observed. The ability to recover swiftly from the pandemic and handle subsequent shocks has determined how countries can reduce deficits and debts. Regulatory tightening, a mix of targeted and untargeted measures, has been employed to protect individuals, businesses, and gender markets in countries significantly affected by energy or food crises.

In 2021, reducing debt became a priority for many economies due to rising inflationary pressures. Countries with high initial debt levels experienced significant reductions, particularly when accompanied by substantial inflation and robust economic growth (Zeufack et al., 2022). It's important to note that the impact of increased inflation on debt ratios was influenced by various factors in emerging market economies and low-income countries, including exchange rate depreciation, primary deficits, and higher borrowing costs (Janssens et al., 2021; Zeufack et al., 2022).

Additionally, a global increase in the cost of food commodities, such as grains and dairy products, was observed according to the FAO's Agricultural Price

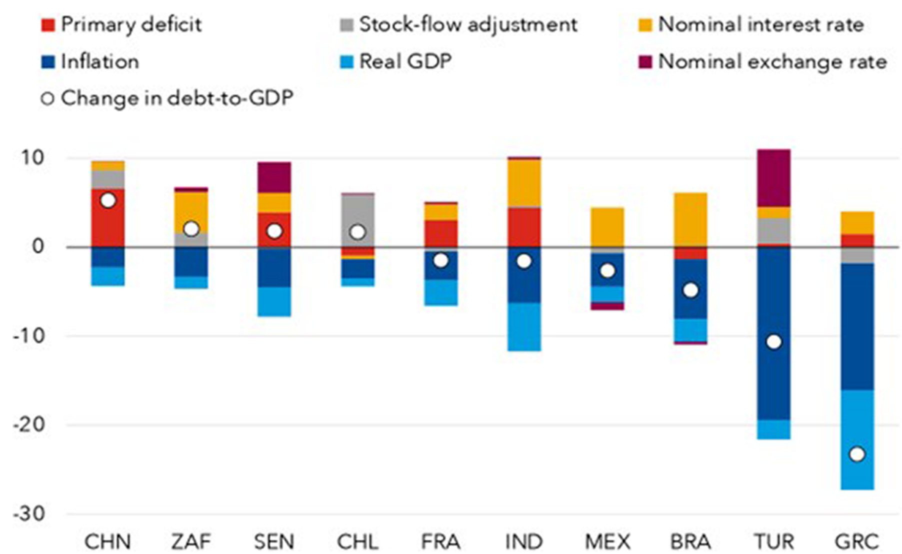

Figure 6. The 2021–2022 projected change in general government debt for a sample of economies in terms of Gross Domestic Product (GDP) (Caselli et al., 2023).

Index (FAO, 2022a). By June 30, 2022, the index had surged by 34% compared to January 1, 2021. Specifically, maize prices rose by about 47%, wheat prices by 42%, and rice prices decreased by 8% compared to January 2021 figures (FAO, 2022a; Ouko & Odiwuor, 2023). This escalation in food prices led significant challenges for economies and highlighted the complex interplay between inflation, debt, and agricultural affordability on a global scale.

3.6. Population growth's effects on agriculture production and consumption

The global population's continuous growth is increasing the demand for food, putting immense pressure on the agri-food sector (Moores & Hunters, 2018). Particularly vulnerable to food insecurity are women and youths (Global Hunger Index Report, 2021). The United Nations (2022) and Clark et al. (2020) anticipate the world's population to peak at around 10.4 billion during the 2080s, emphasizing the crucial role of livestock and crops in addressing global hunger and malnutrition. However, conflicting projections exist, with Vollset et al. (2020) suggesting a peak at 9.7 billion by 2064, indicating uncertainty about future population trends. Despite these projections, approximately 1.02 billion people were undernourished in 2013, primarily in Asia, where 60% of the world's population resided (Zimdahl, 2015). The timing of the population peak remains contentious, impacting efforts to combat hunger and malnutrition (Mutyasira, 2023; Simuunza, 2022; United Nations, 2022). Simuunza (2022), with the help of FAO, conducted a qualitative and quantitative review study to understand how livestock in Zambia contribute to food security amidst complex systemic issues such as drought, floods, and poor policies. The study confirmed Creswell's (2019) claims that a mixed-method paradigm should balance the two techniques by leaning either more toward the qualitative (qual) or the quantitative (quant). As such, Simuunza's study leaned more on qualitative than quantitative methods because it was exploring research. The study found that livestock needs sustainable agriculture and smart management practices to contribute effectively and efficiently to food security for the growing population. A further pragmatic study by Siankwilimba et al. (2024) agreed that the current emergency and disaster declaration by the president of Zambia can only be solved once green investment is promoted and practiced.

Livestock products like milk and meat are increasingly consumed, offering potential solutions to food security challenges, especially for women (Cordeiro et al., 2022). However, high demand for animal protein sources has driven up prices and posed threats to food supply security, exacerbated by events like the COVID-19 pandemic and the Ukraine-Russia conflict (Lin et al., 2023; Tona, 2021). Bovine protein sources are nutrient-rich, but inadequate agricultural service provision hampers their utilization (Adesogan et al., 2020). The ownership of small livestock, such as goats and chickens, particularly benefits women and younger individuals (Debela, 2017;). Small livestock offer affordable protein sources and contribute significantly to nutrition and food security, particularly for vulnerable populations (Siankwilimba et al., 2024; Taruvinga et al., 2022). Meat, being a vital component of the human diet, carries diverse cultural, economic, and health implications (Harrison et al., 2019; Smith et al., 2013).

Meat quality and nutritional values are influenced by various factors, including animal genetics, feeding, and postmortem processes (Tona, 2021). The demand for meat and milk is expected to rise significantly, primarily in developing nations, due to increasing incomes and improved information dissemination systems (COMESA, 2015; Umali-Deininger, 1997). However, achieving global food security goals, especially in regions like Latin America, the Caribbean, Asia, and Africa south of the Sahara, remains a significant challenge (Global Hunger Index Report, 2021). Efforts to address these challenges are critical, requiring sustainable extension delivery systems to ensure effective utilization of available resources and meet the growing demand for nutritious food.

3.7. Emerging themes from studies analyzed

From the 130 articles and report, nine themes emerged around the systemic challenges affecting agricultural development systems, as summated in Table 2.

Additional this research reveals that exposure to systemic agricultural issues worsen the direct effects of lower worker productivity, lower agricultural output, and worse ecological system functionality. While cyclic systemic issues exhibit their indirect impact in the form of damage to infrastructure, non-farm possibilities, prices, and migration's effect on household structure. Systemic agricultural challenges raise issues with social distinction at two levels: macro, through institutions and services, and micro, through family and individual criteria like money, age, and sex. Geographical factors are perceived to have an impact on issues such as the agro-ecological system, market proximity, and public services. These findings are in line with FAO (2024) and Siankwilimba, Hiddlestone-Mumford, et al. (2023).

4. Discussion

4.1. Adaptation and mitigation intervention strategies

Governments worldwide, in line with the SDG's, have committed to eliminating poverty by 2030 while minimizing disruption to the planet's life-support systems (Lade et al., 2017). Given that 78% of the world's poor live in rural agricultural areas, understanding the interconnection between development and the environment is vital (Lade et al., 2017). Current interventions and policies for poverty reduction need urgent evaluation due to the complex forces undermining global agriculture and agricultural extension. Public-private partnerships are essential tools to create a diverse, resilient agricultural economy (Rahman et al., 2022). Private-sector climate action in developing nations can boost agricultural economic growth, technology leadership, and job creation while ensuring stable incomes and food access (Prayitno et al., 2023).

To address challenges posed by global warming and unexpected disease outbreaks, innovative methods of message dissemination beyond farmers' boundaries are crucial. Continuous investment in digital and green agriculture sectors is essential to develop technology solutions addressing pressing issues (Janzen et al., 2024; Lade et al., 2017; Prayitno et al., 2023). Agricultural economic growth must prioritize creating system models that enhance production, especially for women and young people, generating jobs and providing a focused agricultural extension to improve skills and capacity (Siankwilimba, Hiddlestone-Mumford, et al., 2023). A global effort in reskilling and upskilling individuals is essential to prepare for future job demands, integrating cutting-edge technologies to enhance food production's robustness and sustainability (Lamboll et al., 2021; Siankwilimba, Mumba, et al., 2023).

Addressing the risks associated with climate change, the aftermath of COVID-19, and global warming requires a combination of mitigation and adaptation efforts. Mitigation efforts must reduce CO2 emissions, utilizing technologies such as electrification, hydrogen, sustainable bio-based feedstocks, product substitution, and carbon capture utilization and storage (Janzen et al., 2024; Pörtner et al., 2022). Additionally, environmentally friendly methods and technologies like solar energy, proper feeding practices, and sustainable wastewater management are vital to reduce air and water pollution (Form et al., 2018; Hickel & Kallis, 2020; Jiren et al., 2020).

Adaptation strategies should focus on enhancing the capacity to handle negative outcomes (Table 3) while making ethical and sustainable use of new opportunities (Maulu, Hasimuna, Haambiya, et al., 2021). Effective adaptation interventions can focus on institutions and management, livelihood adaptation, and resilience and risk reduction. A combination of these areas is likely to yield better results.

Table 2. Summary of literature themes.

Themes	Results	Authors, with a focus on 2019–2024
Agriculture market systems within the face of complex disruptors	Agriculture supply systems have been disrupted by COVID-19, reducing consumption and productivity further. It also affected the environment and social parameters. Human resources critical for agriculture development remain a challenge in many countries.	Bayar et al., 2023; Janzen et al., 2024; Lin et al., 2023; Mphande et al., 2023; Pyburn et al., 2023; Mwiinde et al., 2022; Lybbert et al., 2024; Rahmandad & Sterman, 2022; Siankwilimba et al., 2022; Alvi et al., 2021; Global Hunger Index Report, 2021; Muhala, Rumieque, et al., 2021; Sinkovics & Reuber, 2021; Hasimuna et al., 2019.
Extension services and climate change	Although climate-smart agriculture has been advanced in many developing countries, soil degradation and deforestation remain the major causes of low rainfall for sustained agriculture. In the face of climate change effects, extension remains critical, but the results show that droughts and floods have continued to surge while extension services remain in place. Temperatures have been increasing, causing genetic transformation in many agricultural inputs.	Almutawa & Alfraih, 2023; Schlüter et al., 2023; Thalheimer et al., 2023; World Resource Institute, 2023; Ringsmuth et al., 2022; Dunkerley, 2021; Maulu, Hasimuna, Haambiya, et al., 2021; Maulu, Hasimuna, Mutale, et al., 2021; Muhala, Chicombo, et al., 2021; Sinkovics & Reuber, 2021; Gössling et al., 2021; Moser, 2010.
Increasing intensity of poverty and hunger based on climate change, COVID-19, and the Russia-Ukraine war	Poverty remains over 60% in most developing countries with access to food and income cited as the major causes. These have been exacerbated by the onset of and in the aftermath of COVID-19 and the Ukraine-Russia conflict, which has drastically reduced the flow of food from the two countries into Africa and Asia. This added to existing climate change systemic issues such as floods and droughts in Asia and Africa.	Almutawa & Alfraih, 2023; Department of Disaster Management Affairs, 2023; Lin et al., 2023; Mphande et al., 2023; Natalia et al., 2023; Siankwilimba, Hiddlestone-Mumford, et al., 2023; Siankwilimba, Mumba, et al., 2023; Tambo et al., 2023; Voegele, 2023; World Bank, 2023; World Health Organization, 2023; United Nations, 2023. FAO, 2022b; FAO and WFP, 2022; Mthembu et al., 2022; Farmery et al., 2021; Kruczkiewicz et al., 2021; Muhala, Chicombo, et al., 2021; Otsuka & Fan, 2021; Limuwa et al., 2018.
Effects of COVID-19 and debt burden on agricultural development and extension provision	Before the onset of COVID-19 and the Russian-Ukraine war, some developing countries, such as Zambia and Mozambique, grappled with debt and other animal diseases, making their economies and agriculture unsustainable. The agricultural extension system was burdened with a lower than World Bank and FAO extension worker-to-farmer ratio standards of 1:400. To date, this systemic challenge continues.	Bayar et al., 2023; Laborde et al., 2023; World Bank, 2023; Harvey et al., 2023; Ministry of Finance & National Planning, 2022; Ragasa et al., 2022; Rennie et al., 2021; World Health Organisation, 2021; Gilbert et al., 2020; Hemida & Ba Abduallah, 2020; Resnick et al., 2020; Stewart et al., 2020; Kharuk et al., 2017.
Access to affordable finance and credit facilities	Access to affordable finance and credit facilities remains limited in developing countries to enhance agriculture production and productivity. Most traditional financial institutions, such as banks, are not willing to lend money to smallholder farmers because of traditional conditionalities such as asset-based collateral. Added to this is the increased inflation rate in most developing countries, which acts as insecurity for both the lenders and the borrowers.	Calice, 2023; Ouko & Odiwuor, 2023; FAO, 2022a; Zeufack et al., 2022; Chung et al., 2021; International Monetary Fund (IMF), 2021; Islam et al., 2021; Janssens et al., 2021; Pan et al., 2021; Chakraborty & Maity, 2020; Chatterjee, 2020.
COVID-19's effects on agriculture production and consumption	Increased inputs for agriculture suffocate smallholder farmers, making it difficult to enhance food and income security. During COVID-19, results show that these inputs increased by between 50% and 200%, while on the other side of the market, consumption was highly restricted, reducing production and productivity. COVID-19 resulted in markets for high-value crops and perishable goods shrinking.	Lin et al., 2023; Mutyasira, 2023; Cordeiro et al., 2022; Simuunza, 2022; Taruvinga et al., 2022; United Nations, 2022; Global Hunger Index, 2021; Tona, 2021; Adesogan et al., 2020; Clark et al., 2020; Vollset et al., 2020; Harrison et al., 2019.
Adaptation and mitigation intervention strategies	Governments have been providing farmer-supported agricultural inputs coupled with climate-smart technologies, but their adoption has been low, leading to continued food security and soil degradation. Governments and collaborating partners, such as the IMF, the World Bank, and other donor countries, provide soft loans to mitigate the effect of COVID-19 and the aftermath to farmers, creating perpetuating dependence, yet necessary strategies.	Ivanovich et al., 2023; Janzen et al., 2024; Prayitno et al., 2023; Pörtner et al., 2022; Rahman et al., 2022; Lamboll et al., 2021; Maulu, Hasimuna, Haambiya, et al., 2021; Amadu et al., 2020; Hickel & Kallis, 2020; Jiren et al., 2020; Baliño et al., 2019; Mwanamwenge & Cook, 2019; Form et al., 2018; Lade et al., 2017.
Access to digital inclusive channel	Most developing countries lag in the utilization of digital technologies to enhance productivity in agricultural sectors. However, COVID-19 accelerated the adoption and usage of digital marketing systems via electronic commerce-buying and selling platforms. Increased extension service provisions between agricultural stakeholders need to be achieved quickly. In most countries, microfinance services have adopted these technologies compared to traditional banks.	Bayar et al., 2023; Siankwilimba et al., 2023; Afesorgbor & Lim, 2022; Siankwilimba et al., 2022.

(*Continued*)

Table 2. Continued.

Themes	Results	Authors, with a focus on 2019–2024
Challenges to mitigation and adaptation intervention strategies	Private-public partnerships have been cited as mitigative intervention strategies in building infrastructure and sharing information between agricultural partners. Research and technology are drivers of business innovations in agriculture. Climate-smart agricultural interventions are a source of climate mitigation. Most countries have worked on mechanization strategies to offset agricultural system systemic challenges. Funding for increased extension service provision is being adopted by most developing countries. Artificial intelligence, as a digital tool, is also transforming the agricultural sector. Control of animal disease via one health system is being strengthened to reduce occurrences. The fight against public sector corruption must be reinforced so that resources meant for agricultural development are not tempered.	Korneeva et al., 2023; Nematchoua et al., 2023; Prayitno et al., 2023; World Bank, 2023; Lybbert et al., 2024; Munkombwe et al., 2022; Maulu et al., 2021; Maulu et al., 2019; Lade et al., 2017.

Table 3. The effects of drought systemic issues on agriculture food production in southern African countries.

	Effects of drought in 2024				
Country	Crop	Livestock	Aquaculture	Electricity	Commodity prices
Zimbabwe	Failure	Starvation	Water input threat	Loadshedding	High
Zambia	Failure	Starvation	Water input threat	Loadshedding	High
Malawi	Failure	Starvation	Water input threat	Loadshedding	High
Angola	Failure	Starvation	Water input threat	Loadshedding	High
Mozambique	Failure	Starvation	Water input threat	Loadshedding	High
Botswana	Failure	Starvation	Water input threat	Loadshedding	High

Agricultural diversification systems, combining crops and animals, and incorporating indigenous knowledge with sustainable extension messaging, can enhance agricultural variety, soil fertility, and resource efficiency (Maulu, Hasimuna, Haambiya, et al., 2021). Strong institutional and policy frameworks, efficient food and resource recycling, and sustainable management systems are essential for successful agricultural diversification and mitigation of climate change effects (Amadu et al., 2020; Baliño et al., 2019; Mwanamwenge & Cook, 2019). Increasing awareness of how global food consumption affects future warming is crucial to encourage more commitment to reducing GHG emissions from food systems and designing effective policies (Ivanovich et al., 2023). With Zimbabwe, Zambia, Malawi, Angola, Mozambique, and Botswana receiving less than 20% of the usual rainfall expected in 2023/2024, large portions of Southern Africa experienced significantly below average rainfall, with devastating results for a population that primarily relies on rainfed agriculture (FAO, 2024). Table 2 shows that dependence on drought-sensitive water supplies and rain-fed subsistence crop cultivation leads to a chronically high vulnerability to rainfall anomalies and a restricted ability to adapt. The current high and rising rates of food insecurity and malnutrition are a result of several factors, including multiple years of high food prices, and the ongoing recovery efforts from floods, agricultural pests and diseases. Elevated rates of deforestation contribute significantly to environmental deterioration nationwide, intensifying the peril and consequences linked to drought. Further analysis indicates that under the current climate, droughts like this one are projected to occur roughly once every 10 years using four different observational data packages. Nonetheless, we found these droughts are twice as likely to occur in El Niño years when the El Niño's influence is taken into account. El Nino is hence a major factor behind the 2024 occurrence.

The most current FAO (2024) study analysis is crucial for identifying global vulnerabilities and the most critical actions that should be taken to improve the efficacy of solutions. However, local solutions are required for climate risk and adaptation efforts, which are situational. The FAO (2024) research accomplishes this by evaluating how climate change affects rural women, young people, and the impoverished by gathering papers with an exceptional collection of data from 24 low- and middle-income countries spread across five continents. The study analyzed socioeconomic data collected from 109,341 rural families across 24 countries, which collectively comprised around 950 million rural inhabitants. We combined this data, both geographically and temporally, with 70 years of georeferenced daily temperature and precipitation records. Additionally, FAO managed to use the data to differentiate between the ways that different climate stressors affect people's wealth, gender, and age-related characteristics, as well as their total, on-farm, and off-farm incomes, labor allocations, and adaptive behaviors. The findings show that better data on how vulnerable rural populations—such as women, youth, and the impoverished—are being impacted by climate change and how they make a living is necessary, to create policies that facilitate inclusive rural transformation processes. To be able to better understand how exposure to weather shocks and climate change affects the drivers of rural transformation and adaptive behaviors across different rural society segments and agro-ecological contexts, we need more comparative, multi-country, and multi-regional evidence—all of which were unavailable initially. Notwithstanding the significant insights provided by FAO (2024), systemic agricultural challenges persist, leading to unexpected outcomes, which this study has attempted to effectively tackle.

4.2. Access to digital inclusive channel

Crises and disruptions provide significant opportunities to accelerate transitions and transform agricultural communication systems globally. Digital media has greatly simplified everyday chores on farm development platforms, facilitating information sharing on production, market expansion, input purchases, and financial transactions (Afesorgbor & Lim, 2022). However, this digital revolution often excludes individuals who are blind or visually impaired, posing challenges to their participation in the digital world. Despite being part of agriculture and extension services platforms, people with visual impairments face barriers due to inaccessible websites and digital strategies employed by businesses.

Research indicates that enabling people with visual impairments to participate fully in the digital world is not only a moral imperative but also a financially rewarding strategy for businesses (Bayar et al., 2023). Consumer businesses with inaccessible digital platforms lose significant revenue annually while catering to the needs of individuals with disabilities can enhance customer loyalty and broaden their consumer base. As the global population ages, the demand for accessible goods and services will increase, posing both challenges and opportunities for businesses. Adapting to these changing demographics will be essential for businesses to remain competitive and cater to the diverse needs of their customers (Afesorgbor & Lim, 2022).

4.3. Challenges to mitigation and adaptation intervention strategies

To effectively address the challenges facing the agricultural sector and extension systems, inclusive interventions must be implemented, considering regional and environmental variations. For example, Nematchoua et al. (2023) findings indicated that in 2100, air temperatures in desert regions are predicted to rise by up to 4.9 °C, which will result in an increase in cooling loads of 34.5% and a rise in the environment, causing uncomfortable rates of 73%. Furthermore, in 2021, Nematchoua et al. (2023) warned that air temperatures in the coldest regions are predicted to rise by up to 5.5 °C, which will result in a decrease in heating loads of up to 15.5% and an increase in comfort rates of up to 25%. Looking at the results, innovations and technologies must be designed to mitigate the variations in temperatures based on regional variation levels and the type of agriculture system being practised.

Adaptation, seen as a short-term solution to climate change, encounter challenges due to conflicting knowledge between formal players and the informal sector, each governed by distinct rules (Maulu, Hasimuna, Haambiya, et al., 2021; Prayitno et al., 2023). Climate-smart agriculture products and services play a vital role, with their success contingent on tailored messages and information delivery to end-users. Agriculture development initiatives, as suggested by Korneeva et al. (2023), need to encompass environmental, social, and economic dimensions.

Cutting-edge developments such as precision agriculture, agroecology, breeding programmes in both plant and animals and digital technology, coupled with legislative initiatives and cooperative strategies, can foster regenerative and sustainable agriculture (Lade et al., 2017; Maulu et al., 2019; Prayitno et al., 2023). Tufa et al. (2024) indicated that willing to pay for improved technologies would enhance increased agricultural production and productivity among smallholder farmers in Malawi. Therefore, low productivity among smallholder farmers that have persisted over many years in different regions could be partially solved by employing private sector-led mechanization services. To arrive on this conclusion, Tufa et al. (2024) conducted research which used data from 1,512 households and the double-bounded contingent valuation method to determine farmers' willingness to pay for mechanized services. To choose the households, the study employed a multistage sampling procedure. The seven districts were selected in the first phase to symbolize a high frequency of Conservation Agriculture promotion. Additionally, the districts represent two market-access groups—low and high—as well as two agroecologies—lowland and mid-elevation.

The findings indicate that, for land preparation, maize shelling, and transportation services, farmers are ready to pay, on average, 11%, 33%, and 5% more than current market rates. Farmers' willingness to pay varies depending on market availability, agroecology, area of farmed land, value of farmer assets, and sex and age group. For transportation services, maize shelling, and land preparation, men are willing to spend 26%, 25%, and 1% more than women. Furthermore, for land preparation services, 90% of male and 40% of female farmers are willing to pay more than or equivalent to the market rate. Smallholder farmers have a significant demand for mechanization services, which highlights the necessity of supplying rural communities with machinery through private sector-run machinery hiring facilities or mechanization service providers.

Information and communication technologies (ICT) are highlighted as essential tools for enhancing productivity, automation, insurance, and resilience in the agricultural sector (Munkombwe et al., 2022). These advancements are crucial for transitioning to an economy aligned with the SDGs and capable of navigating geopolitical and economic uncertainties (Siankwilimba, 2019). Tirelli and Besana (2023) claimed that the circular economy approaches that have been praised to fight climate change in agriculture only include designing for adaptability and disassembly to lower embodied carbon. However, passive design and the use of solar and geothermal energy can meet the needs of agriculture for renewable energy. Even if most of the literature discusses how climate change would affect agriculture in warm climates, overheating due to high temperatures remains the biggest obstacle that is costly to mitigate.

According to a recent study by Zhu et al. (2024), standard procedures based on assessment systems for the interaction between grass and livestock can be put in place, encouraging collaboration across disciplines and regions and providing objective and useful information about how to make grasslands and grazing management more sustainable. Results showed that the number of publications in the field of grass-livestock interaction was increasing annually on a global scale, with interdisciplinary and international collaboration. The United States of America ranked first, followed by Brazil, England, Australia, and China. Globally, this trend was observed. The review results, which ranged from 2000 to 2022 and 2023, were derived from the review paper, which was exported and based on full bibliometric data, including their title, publication date, author names and affiliations, citation count, list of keywords, abstract text, and list of references. In order to evaluate the research on grass-livestock interaction in its broadest sense, this study examined articles about the interactions between grass and livestock. The full bibliometric data from these publications was exported and examined. (1) 11,636 data were produced by the search range of 2000 to 2022; (2) 8,258 data were produced by the control literature type of articles and reviews; and (3) 5,505 valid literature records were obtained after the initial search results were refined, cleaned, and summarized, guaranteeing the quality and utility of the literature data. Although this study has delved into grass livestock interactions, studies found feedlot to be the best approach to increase the productivity of cattle and other livestock (Mumba et al., 2017; Siankwilimba et al., 2024) which is in line with the findings of this study. For example, Piña et al. (2023) investigated the variables influencing precision livestock farming (PFL) in the adoption in beef cattle production, specifically with regard to big data technologies. The study shows that precision livestock farming (PLF) employs big data analytics, robotics, and sensors. By delivering real-time insights for entire farm operations through the integration and analysis of generated data, PLF can improve productivity and lower illness-related losses. The results of a binary probit analysis show that US beef farmers' adoption of big data technology was positively impacted by herd size and their previous use of sensor-based technology. The adoption of big data technologies was also found to be adversely affected by the age of producers. The findings of this study aligned with earlier evaluations of adoption among beef producers, which discovered that farmer age and farm size were prevalent factors influencing technology acceptance.

In another study, Pruitt et al. (2012) investigated the US beef cow-calf producers' use of production systems, management techniques, and technology adoption. The adoption of these systems and technologies was shown to be mainly influenced by farm size and educational attainment. The factors influencing Missouri cow-calf producers' adoption of beef cattle reproductive technology were examined by

Elliott et al. (2013). The use of reproductive technology was found to be influenced by various factors, including producer risk preference, age, operation type, and management characteristics.

Studies on the use of digital technologies have been carried out globally. The factors influencing beef farmers in Sao Paulo, Brazil's adoption of feedlot technology were examined in a study conducted by Carrer et al. (2013). The likelihood of feedlot technology adoption was shown to be influenced by herd size, average price, technical help, involvement in farm associations, training, and proximity to processing plants.

In order to ascertain the factors driving the adoption of seven technological management tools utilized by Canadian cow-calf producers, Jelinski et al. (2019) examined data from Statistics Canada's 2016 census. It was discovered that the adoption of technological management tools was more common among larger farms. Furthermore, the use of computers and laptops for farm management as well as cell phones and tablets were found to be correlated with producer age, with younger producers being more likely to embrace.

Groher et al. (2020) used digital technology by Swiss livestock farmers to review a range of livestock production, including the raising of beef cattle. Groher et al. (2020) discovered that the most popular technology among suckler cows were electronic ear tags, webcams, and electronic weighing systems. Weighing systems and transponder collars were two technologies that farmers growing beef cattle were discovered to employ often. Farmers' age, gender, kind of farm, and barn system were found to have an impact on adoption of digital technology, with larger farms being more likely to do so.

According to a recent study, systemic agricultural challenges can be lethal in social, economic, and environmental magnitude for the rural poor. FAO (2024) indicated that, compared to those in better financial standing, impoverished households lose 5.4% of their annual income to systemic floods and 5% to systemic heat stress. Adaptationally, in rural areas, systemic floods increase the annual income difference between impoverished and non-poor households by over USD 21 billion, while heat stress increases it by more than USD 20 billion.

4.4. Limitations of the study

There are studies that have focused on the major themes of the effects of systemic challenges on agricultural development systems globally and in developing countries. However, although the focus on 2019 through 2023 narrowed down the number of available articles and recency of challenges, agricultural challenges have been cumulative and reinforcing each other since the time agriculture was invented over 10,000 years ago (Siankwilimba, Hidddlestone-Mumford, et al., 2023). Studies that could have explored components of the leadership of nations and agricultural organizations, both public and private, may have been omitted from the study due to the search criteria used. Furthermore, the focus was restricted to publications written in English, which may have resulted in the exclusion of significant studies written in other languages that could have enhanced the study. Extending the inclusion criteria may help improve future research by lessening the effect of publication bias and increasing the analysis's overall depth.

5. Conclusions and future prospects

Extension services play a critical role in promoting climate-smart agriculture principles, assisting smallholder farmers, and ensuring sustainable food production. Embracing interventions aimed at supporting and empowering smallholder producers is imperative for addressing food-related challenges in agriculture. When the world experienced food and financial sincerity around the 1940s and 1950s (Lybbert et al., 2024), the innovative model of the Green Revolution's investment in infrastructure, market development, and agricultural extension, together with advances in agronomy and enhanced germplasm, resulted in a drastic increase in the world's food supply (Lybbert et al., 2024). Between 1950 and 2000, India's agricultural output increased by almost four times, which significantly reduced food insecurity and malnutrition and improved population health and well-being (Lybbert et al., 2024). Since then, disasters like the pandemic have disrupted global agricultural and extension systems, affecting food supply, production, and health workers. To reduce the current level of food insecurity considering the aftermath of COVID-19, the associated debt load, climate change, and the legacy of the war in Russia and Ukraine, lessons from the Green Revolution agriculture investment model must be taken into consideration (World Bank, 2023).

Rising inflation rates have exacerbated the challenges in developing nations, highlighting the need for collaborative solutions. Addressing the implications of an increase of 4.9 °C in deserts and 5.5 °C in the coldest regions by 2100 creates an urgency to act. Innovation and technology are but one consideration, climate-smart agriculture product and services also play a vital role. Extension services in educating farmers around agricultural system practices and quantifying the impact as part of the dialogue with the wider community on food consumption, greenhouse gases, and global debt and hunger requires both government intervention and the media.

Effective agricultural investment management necessitates a comprehensive understanding of how technology and information services are used to address interconnected challenges in the sector. The aftermath of COVID-19, alongside climate change, illiteracy, low productivity, food insecurity, and debt, has disrupted agriculture. Input costs and financing access issues, particularly for marginalized groups, further strain these systems. Coordinated efforts between public and private sectors are fundamental to address these issues. Along with leadership focused on equality and inclusive growth also being essential.

In answering the research question of: What effect does systemic challenges have on agricultural development systems? Our research identified the systemic challenges faced and risks associated with climate change in terms of global warming, the aftermath of COVID-19, impact of recent wars such as the Russian-Ukraine war, food insecurity and debt, and the associated impact on agricultural productivity and development systems. Addressing these risks are needed to minimize the level of carbon dioxide and associated global warming, along with the knock-on effect of malnutrition and hunger. Thereby addressing the 2030 sustainable development goals of reducing greenhouse gases emissions (no. 13), contributing to no poverty (no. 1), zero hunger (no. 2), life on land (no. 15), and responsible consumption and production (no. 12). Significant advancement in innovation and technology has gone some way to overcome the system issues faced that are hindering the ability to feed over 10 billion global inhabitants by 2080.

In responding to these complex challenges, collaborative leadership that drives dialogue among the various stakeholders, both private and in the public domain is crucial. This study contributes to the discourse on sustainable agricultural development and the resilience of extension services in the face of global systemic challenges.

5.1. Future research focus

Inspiring leaders is crucial for sustainable agriculture development, addressing environmental concerns, promoting gender diversity, and adopting new technology. A future research study using a mixed-methods study could help decipher agricultural system complexities and bridge research gaps in developing nations through systems thinking.

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Author contributions

ES generated the idea, defined the objectives, critically reviewed the manuscript, and participated in writing the manuscript. JHM and MEH assisted in defining the objectives, critically reviewed and participated in writing of the manuscript. OJH assisted in defining the objectives, coordinated the writing of the manuscript, and participated in the writing of the manuscript. SM and JM participated in writing and reviewing the manuscript. BHM, CM and GP critically reviewed and made substantial contributions to the manuscript. All the authors read and approved the final manuscript.

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Data availability statement

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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