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Review article

Diversification of agriculture practices as a response to climate change impacts among farmers in low-income countries: A systematic literature review

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ABSTRACT

The primary objective of this study is to systematically review the literature on the diversification of agriculture practice as one of the many ways farmers in low-income countries can respond and adapt to the worsening impacts of climate change. To ascertain the rigor in its methodology, this systematic literature review (SLR) adhered to guidelines outlined in RepOrting standards for Systematic Evidence Syntheses (ROSES); the research question was formulated based on the mnemonics of Population, Interest, and Context (PICo), the inclusion and exclusion criteria were based on timeline publication, document type, language, low-income countries and focused on reviewing empirical evidence studies; the quality was appraised based on Mixed Method Appraisal Tools (MMAT), while data extraction and analyses were executed using thematic analysis. The analytical outcomes yielded three main themes. First is the theme related to crops and varieties-related strategies, which consist of four sub-themes: early maturing crops, use of the drought-tolerant variety, abandoning crops, and introduction of new crop/crop rotation/crop diversity/mixed crop. The second theme is soil and water conservation techniques, which later produced another six sub-themes, namely the use of organic/inorganic fertilizer, water harvesting, irrigation and drainage, tree planting and agroforestry, terracing/contour farming to prevent soil erosion, mulching/stone barriers and agriculture mechanisation related activities. The last theme is planting-related strategies, which consist of three sub-themes: rescheduling the planting calendar, increasing pesticide/herbicide/integrated pest management, and selecting and expanding new areas. Referring to this SLR, there is a pressing need to facilitate farmers facing inadequate resources to adapt effectively to environmental and other change forms. Upon comprehending the present adaptation practices used by farmers, interested parties may offer ideas to strategize effective adaptation plans tailored to farmers' needs, abilities, and interests across low-income countries.

Introduction

Climate change is a change in the weather pattern and other related changes in oceans, land surfaces, and ice sheets, which occurs over time scales of decades or longer (Australian Academy of Science, 2022). Climate change negatively impacts nature and those who rely heavily on its stability. The Intergovernmental Panel on Climate Change (IPCC), in its latest Sixth Assessment Report, claimed that the recent changes in the climate

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systems appear to be widespread, rapid, intensifying, and unprecedented in thousands of years (IPCC, 2021). According to NASA's Goddard Institute for Space Studies (GISS) (2023), the average global temperature on Earth has increased by at least 1.1° Celsius (1.9° Fahrenheit) since 1880. Most of the warming has occurred since 1975, at a rate of roughly 0.15 to 0.20 °C per decade. Moreover, human activities that cause harmful climate change and increases in global temperature seem to result in more frequent and severe extreme climate events (e.g., heatwaves, extreme rainfall, and droughts). Referring to Rodell and Li (2023), the frequency of extreme wet and dry events has increased from four events annually from 2015 to 2021 to three per year in the past 13 years, while the expectation of a higher frequency of Category 4 and 5 storms as temperatures continue to rise (Environmental Defense Fund, 2024).

The changes certainly affect humans (Fig. 1), especially farmers, who rely on nature for daily routines. Farmers' agricultural activities are exposed and vulnerable to a multitude of changes and events in the climate system, affecting their agricultural production, food security, and livelihoods (Shaffril et al., 2018). Food and Agriculture and Organization of the United Nations (2023) has demonstrated the impacts of climate change on agriculture output by estimating the loss and damage for four country-crop pairs – soy in Argentina, wheat in Kazakhstan and Morocco, and maize in South Africa – demonstrates primarily negative impacts on productivity that range from two to ten percent. For the livestock industry, the heat stress has caused an approximately 35 % decrease in milk production, while if ambient temperature increases from 21.1 to 32.2 °C, it can result in a nearly 10 % drop in feed intake for birds from the post-hatch period to 6 weeks of age (Cheng et al., 2022). Climate change also directly impacts livestock health, as extreme events cause temperature-related illnesses, changes in metabolic functions, and morbidity (Ali et al., 2020). According to FOA (2018), the climatic impacts are predicted to reduce fishermen's productivity by up to 6 % by 2100 and 11 % in tropical zones, while decreases in both marine and terrestrial productivity in more than three-quarters of coastal countries are predicted, varying widely in their national capacity to adapt. Despite climatic impacts on agricultural productivity, it should be noted that agriculture itself is a significant greenhouse gas emitter. According to DOA (2021), greenhouse gases from agriculture, particularly livestock production, rice cultivation, and fertilizers, contribute 13 % to 21 % of global emissions, usually carbon dioxide, methane, and nitrous oxide.

The effects of climate change are expected to worsen in the future, wherein adaptation is one of the best strategies for the community to respond to the formidable impacts caused by climate change (IPCC, 2022a). Adaptation refers to changes in processes, practices, and structures to moderate potential damages or benefit from climate change opportunities (United Nations Climate Change, 2024). It also covers autonomous adjustments via ecological and evolutionary processes (IPCC, 2022a). While those in a better economic condition have sufficient resources to facilitate their adaptation process, it is interesting to assess how people in low-income countries with inadequate resources strategize and plan their adaptation to reduce the effects of climate variability.

Those in developed and high-income countries have benefited from cutting-edge technology, expertise, and knowledge to cope with climate change; however, the situation differs across low-income countries. As defined by the World Bank, low-income countries refer to countries with per capita gross national income (GNI) of less than $1,035 in 2020, which has increased to $1,045 in 2021. The countries listed under this category are Ethiopia, Rwanda, Uganda, Afghanistan, Sudan, and Mozambique. As these low-income countries have fewer resources, they suffer the most when global temperatures and sea levels rise, when oceans acidify, and when precipitation patterns shift. Notably, the recovery process from these adverse impacts may take longer. For instance, Hurricane Maria hit Puerto Rico, killed 3000 people, and destroyed most of the basic facilities. It has been reported that the country is still recuperating from the calamity after more than two years, mainly because most of the houses need to be repaired or rebuilt, water supplies restored, some schools and hospitals remained closed, and the economy of the island severely damaged (Mattei et al., 2022).

As climate change affects everything, from where people live to access healthcare facilities, millions may fall into poverty as environmental circumstances worsen. This is particularly true for those impoverished residing in low-income countries. Climate change exacerbates disparities within a country and divides international relations, mainly because some countries are more vulnerable than others. People residing in low-income countries often live on the most fragile land. They are often politically, socially, and economically marginalized, thus exposed to the formidable impacts of climate change (Atube et al., 2021; Etana et al., 2020).

The need for the current systematic literature review (SLR)

Notably, farmers are highly vulnerable to climate change impacts (Shaffril et al., 2018; Beitness et al., 2022; Nazari Nooghabi et al., 2022). A primary adaptation strategy practiced by farmers refers to diversifying their agriculture practices, including early maturing crops, drought-tolerant variety, new crops, and rescheduling the planting calendar (Shaffril et al., 2020; Asravor, 2023; Zakari et al., 2022). These adaptation strategies enable them to sustain their agricultural activities even in challenging climate conditions. Numerous studies have examined this issue, such as Yohannes et al. (2020), Takele et al. (2019), Abera & Tesema (2019), Abid et al. (2020), Diallo et al. (2020), Etana et al. (2020), and Atube et al., (2021). For instance, Yohannes et al. (2020) listed the top ten adaptation strategies practiced by Ethiopian farmers, such as stone bund building, tree planting, and organic fertilizer application. Meanwhile, a study in Malawi conducted by Abid et al. (2020) concluded that the farmers adopted drought and disease-tolerant crops, diversified their crops, and rescheduled their planting time as key ex-post climatic shock coping strategies.

Although the abovementioned studies offer vast perspectives and views that revolve around agriculture practice diversification among farmers, this abundance of sources yields problems rather than provides valuable data if they are not reviewed systematically (Shaffril et al., 2021a). The traditional literature review, which was opted for by most researchers when reviewing empirical evidence due to its simple form, invites multiple issues such as bias in the selection process, less comprehensive, ambiguous, and poor-quality control (Shaffril et al., 2021a; Haddaway et al., 2018). Systematic literature review (SLR) is one way to overcome deficiencies of the traditional literature review. According to Higgins et al. (2011), SLR denotes the comprehensive effort to locate and synthesize related research work using organized, transparent, and replicable procedures at each step in the process. Some benefits of deploying SLR are that it emboldens transparency, heavily focuses on evidence, impacts validity and causality, emphasizes comprehensive search, and controls the review quality by guaranteeing the robustness of evidence (Shaffril et al., 2021a).

The main objective of this study is to systematically review the literature about the diversification of agriculture practice as one effective way for farmers in low-income countries to respond to the worsening impacts of climate change. This study offers several noteworthy contributions to the body of knowledge and practical implications. Scholars may identify the current pattern of agriculture practice diversification among farmers in low-income countries from the outcomes reported in this study, thus enabling them to determine the effective adaptation strategies that must be highlighted in future studies. Through this SLR, interested parties (e.g., policymakers, the general public, researchers, and environmentalists) should realize the importance of determining how farmers with inadequate sources strategize their adaptation to environmental and other forms of change. Imminently, this study enables interested parties to better comprehend the present adaptation practices so that they may facilitate devising strategic adaptation plans tailored to farmers' needs, abilities, and interests in low-income countries.

Methodology

Review Protocol – ROSES

The RepOrting standards for Systematic Evidence Syntheses: pro-forma review protocol (ROSES) was selected as the primary guideline for this SLR due to its strength in reporting with methodological advice; a gold standard method that supports the production of high-quality SLR (Haddaway et al., 2018). ROSES is preferred rather than PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) as according to Haddaway et al. (2018), PRISMA faces 12 key issues if non-medical SLR applies it. Among the issues is heavy emphasis on *meta*-analysis (excludes narrative, qualitative, and mixed synthesis methods), focuses on medicine and health topics, and non-matching terminology (e.g., separating 'screening' from 'eligibility'). Additionally, ROSES is selected as it is a friendlier approach for executing SLR from diverse research design backgrounds (quantitative + qualitative + mixed methods). In addition to ROSES, specific SLR guidelines on climate change outlined by Shaffril et al., (2021a) served as reference in this study. Upon adhering to these two guides, four methodological sections are presented in this study. The SLR began with the formulation of research question based on the mnemonic of Population, Interests, and Context (PICo) and ideas from past SLRs. The second methodological process refers to the systematic search process that comprised of three steps: identification, screening, and eligibility. Next, the quality of the selected articles was appraised by using Mixed Method Appraisal Tools (MMAT) introduced by Hong et al. (2018). Finally, relevant data were extracted from the selected papers and were analysed using inductive thematic analysis.

Formulation of the research question

The research question is an integral aspect of any SLR. According to Shaffril et al. (2021b), the research question is the main reference for SLR as it assists authors in extracting crucial keywords for article searching purposes and guiding them in the data extraction process. The research question in this present SLR was formulated based on PICo – a mnemonic typically used to develop SLR research questions based on qualitative review or synthesis (Lockwood et al., 2015). Before PICo, some ideas for the research question were generated by referring to past SLRs on climate change, such as Shaffril et al. (2020, 2019). Referring to PICo, the following keywords emerged as essential to develop the research question for this study: farmers (population), livelihood diversification and climate change impacts (interest), and low-income countries (context). As a result, the research question formulated in this study is: How can farmers in low-income countries diversify their agriculture practices as a response to climate change impacts?

Systematic search strategies

The third phase of this SLR refers to the systematic search strategies composed of three main processes, namely identification, screening, and eligibility.

Table 1
The search string.

Database	Search string
Scopus	TITLE-ABS-KEY (("Climat* chang*" OR "Climat* risk*" OR "climat* variabilit*" OR "climat* extrem*" OR "climat* uncertaint*" OR "global warming*" OR "temperature ris*" OR "el-nino" OR "la-nina") AND ("Adapt* abilit*" OR "adapt* strateg*" OR "adapt* capacit*" OR "adapt* capabilit*" OR "adapt* strength*" OR "adapt* potential*" OR "adopt* abilit*" OR "adopt* capacity*" OR "adopt* capabilit*" OR "Adopt* potential*" OR "adopt* strategy*") AND (farm* OR gardern* OR plant*))
WoS	TITLE-ABS-KEY (("Climat* chang*" OR "Climat* risk*" OR "climat* variabilit*" OR "climat* extrem*" OR "climat* uncertaint*" OR "global warming*" OR "temperature ris*" OR "el-nino" OR "la-nina") AND ("Adapt* abilit*" OR "adapt* strateg*" OR "adapt* capacit*" OR "adapt* capabilit*" OR "adapt* strength*" OR "adapt* potential*" OR "adopt* abilit*" OR "adopt* capacity*" OR "adopt* capabilit*" OR "Adopt* potential*" OR "adopt* strategy*") AND (farm* OR gardern* OR plant*))

Identification

The initial step is the identification process, which identifies the appropriate keywords for the search process. Based on the research question, three main keywords were applied: climate change, adaptation ability, and farmers. Next, these three keywords were enriched; Shaffril et al. (2021b) accentuated the need to increase the main keywords to retrieve more relevant articles for SLR. In order to enrich the keywords, several synonyms, related terms, and variations for the main keywords were sought. This was carried out by referring to online thesaurus, keywords used in past studies, and keywords suggested by the database (Scopus) and by seeking expert opinions. As a result of this process, the following keywords were identified: climate risks, climate extreme, adaptation strategy, adaptation strength, and gardens (see Table 1). The search process involved two primary databases, Scopus and Web of Science, while Google Scholar was used as a supporting database. Scopus and Web of Science were selected as the primary databases as they offer multiple benefits, including advanced search queries, a vast range of multidisciplinary areas, as well as broader and more inclusive content coverage that includes journals about climate change (Shaffril et al., 2021a; Gusenbauer & Haddaway, 2020). As for Google Scholar, despite the concern expressed by Halevi et al. (2017) about its failure to control quality, Haddaway et al. (2015) and Gusenbauer et al. (2019) asserted that Google Scholar might serve as a strong supporting database with approximately 389 million documents retrievable from its database. However, as advanced manual searching was considered integral to diversifying the search techniques to retrieve more related articles (Cooper et al., 2018), both Scopus and Web of Science were selected as the main databases in this study. The search string was developed based on several essential functions, such as field codes, phrase searching, Boolean operators, truncation, and wild card. In contrast, manual searching (until page 10) based on handpicking technique was applied in Google Scholar. In this process, 5477 articles were selected for the screening process.

Screening

In the second process, screening criteria were set to screen the selected articles (see Table 3 for the selected criteria). First, it was crucial to ensure that the context of the selected articles was low-income countries. The low-income countries were identified based on the list provided by The World Bank (2021) (see Table 2). Articles reported on countries not included in the list were excluded. The following criterion refers to timeline publication, in which publications between 2019 and June 2021 were chosen for this study. The main reason why this timeline was selected is because it is in line with the concept of study maturity discussed by Alexander (2020) and Kraus et al. (2020). The study maturity concept refers to a situation where the number of published articles is higher and, therefore, more topics are investigated. Based on the identification process, the timeline of 2019–2021 has resulted in 5477 potential articles, proving that the study is mature and the timeline chosen is suitable for the SLR. This timeline is also viable for tracing farmers' cutting-edge job diversification patterns from low-income countries, thus enabling future researchers to plan studies based on the latest findings. Only article journals were selected as they offer

Table 2
Countries listed as low-income countries.

Afghanistan	Guinea-Bissau	Somalia
Burkina Faso	Korea, Dem. People's Rep	South Sudan
Burundi	Liberia	Sudan
Central African Republic	Madagascar	Syrian Arab Republic
Chad	Malawi	Togo
Congo, Dem. Rep	Mali	Uganda
Eritrea	Mozambique	Yemen, Rep.
Ethiopia	Niger	Guinea
Gambia	Rwanda	Sierra Leone

primary data and quality. In order to avoid confusion, only articles published in English were included. Based on the research question, only articles containing diversification strategies deployed by farmers as their response to climate change impacts had been chosen. The screening process was conducted automatically using the screening function embedded in the two databases – Scopus and Web of Sciences. At the end of this screening process, 5382 articles were discarded, and 95 articles were retained for the following eligibility step.

Eligibility

Eligibility is the third process performed in this present SLR, whereby the relevancy of each selected article was manually screened by reading the title, abstract, and, if required, the content. As a result, 37 articles were removed due to the absence of a clear explanation of the type of job diversification practiced by farmers, more concentration on agricultural science rather than adaptation aspects, as well as more focus on migration strategy, weather forecasting, and information usage instead of job diversification. Finally, 58 articles were retained for the next step – quality appraisal.

Quality appraisal

The selected articles were appraised for their quality. This process was performed by the corresponding author with the assistance of two co-authors. As the SLR is a mixed-method review (quantitative +

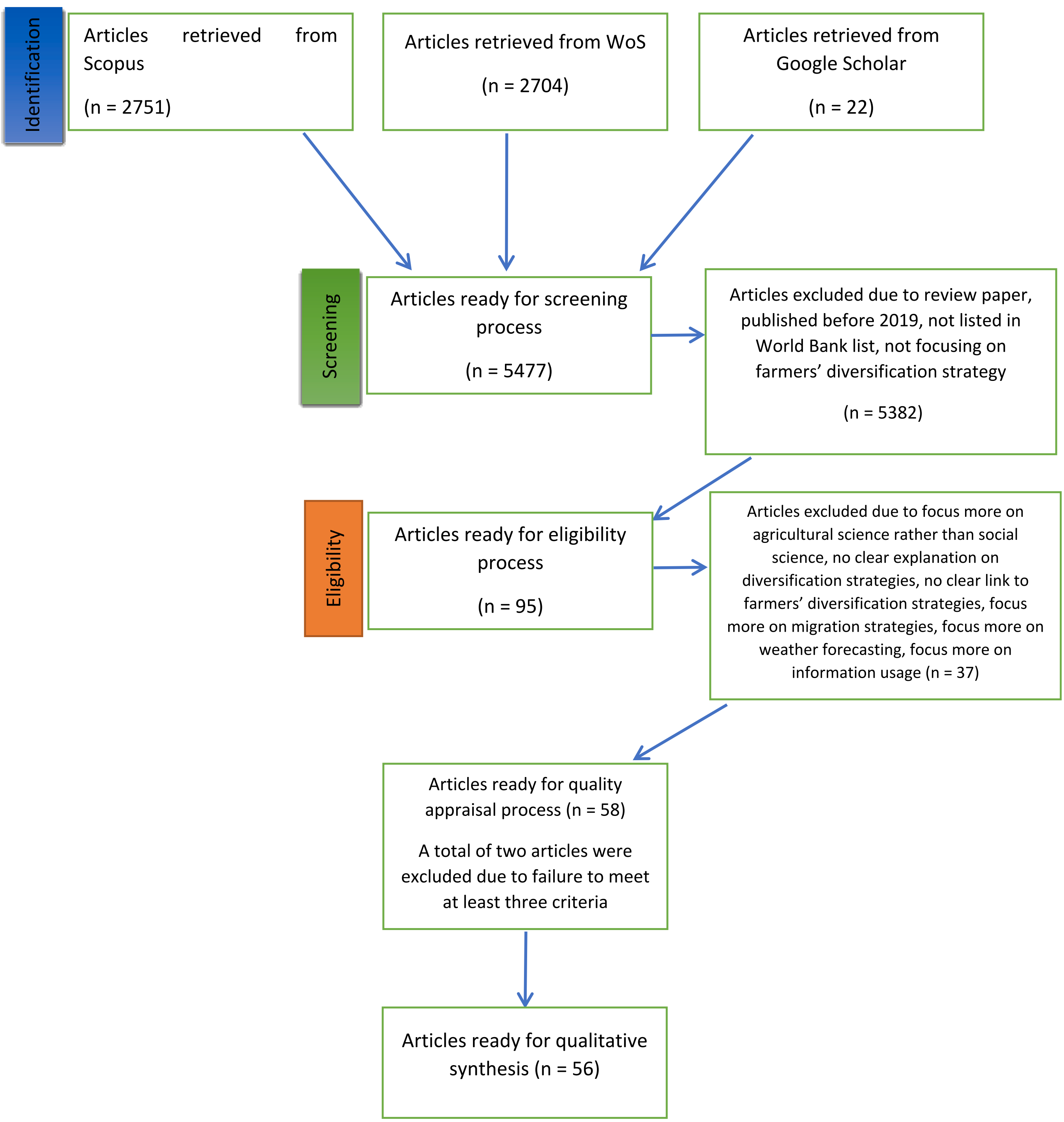

Fig. 1. The flow diagram.

Table 3
Screening and eligibility criteria.

Timeline publication	2019–2021
Document Type	Article journals
Language	English
Countries	Listed in The World Bank list (please refer to Table 2)
Focus of study	Farmers' agricultural practices diversification
Type of data	Primary

Table 4
The quality assessment criteria.

Research design	Assessment criteria
Qualitative	QA1—Is the qualitative approach appropriate to answer the research question? QA2—Are the qualitative data collection methods adequate to address the research question? QA3- Are the findings adequately derived from the data? QA4- Is the interpretation of results sufficiently substantiated by data? QA5—Is there coherence between qualitative data sources, collection, analysis and interpretation?
Quantitative	QA1—Is the sampling strategy relevant to address the research question? QA2- Is the sample representative of the target population? QA3- Are the measurements appropriate? QA4- Is the risk of nonresponse bias low? QA5- Is the statistical analysis appropriate to answer the research question?
Mixed-Method	QA1- Is there an adequate rationale for using a mixed-methods design to address the research question? QA2- Are the different components of the study effectively integrated to answer the research question? QA3- Are the outputs of the integration of qualitative and quantitative components adequately interpreted? QA4- Are divergences and inconsistencies between quantitative and qualitative results adequately addressed? QA5- Do the different components of the study adhere to the quality criteria of each tradition of the methods involved?

Source: Hong et al. (2018).

qualitative + mixed method), the appraisal process was executed by using the Mixed Method Appraisal Tools (MMAT) developed by Hong et al. (2018). Each article was assessed based on five methodological criteria and three answer options (i.e., Yes/No & Do Not Know/Comment) (see Table 4). Articles that satisfied a minimum of three criteria were included in the review. Two articles were excluded in this process as they failed to meet at least three criteria, and only 56 articles were retained for further review.

Data extraction and analysis

The authors read the remaining 56 articles. Guided by the research question, the first authors extracted data from the results and discussion sections, and if needed, other sections in the articles were referred to as well. The SLR is qualitative, whereby the authors extracted relevant data as statements. Although the articles were quantitative, statements explaining the quantitative data were extracted, not the numbers or statistical outcomes. Next, the extracted data were tabulated systematically in a table and validated by another co-author. This is a crucial process to ascertain relevancy, besides minimizing bias in the data selection process.

The SLR is a mixed-method review in nature, although some scholars (see Sandelowski et al., 2006) argued on its methodological suitability while Dixon-Woods et al. (2005) countered that the best way to explore an issue is by looking at it from diverse perspectives. Whittemore and Knafl (2005) added that qualitative synthesis allows mixing the mixed-method research design in a review. Turning to this present SLR, the inductive thematic analysis was performed as it best fits the mixed-method review (Flemming et al., 2019). Thematic analysis is a method that identifies and notes patterns of meaning traced in selected qualitative data (Braun & Clarke, 2006). The thematic analysis addresses research questions related to people's response to climate change, mainly because it covers most research questions, including practices, views, and opinions of individuals (Braun & Clarke, 2021).

The analysis, guided by the six-step thematic analysis prescribed by Braun and Clarke (2006), was conducted by the first authors and assisted by two co-authors. The process began with the authors familiarising themselves with the selected articles by reading the extracted data. This familiarisation step enabled the authors to code interesting features derived from the extracted data, collate those codes into potential themes, and gather all related data to the possible themes. In this stage, three main themes and 15 sub-themes were identified. The next step involved reviewing the themes, whereby the authors checked and rechecked the relevancy of the generated themes with the extracted data. As a result, two sub-themes were discarded. Next, clear definitions and names were given for the identified three main themes and 13 sub-themes. The identified themes are crops and varieties-related strategies (four sub-themes), soil and water conservation techniques (six sub-themes), and planting-related strategies (three sub-themes). The themes were presented to two experts in community development, and both validated the suitability of the generated themes. The following result section reports these themes and sub-themes (see Tables 5 and 6).

Results

Background of the selected studies

A total of 56 articles were analysed in this present SLR, whereby more than half of these articles had explored Ethiopia (29 articles), followed by Uganda (4 articles), Burkina Faso (3 articles), Rwanda (3 articles), Mali (3 articles), Gambia (2 articles), Haiti (2 articles), and Togo (2 articles). Meanwhile, a study was conducted in Mozambique, Sudan, Afghanistan, Niger, Malawi, Burundi, Congo, and Madagascar. In terms of year of publication, 15 articles were published in 2019, followed by 27 and 14 articles in 2020 and 2021, respectively. As for research design, most articles were quantitative (28 articles), 24 deployed the mixed-method approach, and four were qualitative.

The developed themes

Based on the thematic analysis, the following three main themes were identified: crop and varieties related strategies, soil and water conservation techniques, and planting related strategy – the three diversification strategies practiced by farmers. These three leading adaptation practices were further divided into 13 agriculture practices.

Crop and variety strategies

Under the theme of crop and variety strategies, four sub-themes were generated, namely early maturing crops, use of the drought-tolerant variety, abandoning crops, and introduction of new crop/crop rotation/crop diversity/mixed crop.

Early maturing crops

As a result of the uncertain climate condition, one of the adaptation strategies practiced by farmers is to choose early maturing crops (see Sorgho et al., 2020; Hirpha et al., 2020; Gebru et al., 2020; Diallo et al., 2020; Marie et al., 2020; Tesfahun & Chawla, 2020; Asfaw et al., 2019; Sonko et al., 2020). Planting crops that can mature early provides a good

Table 5
The developed themes and sub-themes.

Studies	Study Design	Country	Crop and varieties-related strategies				Soil and water conservation techniques						Planting related strategies		
			EM	DR	AC	CV	OF	WH	TP	TC	MS	AM	RP	IU	EA
Asmamaw et al. (2019)	MX	Ethiopia				√			√						
Bedeke et al. (2019)	QN	Ethiopia		√						√		√			
Tessema et al. (2019)	QN	Ethiopia			√	√									
Takele et al. (2019)	QN	Ethiopia				√		√	√						
Kahsay et al. (2019)	QN	Ethiopia		√		√		√	√	√	√		√		
Mulinde et al (2019)	QN	Uganda			√	√	√					√		√	√
Adego et al. (2019)	MX	Ethiopia		√		√		√					√		
Asfaw et al. (2019)	QN	Ethiopia	√	√			√	√	√		√		√	√	
Abera and Tesema (2019)	MX	Ethiopia		√				√		√			√		
Asmamaw et al. (2020)	QN	Ethiopia					√	√							
Hirpha et al. (2020)	QN	Ethiopia	√	√		√	√			√			√		√
Gebru et al. (2020)	MX	Ethiopia	√	√		√	√	√	√			√	√	√	√
Getie et al. (2020)	QN	Ethiopia				√	√	√	√						
Etana et al. (2020)	MX	Ethiopia				√	√		√	√					
Yohannes et al. (2020)	MX	Ethiopia				√	√	√	√		√				
Marie et al. (2020)	QN	Ethiopia	√	√		√	√	√					√		
Tolera and Senbeta (2020)	MX	Ethiopia				√									
Tesfahun and Chawla (2020)	MX	Ethiopia	√	√		√		√					√		
Tesfahunegn and Gebru (2020)	QN	Ethiopia				√	√	√			√		√		
di Falco et al. (2020)	QN	Ethiopia				√	√		√				√		√
Abebe (2021)	MX	Ethiopia				√			√	√	√		√	√	√
Sertse et al. (2021)	QN	Ethiopia		√		√		√	√		√	√	√		
Gebeyehu et al. (2021)	MX	Ethiopia				√	√								
Mihiretu et al. (2021)	MX	Ethiopia		√		√									
Ayal et al. (2021)	MX	Ethiopia		√		√		√				√			
Mekonnen et al. (2021)	MX	Ethiopia						√					√		
Belachew and Ababu (2021)	QN	Ethiopia				√	√		√				√		
Destaw and Fenta (2021)	QN	Ethiopia				√	√			√			√		
Eshetu et al. (2021)	QN	Ethiopia				√	√		√	√	√		√		
Assaye et al. (2020)	QN	Ethiopia				√		√√					√√		
Zampaligré and Fuchs (2019)	QN	Burkina-Faso		√			√		√		√				
Alvar-Beltran et al. (2020)	QN	Burkina Faso				√	√	√	√					√	
Sorgho et al. (2020)	QL	Burkina-Faso	√			√	√		√				√		
Ntihinyurwa et al. (2019)	MX	Rwanda						√							√
Clay and King (2019)	MX	Rwanda			√				√						√
Nyirandorimana et al. (2020)	QN	Rwanda				√		√			√		√	√	√
Huet et al. (2020)	MX	Mali				√	√						√		
Diallo et al. (2020)	QN	Mali	√				√						√		
Diarra et al. (2021)	MX	Mali		√		√	√		√	√	√	√	√	√	
Nkuba et al. (2020)	MX	Uganda				√		√					√		
Mayanja et al. (2020)	QL	Uganda		√				√		√			√		
Atube et al. (2021)	QN	Uganda		√		√	√		√					√	
Ali et al. (2020)	QN	Togo		√		√			√				√		
Ali (2021)	QN	Togo					√	√	√				√		
Staub et al. (2020)	QL	Haiti		√				√					√		√
Staub and Clarkson (2021)	MX	Haiti		√		√	√								
Bagagnan et al. (2019)	QN	Gambia				√	√								
Sonko et al. (2020)	QN	Gambia	√			√			√	√			√	√	
Salite and Poskitt (2019)	MX	Mozambique											√		
Young and Ismail (2019)	QL	Sudan				√		√					√		
Omerkhil et al. (2020)	MX	Afghanistan		√	√	√									
Ado et al. (2020)	MX	Niger				√	√		√				√		
Tiana (2020)	QN	Madagascar								√					
Nyairo et al. (2020)	MX	Burundi		√				√						√	
Mubalama et al. (2020)	MX	Congo		√		√	√		√				√		
Abid et al. (2020)	QN	Malawi		√		√	√				√		√		

QN = Quantitative studies; QL = Qualitative studies; MX = Mixed-method studies.

response against shorter rainy sessions or long dry seasons (Sorgho et al., 2020; Sonko et al., 2020). According to Sonko et al. (2020), several early maturing crops, including maize and groundnut, have been developed for African farmers. Early maturing crops as an adaptation strategy enabled farmers to alleviate food insecurity and strengthen their farm household resilience against the formidable climate change impacts (Sonko et al., 2020; Marie et al., 2020). Relying on these early maturing crops benefited the farmers through escalated productivity (Diallo et al., 2020; Marie et al., 2020).

Use of drought-tolerant variety

Temperature rise and drought have exerted adverse impacts on crops, thus affecting farmers' yields. Scientists have come out with several solutions to the challenges of these changes, and one of them is Genetically Modified Crops, which shows promising results that can be ultimately applied to agriculture. This type of crop has been known to be more resilient towards extreme weather and offers higher productivity to farmers (Mayanja et al., 2020). Within the scope of this review, the analysis found that some farmers have opted for drought-tolerant crops (see Hirpha et al., 2020; Omerkhil et al., 2020; Gebru et al., 2020; Mihiretu et al., 2021; Diarra et al., 2021; Marie et al., 2020; Tesfahun &

Table 6
The themes and sub-themes.

Crop and varieties-related strategies	EM = Early maturing crops DR = Use of drought-tolerant variety AC = Abandoning crops CV = Introduction of new crop/crop rotation/ crop diversity/mixed crop
Soil and water conservation techniques	OF = Use of organic/inorganic fertilizer WH = Water harvesting, irrigation, and drainage TP = Tree planting and agroforestry TC = Terracing/contour farming to prevent soil erosion MS = Mulching/stone barriers AM = Agriculture mechanisation-related activities
Planting-related strategies	RP = Rescheduling the planting calendar IU = Increasing pesticide/herbicide/integrated pest management EA = Selecting and expansion of new areas

Chawla, 2020; Kahsay et al., 2019; Mubalama et al., 2020; Mayanja et al., 2019; Abera & Tesema, 2019; Asfaw et al., 2019; Staub et al., 2020). Understandably, between 53 % and 80 % of the farmers planted drought-tolerant crops as their top adaptation strategy (Atube et al., 2021; Ali et al., 2020). These drought-tolerant crops assisted the farmers during dry spell as they could harvest more output, minimise crop failure, and avoid potential losses due to climate change (Zampaligre & Fuchs, 2019; Sertse et al., 2021; Bedeke et al., 2019). The Ethiopian farmers, for instance, planted an improved sorghum crop variety called Aburti due to its drought-resistant property and the potential to be harvested within a month (during August) (Ayal et al., 2021). Adego et al. (2019) and Nyairo et al. (2020) verified that the farmers in Ethiopia and Burundi used finger millet, which is a hardy, drought-tolerant crop that maintains its productivity even under low-fertility and low-input systems with access to certified seed and veterinary medicine. Meanwhile, Abid et al. (2020) explained that farmers with the experience of using drought-tolerant crops emerged as the major factor for farmers to continue planting such crops in the future.

Abandoning crops

One of the strategies undertaken by the farmers is abandoning certain crops with low productivity due to climate change impacts. This particular strategy enabled them to save cost, strategize on crops less affected by climatic impacts, and have good market value (Mulinde et al., 2019; Omerkhil et al., 2020). In Kolla and Weynadega regions, for instance, more than 30 % of farmers permanently abandoned growing existing crops at least once in the last two decades (Tessema et al., 2019). In Rwanda, the farmers abandoned sweet potato, cassava, ciraza, and sorghum, which had been previously cultivated due to their low market value (Clay & King, 2019).

Introduction of new crop/crop rotation/crop diversity/mixed crop

Some farmers have initiated new crops in their farms to sustain their agricultural activities (see Diarra et al., 2021; Mihiretu et al., 2021; Gebeyehu et al., 2021; Huet et al., 2020; Omerkhil et al., 2020; Abebe, 2021; Tesfahunegn & Gebru, 2020; Ali, 2021; Getie et al., 2020; Yohannes et al., 2020; Assaye et al., 2020). For example, Ethiopian farmers from the Kola region grew at least one new crop in the past two decades, while some planted vegetables, fruits, and other cash crops (Ayal et al., 2021; Tessema et al., 2019). In Haiti, the farmers planted 13 new crops (e.g., broccoli and sweet potatoes) mainly because these crops have high market value and their suitability to the local climate (Staub & Clarkson, 2021). Crop rotation is another strategy practiced by farmers, where different crops are planted due to their suitability to the current climate (Alvar-Beltrán et al., 2020; Abid et al., 2020; Asfaw et al., 2019; Young & Ismail, 2019; Bagagnan et al., 2019). In Gambia, women usually performed crop rotation at better-off and larger farms. Such a strategy ensures sufficient food inventories during low-yield years, as harvested crops from a larger area produce adequate volume for consumption (Sonko et al., 2020).

In order to assuage climatic impacts, farmers have implemented mixed cropping (Eshetu et al., 2021; Belachew & Ababu, 2021; Destaw & Fenta, 2021; Hirpha et al., 2020; Kahsay et al., 2019; Tesfahun & Chawla, 2020; Asmamaw et al., 2019; Etana et al., 2020). Mixed cropping refers to cultivating two or more crops simultaneously in one plot of land (Marie et al., 2020). This coping strategy enables farmers to cultivate a wide range of crops instead of adhering to a conventional farming model that promotes the cultivation of a commonly grown major crop in each cropping season (Sertse et al., 2021; Takele et al., 2019). Apart from yielding more productivity and income with mixed crops, the farmers employed this method as a precaution. If the main crops fail to produce the desired productivity, other cultivated crops should be able to cover the losses of the main crop – this strategy minimises the risk of complete crop failure as different crops are affected differently by climate events (Mubalama et al., 2020; Sorgho et al., 2020; Ado et al., 2020; Mulinde et al., 2019).

Atube et al. (2021) and Adego et al. (2019) revealed that planting different crop varieties was farmers' main adaptation strategy, as most chose crops that could tolerate the impact of climate change and minimize expected risks. Besides cultivating the main crops, farmers from the Kola region in Ethiopia cultivated onions, while a few farmers grew maize, sorghum, teff, tomato, potato, beer-barley, cabbage, and pea (10.5 %) (Tessema et al., 2019). Some farmers integrated crops with livestock farming systems, and among their main choices of livestock were drought-resistant animal species such as camels and goats (Tolera & Senbeta, 2020; Ayal et al., 2021; Ado et al., 2020; Gebru et al., 2020; Nyirandorimana et al., 2020). In Togo, farm households that implemented crop and livestock integration had at least cattle or poultry that functioned as informal insurance in case of poor harvest due to climatic impacts (Ali, 2020). When their crops were severely affected by climatic impacts, the farmers increased the number of livestock to double their production and vice versa if their livestock did not generate the expected productivity (Nkuba et al., 2020; di Falco et al., 2020).

Soil and water conservation techniques

The second theme is related to soil and water conservation techniques, and it consists of six sub-themes, namely the use of organic/ inorganic fertilizer; water harvesting, irrigation, and drainage; tree planting and agro-forestry; terracing/contour farming to prevent soil erosion; mulching/stone barriers and agriculture mechanisation related activities.

Use of organic/inorganic fertiliser

As soil might be affected by extreme weather conditions or climatic impacts, one of the responses among the farmers is to conserve the soil on their farm and communal land (Belachew & Ababu, 2021; Mihiretu et al., 2021; Getie et al., 2020; Mubalama et al., 2020; Etana et al., 2020; Marie et al., 2020). The farmers have practiced several soil conservation techniques, and one of them refers to the use of organic fertiliser (Staub & Clarkson, 2021; Gebru et al., 2020; Ali, 2021; Diarra et al., 2021; Ado et al., 2020; Asmamaw et al., 2020; Sorgho et al., 2020; Destaw & Fenta, 2021; Alvar-Beltran, 2020). This is the dominant practice in some countries (e.g., Mali & Togo), where the farmers fertilise their agricultural land (Diallo et al., 2020; Ali, 2021). Yohannes et al. (2020) disclosed that manure was the most preferred organic fertiliser to improve land fertility, especially among experienced farmers, whereas Zampaligre and Fuchs (2019) claimed that most of the organic fertilisers were extracted from crop residues, livestock manure, and other household residues, typically to fertilise soils and to improve crop production.

Some farmers used fertilisers and adjusted the amount of fertilisers used (Eshetu et al., 2021) by either increasing or reducing the amount of fertilisers used (Huet et al., 2020; di Faclo et al., 2020). Staub et al., (2019) discovered that farmers re-applied fertiliser to fertilise their agricultural land, while Tesfahunegn and Gebru (2020) concluded that some farmers changed their fertiliser type, rate, and time of application. Although it might affect their health in the long term, a small number of farmers continued depending on chemical fertiliser as it can expedite the land fertilisation process, while concurrently increasing their yields (Mulinde et al., 2019; Hirpha et al., 2020; Atube et al., 2021). Bagagnan et al., (2019), nonetheless, asserted that not all farmers chose chemical fertiliser as it was and still is the costliest practice.

Water harvesting, irrigation, and drainage

Water harvesting is vital in farming to ensure adequate farm irrigation (Staub et al., 2020). Having harvested water resources ascertains continuous water supply for farmers during the dry season so they can always maintain their agricultural productivity. There are many ways for farmers to harvest water for their farms; one of them is by digging water wells, as most of them rely on shallow and hand-dug wells (Gebru et al., 2020; Yohannes et al., 2020; Nyirandorimana et al., 2020). Instead of digging wells to harvest natural water resources, some farmers depend on the rainwater harvesting technique (Nyairo et al., 2020; Mayanja et al., 2020). To store their harvested water, most farmers construct dams and ponds to consistently check the water level to ensure adequate water supply for their farms (Kahsay et al., 2019; Tesfahunegn & Gebru, 2020). Those with financial capacity construct infrastructure and concrete tanks, while others implement technological solutions such as ground leveling and embankment (Alvar-Beltrán et al., 2020; Abera & Tesema, 2019).

Irrigation has been one of the many ways implemented by farmers to ascertain continuous water supply for their farms, which is crucial to minimise drought risks (Adego et al., 2019; Ali, 2021; Ayal et al., 2021; Mekonnen et al., 2021; Asmamaw et al., 2020; Marie et al., 2020; Nkuba et al., 2020; Tesfahun & Chawla, 2020; Assaye et al., 2020). Most irrigation practices are sourced from the nearest river to save farming costs, while some are sourced from watersheds (Takele et al., 2019; Young & Ismail, 2019; Getie et al., 2020). According to Etana et al. (2020), midland farmers commonly depend on small streams to irrigate small plots of land to produce vegetables. In contrast, irrigation in lowland areas is sourced from the most significant rivers. Farm irrigation denotes the importance of gaining access to water, irrigable land, and financial capital to purchase equipment. As a result, irrigation is limited to those who own it, while others lease from elders who lack a labor force or from those with surplus irrigable land (Adego et al., 2019). As saving farming costs is imminent for small-scale farmers, they change patterns and timing to avoid extra irrigation costs, while some increase the use of small-scale irrigation instead of investing in large-scale irrigation (Sertse et al., 2021; Asfaw et al., 2019). Some farmers also claimed that drainage is one of the best responses to extreme weather, such as heavy rain or inundation (Staub et al., 2019; Ntihinyurwa et al., 2019). Farmers in Rwanda, for example, placed their best efforts to have drainage infrastructure on their farms even though they are facing problems related to land ownership and boundaries (Ntihinyurwa et al., 2019).

Tree planting and agroforestry

Tree planting and agroforestry are some strategies implemented to enhance resilience among farmers towards climatic impacts, significantly to minimise water usage and soil erosion (Takele et al., 2019; Belachew & Alabu, 2021; Ali, 2021; Diarra et al., 2021; Etana et al., 2020; Yohannes et al., 2020; di Falco et al., 2020; Sorgho et al., 2020; Mubalama et al., 2020; Ali et al., 2020; Ado et al., 2020; Asmamaw et al., 2020; Asfaw et al., 2019; Sonko et al., 2020). There are several reasons to deploy these adaptation strategies. According to Zampaligre and Fuchs (2019), farmers in Burkina-Faso protected and preserved tree or shrubs and their seedlings to promote regeneration of degraded soils, as well as to create multiple-use agroforestry systems. In Rwanda, the adoption of woodlots has increased due to their perceived resilience to climatic impacts and their importance as a source of income once the wood is harvested and sold for charcoal or construction purposes (Clay & King, 2019). Eshetu et al. (2021) and Sertse et al. (2021) revealed the importance of shade trees to serve as natural shade for their crops or as wind or hailstorm break when the temperature is hot, as well as to improve soil structure and protect it from erosion. Agroforestry is also effective in managing flood and drought, mainly because it enhances water catchment, reduces soil loss, and stabilizes slopes (Atube et al., 2021; Kahsay et al., 2019; Gebru et al., 2020; Abebe, 2021; Getie et al., 2020; Alvar-Beltrán et al., 2020).

Terracing/contour farming to prevent soil erosion

Terracing is a farming technique where terraces are built on the slopes of hills and mountains for the cultivation of crops. One primary goal of implementing this technique is to control and prevent soil erosion (Abera & Tesema, 2019; Kahsay et al., 2019; Bedeke et al., 2019; Etana et al., 2020; Destaw & Fenta, 2021; Hirpha et al., 2020). Terracing is essential, as highlighted by Eshetu et al., (2021), especially in areas where the topography is undulating landscape. Abebe (2021) emphasised that terraces are important for farmers to hinder flooding. In Madagascar, farmers practice terracing due to the stagnation of yields in irrigated lowland areas and demographic growth (Tiana, 2020). Meanwhile, contour farming refers to the practice of tilling sloped land along the lines of consistent elevation to conserve rainwater and to prevent soil erosion. Contour farming acts as reservoirs to catch and hold rainwater, thus increasing infiltration and a more uniform distribution of water (Diarra et al., 2021; Mayanja et al., 2020). The Gambian farmers have been practising contour farming in agriculture land, signifying the shift from river banks to higher grounds (Sonko et al., 2020).

Mulching/stone barriers

Mulching is a method employed by local farmers, covering the soil surface with organic residues (Diarra et al., 2021; Eshetu et al., 2021; Asfaw et al., 2019). Some benefits reaped by farmers via mulching include soil moisture conservation, water conservation, minimum soil compaction and erosion, regulation of soil temperature, and soil fertility improvement (Sertse et al., 2021; Abebe et al., 2021; Abid et al., 2020; Nyirandorimana et al., 2020). Laying stone bunds in fields indicates a farming technique to check runoff and to minimise erosion (Kahsay et al., 2019; Diarra et al., 2021; Yohannes et al., 2020). In Sahel, for instance, stone bunds have been used to slow down, filter, and spread out runoff water, thus increasing infiltration and conserving more moisture in the soil for a more extended period that further alleviate water stress during dry spell (Zampaligre & Fuchs, 2019). Additionally, constructing a stone bund in farms enables farmers to build a layer of fine soil and manure particles rich in nutrients (Abebe, 2021; Tesfahunegn & Gebru, 2020; Asfaw et al., 2019; Diarra et al., 2021).

Agriculture mechanisation-related activities

The next theme is agriculture mechanisation-related activities. One of them refers to tillage or the mechanical manipulation of soil for crop production that significantly affects the soil characteristics, such as soil water conservation, soil temperature, infiltration, and evapotranspiration processes (Sertse et al., 2021; Diarra et al., 2021; Gebru et al., 2020; Bedeke et al., 2019). The Ethiopian farmers combined low-cost conservation tillage practices, such as the use of green manure and crop residue, which could lower the cost of chemical fertiliser, increase farmers' profits, as well as maintaining soil fertility and moisture content (Bedeke et al., 2019). Farmers tend to depend on agriculture technology to address climate change impacts. Some rely on biophysical soil and water harvesting technologies, such as trenches, terracing, water channels, flood diversion, moisture trapping, and gully treatment at farmland (Ayal et al., 2021). Such advanced technologies aid farmers to optimise land use, increase their output, and systematise their farming management (Bedeke et al., 2019; Mulinde et al., 2019). Embracing size-neutral technologies, such as novel agricultural input use system and farm machinery that substitutes the human labour, enables large-scale farmers to efficiently use their landholdings (Bedeke et al., 2019).

Planting-related strategies

The last theme is planting-related strategies and consists if three sub themes related to rescheduling the planting calendar, increased use of pesticide/herbicide/integrated pest management and selecting and expansion of new areas.

Rescheduling the planting calendar

Farmers re-schedule their planting calendar as a response towards climate change impacts, which involves early- and/or late-season planting (Gebru et al., 2020; Diarra et al., 2021; Staub et al., 2020; Belachew & Ababu, 2021; Diallo et al., 2020; Nkuba et al., 2020; Assaye et al., 2020; Asfaw et al., 2019; Abebe, 2021; Ado et al., 2020; Sonko et al., 2020; Marie et al., 2020; Adego et al., 2019; Abera & Tesema, 2019). Some have changed their farming calendar to avoid the dry season, while others have re-schedules their planting activities due to the heavy rainy season; whereby these changes are inconsistent across locations, possibly due to different agro-ecological zones (Sorgho et al., 2020; Destaw & Fenta, 2021; Hirpha et al., 2020; Eshetu et al., 2021; Mekonnen et al., 2021; Ali et al., 2020; Tesfahun & Chawla, 2020; Tesfahunegn & Gebru, 2020; Mubalama et al., 2020). Most of the activities that need to be rescheduled are related to crop sowing and harvesting dates based on the changes that occur in local weather conditions (Sertse et al., 2021; Abid et al., 2020; Ali et al., 2020; Huet et al., 2020; di Falco et al., 2020; Nyirandorimana et al., 2020; Staub et al., 2020; Young & Ismail, 2019). In response to the late-onset short rainy season, the Ethiopian farmers, for instance, have rescheduled the crop calendar by sowing crop varieties to be harvested (barely, teff, and wheat) on the onset of the main rainy season from October to December (Kahsay et al., 2019). In Mozambique, farmers have rescheduled their planting months (September-December) to other months as a response to rainfall unpredictability, including planting during the winter season (April-August) (Salite & Poskitt, 2019). In contrast, farmers in Uganda have been practising early harvest to prevent their farms from extreme weather impacts if left in the soil unharvested – as is the norm for keeping root crops for future consumption (Mayanja et al., 2020).

Increased use of pesticide/herbicide/integrated pest management

Farmers have heavily relied on pesticides, insecticides, and herbicides, while some have integrated their pest management (Mulinde et al., 2019; Asfaw et al., 2019; Nyairo et al., 2020; Diarra et al., 2021; Sonko et al., 2020; Abebe, 2021). Some benefits farmers gain by depending on these pesticides are enhanced productivity, protection of crops, avoidance of yield loss, vector disease control, and maintenance of food quality (Gebru et al., 2020). Depending on the situation, the usage of pesticides on their farm may be increased or reduced (Atube et al., 2021; Nyirandorimana et al., 2020). For instance, pest attack (e.g., caterpillar) forces farmers to use more pesticides to control it, or if there is more market demand for their crops, they will apply more pesticides despite their adverse impacts on human health and the environment (Alvar-Beltran et al., 2020).

Selecting and expansion of new areas

Some farmers have decided to farm in other areas after their lands are damaged by climatic change impacts or as a precautionary measure (Gebru et al., 2020; Hirpha et al., 2020; Staub et al., 2020; di Falco et al., 2020; Abebe et al., 2020). In Rwanda, the farmers have selected valley land as a dry season cultivation option as this area is highly fertile and permits cultivation through long dry periods, whereas farmers in Uganda and Ethiopia have rented more agricultural land to grow coffee-banana-maize (Clay & King, 2019; Mulinde et al., 2019; Abebe, 2021). This diversification strategy has enabled farmers to grow multiple crops with a range of adaptation capacities in varying growing conditions (soil type, slope, microclimate variations, etc.), while concurrently allowing them to hinder flood-prone areas (Ntihinyurwa et al., 2019; Nyirandorimana et al., 2020).

Discussion

Notably, many farmers in low-income countries rely on three leading adaptation practices related to crop and variety strategies, soil and water conservation techniques, and planting-related strategies. Based on these three strategies, farmers further expand their practices into a wide range of specific agriculture practices to combat the climatic impacts. The resulting themes evidenced that farmers in low-income countries were highly heterogeneous in their decision to diversify their agricultural practices, where most of them combined their farming practices as the best ways to address climate change impacts.

Scholars have linked farmers' decisions to diversify their agricultural practices with demographic factors such as age, experience, and education. Destaw and Fenta (2021) verified that age positively correlated significantly with terracing, changing planting dates, and diversifying crops. They found that the older the farmers, the higher the possibility they diversified their agriculture practices, attributable to aged farmers' vast experience and their possession of better climate knowledge. Acquisition of information and knowledge from several sources, such as colleagues, extension officers, community leaders, family, and media, can be crucial factors as well. Those with better climate change information and knowledge are more ready to practice changing planting dates, planting trees, and deploying soil and water conservation techniques (Belachew & Ababu, 2021). Notably, farmers with more information and knowledge about combating the effects of climate change are more likely to adopt improved methods. They are expected to be more efficient in comprehending and gaining new technologies than those with less or no information and knowledge (Belachew & Ababu, 2021). A study by Abu Samah et al. (2019) concluded that those with better educational achievement have better adaptation skills for several reasons. Those with better education have more access to information, and their technology literacy assists them in attaining more climate-related information (e.g., diversification of livelihood skills). Second, the educated group was found to possess more skills to diversify their livelihood options and have better risk management, which, therefore, strengthens their climate change adaptation practices. In low-income countries, the non-adaptability to climate change impacts on agriculture places a significant burden, especially on smallholder farmers.

Although the review has explained 13 adaptation strategies related to their agricultural practice, many farmers still face obstacles that hinder their ability to effectively respond to the changing climate conditions. One of the obstacles is their limited access to financial capital, which causes them to be unable to implement the best adaptation strategies (Shaffril et al., 2018). Although some institutions or groups offer loans to these farmers, only a handful have been given this opportunity. The farmers, especially the poor, are often excluded, assuming that they are incapable of returning the loan or claiming to use the money to buy consumption goods without making any productive investment (Etana et al., 2020). If they fail to repay the given loan, perhaps due to less productive yield, they may be obliged to dispose of the very few assets they possess to repay their loan, thus burdensome to the farmers (Etana et al., 2020). As a result, most farmers opted for low-cost diversification strategies as they preferred relying on nature – irrigation from the river and tree planting instead of mechanisation-based adaptation strategies. Although mechanisation-based strategies are practiced by some farmers, most of them avoid such practices due to the high cost involved. Moreover, low-income countries can breathe a sigh of relief because the UN recently, through the 27th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP27), has decided to establish and operationalize a loss and damage fund. This fund seems to benefit low-income countries as it attempts to bridge the financial gap in climate finance, particularly for adaptation, loss, and damage. Several funding options are planned for windfall taxes on fossil fuel companies, debt for loss and damage swaps, international taxes, and dedicated finance facilities under the UN Framework Convention on Climate Change.

Furthermore, farmers in low-income countries, who often operate on limited land, face a lack of resources and capacity to adapt to the rapidly changing climate conditions, which results in increased vulnerability to crop failures, reduced yields, and severe economic losses (Atube et al., 2021). Decreased productivity due to climatic impacts also contributes to food insecurity and financial instability in low-income regions where most rely heavily on agriculture for sustenance and income (Adego et al., 2019). Eventually, such challenges lead to increased poverty levels as farmers reduce income due to crop and livestock losses, further exacerbating the cycle of poverty in vulnerable regions, which later makes it more difficult for them to adapt to the worsening climatic effects.

Conclusion

Notably, this present SLR verifies that farmers have diversified their agriculture practice based on three main strategies: crop and varieties strategies, soil and water conservation techniques, and related strategies. Based on the review, most farmers seemed to select low-cost diversification strategies as they preferred relying on nature, such as irrigation from the river, water harvesting, terracing, mulching, agroforestry, and tree planting. The influence of some demographic data is discussed in the review; for example, older farmers are more likely to diversify their agriculture practices due to their vast experience and better climate knowledge, while educated are seen to have more access to information and their technology literacy assists them in attaining more climate-related information. Other factors that might influence their diversification strategies are exposure to information, knowledge, and education, which are motivating factors. This study has several limitations. First, in any SLR, they are exposed to inconsistencies in inclusion and exclusion criteria. In this study, for instance, focusing on specific geographic regions, such as low-income countries, can limit the generalizability of the review's findings. Second, as the present SLR is in a mixed-method systematic review, the study cannot run a *meta*-analysis on the selected documents. Lastly, any reported findings that are not published are not included in the present SLR, which might increase the reporting bias of the study.

Recommendation for future studies

Based on the review, several considerations for future studies are listed. Despite the positive indicator that more studies have been conducted in Ethiopia and other African countries, the focus should also be on different continents, such as Asia, especially in conflicted countries (e.g., Afghanistan, Syria, and Yemen). Conducting more studies across these countries is considered as unique as scholars can explore how wars and conflicts might or might not affect farmers' adaptation strategies. Moreover, as the farmers less practice specific strategies (e.g., abandoning crops & agriculture mechanisation activities), scholars should begin exploring why these strategies are less preferred. On top of that, explanatory research work on the vast diversification strategies is needed to trace their origins, connections, and implications, as well as how they change throughout policymaking and implementation. The RepOrting standards for Systematic Evidence Syntheses: pro-forma review protocol or ROSES, the primary guidance for this SLR, should be used more by future scholars as it is designed explicitly for environmental-related review. Future scholars might be interested in conducting a methodological study whereby empirical evidence comparing PRISMA and ROSES can explain the advantages and disadvantages of both protocols' guidance in climate change adaptation-related studies.

Recommendation for policymakers

The output of this review can guide policymakers' strategies to strengthen farmers' adaptation ability further. First, since agricultural practice diversification is among the main adaptation strategies by farmers in low-income countries, policymakers can offer technical-related assistance to expand their existing agricultural practice, making them more diverse in their agricultural-related and livelihood skills. These diverse skills can help them improve their resilience, increase their farming productivity, sustain farming families, and explore new opportunities. Second, the review noted that financial capital is the main obstacle that hinders farmers from maximizing their adaptation strategies; offering financial assistance or credit programs with less interest and bureaucracy to the farmers can be effective strategies for policymakers. This effort widens the finance access for smallholder farmers, enabling them to access improved inputs like seeds, fertilizer, and advanced farming equipment or technologies. According to Da Costa and Kovalevski (2022), for policymakers, the best risk-sharing strategies through weather-indexed crop insurance are related to several aspects. First, to utilize weather-based index insurances whereby to ensure the success of this scheme, the payouts need to be based on weather indices objectively determined for specific agricultural regions, removing the need for individual loss assessments and making the insurance schemes more affordable and accessible to farmers in low-income countries. Second, the insurance scheme must be able to redistribute agricultural risks. The scheme must be able to redistribute the risk of agricultural failures, resulting in a more resilient farming system towards climate-related risks and, at the same time, offering support to strengthen farmers' adaptation. Third, the insurance needs to come together with financial literacy as it will educate the farmers on the importance of weather crop-based insurance. Lastly, the insurance scheme must be aligned with Sustainable Development Goals (SDGs), particularly SDG 2 on zero hunger, SDG 10 on reducing inequalities, and SDG 13 on climate action.

Credit authorship contribution statement

Hayrol Azril Mohamed Shaffril: Conceptualization, Formal analysis, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. **Asnarulkhadi Abu Samah:** Conceptualization, Writing – review & editing, Resources, Supervision. **Samsul Farid Samsuddin:** Methodology, Resources. **Nobaya Ahmad:** Conceptualization, Resources. **Fredoline Tangang:** Conceptualization, Writing – review & editing. **Shaufique Fahmi Ahmad Sidique:** Formal analysis, Resources. **Haliza Abdul Rahman:** Resources. **Nik Ahmad Sufian Burhan:** Resources. **Jasmin Arif Shah:** Resources. **Nurul Amiera Khalid:** Resources.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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Appendix

Data extraction table

Themes/sub-themes CROP AND VARITIES RELATED STRATEGIES	Extracted data
Early maturing crops	• The use of early maturing variety was preferred by farmers to reduce the impacts of climate change due In this region, the most important and valued characteristic being a short maturation cycle, which allows the farmers to adapt to a shorter rainy season. "(Sorgho et al., 2020) • Using improved crop varieties, growing early maturing crop varieties (Hirpha et al., 2020) • New high yielding crop variety, Short maturing crop varieties (Gebru et al., 2020) • There is also evidence to suggest that the majority of the maize farmers who used planting of short duration crops as a climate change adaptation strategy are more food secure (Diallo et al., 2020) • For example, the farmers in the district tend to recover, multiply and use barley crop varieties having short growth periods. Another practice is the increasing tendency of planting teff (Eragrostis teff) and wheat varieties which have short growth periods as an adjustment to erratic or reduced rainfall. (Marie et al., 2020) • Cultivating early maturing variety(Tesfahun and Chawla, 2020) • Switching to short maturing crops (Asfaw et al., 2019) • With regard to the use of genetically modified or improved seeds and cultivars, there are now a selection of seeds available with varying characteristics. In this region, the most important and valued characteristic being a short maturation cycle, which allows the farmers to adapt to a shorter rainy season (Sorgho et al., 2020) • Many of which mature within a period of time that is shorter than in the case of major grains. A number of early maturing crops have been and are being developed for African farmers including maize and groundnut. Knowing about the early maturing crops as an adaptation strategy to alleviate food insecurity risk and strengthen the farm household resilience against the progressive climate change decreases (Sonko et al., 2020)
Use of drought-tolerant variety	• Use of drought-tolerant and high-yielding crop varieties that are adapted to specific agro-ecological zones. If used appropriately, these crop varieties contribute to increase crop yields and to reduce crop failure caused by droughts and dry spells (Zampaligre and Fuchs, 2019) • using drought resistant crop varieties (Hirpha et al., 2020) • cultivation of drought resistant crop varieties (Omerkhil et al., 2020) • Drought resistant crops (Gebru et al., 2020) • Farmers were also producing improved sorghum crop variety called Aburti. It is drought resistant and can be harvested in a month, during August (Ayal et al., 2021) • Water resistant rice was introduced to the frequently-flooded Fogera plain. In the area, drought-resistant crops such as finger millet are preferred for times of severe drought but have longer growth periods than other crops. (Adego et al., 2019). • Planting drought-resistant crop varieties was the second most (80 %) adopted strategy by farmers (Atube et al., 2021). • Farmers were planting drought resistant and short season varieties (Mihiretu et al., 2021) • Use of drought-tolerant variety (Diarra et al., 2021) • Which is the cultivation of climate-smart seed varieties, which are more heat tolerant and drought resistant, which farmers adopt to avoid the potential losses caused by the climate changes (Sertse et al., 2021) • Use of drought-resistant crop varieties (Marie et al., 2020) • Along with the use of drought-resistant maize varieties allows farmers to increase productivity while building resilience to climate change more than a subset of these strategies (Bedeke et al. (2019) • Consequently, combing drought-resistant maize varieties along with chemical fertilizers allows farmers to increase productivity and maximize their net economic returns while dealing with climate change (Bedeke et al., 2019). • During the short rain season, farmers grow potato and sorghum that are drought-resistant (Kahsay et al., 2019). • Growing drought resistant crops and complete change in crops grown where both pastoralists and agropastoralists adopt new and improved varieties of non-traditional but higher income earning crops like eggplants, green pepper mushrooms (Mayanja et al., 2020) • Use of drought-tolerant varieties (Tesfahun and Chawla, 2020) • Further, farmers who anticipate drought based on their previous experiences go for drought-tolerant crops. Many farmers who used drought-tolerant varieties re-ported these varieties had a positive impact on their crop harvest (Abid et al., 2020) • Growing drought-tolerant crops (Abid et al., 2020) • Adoption of drought tolerant and early maturing crop varieties (Abera and Tesema, 2019) • Use of resistant varieties (Mubalama et al., 2020) • On average 53.60 % of the respondents have decided to use the selected seeds that are high yield and drought tolerant to adapt to climate conditions, (Ali et al., 2020) • Growing drought-resistant crop varieties (Asfaw et al., 2019) • Salvage surviving crops, Replant crops that are more drought-resistant (roots, tubers) (Staub et al., 2020) • Already, the cluster grows finger millet, a hardy drought-tolerant crop that remains productive even under low-fertility, low-input systems, and has access to certified seed and veterinary medicine (Nyairo et al., 2020)
Abandoning crops	• Abandoning existing crops. Relatively high percentage of farmers in Kolla (65 per cent) and Weynadega (30 per cent) permanently abandoned growing existing crops at least once in the last two decades (Tessema et al., 2019)

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Themes/sub-themes CROP AND VARITIES RELATED STRATEGIES	Extracted data
	• First, four crops that were once extensively cultivated (sweet potato, cassava, ciraza, and sorghum) are now effectively forbidden by the GoR. According to respondents and local leaders, the chief reason for this shift is that these crops are not part of the CIP due to their low market values. (Clay and King, 2019) • Dropping of crops within coffee maize-beans system (Mulinde et al., 2019) • Besides this, some families abandoned cultivation of some crops having low productivity and the others obtained financial support for cultivaton, as reported by the farmers during survey (Omerkhil et al., 2020)
Introduction of new crop/crop rotation/crop diversity/mixed crop	• Due to erratic rainfall and recurrent drought farmers are shifting from cereal and pulse crops to vegetables, fruits and other cash crops productions (Ayal et al., 2021) • Change in crop type (20.81 %), This mixed farming includes cereal and horticultural crop production, livestock farming and honey productions (Eshetu et al., 2021) • Using different enterprises (different crops or livestock) (Belachew and Ababu, 2021) • Introduction of new crops (Diarra et al., 2021) • In addition to methods already widely used in the region, such as multi-cropping, crop rotation (Sorgho et al., 2020) • Include crop combinations (i.e., mainly a combination of Pennisetum glaucum, Sorghum bicolor and Vigna unguiculata) (Ado et al., 2020) • Adopting new crops. The majority (95 per cent) of farmers in Kolla zone started growing at least one new crop in the past 20 years. The percentage in the rest of the AEZs is relatively lower than Kolla and ranges between 72 and 78 per cent. Few (13 per cent) farmers adopted more than one crop. In Kolla and Weynadega, the majority (>80 per cent) of the adoptions involve mung bean (Tessema et al., 2019) • Change in crop varieties, livestock integration, Mono-cropping system, Inter-cropping system, Crop rotation system (Ali, 2021). • Farmers were used the conserved feed sources followed by diversifying livestock types (Mihiretu et al., 2021) • livestock diversification (95 %) are among important strategies (Gebeyehu et al., 2021) • Crop diversification (Hirpha et al., 2020) • Crop and livestock diversification (Destaw and Fenta, 2021) • Changing the choice of crops (e.g. growing more fodder crops) at farm level (Huet et al., 2020) • Farmers were practicing destocking, cut and carry livestock feeding and shifting from cattle to goats and camel. However, the degraded rugged topographic was not conducive to Camel production. This is because camel could not freely move and access leaves of tress and vegetations for their survival (Ayal et al., 2021) • Planting different crop varieties was the most widely practiced (96 % overall) respectively, adopting the planting of different crop varieties that can tolerate the effects of climate change to improve crop productivity (Atube et al., 2021). • In our study context, crop diversification refers to as cultivation of a large number of crops rather than a conventional farming model, where a commonly grown major crop is cultivated in each cropping season. (Sertse et al., 2021) • Sow a combination of crops for minimizing the expected risks (Adego et al., 2019). • Mixed cropping, Crop rotation (Takele et al., 2019). • Diversity coping strategies (Asmamaw et al., 2019) • Use of crop varieties (Mulinde et al., 2019; Assaye et al., 2020) • Cultivation of new crops (Omerkhi et al., 2020) • In Kolla, a good number (17 per cent) of farmers also started growing onion. The other crops seldom adopted in the two zones are maize, sorghum, teff and tomato. In the Dega and Wurch zones, the most frequently adopted crop is potato, where it accounts 32 and 87.5 per cent of the new adoptions in the two zones, respectively. In Dega, the other crops adopted are beer-barley (18 per cent), cabbage (10.5 per cent) and pea (10.5 per cent). The other crops reported are apple, fava bean, wheat, onion and garlic. In Wurch zone, cabbage (8 per cent) and pea (4 per cent) are adopted by few famers. (Tessema et al., 2019) • Wheat, and barley crop varieties with a long main rainy season (Kahsay et al., 2019). • The masho is also short maturing crop Varity (Ayal et al., 2021) • Re-sowing, possibly with another variety (Huet et al., 2021) • Integrating crops and livestock (i.e. rearing animals on farms) (Ado et al., 2020) • Crop rotation, Mixed cropping, Changing from livestock to crop production, Use mixed crop-livestock farming system, Changing from crop production to livestock (Gebru et al., 2020) • Intensifying crop productivity and destocking in the two watersheds (Getie et al., 2020) • Change crop type (Etana et al., 2020) • Livestock rearing (Yohannes et al., 2020) • In order to alleviate these problems, farmers have implemented mixed farming, mixed cropping – Mixed cropping refers to the cultivation of two or more crops at the same time in one plot of land. Moreover, the sampled households reported that they used to mix the main crop with complementary crops such as barely with Faba bean or tomato, barley with sorghum, chickpea with sunflower and maize with beans and peas in the study areas.(Marie et al., 2020) • Crop diversify, Livestock diversify (Nkuba et al., 2020). • Drought-resistant animal species such as camel (17 %) and goats (93 %). As camels and goats are browsers, keeping them enables the herders to take advantage of the increased availability of shrubs and trees caused by bush encroachment (Tolera and Senbeta, 2020) • Crop diversification (Tesfahun and asma, 2020) • Gradual shift from enat coffee (wild-type (un-improved coffee plant) to project coffee (improved coffee plant that is developed by breeding) (Abebe, 2021) • Changing in crop varieties, Changing in crop type (Tesfahunegn and Gebru, 2020) • Change crop variety, Change crop type, Increase the number of livestock, Decrease the number of livestock, Diversify livestock feeds, Change livestock feeds, Mix crop and livestock production, Change from livestock to crop production, Change from crop to livestock (di Falco et al., 2020) • Crop rotation (Alvar-Beltran et al., 2020) • Inter-cropping (Abid et al., 2020) • Multiple cropping/Intercropping/planting in rows/crop diversification, Crop rotation or conservation tillage (Asfaw et al., 2019)

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Themes/sub-themes CROP AND VARITIES RELATED STRATEGIES	Extracted data
	• Diversifying crops (Sorgho et al., 2020) • Crop diversification which implies growing a number of different crops in the same plot or in different plots reduces the risk of complete crop failure as different crops are affected differently by climate events (Mubalama et al., 2020) • The most implemented adaptation measure seems to be the crop rotation technique (Bagagnan et al., 2019) • It is likely associated with women commonly cultivating a wider variety of crops, including vegetables, Clearly, the better off and larger farms apply crop rotation, which seems to assure household members of having sufficient food inventories as could be expected if crops, even in years of lower yields, harvested from a larger area produce adequate volume. (Sonko et al., 2020) • Multi-cropping, crop rotation (Sorgho et al., 2020) • These changes included growing a range of new crops (thirteen different crops across the sample), the most popular being sweet peppers and broccoli. Farmers provided reasons for trying these new crops which included their marketability and their suitability to the local climate (Staub and Clarkson, 2021) • Most of the farmers adopted the integration of crops and livestock (12.0 %) to supplement rice yields during adverse climatic conditions (Nyirandorimana et al., 2020) • Inter-cropping (Young and Ismail, 2019) • On average, 37 % of the respondents have adopted for the mono-cropping system and 23.20 % only have used the inter-cropping system (Ali et al., 2020) • Each farm household that implemented crop and livestock integration has at least cattle or poultry that serves as an informal insurance in case of poor harvest because of CC (Ali, 2021) • Approximately 59.66 % of households change crop varieties, while 66.90 % have used crop and livestock integration practices (Ali, 2021) • Improved crop varieties (Bagagnan et al., 2019; Assaye et al., 2020)
SOIL AND WATER CONSERVATION TECHNIQUES	
Use of organic/inorganic fertiliser	• Compost preparation to increase land fertility (Gebru et al., 2020) • Production and use of organic matter extracted from crop residues, livestock manure and other household residues, typically to fertilize soils. Composting is typically more widely practiced by crop farmers and agro-pastoralists than by pastoralists to improve soil fertility and improve crop production (Zampaligre and Fuchs, 2019) • Implementing soil conservation techniques (Hirpha et al., 2020) • In terms of coping strategies, the highland and midland agro-ecologies are better off in natural resources management (soil and water conservation and enclosure) (Asmamaw et al., 2020) • The use of organic fertilizer (Ali, 2021). • Use of organic manure (Diarra et al., 2021; Ado et al., 2020) • Use fertilizer (Destaw and Fenta, 2021) • change in the amount of fertilizer use (23.82 %) and pesticides (10 %) applied (Eshetu et al., 2021) • Use of fertilizer (Asmamaw et al., 2020) • The use of organic fertilizers (Sorgho et al., 2020) • Included increasing the dose of fertiliser (Huet et al., 2020) • Use of insecticides and mineral fertilizers (Ado et al., 2020) • Soil and water conservation (Mihiretu et al., 2021) • Soil–water conservation techniques (Belachew and Ababu, 2021) • Soil conservation measures (i.e. covering the soil with crop residues) (Ado et al., 2020) • Apply farmyard manure/organic fertilizer (Gebru et al., 2020) • Taking different soil and water conservation measure on their farm and communal land (Getie et al., 2020) • Very few households produced compost for use around homesteads (Etana et al., 2020). • The dominant forms of adaptation strategies the farmers used to mitigate against climate change in southern Mali included the use of organic fertilizers (Diallo et al., 2020) • Organic fertilizer application – Manure is most preferred technology to improve land fertility in many other areas and practiced by some respondents for over 21 average years in the study areas, (Yohannes et al., 2020) • Water and soil conservation technique (Marie et al., 2020) • Changing in fertilizer type, rate and time of application (Tesfahunegn and Gebru, 2020) • Change fertilizer applications, Increase fertilizer applications, Decrease fertilizer applications (di Falco et al., 2020) • Application of organic matter (Alvar-Beltran, 2020) • Re-apply fertilizer and apply pesticide (Staub et al., 2020) • The use of organic fertilizers (Sorgho et al., 2020) • Practice of organic farming (Mubalama et al., 2020) • The use of natural fertilizer, while the use of Chemical fertilizers is ranked third though it is stated by the farmers as the most preferred adaptation measure. The cost might play a role in the implementation of this technique since it is stated as the most expensive one by the farmers (Bagagnan et al., 2019) • Water diversion technique (Bagagnan et al., 2019) • Incorporating compost manure (Staub and Clarkson, 2021) • The use of organic fertilizer was implemented by 67.05 % of respondents (Ali, 2021) • The common (generalized) adaptation practices among the farm-household systems included the use of inorganic fertilizers to improve soil productivity (Mulinde et al., 2019) • Apply inorganic fertilizer (Gebru et al., 2020) • Increasing use of agricultural inputs such as compost and chemical fertilizers (Hirpha et al., 2020) • The use of chemical fertilizers (24 %) was the least adopted adaptation strategy by farmers (Atube et al., 2021)
Water harvesting and irrigation	• Small irrigation from river/ spring Sowing short matures crops (Takele et al., 2019). • Irrigation (Adego et al., 2019). • River-diverted irrigation and water harvesting through collecting surface runoff in wells covered by geomembrane were also encouraged by the government. However, water harvesting failed to achieve its objective due to a tear in the geomembrane, the water gets warm, is not suitable for crops and is labor demanding. The application of irrigation also requires access to water, irrigable land and financial capital for purchasing equipment. As a result, irrigation is limited to those who own it and others lease from elders that lack labor or from those who had surplus irrigable land (Adego et al., 2019). • Irrigation practices, Soil and water conservation practice (Ali, 2021)

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Themes/sub-themes CROP AND VARITIES RELATED STRATEGIES	Extracted data
	• Irrigation is considered the best option to reduce the drought risk. Onion is the main vegetable produced via the small irrigation schemes (Ayal et al., 2021) • Irrigation (Mekonen et al., 2021; Asmamaw et al., 2020) • Pond making for small scale-scale irrigation, Using irrigation from well, dam, river, Water harvesting, digging water wells (Gebru et al., 2020) • Practicing irrigation development (Getie et al., 2020) • Check dam (Kahsay et al., 2019). • Water management practices refer to the changing patterns and timing of irrigation to avoid extra irrigation costs (Sertse et al., 2021) • In the midland areas, many farmers relied on small streams to irrigate small plots of land to produce vegetables. Irrigation in some parts of the lowland areas was mainly based on one of the largest rivers in Ethiopia, Awash, Water harvesting and hand-dug wells were used by very few farmers to produce vegetables. (Etana et al., 2020) • rainwater harvesting and using hand-dug wells (Yohannes et al., 2020) • Irrigation (Marie et al., 2020; Assaye et al., 2020) • Soil water conservation (Nkuba et al., 2020) • Searching for alternative sources of water A participant during one excessive drought period: ' … had to use a truck to fetch water from a distant valley tank for our cattle to drink'. (Pastoralist, Buwana-Nakaseke). While some households can afford to do this, others temporarily migrate and settle with the cattle in areas closer to the lakeside, completely abandoning their homes through the dry season (Mayanja et al., 2020) • Practicing soil and water conservation strategies (Tesfahun and Chawla, 2020) • Water harvesting techniques mainly check dams, gabion, ponds, semi-moon to supply water for irrigation, Use of shallow wells and hand-dung wells during dry-season (Tesfahunegn and Gebru, 2020) • The use of water conservation strategies, including infrastructures for storing water, was relatively low due to the low purchasing power of farmers across the country, particularly of smallholder farmers in the Sahel. In fact, 49 % of the farmers across the country acknowledged having no means to procure water conservation and/or irrigation infrastructures in their fields. The most prevalent strategy noted was shared water resources from reservoirs and water wells (26 % and 24 %, respectively). The use of technological solutions, such as ground levelling and embankments, were generally embraced by large-scale rice and maize farmers located in the Soudanian zone (27 % and 21 %, respectively) (Alvar-Beltran et al., 2020). • Increased use of small-scale irrigation, Increased use of soil and water conservation (terracing, water harvesting, area closure, and etc.) technologies(Abera and Tesema, 2019) • Irrigation (Asfaw et al., 2019) • Add salt to the water (Staub et al., 2020) • Access water in alternative ways (Staub et al.,2020) • Rainwater harvesting technique used (Nyairo et al., 2020) • The most adopted methods of adaption to increase yield are supplementary irrigation (10.8 %), use of shallows for water irrigation (Nyirandorimana et al., 2020) • Farming communities have expanded and intensified their agricultural production to include irrigated agriculture,dry season irrigated farms (Young and Ismail, 2019) • While 57.24 % have used soil and water conservation practice (Ali, 2021)
Tree planting and agroforestry	• Farmer-managed natural regeneration (FMNR) • Farmer's protection and preservation of trees or shrubs, as well as tree and shrub seedlings, on their farms to promote regeneration of degraded soils and to create multiple-use agroforestry systems(Zampaligre and Fuchs, 2019) • Planting trees (leguminous plants and indigenous fruit trees are more preferred such as Faidherbia albida, Piliostigma reticulatum, Combretum nigricans, Adansonia digitata, Balanites aegyptiaca and Guiera senegalensis) (Ado et al., 2020). • Increased adoption of woodlots for charcoal Woodlots are widely seen to have proliferated in Kibirizi over the past ten years. Over 74 percent of survey respondents noted that trees have increased in their umudugudu during this period. This is due to the perceived resilience of woodlots to climatic shocks and their importance as a source of cash once the wood is harvested and sold for charcoal or for construction. This strategy however is seen to benefit the rich compared to the poor,. Indeed, while half of wealthier households report expanding woodlots in the past ten years, only 8 percent of the poorest households have planted more trees in that time period (Clay and King, 2019) • Tree planting/wood lot (Takele et al., 2019) • Tree planting (Belachew and Ababu, 2021) • Such as agroforestry practices through home garden, tree garden, perennial crops; (Asmamaw et al., 2020) • Reforesting (Sorgho et al., 2020) • Planting trees (Ali, 2021; Gebru et al., 2020) • Tree planting (Diarra et al., 2021) • In the study area, increasing the amount of shade trees was the most often taken measures by farmers to reduce the impact of climate change on soil and water conservation. Planting shade trees is mainly ascribed to provide natural shades for coffee and their livestock or as a wind or hail storm break when the temperature is hot (Eshetu et al., 2021) • And tree planting (39 %) probably to reduce soil erosion and improve water catchment (Atube et al., 2021). • Besides, SWC farmers planted trees as an adaptation and mitigation measure to prevent land erosion caused by heavy rainfall (Kahsay et al., 2019). • Household also reported plantation of trees as an adaptation measure to cope with the increasing temperature, which, according to their perspective, not only reduces the negative impact of heatwaves on the crop health but also improves soil structure and protect it from erosion (Sertse et al., 2021) • Managing floods and droughts using reforestation program (Gebru et al., 2020) • The households were practicing planting multipurpose trees and shrubs on their farmland (Getie et al., 2020) • Planting tree (Etana et al., 2020; Yohannes et al., 2020) • Expansion of eucalyptus tree plantation, Planting trees in-between the coffee plants, the majority of the farmers use traditional soil and water conservation practices such as planting elephant grass (Pennisetum purpureum) to reduce soil loss., Plant tree to stabilize slopes (Abebe, 2021) • Tree planting (Falco et al., 2020) • Agroforestry, and the use of furrows (Alvar-Beltran et al, 2020) • Planting trees (agroforestry)/planting along the contour (Asfaw et al., 2019)

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Themes/sub-themes CROP AND VARITIES RELATED STRATEGIES	Extracted data
	• Reforesting (Sorgho et al., 2020) • Agroforestry practice (Mubalama et al., 2020) • Respondents from farms practicing agroforestry have a 6.8 % higher probability of knowing about crop diversification than those where agroforestry has not been practiced (Sonko et al., 2020) • A total of 40.20 % of the respondents were involved in agroforestry systems (Ali et al., 2020) • Agroforestry and tree planting (Ali, 2021)
Terracing/contour farming to prevent soil erosion	• To reduce and protect from such adverse environmental change impacts, farmers are adopting SWC practices such as micro dams and terracing. Such adaptation practices allow to control and off course prevent erosion in three different but interrelated ways (Bedeke et al., 2019) • Currently, in the study area, planting grass strips and construction of terrace are dominantly practices in each year to conserve soil and water. This is particularly true in area where the topography is undulating landscape.(Eshetu et al., 2021) • Built bench terrace (Kahsay et al., 2019) • Terracing as soil and water conservation strategy (36.7 %) (Destaw and Fenta, 2021; Hirpha et al., 2020) • Terracing was the dominant land management activity in the study areas (Etana et al., 2020) • Build small terraces (in farm) to prevent flooding and soil erosion (Abebe, 2021) • Increased use of soil and water conservation (terracing) (Abera and Tesema, 2019) • Alley farming (Sonko et al., 2020) • For that purpose and also for other crop cultivation, farmers extend their agricultural activities on the hillsides due to the stagnation of yields in the irrigated lowland areas and demographic growth (Tiana, 2020) • Contour farming (Diarra et al., 2021) • Adaptation has included regularly making contours as well as compost manure for their gardens (Mayanja et al., 2020) • Contour farming can be practiced in the region considered in the current study as the location of agricultural land shifts away from the bank of the river to higher ground (Sonko et al., 2020) • Hedge (Diarra et al., 2021) • Strip (Diarra et al., 2021)
Mulching/stone barriers	• Mulching is also a local practice where farming communities cover the soil surface with organic residues to avoid moisture loss and maintain soil fertility (Sertse et al.,2021) • Mulching (Diarra et al., 2021; Eshetu et al., 2021) • Mulching to retain soil moisture (Abebe, 2021) • Like making channels to clear standing water from the fields or to do mulching in the field to protect plants from heating (Abid et al., 2020) • Mulching technology (Asfaw et al., 2019) • Water conservation through mulching (Nyirandorimana et al., 2020) • Cover crop (Diarra et al., 2021) • Cover the soil around the coffee roots with leaves (Abebe, 2021). • Stone bunds Well-known soil and water conservation technique that is endogenous to the Sahel. Stone bunds are used along contour lines to slow down, filter and spread out runoff water, thus increasing infiltration and reducing soil erosion (Zampaligre and Fuchs, 2019) • Soil bunds (Kahsay et al., 2019) • Stone barriers (Diarra et al., 2021) • Stone bund building (Yohannes et al., 2020) • Make soil and small stone bunds in farm (Abebe, 2021) • Stone and soil bunds that increases soil moisture (Tesfahunegn and Gebru, 2020) • Terracing on the slope land (stone/bund) (Asfaw et al., 2019)
Agriculture mechanisation related activities	• Combining conservation tillage – promotion of low-cost conservation tillage practices such as green manure and crop residue help farmers to reduce the cost of chemical fertilizer whilst maintaining soil fertility and moisture content (Bedeke et al., 2019; Sertse et al., 2021; Diarra et al., 2021; Gebru et al., 2020) • Farmers use improved agricultural technologies to optimize land use, productivity and return to inputs by changing land management system. Promoting the adoption of size-neutral technologies such as novel agricultural input use system and farm machinery that substitutes the human labour, eventually allow the large farmers to make efficient use of their landholdings (Bedeke et al., 2019) • The farmers have been implementing various biophysical soil and water harvesting technologies including trenches, terracing, water cannels, flood diversion, moisture trapping, gully treatment at farmland and communal level through campaign (Ayal et al., 2021) • Adoption of structural technologies (Mulinde et al., 2019) • Agricultural mechanization (Diarra et al., 2021)
PLANTING-RELATED STRATEGIES	
Rescheduling the planting calendar	• During the late-onset small rainy season, farmers reschedule the crop calendar by sowing crop varieties to be harvested (barely, teff, and wheat) on the onset of the main rainy season in October–December (Kahsay et al., 2019). • Change in planting, weeding and harvesting dates (Gebru et al., 2020) • Other specific practices that the farmers have applied include changing planting dates (early- and/ or late-season planting) (Ado et al., 2020) • Early field preparation and planting (before the start of the rain) (Sorgho et al., 2020) • Changing planting date (18.4 %) (Destaw and Fenta, 2021; Hirpha et al., 2020) • Changes in planting dates (24.6 %) (Eshetu et al., 2021) • Late sowing (Diarra et al., 2021) • Changing the date of planting and harvesting(Mekonnen et al., 2021) • Planting early maturing crops, Adjustment of sowing time (Ali, 2021) • Modifying planting and harvesting time were identified as common adaptation strategies in the study area (Adego et al., 2019). • While changing cultivation dates indicate changing crop sowing and harvesting dates according to the changes in local weather conditions (Sertse et al., 2021) • Use different planting dates (Belachew and Ababu, 2021)

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Themes/sub-themes CROP AND VARITIES RELATED STRATEGIES	Extracted data
	• With respect to the agronomic domain, farmers adapted their field management in 19 % of the cases by re-sowing, possibly with another variety, or changing the harvesting date (Huet et al., 2020) • Changing of planting dates (Diallo et al., 2020; Assaye et al., 2020) • Early and late planting (changing sowing period) (Marie et al., 2020) • Planting date changes (Nkuba et al., 2020) • The premature harvesting was not exactly about the food crops, for example cassava, being immature but they were harvested earlier than desired as a coping strategy to prevent them being affected by climatic extremes if left in the soil unharvested – as is the norm for keeping root crops for future consumption (Mayanja et al., 2020) • Another strategy adapted is that participants do not follow the 'normal' planting season. Particularly since the food shortage period in 2011, people have delayed the planting season which would normally start in March (Mayanja et al., 2020) • Changing planting date (Tesfahun and Chawla, 2020; Assaye et al., 2020) • Delaying the planting time (Abebe, 2021) • Changing in planting time (Tesfahunegn and Gebru, 2020) • Sowing crops early (Abid et al., 2020) • Changing the cropping calendar of agricultural activities (Abera and Tesema, 2019) • Changing farming calendar (Asfaw et al., 2019) • Wait for adequate conditions and replant (Staub et al., 2020) • early field preparation and planting (before the start of the rain) (Sorgho et al., 2020) • Farmers in Mozambique have strategically shifted planting months from September–December to other months due to rainfall unpredictability, including planting during the winter season (from April to August) (Salite and Poskitt, 2019) • Shifting planting dates (Nyirandorimana et al., 2020) • With women nomads beginning to cultivate in the rainy season, (Young and Ismail, 2019) • The results show that adjustment of sowing time are the mosted used adaptation measures (Ali et al., 2020) • Planting early maturing crops. Also, 57.95 % of the households adjusted the sowing time due to shortage in the duration of the rainy season (Ali, 2021) • Early planting of crops (Mubalama et al., 2020) • Change planting dates (di Falco et al., 2020)
Increased use of pesticide/herbicide/ integrated pest management	• Pesticide use (Mulinde et al., 2019). • Intensive use of insecticides (63 %) (Atube et al., 2021) • Soudanian farmers widely used agrochemical herbicides (93 %, e.g., Gliphader), synthetic fertilizers (82 %, e.g., urea-CO (NH2), N, P, K, and phosphate-PO4 3-), as well as pesticides and insecticides (41 % and 73 %, respectively, e.g., Cypercal and Caiman Rouge); whereas Soudanian and Sahelian farmers, particularly the latter, used the previous products to a lesser extent (58 % insecticides, 55 % synthetic fertilizers, 39 % herbicides, and 9 % pesticides, on average) (Alvar-Beltran et al., 2020) • Application of herbicides/insecticides (Asfaw et al., 2019) • Purchase of fertilizers, Purchase of pesticides, Purchase of veterinary medicines (Nyairo et al., 2020) • Integrated pest management (Diarra et al., 2021) • Integrated pest management (Sonko et al., 2020) • Increase use of herbicide (Diarra et al., 2021) • Proper usage of pesticides and herbicides (Gebru et al., 2020) • Herbicide use (Mulinde et al., 2019; Diarra et al., 2021). • Apply wood ash around the coffee plant to deal the spared of coffee berry disease (CBD) (Abebe, 2021) • The intensification of pest control (11.6 %) due to emergence of diseases in crops (Nyirandorimana et al., 2020) • Use of pest/disease-resistant (Diarra et al., 2021)
Selecting and expansion of new areas	• With marshland circumscribed by CIP cropping systems, valley land has taken on renewed importance as a dry season cultivation option. Qualitative analysis of interviews clarifies that there are several intersecting reasons for this. For one, valley land can be highly fertile and permit cultivation through long dry periods. Secondly, valleys are now the only place where prohibited but important food security crops like sweet potato and sorghum are, unofficially, allowed to be cultivated (Clay and King, 2019) • Change the quantity of land under cultivation, Moving to different farm site (Gebru et al., 2020) • Accordingly, the respondents identified different adaptation activities which include changing quantity of land under cultivation (Hirpha et al., 2020) • Renting more agricultural land within coffee-banana-maize (Mulinde et al., 2019) • Multiple land holdings with different shapes in different locations allow farmers to grow multiple crops with different adaptation capacities in different growing conditions (soil type, slope, microclimate variations, etc.). (Ntihinyurwa et al., 2019) • Expansion of coffee plants against enset plants (Abebe, 2021) • Increase amount of land under production, Change field location, Decrease amount of land under production (di Falco et al., 2020) • Diversification of plot locations (Staub et al., 2020) • Avoiding flood-prone areas (Nyirandorimana et al., 2020)

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