Renewable Agriculture and Food Systems

cambridge.org/raf

Farmers' resilience to climate change through the circular economy and sustainable agriculture: a review from developed and developing countries

Yahya Shafiyuddin Hilmi[1,2], József Tóth[3], Zoltán Gabnai[4], Gábor Király[5] and Ágoston Temesi[6]

[1]Doctoral School of Economics and Regional Science, Hungarian University of Agriculture and Life Sciences, 2100 Gödöllő, Hungary; [2]Department of Agricultural Socio-economics, Faculty of Agriculture, Universitas Gadjah Mada, 55281 Yogyakarta, Indonesia; [3]Institute of Sustainable Development, Corvinus University of Budapest, 1093 Budapest, Hungary; [4]Institute of Applied Economics, Faculty of Economics and Business, University of Debrecen, 4032 Debrecen, Hungary; [5]Social Research Department, Institute of Agricultural Economics, 1093 Budapest, Hungary and [6]Institute of Agricultural and Food Economics, Hungarian University of Agriculture and Life Sciences, 1118 Budapest, Hungary

Review Article

Cite this article: Hilmi YS, Tóth J, Gabnai Z, Király G, Temesi Á (2024). Farmers' resilience to climate change through the circular economy and sustainable agriculture: a review from developed and developing countries. *Renewable Agriculture and Food Systems* **39**, e15, 1–11. https://doi.org/10.1017/S1742170524000097

Received: 21 September 2023
Revised: 28 February 2024
Accepted: 15 March 2024

Keywords:
adaptation; circular agriculture; livelihood; regulation; sustainable development

Corresponding author:
Yahya Shafiyuddin Hilmi;
Email: hilmi.yahya.shafiyuddin@phd.uni-mate.hu

Abstract

Farmers struggle to combat uncertain climate issues while encountering pressure on conventional farming practices that lead to carbon emissions, water and soil pollution, and other environmental harms. A growing body of literature investigated circular economy and sustainable practices to support environmental-friendly agriculture activities while providing opportunities for farmers to improve their farm income. Therefore, a study synthesizing previous literature while identifying actual policy to boost farmers' implementation of sustainable agriculture is worthwhile. Using the Systematic Literature Review analysis, this paper aims to identify farmers' views on climate change adaptation and mitigation, challenges in implementing circular economy and sustainable practices, and policies to support farmers' transition toward sustainable agriculture in developed and developing countries. We found that (1) farmers' awareness of climate change, knowledge and skills are prominent for adapting and mitigating climate change in both types of countries, (2) farmland size, risks of income loss, and training and extension services influenced farmers' adaptation and mitigation strategies for climate change in developing countries, (3) farmers in both types of countries experienced uncertainty in economic profits and legislative issues when adopting sustainable practices, while farmers in developing countries issued significant up-front expenses to acquire technology to adopt sustainable practices, (4) financial access and incentives through policy can be valuable to develop sustainable livelihoods, especially for farm households.

Introduction

Climate change (CC) poses a notable challenge to agricultural systems, particularly for smallholder farmers who rely heavily on natural resources to sustain their livelihoods (Cohn et al., 2017). Climate variability, including changes in rainfall patterns, temperature, and extreme weather events, can negatively affect crop yields and farmers' well-being (Zamasiya, Nyikahadzoi and Mukamuri, 2017). In response, farmers have been exposed to several solutions and adapted their practices to mitigate the impacts of CC while facilitating sustainable food production, including sustainable agriculture (SA) concepts (Setsoafia, Ma and Renwick, 2022).

Sustainable agriculture practices (SAPs) can be depicted in several forms (Velten et al., 2015). Nevertheless, it can be simplified as practices that involve techniques to conserve natural resources, such as soil, water, and biodiversity, while enabling ecological processes that support food production. These practices include agroforestry, conservation agriculture, and integrated crop-livestock systems (Zeweld et al., 2018). Research has shown that these practices promote climate resilience and mitigate CC by improving soil health, enhancing water retention, increasing biodiversity, and reducing greenhouse gas emissions (Zeweld et al., 2018; Rakotovao et al., 2021).

Despite conceivable advantages, farmers' adoption of SAPs must be improved in many parts of the world. Some farmers perceive SA as a risky, expensive, and time-consuming technique and require access to the necessary resources, such as finance and technical support, to effectively implement the practice (Roesch-McNally, Garrett and Fery, 2020). A previously published study indicates that farmers are more interested in practices that can boost productivity, reduce costs, and diversify income sources while mitigating the impacts of CC (Makate,

Makate and Mango, 2017). Meanwhile, farmers in Germany were found to be influenced by a 'hedonic motivation' in inventing 'smart' products and adopting SAPs (Schukat and Heise, 2021).

One of the critical aspects of SAPs is the effective use of resources. Circular economy (CE) emphasizes the regenerative use of resources and the reduction of waste and pollution through closed-loop systems (Kirchherr, Reike and Hekkert, 2017). Hence, the introduction of CE in agriculture, often called circular agriculture (CA), glimpses an excellent deal for farmers to adopt SAPs. CA involves the integration of CE principles into agricultural systems to promote sustainable food production by providing economic gains, enhancing resource use, and reducing waste (Velasco-Muñoz et al., 2021).

Some studies have been conducted in a regional scope about farmers' views on strengthening their resilience to CC by incorporating CE and SAPs. Nevertheless, only a limited study comprehends what has been examined so far and exposes the uniqueness of each region's implementation of the practice. We, therefore, developed research questions as follows:

1. What influences farmers' decision to adapt and mitigate CC?
2. What are the challenges in implementing CE and SAPs at the farm level?
3. How can policies support farmers' transition toward SA?

This study's structure is organized as follows. After the introductory part, our method of selecting and screening the literature was explained. Following the method is the result of our analysis. We explained the result section in two sub-sections: developed and developing countries. Then, we answered this study's research questions in the discussion section. At the end of this paper, we provided conclusions, study limitations, and further research recommendations.

Material and methods

The review followed the PRISMA-P protocol to conduct Systematic Literature Review, as illustrated in Figure 1. We utilized Scopus and Web of Science (WOS) as our scientific databases and a set of search keywords: circular economy, climate change, adaptation and mitigation, sustainable agriculture, farmers, and policy and regulations, to collect the necessary literature. Keywords are executed based on field tags 'TS' or to search the title, abstract, and author keywords within a record in WOS and 'Title, Abstract, and Keyword' in Scopus search settings in December 2022.

As for the additional criteria, we select only primary studies or original articles published in English. Books, book chapters, conference papers, and review articles were excluded. Then, the selection resulted in a total of 123 articles from Scopus and 141 articles from WOS. After combining literature from both databases and sorting out 81 duplications, 183 original articles were ready for the next steps of the review: abstract and full-text reviews.

During these advanced reviews, we employed the following PICO criteria as a basis for sorting out the literature:

- Participants (P): farmers, smallholder/small-scale farmers
- Interventions (I): policy and regulations, incentives, subsidies, innovations
- Comparisons (C): before and after intervention
- Outcome (O): farmers' resilience on CC, sustainable production, better on-farm income, farmers' improved adoption of SAPs

Our analysis specifically focused on identifying farmers' views on CE and SAPs to strengthen their resilience on CC and increase farm productivity. Hence, we excluded research with limited findings to those topics and ones with more technical approaches instead of elaborating farmers' socioeconomic perspectives on related practices. As we reached the final number of selections (Fig. 1), at least two authors contributed to evaluating articles in each step of the review.

Results

Following our review analysis, we classified 51 final articles based on the country's economic development level, as seen in Table 1. We followed the classification from the Department of Economic and Social Affairs of the United Nations (The United Nations, 2022). In the initial part of this section, we briefly explained the number of literatures in developed vs developing countries and the most studied country. Then, we explained our findings based on farmers' situation in each country. The list of our literature can be seen in Appendix 1.

Overview

The topic of CE and SAPs has been studied for a while. In the focus of our study, the first few papers have been published in 2009 (Barbier et al., 2009; Bryan et al., 2009). The publications related to this topic have exponentially increased since 2018 and peaked in 2022. From these articles, only seven (14%) have been conducted in developed countries. Forty-four articles (86%) studied developing countries.

This review has selected studies conducted in almost all continents in the world. There are studies from Asia, Africa, North America, South America, and Europe. From these continents, a total of 29 countries have been studied. Africa was the most studied continent, with 14 countries in the review. Second is the continent of Asia (9 countries). Among all these continents, India (Asia) is the most studied country with seven related articles followed by Pakistan (Asia) and Ethiopia (Africa) with five articles each country.

Farmers in developed countries

Farmers in developed countries were concerned about CC and its impact on their farm yield. Hence, they understand the importance of adaptation and mitigation strategies (Maharjan, Gonzalvo and Aala, 2022a; Mohring, Finger and Dalhaus, 2022; Roesch-McNally, Garrett and Fery, 2020). Some farmers perceived these importances to shift to environmental-friendly practices (Maharjan, Gonzalvo and Aala, 2022a; Mohring, Finger and Dalhaus, 2022). Nevertheless, these practices may not be economically profitable (Gutschow, Bartkowski and Felipe-Lucia, 2021).

In the U.S., small-scale farmers agreed to shift their farming practices to encounter climate uncertainties and aimed for long-term farming benefits. However, their limited knowledge and skills to deal with the issue must be addressed (Roesch-McNally, Garrett and Fery, 2020).

In Japan, a study found that some farmers perceived environmental conservation agriculture (ECA) as a strategy to mitigate CC. Limiting the use of pesticides or chemical substances will benefit the environment, according to participants with high concerns about biodiversity and ecological resources (Maharjan, Gonzalvo and Aala, 2022a). In another study, Maharjan,

https://doi.org/10.1017/S1742170524000097 Published online by Cambridge University Press

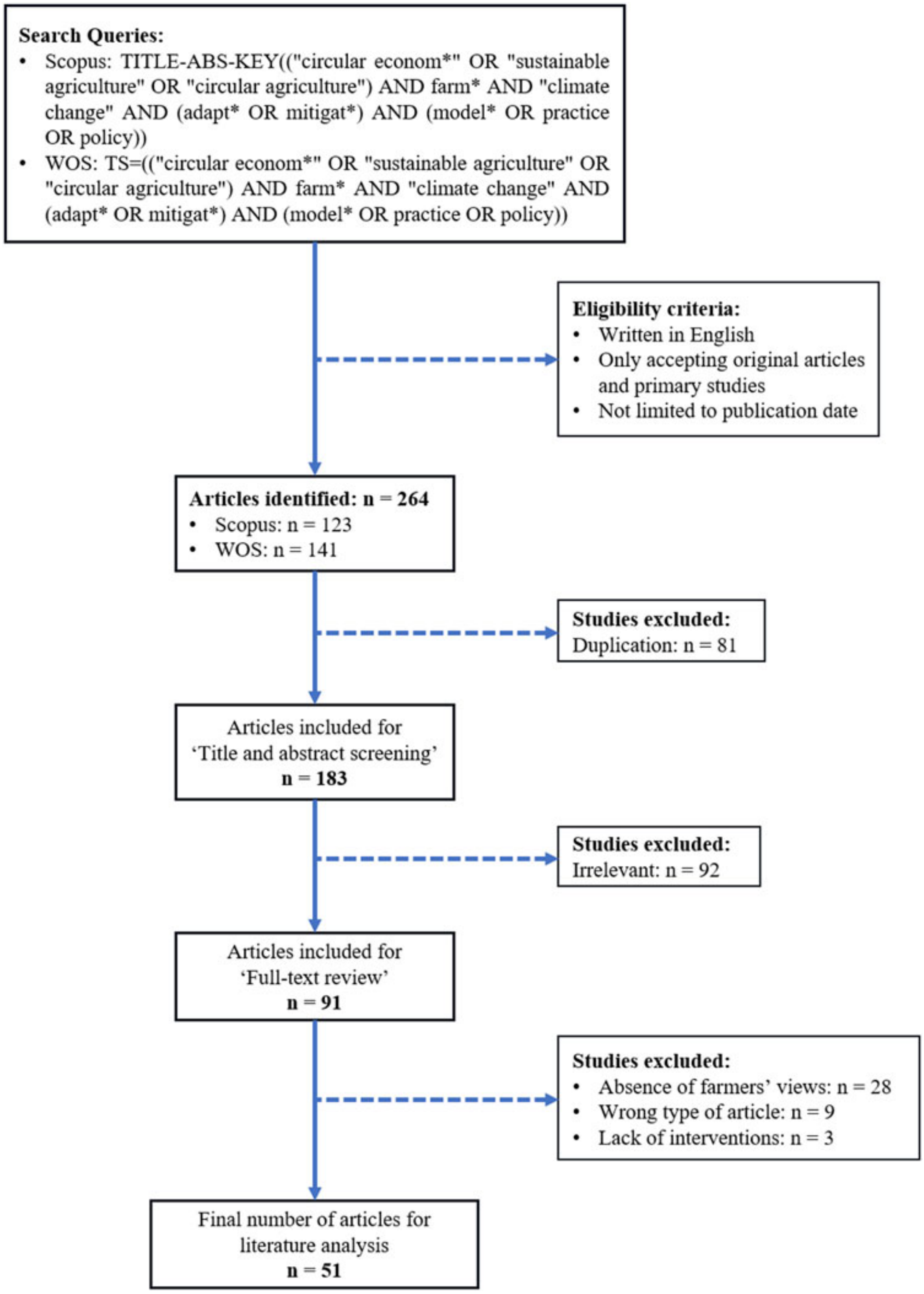

Figure 1. Systematic literature review under the PRISMA-P protocol.

Gonzalvo and Aala (2022b) found that ECA has allowed Japanese farmers to earn higher profits by direct selling to consumers.

Regarding European studies, field observation and experiments among farmers in Switzerland found that they adapt to extreme heat by reducing their insecticide use. It allows farmers to overcome the excessive effect of the insecticide that could damage their farms. Besides that, this practice results in lower total costs of crop production (Mohring, Finger and Dalhaus, 2022).

Gutschow, Bartkowski and Felipe-Lucia (2021) found that implementing diversified crop rotations as a CC mitigation strategy could be more economically viable. According to a survey among German farmers, most environmental-friendly practices are not perceived as a 'business-viable' strategy as they limit revenue margins and threaten the agribusiness's survival level (Gutschow, Bartkowski and Felipe-Lucia, 2021). On the other hand, smart farming provides more resource-efficient, sustainable, and profitable production for German farmers (Schukat and Heise, 2021). Hence, it receives a positive perception among surveyed farmers. According to their study, economic benefit and resource effectiveness have influenced their behavioral intention to use 'smart' tools.

In the Netherlands, a study by de Lauwere, Slegers and Meeusen (2022) mentioned about CA. They found that economic value is not the only factor when Dutch farmers highly perceive

Table 1. Study reference based on the country's economic development level

Type of the country	Country's name	References	Key findings
Developed economies	U.S.	Roesch-McNally, Garrett and Fery (2020)	- Farmers' awareness of climate change and knowledge and skills determine their decision to adopt climate-related adaptation and mitigation strategies (Mohring, Finger and Dalhaus, 2022; Roesch-McNally, Garrett and Fery, 2020). - Farmers are also aware to improve the environment (Maharjan, Gonzalvo and Aala, 2022a; Mohring, Finger and Dalhaus, 2022). - Although economic profits were found to be essential (Gutschow, Bartkowski and Felipe-Lucia, 2021; Schukat and Heise, 2021), knowledge, environmental resistance, and legislative issues were barriers for farmers in implementing sustainable agriculture practices (de Lauwere, Slegers and Meeusen, 2022). - An article has mentioned circular agriculture (de Lauwere, Slegers and Meeusen, 2022). - No paper has mentioned the actual policies related to the topic of the study.
	Japan	Maharjan, Gonzalvo and Aala (2022a; 2022b)	
	Switzerland	Mohring, Finger and Dalhaus (2022)	
	Germany	Gutschow, Bartkowski and Felipe-Lucia (2021); Schukat and Heise (2021)	
	Netherlands	de Lauwere, Slegers and Meeusen (2022)	
Developing economies	Brazil	Foguesatto, Borges and Machado (2019); Martinez, Maia and Garcia (2022)	- Besides awareness of the climate change issues and knowledge and skills, risk of income loss, farm size, and training and extension services influence farmers' decision to the adaptation and mitigation strategies (Byrareddy et al., 2021; Ma et al., 2022; Maleksaeidi et al., 2016; Musafiri et al., 2022; Samuel and Sylvia, 2019; Setsoafia, Ma and Renwick, 2022; Singh et al., 2021; Sohail and Chen, 2022; Wilk, Andersson and Warburton, 2013; Zeweld et al., 2018). - High cost of production and financial access were the common barriers for farmers to implement sustainable practice (Bhalerao et al., 2022; Bosma et al., 2012; Branca et al., 2021; Branca et al., 2022; Kopytko, 2019; Sarkar et al., 2022). - No article has mentioned circular economy and its relation to the topic of the study. - Policies such as the Low Carbon Agriculture Plan (Foguesatto, Borges and Machado, 2019) and India's Protection of Plant Varieties and Farmers' Rights Act (Kopytko, 2019) support the development of sustainable agriculture.
	Mexico	Torres, Kallas and Herrera (2020)	
	Bangladesh	Alauddin et al. (2020); Sarkar et al. (2022)	
	India	Bhalerao et al. (2022); Das, Ansari and Ghosh (2022); Kopytko (2019); Singh et al. (2020); Singh et al. (2021); Trivedi and Sunder (2021); Upadhaya et al. (2020)	
	Pakistan	Iqbal et al. (2020); Jabbar et al. (2022); Kiani et al. (2021); Sikandar et al. (2022); Sohail and Chen (2022)	
	Iran	Maleksaeidi et al. (2016)	
	China	Liu et al. (2022); Ma et al. (2022); Quan et al. (2019)	
	Vietnam	Bosma et al. (2012); Byrareddy et al. (2021); Luu (2020)	
	Indonesia	Hidayat et al. (2020)	
	Malaysia	Masud et al. (2022)	
	Morocco	Kmoch et al. (2018)	
	Ethiopia	Abi et al. (2019); Branca et al. (2022); Bryan et al. (2009); Kristjanson et al. (2012); Zeweld et al. (2018)	
	Kenya	Kristjanson et al. (2012); Musafiri et al. (2022)	
	Madagascar	Rakotovao et al. (2021)	
	Malawi	Branca et al. (2021); Branca et al. (2022); Makate, Makate and Mango (2017)	
	Mozambique	Makate, Makate and Mango (2017)	
	Tanzania	Branca et al. (2022)	
	Uganda	Kristjanson et al. (2012); Maggio, Mastrorillo and Sitko (2022)	
	Zambia	Branca et al. (2021); Makate, Makate and Mango (2017); Siulemba and Moodley (2014)	

Cameroon	Molua (2022)
South Africa	Branca et al. (2022); Bryan et al. (2009); Samuel and Sylvia (2019); Wilk, Andersson and Warburton (2013)
Burkina Faso	Barbier et al. (2009)
Ghana	Setsoafia, Ma and Renwick (2022)
Nigeria	Nwobodo et al. (2022)

CA. Instead, they were motivated by social and environmental values. Nevertheless, the knowledge barrier limits farmers' transition toward CA. Environmental resistance due to excessive use of chemicals in the past and legislative issues make the effort more challenging for Dutch farmers.

Farmers in developing countries

Like those in developed countries, farmers in developing countries anticipated CC impacts on their farmland (Makate, Makate and Mango, 2017; Molua, 2022). Farmers perceive climate variability as a crucial stressor to ecological and socioeconomic issues (Singh et al., 2020). Farm income is expected to be lost without an adaptation strategy (Kristjanson et al., 2012; Liu et al., 2022; Molua, 2022). Nevertheless, CC adaptation issues should be addressed based on the specific socioeconomic conditions of a region (Bryan et al., 2009; Liu et al., 2022; Setsoafia, Ma and Renwick, 2022).

Most of the selected papers in developing countries have been studied in the continent of Africa ($n = 14$). From northern Africa, Kmoch et al. (2018) found the importance of a local knowledge approach to match the specific area or socioeconomic conditions and strengthen local innovation processes for Moroccan farmers' adaptation to climate uncertainties.

Regarding studies in sub-Saharan Africa (Western, Central, Eastern, and Southern Africa), some researchers incorporated multiple countries as their study area (Branca et al., 2021; Branca et al., 2022; Bryan et al., 2009; Kristjanson et al., 2012; Makate, Makate and Mango, 2017). Meanwhile, some researches have been done in a single country (Abi et al., 2019; Barbier et al., 2009; Musafiri et al., 2022; Rakotovao et al., 2021; Maggio, Mastrorillo and Sitko, 2022; Molua, 2022; Nwobodo et al., 2022; Samuel and Sylvia, 2019; Setsoafia, Ma and Renwick, 2022; Siulemba and Moodley, 2014; Wilk, Andersson and Warburton, 2013; Zeweld et al., 2018).

Barbier et al. (2009) found that farmers in Burkina Faso have adopted several techniques to increase yield and reduce its variability. Growing land scarcity and new market opportunities are why farmers adopt those practices. Meanwhile, Rakotovao et al. (2021) utilized several scenarios related to agroecology in Madagascar and found that the practice can help increase smallholder farmers' productivity and profitability in the long run while mitigating CC. Nwobodo et al. (2022) found that economic benefits such as financial inclusion schemes can be considered to motivate Nigerian farmers to adopt a 'greener' practice. Moreover, the level of knowledge also influences farmers' implementation of SAPs.

Bryan et al. (2009) chose farmers in South Africa and Ethiopia as their study participants. They found that improved agricultural technologies, water storage facilities, irrigation, and crop varieties may increase practices related to CC adaptation at the farm level. Moreover, farmers' access to extension services and financial support is essential. Regarding South Africa, Wilk, Andersson and Warburton (2013) found that high costs of production inputs, limited access to knowledge, and agricultural techniques affect small-scale farmers' adaptive capacity. Meanwhile, Samuel and Sylvia (2019) found that farmers' awareness of climate issues, irrigation access, and the extension officers' frequency of visits influence farmers' adaptation strategies.

Kristjanson et al. (2012) found that climate issues were vital to farmers' adaptation to SAPs in Ethiopia, Kenya, Uganda, and Tanzania. Musafiri et al. (2022) found that despite their awareness

https://doi.org/10.1017/S1742170524000097 Published online by Cambridge University Press

of CC's drivers and effects, Kenyan smallholders' capacity to adapt has been limited by unpredictable weather patterns, financial constraints, and lack of agricultural training. Their study also found that farmers' groups have negatively influenced smallholders' adaptation practice. In Uganda, a study found that organic fertilizer and maize-legume intercropping as a single package can improve the value of crop production and resilience toward high-temperature deviations. The study argued that an increase in farmers' level of strategy adoption would increase the overall benefits (Maggio, Mastrorillo and Sitko, 2022).

Maggio's findings were supported by Setsoafia, Ma and Renwick (2022). They found that adopting the whole practice by improving seeds, fertilizers, and conserving soil and water can stimulate better impacts than a partial adoption of single or two practices. Ghanaian farmers' decision to adopt SAPs has been affected by the household's socio-demographical aspects, plot-level characteristics, extension services, and locations. In Cameroon, Molua (2022) found that market access, farming experience, farm size, land tenure security, access to extension, and agroforestry practice enhanced farmers' potential to adapt to climate issues.

In addition to studies conducted in Ethiopia, Zeweld et al. (2018) found that Ethiopian farmers' adoption of land management practices (agroforestry, crop rotation, and compost) has been influenced by their attitudes, access to information, educational level, group membership, social capital, risk attitudes, and labor supply. Moreover, Abi et al. (2019) added to the literature about Ethiopian farmers that their awareness to reduce drought can be elevated through an adapted training for mass-mobilization approach. Their findings found that farmers who followed the training were better at mitigating future drought and more aware of the possible impacts of drought on farmland.

In Zambia, Siulemba and Moodley (2014) found no difference between farmers' genders regarding their practice of managing natural resources. The study also found that larger families engage better in SAPs than smaller ones. Furthermore, Makate, Makate and Mango (2017) conducted a study in the multiple countries of Malawi, Mozambique, and Zambia. They have found that farmers' perception of CC results in a shift to more conservation practices, including Integrated Soil Fertility Management. This method, which utilizes inorganic fertilizers, compost manure, and farmyard manure, is essential for the sustainable intensification of agriculture in sub-Saharan Africa (Makate, Makate and Mango, 2017; Vanlauwe et al., 2014).

Branca et al. (2021) also studied farmers in Malawi and Zambia. They found that according to the socioeconomic characteristics, applying suitable technology for a climate-smart agriculture practice requires high up-front costs. Nevertheless, they argue that farmers will receive significant economic returns when they switch their conventional practices to climate-smart ones (Branca et al., 2021). Another study was conducted by Branca et al. (2022); this time, they chose Ethiopia, Malawi, South Africa, and Tanzania as their study areas. They found that farmers with better financial and food-secure status are likelier to adopt agricultural technology innovations. Following their previous study in Malawi and Zambia, this time, they argue that technology packages need to consider the complexity and diversity of the smallholder farming systems (Branca et al., 2022).

Regarding situations in the continent of Asia, Alauddin et al. (2020) found that alternate wetting and drying irrigation can help Bangladeshi farmers save water resources and irrigation costs while increasing crop yield. Farmers' adoption of this technique was affected by the age and education level of the household head, access to weather information, land ownership, typography, and soil type. Sarkar et al. (2022) found that necessary resources, knowledge, skills, and training facilities can improve Bangladeshi farmers' adoption of SAPs.

Farmers in India perceived climate variability as crucial to ecological, socioeconomic, and political issues (Singh et al., 2020). Natural conservation and financial access were determinants for farmers to adopt sustainable techniques (Kopytko, 2019). Remunerative markets (agritourism, contract farming, and integrated food processing) can help support farmers' financial sustainability (Trivedi and Sunder, 2021). Singh et al. (2021) found that flood-recession farming can upscale community livelihood and food security and improve environmental conditions near the river. Farmers' adoption of this strategy was affected by the farmers' skills and the invention of new technologies. Subsequently, farmers affected by declining water availability and soil fertility adopted low-cost measures to sustain their livelihoods (Bhalerao et al., 2022). Farmers in India produce foods while practicing SA by modifying their farming system based on traditional beliefs (Upadhaya et al., 2020). Moreover, Das, Ansari and Ghosh (2022) found that Indian farmers prefer to adopt climate-smart agriculture through indigenous technical knowledge.

Meanwhile, Pakistan has strong linkages between farmers' knowledge and adaptation strategies, food security, risk assessment, and livelihood assets (Sohail and Chen, 2022). According to their study, farmers are expected to reduce risks as low as possible at any time. Regarding farmers' knowledge and adaptation strategies, Jabbar et al. (2022) found that the Farmer Field Schools improve farmers' adoption of SAPs. Moreover, farmers' participation in the program was influenced by the usage rate of information and communications technology, land tenure status, and extension services. A study by Iqbal et al. (2020) found that small dams can be a priority for risk management strategy as this country also experiences water shortages. Regardless, Kiani et al. (2021) found that Pakistani farmers experienced a significant loss of farm income due to crop diversification practices. The agricultural diversification strategy was environmentally safe yet financially unviable and required excessive implementation time (Kiani et al., 2021). Sikandar et al. (2022) argued that foreign aid is one of the solutions to improve a positive relationship between SAPs and farm production.

Climate warming and low farming incomes motivate Chinese farmers to adopt SAPs (Liu et al., 2022). Other than that, the cultivated area's size, cognition skills, and the accessibility of information influence farmers' adaptation decisions (Quan et al., 2019). Chinese farmers' choice of crop variety depends on the risk of income loss, where they prefer a variety with low potential yield reduction (Ma et al., 2022). Quan et al. (2019) also found that limited adaptation strategies to CC may result in false practices, such as excessive irrigation and chemical application, and negatively affect wheat yields.

In Vietnam, Bosma et al. (2012) examined implementing the rice-fish farming system. Findings show that this system will provide farmers with a higher farm income and productivity. However, higher input costs are needed than conventional farming systems, and farmers with better access to financial support are more likely to adopt the new farming systems. Byrareddy et al. (2021) found that Vietnamese farmers who implement a combination of mulching and irrigation practices experienced a better adaptation to climate issues than those adopting only the irrigation system. In this case, the adoption of mulching practices was influenced by the farming experience during the drought season. A study by Luu (2020) investigated that Vietnamese farmers' adoption of climate-smart agriculture is determined by educational level, social capital, access to credit, farmland size, tenure status, extension service, and market constraint. Farmers with large production scales are more financially capable and likely to afford climate-smart agriculture technology.

In Malaysia, a study by Masud et al. (2022) found that economic, social, natural, and institutional barriers limit farmers' adaptation to CC. Financial accessibility and price stability of all agricultural inputs are needed to improve farmers' adaptation practices. Moreover, a study by Maleksaeidi et al. (2016) in Iran found that farm households' resilience to CC can be increased by improving knowledge management.

In South America, a study by Foguesatto, Borges and Machado (2019) investigated Brazilian farmers' adaptation and mitigation of CC by examining their pro-environmental behavior. Farmers classified as 'eco-centric farmers' use their sense of environmental and cultural concerns in implementing pro-environmental behavior. On the other hand, their study explained that farmers who use economic value as their drivers for pro-environmental behavior will be attracted by financial incentives to adopt sustainable practices. The latter type of farmer was also found in a study in Mexico (Torres, Kallas and Herrera, 2020). Torres et al. found that Mexican farmers prefer adaptation rather than mitigation actions due to the 'instant' benefit once it is adopted. In short, farmers prioritized actions that provide short-run economic benefits.

Discussion

Factors affecting farmers' decision to adapt and mitigate climate change

CC is expected to happen globally, meaning that farmers in developed and developing countries may suffer from climate uncertainties. Farmers in both types of countries are aware of the CC's impact on their farm production, and the importance of adaptation and mitigation strategies (Maharjan, Gonzalvo and Aala, 2022a; Mohring, Finger and Dalhaus, 2022; Musafiri et al., 2022; Roesch-McNally, Garrett and Fery, 2020; Samuel and Sylvia, 2019). Regardless, farmers in developed countries may think beyond current impact of the CC. They are more likely to be engaged with mitigation strategies to improve the environment (Maharjan, Gonzalvo and Aala, 2022a).

The similarity between two farmers can be seen through knowledge and skills. Farmers were influenced by the level of knowledge and skill to adopt strategies to adapt and mitigate CC (Maleksaeidi et al., 2016; Roesch-McNally, Garrett and Fery, 2020; Singh et al., 2021; Sohail and Chen, 2022; Wilk, Andersson and Warburton, 2013). Local or indigenous-based knowledge management was found to be preferred by farmers in developing countries (Das, Ansari and Ghosh, 2022; Kmoch et al., 2018). We argue that a local knowledge approach could be helpful for smallholder farmers to engage with location-specific adaptation strategies, and to improve adaptation options based on innovations in their area. One of the examples we found from our analysis is the Integrated Soil Fertility Management for an intensification strategy in sub-Saharan Africa (Makate, Makate and Mango, 2017; Vanlauwe et al., 2014). Literature may support our argument considering that socioeconomic conditions in specific locations are necessary when addressing CC adaptation strategies (Bryan et al., 2009; Liu et al., 2022; Setsoafia, Ma and Renwick, 2022).

It is understandable that farmers in developed countries have a bigger chance to improve their agricultural practices into a more environment-friendly ones. One of the reasons is farmland size and ownership. Unlike in developed economies, most agricultural fields in developing economies are cultivated by smallholder-type of farmers. Farmers who own small scale of agricultural land were more vulnerable to CC compared to farmers with larger land ownerships; hence, affecting their capacity to adopt strategies (Luu, 2020; Molua, 2022; Quan et al., 2019; Wilk, Andersson and Warburton, 2013).

Following the explanation in the previous paragraph, farmers in developing countries are more likely to avoid the risk of adopting adaptation strategies (Byrareddy et al., 2021; Ma et al., 2022; Sohail and Chen, 2022; Zeweld et al., 2018). Their initiatives to conduct 'experiments' could be limited considering the smaller farmland size and the risk of losing their main source of income. Farmers in this type of countries may not have a full ownership of the farmland. Some land tenure-schemes were found, including farming without owning the land or land leasing. Farmers could use this type of scheme as an alternative to the purchase of land for agriculture. However, this can also affect their engagement to certain CC adaptation and mitigation strategies, considering that they have less risk of land sustainability compared to those who own the land (Adenuga, Jack and McCarry, 2021).

Training and extension services may help farmers to build their capacity to adopt CC's adaptation and mitigation strategies, especially in developing economies (Abi et al., 2019; Musafiri et al., 2022; Samuel and Sylvia, 2019; Setsoafia, Ma and Renwick, 2022). Training or capacity-building programs should modify the concept of SAPs to their traditional or local beliefs. Farmers in developing countries tend to prefer local-based knowledge. We believe this effort shall improve their acceptance of the program and the practice. Farmer Field Schools might be a great example of moderating indigenous knowledge and techniques and new perspectives on conducting SA (Jabbar et al., 2022).

Furthermore, extension services can help farmers in creating farmer groups. Farmer groups can help smallholder farmers encountering CC issues through collective work (Musafiri et al., 2022). However, training sets and extension services must be adapted to each location's socioeconomic characteristics. The reason is due to the uniqueness of the location. For example, Musafiri et al. (2022) found that Kenyan farmers perceive farmer groups to provide value addition and commercialization of farming activities. These farmers did not perceive farmer groups as a medium to help them mitigate CC. Nevertheless, these efforts are essential in improving farmers' adoption of CE and sustainable practices.

Challenges in implementing circular economy and sustainable practices

Conventional practices are known for the high intensity of agriculture inputs to produce a high number of yields without considering the long-term impact of the practice, especially on the environment. Farmers, unfortunately, were linked with this type of imbalance practice between economic and ecological trade-offs. A more sustainable practice yet resource-effective is required to overcome these issues.

Several practices provide farmers in developed and developing countries with opportunities to implement SA and CE. Agriculture practice should be ecologically and economically profitable in developed economies, where farmers tend to be

https://doi.org/10.1017/S1742170524000097 Published online by Cambridge University Press

more aware of conserving natural resources (Maharjan, Gonzalvo and Aala, 2022a). ECA allows farmers to improve environmental resources and biodiversity (Maharjan, Gonzalvo and Aala, 2022a). In addition, farmers will likely receive higher profits if they incorporate direct selling to consumers (farmers-to-consumers) in their agribusiness (Maharjan, Gonzalvo and Aala, 2022b).

Meanwhile, farmers in developing countries also delivered examples of sustainable practices. Practices such as using organic fertilizer and intercropping maize and legumes (Maggio, Mastrorillo and Sitko, 2022) and combining mulching and irrigation with farming activities can help farmers adapt to CC (Byrareddy et al., 2021). Remunerative markets, such as agritourism or contract farming, and the rice-fish farming system can generate high farm income and productivity, hence providing farmers with financial sustainability (Bosma et al., 2012; Trivedi and Sunder, 2021). Moreover, agroecology or flood recession farming can also provide such benefits while mitigating CC and improving environmental conditions (Rakotovao et al., 2021; Singh et al., 2021). Regarding location-specific practice, Integrated Soil Fertility Management benefits farmers in sub-Saharan Africa in intensifying their agriculture sustainably (Makate, Makate and Mango, 2017; Vanlauwe et al., 2014).

Regardless of the possible benefits, farmers in both types of countries have been experiencing issues implementing SAPs. Gutschow, Bartkowski and Felipe-Lucia (2021) found that diversifying crop rotations is not economically viable, according to farmers in a developed country. Findings from the developing world by Kiani et al. (2021) show a significant loss of farm income due to similar practices.

From these examples, environmentally beneficial practices must be improved to offer farmers economic gains and time-effective management. Such barriers to gaining more profits will impact how farmers perceive and adapt to innovations, especially in the developing world. Farmers attracted to innovation tend to analyze their peer's situations after implementing a system (Martinez, Maia and Garcia, 2022). Nevertheless, farmers who experience economic profits when adopting new practices will have a better perception. This situation also shows how important it can be to address economic profits and new market opportunities for SA development. Studies in developed and developing countries show farmers' acceptance of these benefits (Barbier et al., 2009; Schukat and Heise, 2021).

Another challenge farmers face is the high production cost, especially farmers in the developing economies. A climate-smart agriculture practice requires a considerable investment to apply for a suitable technology (Branca et al., 2021). A similar case exists in the rice-fish farming system (Bosma et al., 2012). Therefore, efficiently managing resources and costs is essential in developing SA at the farm level. This concept can be found in the CE (Kirchherr, Reike and Hekkert, 2017).

Interestingly, the term 'circular economy' or 'circular agriculture' is barely mentioned in our literature. Only a study by de Lauwere, Slegers and Meeusen (2022) has mentioned the terms. However, several practices implemented by farmers in developed and developing countries may have applied the 'circular' concept. For example, 'smart farming' provides a more resource-efficient, sustainable, and profitable production among farmers in developed countries (Schukat and Heise, 2021). In a developing country, alternate wetting and drying irrigation can help farmers manage water resources and irrigation costs efficiently while increasing crop yield (Alauddin et al., 2020). These examples show that using less or reusing/recycling agriculture resources means farmers need less production cost, which aligns with the concept of CA (Velasco-Muñoz et al., 2021). Additionally, achieving lower production costs has allowed farmers to increase their profit margin (Kirchherr, Reike and Hekkert, 2017), especially when gaining premiums is possible.

Policy support to sustainable agriculture development

Institutional support through legislative and government bodies may influence SA development at the farm level. Regarding this matter, policies can directly and indirectly affect farmers' implementation of sustainable practices, and farmers in developed and developing countries experience the issue. For example, government obligations demotivate Dutch farmers with high initiatives for sustainable practices. These farmers see their farms as businesses, though the current regulation seems to lack incentives, and they argue that it is more suitable for a conventional farming system (de Lauwere, Slegers and Meeusen, 2022). In Pakistan, inconsistent public policies have notably distracted agricultural productivity and farmers' livelihood. Farmers have identified the issue of inconsistencies as their highest source of risk (Iqbal et al., 2020).

A study from Indonesia provides an example of what Iqbal et al. found in Pakistan. Hidayat et al. (2020) mentioned the Green Revolution program during the 1970s. The program, which was a national mandatory, has shifted the traditional ecological knowledge-based practices to high-productivity-minded farming systems. However, the program produces debatable outputs: increased farm production and profitability but highly dependent on chemical applications. Despite receiving economic benefits, this program may not apply to the current situation where global markets demand more sustainably earned agriculture yields.

Another policy example can be seen in India's Protection of Plant Varieties and Farmers' Rights Act. Regarding this policy, Kopytko (2019) found that it aimed to help farmers in India practice sustainable seed innovation. An issue was to decide whether to recognize farmers or the community belongs to the farmer. Also, Kopytko acknowledged the differences between benefits received by plant breeders and farmers. Thus, improvements have been made to ensure the Act benefits the awardee of breeding new varieties.

Furthermore, government bodies can support farmers with attractive policies in terms of providing them economic profit and environmental conservations. In this case, Brazil's Low Carbon Agriculture Plan may be an excellent example of a policy that can serve both objectives. Foguesatto, Borges and Machado (2019) argue that this program will not only help reduce the environmental impacts of their activities but also provide credits to invest in the agricultural system as proof of incentives-benefits.

With our limited scope of policy evaluations regarding the implementation of CE and SA at the farm level, further research should quantitatively analyze the effect of several public policies on farmers' implementation of the practice in developed and developing countries. An exciting finding from Sikandar et al. (2022) worth mentioning is the effect of foreign aid farmers need in developing countries to successfully connect SAPs and high agricultural production. In addition, our findings admitted narrow literature on policy mentioning CE and farmers.

Framework development

Based on the discussion in the previous three subsections, a framework has been created to clearly understand the issue of CC and SA at the farm level (Fig. 2). The framework explained

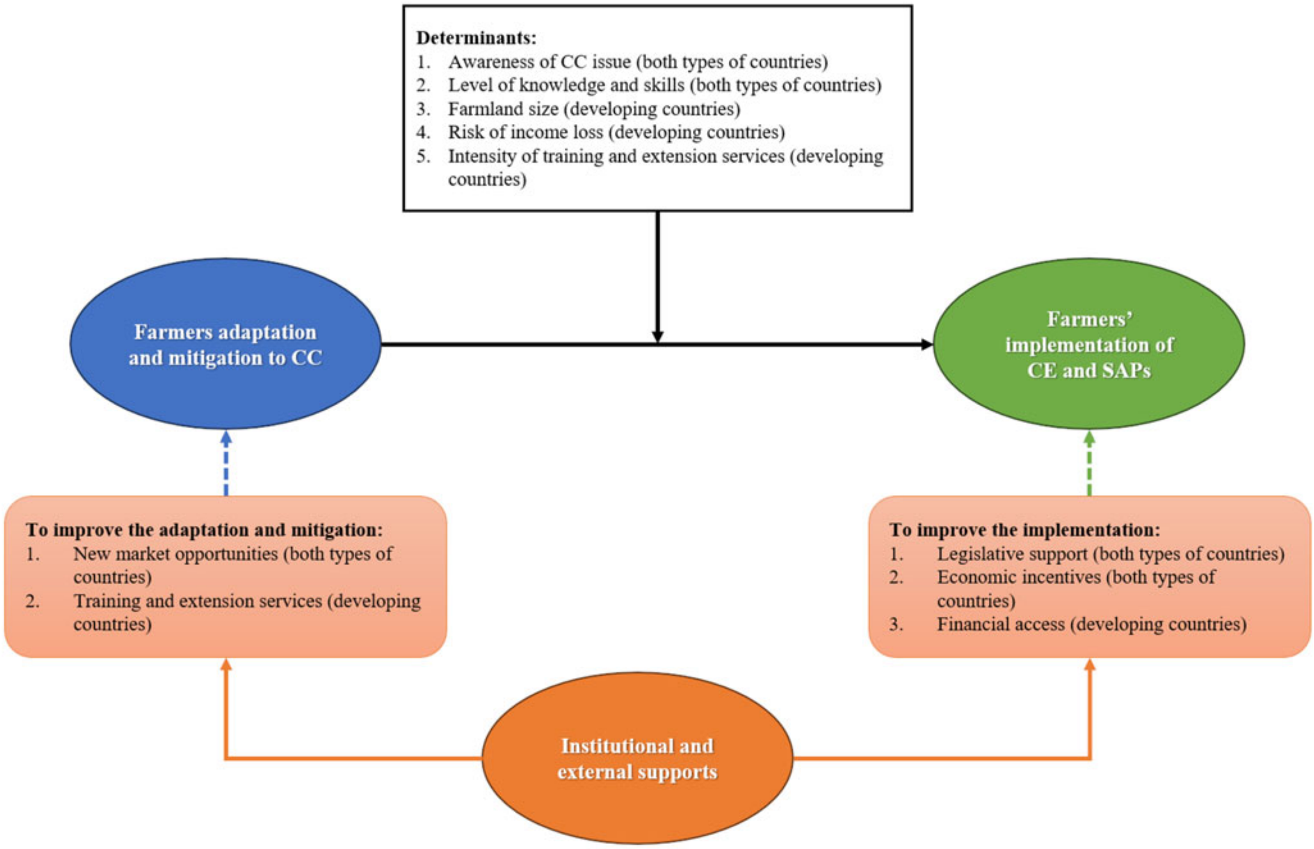

Figure 2. Framework developed from the study results.

how farmers' adoption of CC adaptation and mitigation is connected to farmers' implementation of CE and SAPs and is determined by two factors for farmers in developed and developing countries and three factors for a particular developing country's case. Furthermore, institutional and external supports such as policies could help improve the issue.

The framework, as seen in Figure 2, also provides ideas for policymakers to enhance future farmers' take on CC and its adaptation and mitigation strategies to develop an accountable solution for each location. For example, awareness of the CC issue and the level of knowledge and skill for farmers in developing countries can be improved by providing training and extension services. Moreover, farmers in developing countries are vulnerable to the risk of income loss. Thus, providing them with financial access will be crucial. On the other hand, farmers in developed countries might be interested in new market opportunities and economic incentives.

Our framework can be a basis for further study recommendations. The researcher may conduct a case-based study on crucial points such as (1) developing new market opportunities that are beneficial for many parties, (2) identifying types of effective methods for training and extension services, and (3) providing incentive schemes that are suitable for specific locations.

Conclusions

Based on the literature analysis, awareness of CC issues and the level of knowledge and skills can be significant in farmers' adoption of CC adaptation and mitigation in developed and developing countries. Meanwhile, farmers, particularly in developing countries, often mention farmland size, the level of risks, and the intensity of training and extension services as their deciding factors to the adaptation and mitigation strategies. Subsequently, implementing CE and SAPs among farmers in developing countries depends on technological costs and financial access. Therefore, government and institutional roles are essential in constructing new markets that are accessible to farmers. Moreover, policies supporting the creation of organizational bodies or farmer groups will complete the efforts.

Our review and analysis of the literature's main findings can help stakeholders, especially government and institutions related to agriculture, to develop programs and policies to support farmers' transition toward SA. With the emergence of climatic issues in agriculture, this study encouraged stakeholders to improve farmers' knowledge and skills through training and extension services, especially for farmers in developing countries.

Further research exploring the most effective training methods to improve farmers' knowledge and skills to adapt and mitigate CC can be crucial. Research may also identify schemes for providing incentives and financial support for farmers regarding their implementation of CE and sustainable practices. Moreover, research incorporating multiple study areas will help understand the importance of location-specific solutions. In addition, a more detailed policy evaluation is needed to investigate how much government support has been given to help farmers implement better agriculture.

Despite this study's importance in understanding farmers' strategies and practices to adapt and mitigate CC, we acknowledged that our Boolean queries extract only a limited number of studies from developed countries. This concern results in limited comparison between farmers' situation in developed and developing countries. Therefore, our review is instead to investigate each country's situation without comparing one-to-one issues due to the imbalanced number of references. Another concern is regarding case-based studies written in non-English language which we decided not to be included in this review study.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S1742170524000097

Author contributions. The first author named is lead and corresponding author. We describe each author's contributions to the paper as follows: conceptualization: J. T., Y. S. H., and Á. T.; funding acquisition: J. T.; investigation: all authors; methodology: Y. S. H. and Á. T.; supervision: Á. T. and J. T.; writing – original draft: Y. S. H.; writing – review and editing: G. K., Z. G., J. T., and Á. T. All authors have read and approved the final manuscript.

Funding statement. This study was funded by the research project OTKA K 143370 'Agricultural climate change adaptation and circular economic behavior'. Y. S. H. thanks the support of the Stipendium Hungaricum Scholarship and the Tempus Public Foundation. Á. T. thanks the support of the János Bolyai Research Scholarship of the Hungarian Academy of Sciences.

Competing interests. None.

References

Abi, M., Kessler, A., Oosterveer, P. and Tolossa, D. (2019) 'Adapting the current mass mobilization approach in Ethiopia to enhance its impact on sustainable land management: lessons from the Sago-kara watershed', *Journal of Environmental Management*, **248**, p. 109336.

Adenuga, A.H., Jack, C. and McCarry, R. (2021) 'The case for long-term land leasing: a review of the empirical literature', *Land*, **10**, p. 238.

Alauddin, M., Sarker, M.A.R., Islam, Z. and Tisdell, C. (2020) 'Adoption of alternate wetting and drying (AWD) irrigation as a water-saving technology in Bangladesh: economic and environmental considerations', *Land Use Policy*, **91**, p. 104430.

Barbier, B., Yacouba, H., Karambiri, H., Zorome, M. and Some, B. (2009) 'Human vulnerability to climate variability in the Sahel: Farmers' adaptation strategies in Northern Burkina Faso', *Environmental Management*, **43**, pp. 790–803.

Bhalerao, A.K., Rasche, L., Scheffran, J. and Schneider, U.A. (2022) 'Sustainable agriculture in Northeastern India: how do tribal farmers perceive and respond to climate change?', *International Journal of Sustainable Development & World Ecology*, **29**(4), pp. 291–302.

Bosma, R.H., Nhan, D.K., Udo, H.M.J. and Kaymak, U. (2012) 'Factors affecting farmers' adoption of integrated rice-fish farming systems in the Mekong delta, Vietnam', *Reviews in Aquaculture*, **4**, pp. 178–90.

Branca, G., Arslan, A., Paolantonio, A., Grewer, U., Cattaneo, A., Cavatassi, R., Lipper, L., Hillier, J. and Vetter, S. (2021) 'Assessing the economic and mitigation benefits of climate-smart agriculture and its implications for political economy: a case study in Southern Africa', *Journal of Cleaner Production*, **285**, p. 125161.

Branca, G., Cacchiarelli, L., Haug, R. and Sorrentino, A. (2022) 'Promoting sustainable change of smallholders' agriculture in Africa: policy and institutional implications from a socio-economic cross-country comparative analysis', *Journal of Cleaner Production*, **358**, p. 131949.

Bryan, E., Deressa, T.T., Gbetibouo, G.A. and Ringler, C. (2009) 'Adaptation to climate change in Ethiopia and South Africa: options and constraints', *Environmental Science & Policy*, **12**, pp. 413–26.

Byrareddy, V., Kouadio, L., Mushtaq, S., Kath, J. and Stone, R. (2021) 'Coping with drought: lessons learned from robusta coffee growers in Vietnam', *Climate Services*, **22**, p. 100229.

Cohn, A.S., Newton, P., Gil, J.D.B., Kuhl, L., Samberg, L., Ricciardi, V., Manly, J.R. and Northrop, S. (2017) 'Smallholder agriculture and climate change', *Annual Review of Environment and Resources*, **42**, pp. 347–75.

Das, U., Ansari, M.A. and Ghosh, S. (2022) 'Effectiveness and upscaling potential of climate smart agriculture interventions: farmers? Participatory prioritization and livelihood indicators as its determinants', *Agricultural System*, **203**, p. 103515.

de Lauwere, C., Slegers, M. and Meeusen, M. (2022) 'The influence of behavioural factors and external conditions on Dutch farmers? Decision making in the transition towards circular agriculture', *Land Use Policy*, **120**, p. 106253.

Foguesatto, C.R., Borges, J.A.R. and Machado, J.A.D. (2019) 'Farmers' typologies regarding environmental values and climate change: evidence from southern Brazil', *Journal of Cleaner Production*, **232**, pp. 400–7.

Gutschow, M., Bartkowski, B. and Felipe-Lucia, M.R. (2021) 'Farmers' action space to adopt sustainable practices: a study of arable farming in Saxony', *Regional Environmental Change*, **21**, p. 103.

Hidayat, R.A., Iskandar, J., Gunawan, B. and Partasasmita, R. (2020) 'Impact of green revolution on rice cultivation practices and production system: a case study in Sindang hamlet, Rancakalong village, Sumedang district, West Java, Indonesia', *Biodiversitas: Journal of Biological Diversity*, **21**(3), pp. 1258–65.

Iqbal, M.A., Abbas, A., Naqvi, S.A.A., Rizwan, M., Samie, A. and Ahmed, U.I. (2020) 'Drivers of farm households' perceived risk sources and factors affecting uptake of mitigation strategies in Punjab Pakistan: implications for sustainable agriculture', *Sustainability*, **12**, p. 9895.

Jabbar, A., Liu, W., Wang, Y., Zhang, J., Wu, Q. and Peng, J.C. (2022) 'Exploring the impact of Farmer Field Schools on the adoption of sustainable agricultural practices and farm production: a case of Pakistani citrus growers', *Agronomy*, **12**, p. 2054.

Kiani, A.K., Sardar, A., Khan, W.U., He, Y.G., Bilgic, A., Kuslu, Y. and Raja, M.A.Z. (2021) 'Role of agricultural diversification in improving resilience to climate change: an empirical analysis with Gaussian Paradigm', *Sustainability*, **13**, p. 9539.

Kirchherr, J., Reike, D. and Hekkert, M. (2017) 'Conceptualizing the circular economy: an analysis of 114 definitions', *Resources, Conservation and Recycling*, **127**, pp. 221–32.

Kmoch, L., Pagella, T., Palm, M. and Sinclair, F. (2018) 'Using local agroecological knowledge in climate change adaptation: a study of tree-based options in Northern Morocco', *Sustainability*, **10**, p. 3719.

Kopytko, N. (2019) 'Supporting sustainable innovations: an examination of India farmer agrobiodiversity conservation', *The Journal of Environment & Development*, **0**(0), pp. 1–26. https://doi.org/10.1177/1070496519870299

Kristjanson, P., Neufeldt, H., Gassner, A., Mango, J., Kyazze, F.B., Desta, S., Sayula, G., Thiede, B., Forch, W., Thornton, P.K. and Coe, R. (2012) 'Are food insecure smallholder households making changes in their farming practices?', *Evidence from East Africa. Food Sec*, **4**, pp. 381–97.

Liu, X.Q., Liu, Y.S., Rui, Y., Zhang, J. and Zhao, X.Z. (2022) 'Evaluation of sustainable agriculture and rural development in agro-pastoral ecotone under climate change: a comparative study of three villages in the Shenfu coalfield, China', *Journal of Rural Studies*, **93**, pp. 504–12.

Luu, D.T. (2020) 'Origins of farmers' adoption of multiple climate-smart agriculture management practices in the Vietnamese Mekong Delta', *Makara Hubs-Asia*, **24**(2), pp. 141–53.

Ma, J.L., Qu, J.J., Khan, N. and Zhang, H.J. (2022) 'Towards sustainable agricultural development for edible beans in China: evidence from 848 households', *Sustainability*, **14**, p. 9328.

Maggio, G., Mastrorillo, M. and Sitko, N.J. (2022) 'Adapting to high temperatures: effect of farm practices and their adoption duration on total value of crop production in Uganda', *American Journal of Agricultural Economics*, **104**(1), pp. 385–403.

Maharjan, K.L., Gonzalvo, C.M. and Aala, W.F. (2022a) 'Drivers of environmental conservation agriculture in Sado Island, Niigata Prefecture, Japan', *Sustainability*, **14**, p. 9881.

Maharjan, K.L., Gonzalvo, C.M. and Aala, W.F. (2022b) 'Dynamics of environmental conservation agriculture (ECA) utilization among Fujioka farmers in Japan with high biodiversity conservation awareness but low ECA interest', *Sustainability*, **14**(9), p. 5296.

Makate, C., Makate, M. and Mango, N. (2017) 'Smallholder farmers' perceptions on climate change and the use of sustainable agricultural practices in the Chinyanja Triangle, Southern Africa', *Social Sciences*, **6**(30), pp. 1–14. https://doi.org/10.3390/socsci6010030

Maleksaeidi, H., Karami, E., Zamani, G.H., Rezaei-Moghaddam, K., Hayati, D. and Masoudi, M. (2016) 'Discovering and characterizing farm households' resilience under water scarcity', *Environment, Development and Sustainability*, **18**, pp. 499–525.

Martinez, D.M., Maia, A.G. and Garcia, J.R. (2022) 'Spatial diffusion of efficient irrigation systems: a study of Sao Paulo, Brazil', *Australian Journal of Agricultural and Resource Economics*, **66**, pp. 690–712.

Masud, M.M., Akhtar, R., Al Mamun, A., Uddin, M.S., Siyu, L. and Yang, Q. (2022) 'Modelling the sustainable agriculture management adaptation practices: using adaptive capacity as a mediator. Front', *Environmental Science*, **10**, p. 963465.

Mohring, N., Finger, R. and Dalhaus, T. (2022) 'Extreme heat reduces insecticide use under real field conditions', *Science of the Total Environment*, **819**, p. 152043.

Molua, E.L. (2022) 'Private farmland autonomous adaptation to climate variability and change in Cameroon', *Rural Society*, **31**(2), pp. 115–35.

Musafiri, C.M., Kiboi, M., Macharia, J., Ng'etich, O.K., Kosgei, D.K., Mulianga, B., Okoti, M. and Ngetich, F.K. (2022) 'Smallholders' adaptation to climate change in Western Kenya: considering socioeconomic, institutional, and biophysical determinants', *Environmental Challenges*, **7**, p. 100489.

Nwobodo, C.E., Nwokolo, B., Iwuchukwu, J.C., Ohagwu, V.A. and Ozioko, R.I. (2022) 'Determinants of ruminant farmers' use of sustainable production practices for climate change adaptation and mitigation in Enugu State, Nigeria', *Frontiers in Veterinary Science*, **9**, p. 735139.

Quan, S.P., Li, Y.M., Song, J.X., Zhang, T. and Wang, M.Y. (2019) 'Adaptation to climate change and its impacts on wheat yield: perspective of farmers in Henan of China', *Sustainability*, **11**, p. 1928.

Rakotovao, N.H., Chevallier, T., Chapuis-Lardy, L., Deffontaines, S., Mathe, S., Ramaro, M.A., Rakotoniamonjy, T.H., Lepage, A., Masso, C., Albrecht, A. and Razafimbelo, T.M. (2021) 'Impacts on greenhouse gas balance and rural economy after agroecology development in Itasy Madagascar', *Journal of Cleaner Production*, **291**, p. 125220.

Roesch-McNally, G., Garrett, A. and Fery, M. (2020) 'Assessing perception of climate risk and adaptation among small farmers in Oregon's Willamette Valley', *Renewable Agriculture and Food Systems*, **35**, pp. 626–30.

Samuel, O.O. and Sylvia, T.S. (2019) 'Establishing the nexus between climate change adaptation strategy and smallholder farmers' food security status in South Africa: a bi-casual effect using instrumental variable approach', *Cogent Social Sciences*, **5**, p. 1656402.

Sarkar, A., Wang, H.Y., Rahman, A., Azim, J.A., Memon, W.H. and Qian, L. (2022) 'Structural equation model of young farmers' intention to adopt sustainable agriculture: a case study in Bangladesh', *Renewable Agriculture and Food Systems*, **37**, pp. 142–54.

Schukat, S. and Heise, H. (2021) 'Towards an understanding of the behavioral intentions and actual use of smart products among German farmers', *Sustainability*, **13**, p. 6666.

Setsoafia, E.D., Ma, W. and Renwick, A. (2022) 'Effects of sustainable agricultural practices on farm income and food security in northern Ghana', *Agricultural and Food Economics*, **10**(9), pp. 1–15. https://doi.org/10.1186/s40100-022-00216-9

Sikandar, F., Erokhin, V., Xin, L., Sidorova, M., Ivolga, A. and Bobryshev, A. (2022) 'Sustainable agriculture and rural poverty eradication in Pakistan: the role of foreign aid and government policies', *Sustainability*, **14**, p. 14751.

Singh, R., Patel, S.K., Tiwari, A.K. and Singh, G.S. (2021) 'Assessment of flood recession farming for livelihood provision, food security and environmental sustainability in the Ganga River Basin', *Current Research in Environmental Sustainability*, **3**, p. 100038.

Singh, R.K., Singh, A., Kumar, S., Sheoran, P., Sharma, D.K., Stringer, L.C., Quinn, C.H., Kumar, A. and Singh, D. (2020) 'Perceived climate variability and compounding stressors: implications for risks to livelihoods of smallholder Indian farmers', *Environmental Management*, **66**, pp. 826–44.

Siulemba, G.K. and Moodley, V. (2014) 'A gendered analysis of sustainable agricultural practices with changing climate in the Chankumba agricultural community Zambia', *Agenda (Durban, South Africa)*, **28**(3), pp. 135–46.

Sohail, M.T. and Chen, S.M. (2022) 'A systematic PLS-SEM approach on assessment of indigenous knowledge in adapting to floods: a way forward to sustainable agriculture', *Frontiers of Plant Science*, **13**, p. 990785.

The United Nations. (2022) The Department of Economic and Social Affairs of the United Nations (UN DESA): World Economic Situation and Prospects 2022. https://www.un.org/development/desa/dpad/wp-content/uploads/sites/45/WESP2022_ANNEX.pdf (Accessed 14 April 2023).

Torres, M.A.O., Kallas, Z. and Herrera, S.I.O. (2020) 'Farmers' environmental perceptions and preferences regarding climate change adaptation and mitigation actions; towards a sustainable agricultural system in Mexico', *Land Use Policy*, **99**, p. 105031.

Trivedi, S. and Sunder, R.G. (2021) 'Creating sustainable agriculture supply chain ecosystem for remunerative markets under changing climate in Uttarakhand', *International Journal of Social Ecology and Sustainable Development*, **12**(4), pp. 48–57.

Upadhaya, K., Barik, S.K., Kharbhih, V.M., Nongbri, G., Debnath, G., Gupta, A. and Ojha, A. (2020) 'Traditional bun shifting cultivation practice in Meghalaya, Northeast India', *Energy, Ecology and Environment*, **5**(1), pp. 34–46.

Vanlauwe, B., Wendt, J., Giller, K.E., Corbeels, M., Gerard, B. and Nolte, C. (2014) 'A fourth principle is required to define Conservation Agriculture in sub-Saharan Africa: the appropriate use of fertilizer to enhance crop productivity', *Field Crops Research*, **15**, pp. 10–3.

Velasco-Muñoz, J.F., Mendoza, J.M.F., Aznar-Sánchez, J.A. and Gallego-Schmid, A. (2021) 'Circular economy implementation in the agricultural sector: definition, strategies and indicators', *Resources, Conservation and Recycling*, **170**, p. 105618.

Velten, S., Leventon, J., Jager, N. and Newig, J. (2015) 'What is sustainable agriculture? A systematic review', *Sustainability*, **7**(6), pp. 7833–65.

Wilk, J., Andersson, L. and Warburton, M. (2013) 'Adaptation to climate change and other stressors among commercial and small-scale South African farmers', *Regional Environmental Change*, **13**, pp. 273–86.

Zamasiya, B., Nyikahadzoi, K. and Mukamuri, B.B. (2017) 'Factors influencing smallholder farmers' behavioural intention towards adaptation to climate change in transitional climatic zones: a case study of Hwedza District in Zimbabwe', *Journal of Environmental Management*, **198**, pp. 233–9.

Zeweld, W., Van Huylenbroeck, G., Tesfay, G., Azadi, H. and Speelman, S. (2018) 'Impacts of socio-psychological factors on actual adoption of sustainable land management practices in dryland and water stressed areas', *Sustainability*, **10**, p. 2963.