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Systematic Review

A Systematic Review of Agroecology Strategies for Adapting to Climate Change Impacts on Smallholder Crop Farmers' Livelihoods in South Africa

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Abstract: This systematic review identified the prevalence, effectiveness, and potential benefits of agroecology strategies in promoting sustainable agriculture practices implemented by smallholder crop farmers in South Africa. The review carried out a comprehensive literature search across various academic databases, including PubMed, Scopus, and Web of science. The relevant studies were screened and selected based on predetermined inclusion criteria where a total of 262 articles were extracted and reduced to 30 articles for this systematic review. Data were extracted and synthesised to classify patterns and trends in the adoption of agroecology elements. The results obtained from the review of this study highlights the identification of specific strategies such as indigenous crop varieties, conservation agriculture, intercropping, agroforestry, drought-tolerant crop varieties, and water management strategies. These outcomes demonstrated insights into the prevalence of different strategies applied by smallholder crop farmers in South Africa. Furthermore, the review determined the reported benefits, such as increased crop resilience, improved soil fertility, and enhanced water use efficiency. These benefits were assessed on the available evidence from the selected studies. This review contributes to a better understanding of agroecology practices in South African. The results can inform policymakers, researchers, and farmers in developing appropriate strategies to enhance sustainable agricultural practices.

Keywords: agroecological strategies; sustainable agriculture; smallholder crop farmers; South Africa

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1. Introduction

Agriculture plays a vital role in global food security and the livelihoods of millions of people. However, the agricultural sector faces numerous challenges, including climate change, diminishing natural resources, and the need to feed a growing population (Dlamini et al., 2023) [1]. Additionally, climate change is increasing the occurrence of floods, drought and other climate extremes (Gemeda et al., 2023) [2]. These pressures may compromise the agricultural sector's ability to meet the needs of a growing population and ensure food security. Without rapid and effective adaptation, climate change will continue to have devastating consequences (Vögt et al., 2023) [3]. In this context, the concept of agroecology has gained significant attention as a promising approach to address these challenges and promote sustainable and resilient agricultural systems.

Climate change is a pressing global issue that presents significant threats to various sectors, including agriculture (IPCC, 2014; Gomez-Zavaglia et al., 2020; Dlamini et al., 2023; Maluleke et al., 2024 [1,4–6]. The African continent has a higher proportion of people who are vulnerable to the effects of climate change than any other region in the world (Weber et al., 2018; Gobir et al., 2021) [7,8]. Africa's continent is vulnerable to the effects of climate change due to its reliance on natural resources. The continent is heavily dependent on rain-fed agriculture, which is sensitive to changes in rainfall patterns. In addition, the

continent's vulnerability to climate is further exacerbated by its low adaptive capacity (Weber et al., 2018; Mthembu and Hlophe, 2021; [7,9].

In South Africa, smallholder crop farmers are vulnerable to the adverse impacts of climate change on their livelihoods (Nkambule et al., 2019; Thinda et al., 2020; Okolie et al., 2023; Serote et al., 2023; Ubisi et al., 2023) [10–14]. The negative effects of climate change affect smallholder farmers mostly in developing countries, who depend on natural resources for their livelihoods (Ndlovu et al., 2021; Serote et al., 2023; Okolle et al., 2023) [12,13,15]. Changes in rainfall patterns, increased temperatures, and extreme weather events can disrupt crop production, reduce yields, and jeopardise food security for these farmers (Nhemachena and Hassan, 2007; Thinda et al., 2020) [11,16]. In response, the adoption of agroecology strategies has gained attention as a promising approach to enhance the resilience and adaptive capacity of smallholder farmers in the face of climate change (Altieri, 2018; Odusola, 2021; Kerr et al., 2023) [17–19].

Agroecology represents a holistic and interdisciplinary approach that integrates ecological principles and practices into agricultural systems. It underscores the importance of biodiversity, ecological processes, and local knowledge in enhancing productivity, resilience, and sustainability. Agroecology is the application of science of ecology to agricultural systems (Zenda and Heyns, 2017; Rudolph, Muchesa and Kroll, 2020; Kesselman, Ngcoya and Casale, 2021) [20–22]. Agroecology promotes the integration of ecological principles into agricultural systems (FAO, 2018) [23]. It accentuates sustainable farming practices that enhance biodiversity, soil health, and ecosystem services while minimising external inputs (Gliessman, 2014) [24]. Agroecology strategies include the use of indigenous and drought-tolerant crop varieties, conservation agriculture practices, intercropping, agroforestry, and water management techniques (Tittonell, 2014 [25]). These strategies aim to improve crop resilience, soil fertility, water use efficiency, and overall farm productivity, thereby enhancing the livelihoods of smallholder crop farmers (Akanmu et al., 2023) [26]. In addition, the adoption of agroecological techniques by smallholder farmers is crucial to ensuring food security (Akanmu et al., 2023) [26].

While agroecology has shown promise in the context of climate change adaptation, there is a need to consolidate, analyse and interrogate the results reported in the existing literature. Numerous studies have investigated the effectiveness, challenges, and outcomes of agro-ecology strategies for smallholder farmers in South Africa (Mugwanya, 2019; Mutenje et al., 2020) [27,28]. However, the findings from these studies are scattered across various sources, making it difficult to obtain a comprehensive understanding of the overall picture.

The effectiveness of agroecology strategies in addressing climate change is highly dependent on the local agroclimatic conditions. Different regions in South Africa experience different agroclimatic conditions and these conditions are changing over time due to climate change. This variability creates challenges for implementing effective agroecology strategies due to ongoing climate change (Trnka et al., 2021) [29]. Studies have shown that climate change is accelerating significantly, impacting local agroclimatic conditions and subsequently influencing the effectiveness of agroecology strategies (Calleja-Cabrera et al., 2020) [30]. Furthermore, the link between climate variability and food insecurity emphasises the need to consider local agroclimatic conditions when implementing agroecology strategies to address climate change (Thornton et al., 2014) [31]. Farmers' perceptions of climate change also vary across different agroecologies, highlighting the localised nature of agroclimatic conditions and their influence on the adoption and effectiveness of agroecology strategies (Esayas et al., 2019) [32]. Additionally, the prevalence of diseases such as bovine trypanosomosis and the density of its vectors are influenced by agroclimatic conditions, further emphasising the need to tailor agroecology strategies to local contexts (Kahsay et al., 2019) [33].

Moreover, the genetic diversity of crops within specific agroclimatic conditions indicates adaptation to local climate, suggesting that agroecology strategies should be context-specific to effectively mitigate climate change impacts (Amante and Tesgera, 2020) [34]. Local genetic resources and traditional practices gain importance in sustainable agricultural production, emphasising the significance of considering agroclimatic conditions in

agroecology strategies (Izzatullayeva et al., 2014) [35]. The observed poor adaptation of some cultivars to local agroclimatic conditions further underscores the necessity of aligning agroecology strategies with specific local conditions to enhance their effectiveness in addressing climate change (Jaćimović et al., 2020) [36].

A systematic review offers a rigorous and comprehensive approach to synthesise the available evidence. By systematically searching, selecting, and analysing relevant studies, such a systematic review can provide a consolidated and unbiased summary of the results, identify key patterns and trends, and assess the overall effectiveness of agroecology strategies in South Africa (Haddaway et al., 2018) [37]. These results can contribute to evidence-based decision-making, inform policy development.

This review aims to address the research gap regarding the utilisation of agroecology strategies for climate change adaptation among smallholder crop farmers in South Africa and will provide a comprehensive and current understanding of the effectiveness, challenges, and outcomes of agroecology practices in enhancing the livelihoods and resilience of smallholder farmers. The results of this review will offer important insights for policymakers, researchers, and practitioners seeking to promote sustainable agricultural approaches and support the adaptation of smallholder farmers to the impacts of climate change guide future research efforts, facilitate the adoption and scaling-up of successful agroecological practices.

The FAO's 10 Elements of Agroecology framework is a holistic tool that helps countries achieve transformative change towards sustainable agriculture and food systems (Barrios et al., 2020) [38]. It describes how different elements interact and how they can create desirable outcomes. The elements can be used by practitioners and decision-makers to plan, implement, manage, and evaluate agroecological transitions. This review paper is based on climate change resilience; an element of agroecological framework. It refers to the capacity of agroecological systems to adapt to and cope with the effects of climate change. This includes the ability to maintain food production, protect natural resources and ensure livelihoods in the face of climate change. It also includes the ability to bounce back and adapt to changing climate conditions.

2. Materials and Methods

A protocol was developed to outline the objectives, inclusion and exclusion criteria, search strategy, data extraction methods, and quality assessment procedures (Figure 1). The inclusion criteria specified that the studies must be peer-reviewed articles, dissertations, or reports focused on agroecology strategies utilised by smallholder crop farmers in South Africa to adapt to climate change impacts on their livelihoods. The publication date range for the search was set between January 2010 and December 2023.

A systematic search was conducted in electronic databases, including Scopus, Web of Science, and PubMed. Relevant keywords such as "agroecology", "climate change", "smallholder farmers", and "South Africa" were used to identify potentially relevant studies. The search strategy included combining these keywords using appropriate Boolean operators (e.g., AND, OR).

The retrieved studies were screened based on their titles and abstracts to identify potentially relevant studies. The full texts of the selected studies were obtained for further evaluation. The inclusion criteria were applied to determine the final set of studies to be included in the systematic review.

A standardised data extraction form was developed to collect relevant information from the included studies. Key data elements were extracted, including study characteristics (e.g., study design, sample size), agroecology strategies employed, outcomes measured, and findings reported. Multiple reviewers were involved in the data extraction process to ensure consistency and accuracy.

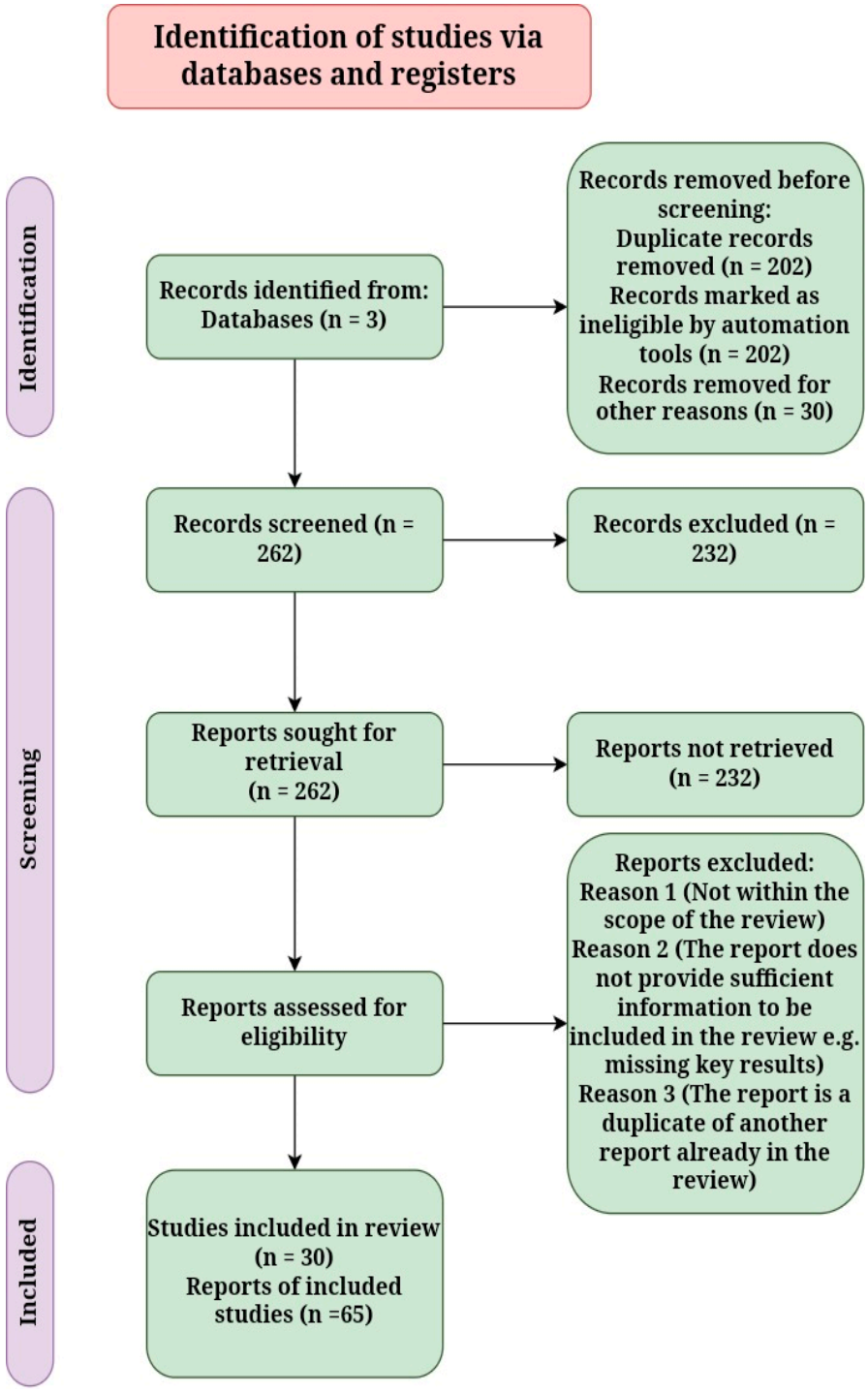

Figure 1. Prisma flow diagram for the current study.

The included studies were critically appraised to assess their quality and risk of bias. Appropriate tools such as critical appraisal skills programme (CASP) Tools or checklists were used to evaluate the methodological rigour, internal validity, and external validity of the studies.

The extracted data were analysed and synthesised to identify common themes, patterns, and trends. The findings of the included studies were summarised in a clear and structured manner, highlighting the main outcomes, challenges, and benefits of agroecology strategies.

3. Results

The initial search yielded a total of 262 articles. After screening and applying inclusion criteria, 30 studies were selected for detailed analysis. From this review, the findings regarding the use of agroecological strategies by smallholder farmers in South Africa were categorised into different themes such as conservation agriculture, drought tolerant crop varieties, water management, indigenous crop varieties, crop management and agroforestry. The findings indicate that many smallholder crop farmers in South Africa have utilised various agroecology strategies to adapt to climate change impacts. These strategies include the use of indigenous and drought-tolerant crop varieties, conservation agriculture practices, intercropping, agroforestry, crop management and water management techniques. The studies show that these practices can have many benefits, including increasing crop resilience, improving soil fertility and using water more efficiently. This could lead to improved livelihoods for smallholder farmers (Figure 2).

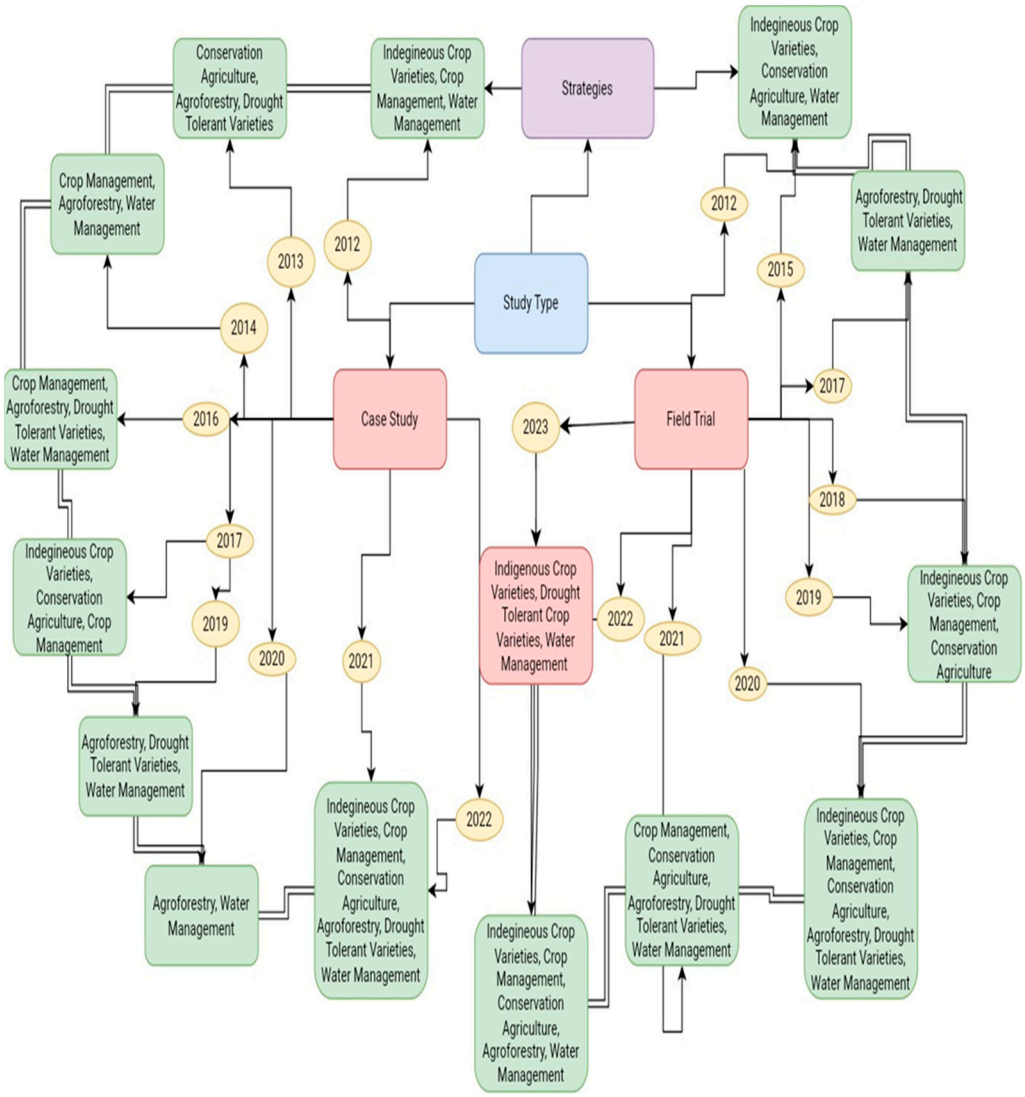

Figure 2. Agroecology strategies utilised by smallholder crop farmers in South Africa.

Agroecology is a holistic approach that combines ecological and social perspectives to create sustainable and equitable food systems. It aims to optimise the interactions between plants, animals, humans, and the environment, while addressing the social dimensions that are essential for a fair and sustainable food system.

It is a bottom-up approach that emphasises local, place-based solutions to address specific problems. It draws on the knowledge and experience of farmers and communities, combining this practical and traditional knowledge with scientific research. This co-creation of knowledge empowers farmers and communities to be key agents of change, enhancing their autonomy and ability to adapt to changing conditions. In this way, agroecology fosters resilience, sustainability, and social and economic justice.

While conventional agricultural practices often focus on fixing specific problems within an unsustainable system, agroecology aims to transform the system as a whole. It takes a holistic approach, addressing root causes and providing long-term solutions that address the social, economic, and environmental dimensions of food systems. This includes recognising and promoting the rights of marginalised groups, such as women, youth, and indigenous peoples. Ultimately, agroecology seeks to create more just sustainable, and resilient food systems.

Table 1 provides a comprehensive overview of the agroecology strategies employed by smallholder crop farmers in South Africa, based on the selected studies. It presents a breakdown of the strategies studied in each research article, allowing us to observe the prevalence and combination of different approaches.

Table 1. Agroecology strategies utilized by smallholder crop farmers in South Africa.

Study	
Study 1	Indigenous crop varieties, intercropping, water management
Study 2	Conservation agriculture, agroforestry, drought-tolerant crop varieties
Study 3	Intercropping, water management, agroforestry
Study 4	Conservation agriculture, indigenous crop varieties, water management
Study 5	Drought-tolerant crop varieties, agroforestry, water management
Study 6	Indigenous crop varieties, conservation agriculture, intercropping
Study 7	Agroforestry, water management, drought-tolerant crop varieties
Study 8	Conservation agriculture, intercropping, indigenous crop varieties
Study 9	Water management, agroforestry, drought-tolerant crop varieties
Study 10	Intercropping, indigenous crop varieties, conservation agriculture
Study 11	Drought-tolerant crop varieties, water management, agroforestry
Study 12	Conservation agriculture, intercropping, drought-tolerant crop varieties
Study 13	Indigenous crop varieties, water management, agroforestry
Study 14	Intercropping, agroforestry, conservation agriculture
Study 15	Drought-tolerant crop varieties, water management, indigenous crop varieties
Study 16	Planting of improved seed, application of chemical fertilizer, changing planting date, application of pesticide/herbicides, mixed cropping, nulching, rainwater harvesting, irrigation, planting of trees
Study 17	Alterations to soil and crop management, crop rotations, and water conservation techniques.
Study 18	Drought-tolerant seeds, shorter cycle crops, diversification of crops, changing planting dates, small-scale irrigation
Study 19	Planting early-maturing plants and drought-tolerant crops, altering planting dates, crop diversification, and irrigating
Study 20	Early maturing variety, soil and water conservation, tree planting, migration, varying planting dates, mulching, improved variety
Study 21	Water harvesting, change of crop variety, soil conservation, improved soil fertility, crop diversification and changing of crop type
Study 22	Improved crop varieties, varying planting dates, soil and water conservation, tree planting
Study 23	Soil and water management
Study 24	Changing crop types, planting schedule and crop rotation, water management and zero tillage
Study 25	Changing planting dates, planted drought resistant or short season crops, soil conservation, diversification, planting trees and irrigation
Study 26	Drought tolerant varieties, shifting planting dates, irrigation, conservation agriculture
Study 27	Drought resistant crops, changing planting dates, planting crop varieties, mixed cropping, conservation agriculture, adjusting fertilise inputs, irrigation systems, rain harvesting and drilling boreholes
Study 28	Planting drought tolerant variety and changing of planting time
Study 29	Shifting planting dates, reduced cultivated area, drought-resistant varieties, crop diversification, and intercropping
Study 30	Changing fertilizer, water harvesting and planting drought resistant varieties

Table 2 shows the presence or absence of specific agroecology strategies in each study. It reveals that the selected studies encompass a range of strategies, including the use of indigenous crop varieties, conservation agriculture practices, intercropping, agroforestry, drought-tolerant crop varieties, and water management techniques. This indicates that smallholder farmers in South Africa are employing diverse approaches to adapt to the impacts of climate change on their crop production.

Table 2. The presence or absence of specific agroecology strategies in each study.

Study	Indigenous Crop Varieties	Conservation Agriculture	Intercropping	Agroforestry	Drought-Tolerant Crop Varieties	Water Management
1	Yes	No	Yes	No	No	Yes
2	No	Yes	No	Yes	Yes	No
3	No	No	Yes	Yes	No	Yes
4	Yes	Yes	No	No	No	Yes
5	No	No	No	Yes	Yes	Yes
6	Yes	Yes	Yes	No	No	No
7	No	No	No	Yes	Yes	Yes
8	Yes	Yes	Yes	No	No	No
9	No	No	No	Yes	Yes	Yes
10	Yes	Yes	Yes	No	No	No
11	No	No	No	Yes	Yes	Yes
12	No	Yes	Yes	No	Yes	No
13	Yes	No	No	Yes	No	Yes
14	No	Yes	Yes	Yes	No	No
15	Yes	No	No	No	Yes	Yes
16	No	No	Yes	Yes	No	Yes
17	No	Yes	Yes	No	No	Yes
18	Yes	Yes	No	No	Yes	Yes
19	Yes	No	Yes	No	Yes	Yes
20	No	Yes	No	Yes	No	Yes
21	No	Yes	Yes	No	No	Yes
22	No	Yes	Yes	Yes	No	Yes
23	Yes	Yes	No	No	No	Yes
24	Yes	Yes	Yes	No	Yes	Yes
25	No	Yes	Yes	Yes	Yes	Yes
26	No	Yes	Yes	No	Yes	Yes
27	No	Yes	Yes	No	Yes	Yes
28	No	No	Yes	No	Yes	No
29	No	Yes	Yes	No	No	No
30	No	No	Yes	No	Yes	Yes

Table 3 highlights the reported benefits of these agroecology strategies. The findings indicate that many of these strategies contribute positively to agricultural outcomes. Increased crop resilience, improved soil fertility, and enhanced water use efficiency are among the benefits observed in various studies. These findings suggest that the adoption of agroecology practices can potentially improve the livelihoods of smallholder farmers by increasing their agricultural productivity and sustainability.

Figure 3 illustrates the benefits of agroecology strategies for smallholder farmers in South Africa. A review of the literature found that water use efficiency was the most frequently reported benefit of agroecology strategies, followed by soil fertility benefits and

increased crop resilience. This suggests that agroecology practices may have the greatest impact on water use efficiency in the short term, while other benefits such as increased crop resilience may take longer to be realised.

Table 3. Benefits of Agroecology strategies utilised by smallholder crop farmers in South Africa.

Study	Increased Crop Resilience	Improved Soil Fertility	Enhance Water Use Efficiency
1	Yes	Yes	Yes
2	No	Yes	Yes
3	Yes	No	Yes
4	Yes	Yes	Yes
5	No	No	Yes
6	Yes	Yes	No
7	No	Yes	Yes
8	Yes	Yes	No
9	No	Yes	Yes
10	Yes	No	Yes
11	No	No	Yes
12	Yes	Yes	No
13	Yes	No	Yes
14	No	Yes	No
15	No	Yes	Yes
16	Yes	Yes	Yes
17	Yes	Yes	No
18	Yes	Yes	Yes
19	No	No	Yes
20	No	Yes	Yes
21	Yes	Yes	Yes
22	Yes	No	Yes
23	No	Yes	Yes
24	Yes	No	Yes
25	Yes	No	No
26	No	No	Yes
27	Yes	No	Yes
28	No	Yes	No
29	Yes	Yes	No
30	No	Yes	Yes

Table 4 provides insights into the characteristics of the selected studies. It includes information such as the year of the study, study design, and sample size. This information helps to contextualise the findings and provides a basis for assessing the reliability and generalisability of the results. The studies span 10 years different years, indicating that research on agroecology strategies in South Africa. The inclusion of diverse study designs, such as field trials and case studies, indicates a comprehensive approach to understanding the effectiveness of these strategies. Diverse study designs are critical to ensuring that a research project is robust and comprehensive. A single study design may not be able to fully capture the nuances of a complex issue. By including a range of study designs, the researchers can obtain a more holistic view of the issue and understand how different strategies work in different settings. The variation in sample sizes reflects the different

scales at which the studies were conducted, ranging from small-scale investigations to larger-scale assessments.

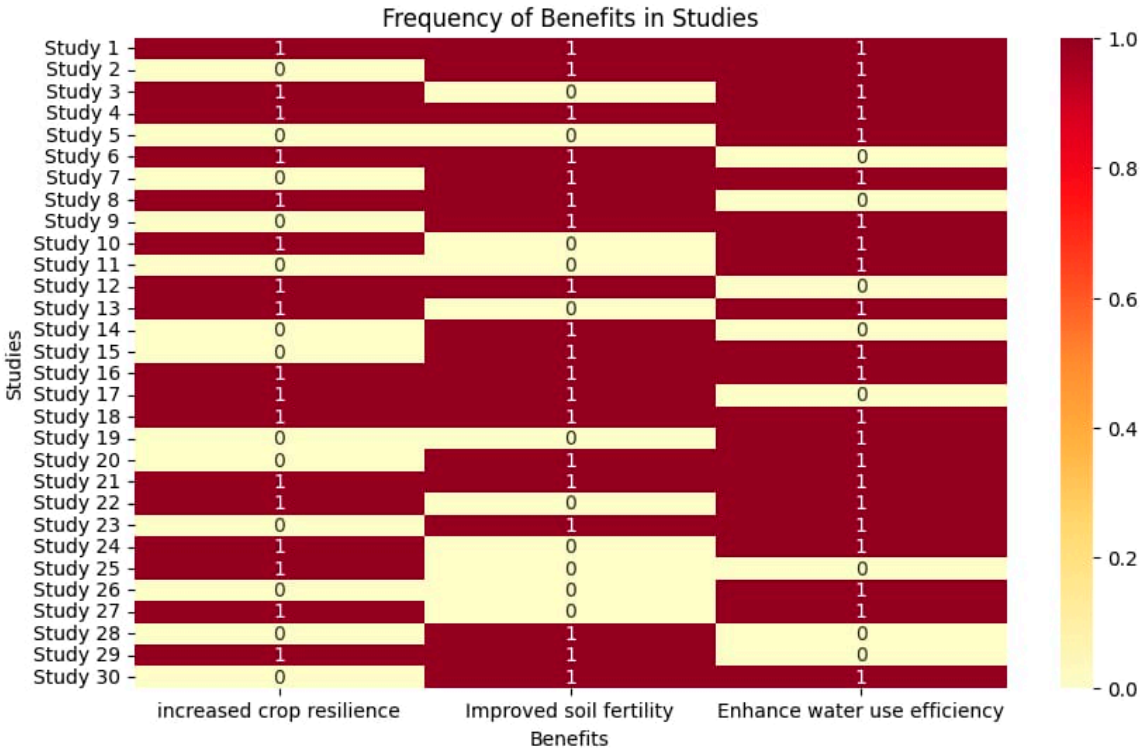

Figure 3. Heat map of benefits of agroecology strategies utilisation by smallholder crop farmers in South Africa.

Table 4. Study characteristics of selected studies.

Study	Year	Study Design	Sample Size
1	2012	Case study	20
2	2013	Case study	30
3	2014	Case study	25
4	2015	Field trial	100
5	2016	Case study	35
6	2017	Case study	22
7	2017	Field trial	50
8	2018	Field trial	60
9	2019	Case study	28
10	2019	Field trial	80
11	2020	Field trial	70
12	2021	Field trial	90
13	2022	Field Trial	45
14	2022	Case study	22
15	2023	Field trial	90
16	2021	Field trial	16

Table 4. *Cont.*

Study	Year	Study Design	Sample Size
17	2021	Field Trial	120
18	2020	Field trial	224
19	2022	Case study	200
20	2020	Case study	183
21	2020	Field trial	391
22	2022	Case study	183
23	2012	Field	300
24	2021	Case study	90
25	2021	Case study	328
26	2021	Field	160
27	2022	Case study	18
28	2016	Case study	70
29	2021	Field	200
30	2021	Case study	235

4. Discussion

The review findings suggest that agroecology strategies have the potential to enhance the adaptive capacity of smallholder crop farmers in South Africa. However, the adoption and scaling-up of these practices face several challenges, including economic challenges faced by smallholder farmers, social and cultural factors, and institutional barriers.

One of the key reasons for the limited adoption of agroecology strategies is the economic challenges faced by smallholder farmers. Agroecology often requires initial investments in sustainable farming practices, such as organic inputs, crop diversification, and agroforestry. These initial investments may pose financial barriers for small-scale farmers who may lack access to credit or financial resources. Additionally, the transition to agroecology may involve a period of adjustment and lower yields during the initial phases, which can be financially challenging for farmers who rely on their agricultural production for their livelihoods.

Social and cultural factors also play a significant role in the adoption of agroecology strategies. Traditional farming practices and knowledge systems may be deeply ingrained in farming communities, making it challenging for farmers to transition to new and unfamiliar agroecological methods. Moreover, social norms and perceptions within farming communities may influence the willingness of farmers to adopt new practices, particularly if there is a lack of awareness or understanding of the potential benefits of agroecology.

Institutional barriers, such as limited access to extension services, technical support, and market opportunities for agroecological products, also contribute to the low adoption of agroecology strategies among farmers in South Africa. The lack of supportive policies and incentives for agroecological practices may further hinder farmers from transitioning to sustainable farming methods.

Additionally, the socio-economic context and local agroecological conditions influence the effectiveness of these strategies. The socio-economic context and local agroecological conditions can have a significant impact on the effectiveness of adaptation strategies. For example, in some communities, traditional agricultural practices, such as subsistence farming, may not be compatible with the types of adaptation strategies that are being promoted by outside organisations. One major challenge related to the socio-economic context is the high level of poverty among smallholder farmers in South Africa. Many farmers lack the financial resources to invest in agroecological practices, such as organic fertilisers or drought-tolerant crops. In addition, farmers may not have access to the

information or training needed to successfully adopt agroecology strategies. Furthermore, farmers may be reluctant to adopt new practices if they believe they will be less productive or profitable than their current practices.

It is important to note that these challenges are not static, and that they can change over time. For example, climate change is expected to have a significant impact on the agroecological conditions in South Africa, with hotter and drier conditions predicted in the future. This could lead to additional challenges for farmers, such as increased water stress and the need for new crop varieties that are adapted to changing conditions. As such, it is important to regularly assess the local agroecological conditions and the broader context in which farmers are operating when developing adaptation strategies to climate change. The review emphasises the need for tailored approaches, capacity building, supportive policies, and multi-stakeholder engagement to promote the widespread adoption of agroecology practices among smallholder farmers.

There are various agroecology strategies that are being utilised by smallholder crop farmers in South Africa such as the use of indigenous crop varieties, conservation agriculture, intercropping, agroforestry, planting drought-tolerant crop varieties and water management strategies. These strategies will be explained in the following paragraphs.

Indigenous crop varieties are often well-adapted to the local climate and environmental conditions, making them a valuable resource for building resilience to climate change. For example, many indigenous crops are drought-resistant, can withstand high temperatures, and are able to tolerate poor soils. They may also have other beneficial traits, such as disease resistance, high nutrient content, or resistance to pests. By using indigenous crop varieties, farmers can maintain yields even in the face of climate change.

Conservation agriculture is a farming system that relies on practices such as minimal soil disturbance, crop rotation, and the use of cover crops. It is a particularly effective adaptation strategy for climate change since it helps to improve soil health and fertility, enhance water retention, and reduce the risk of soil erosion. By implementing these practices, farmers can increase the resilience of their crops and maintain productivity even in the face of extreme weather events such as droughts or floods. It also has the added benefits of improving water quality, biodiversity, and carbon sequestration.

Intercropping is another agroecological practice that can help farmers adapt to climate change. It involves planting two or more crops together in the same area, rather than growing them separately. This can help to improve soil health, increase yields, and diversify farm income. It also has the benefit of reducing the impact of pests and diseases, since different crops have different susceptibilities to pests and diseases. Additionally, intercropping can help to reduce the need for inputs such as fertilizer and water.

Agroforestry is a practice that combines agriculture and forestry to create productive, diverse, and sustainable land-use systems. It is a particularly effective adaptation strategy for climate change since it can help to improve soil health, increase biodiversity, and provide shade and wind protection for crops. It can also reduce soil erosion and improve water quality. Additionally, agroforestry can help to mitigate climate change by sequestering carbon.

Planting drought-tolerant crop varieties is another effective adaptation strategy for climate change. Drought-tolerant crops are able to withstand periods of low water availability, which is becoming more common due to climate change. They can maintain their productivity even when there is less rainfall, making them a valuable tool for farmers. Some examples of drought-tolerant crops include sorghum, millet, and cowpeas.

Water management strategies are crucial for adapting to climate change, especially in regions where water is already scarce. These strategies can include rainwater harvesting, the use of efficient irrigation techniques, and the use of mulch to reduce water evaporation. Additionally, it is important to conserve water resources by reducing water loss through leakage and evaporation and promoting water-saving behaviors among farmers.

5. Conclusions

This systematic review highlights the importance of agroecology strategies in enabling smallholder crop farmers in South Africa to adapt to the impact of climate change on their livelihoods. The findings underscore the potential benefits of agroecology practices in enhancing resilience, promoting sustainable agriculture, and improving smallholder farmers' well-being. However, addressing the challenges associated with adoption and scaling-up is crucial. Policymakers, researchers, and practitioners need to collaborate to develop context-specific strategies, provide necessary resources, and create an enabling environment for the widespread adoption of agroecology practices among smallholder crop farmers in South Africa. Future studies should conduct a meta-analysis of existing studies on the topic, synthesizing the results of multiple studies to identify the most effective agroecological strategies for adapting to climate change.

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