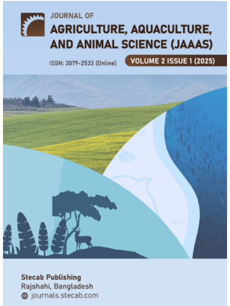

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Research Article

Impact of Sustainable Agricultural Practices on Farm Productivity, Yield, and Climate Resilience Among Smallholder Farmers in Zambia

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About Article

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ABSTRACT

This study investigated the impact of sustainable agricultural practices on farm productivity, crop yield, and climate resilience among smallholder farmers across Zambia. A mixed-methods approach, combining qualitative and quantitative data collection methods was used to collect responses from 244 farmers. To ensure a diverse representation across different types of farming and regions, stratified random sampling was used. Key findings reveal that the majority of farmers (75%) adopted conservation agriculture, including practices like minimum soil disturbance, crop rotation, and permanent soil cover, which significantly enhanced soil health, water retention, and resilience to climate variability. A notable 53% of farmers also engaged in soil fertility management practices, such as composting and green manure, further contributing to increased yields and long-term productivity. In terms of farm size, 44% of farmers managed small plots (1-5 hectares), with the majority (51%) practicing mixed farming. This diversification of crops and livestock contributed to increased climate resilience. The study also highlighted the role of education, with 38.5% of respondents holding tertiary qualifications, which enabled the adoption of innovative, climate-smart practices. These findings highlight the importance of sustainable agricultural practices in boosting productivity, enhancing farm resilience, and mitigating climate change effects, particularly for smallholder farmers in Zambia.

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1. INTRODUCTION

Agriculture serves as the spine of Zambia's economy, contributing about 20% to the country's Gross Domestic Product (GDP), and providing employment opportunities for over 70% of the rural population. In addition, the sector is critical in enhancing food security and livelihoods (Zambia Development Agency, 2024; World Bank, 2012). However, the agricultural sector in Zambia is predominantly smallholder-based, with an estimated 1.6 million smallholder farmers who rely heavily on rain-fed farming (Farm to Mark*et* Alliance, 2022).

Smallholder farmers are critical to Zambia`s food security, producing about 80% of the country`s staple foods, such as maize, cassava, and millet (FAO, 2021). Despite its importance, the agricultural sector faces significant challenges, including low soil fertility, limited access to improved agricultural inputs, and vulnerability to climate change effects such as erratic rainfall and prolonged droughts. In order to address these challenges, the adoption of sustainable agricultural practices has become critical for enhancing farm productivity, improving crop yields, and building climate resilience among smallholder farmers.

Sustainable agricultural practices such as conservation agriculture, organic soil fertility management, agroforestry, and climate-smart agriculture have gained prominence in Zambia and the broader Southern African region. These practices are rooted in principles of soil health restoration, biodiversity conservation, and efficient resource use, aligning with global calls for sustainable development and climate change mitigation (Lal *et al.*, 2023; FAO, 2021). By fostering ecological balance and enhancing adaptive capacities, SAPs contribute to long-term agricultural sustainability and socio-economic resilience (FAO, 2018; Lal, 2015).

Despite their potential, the adoption of SAPs among Zambian farmers remains uneven due to various socio-economic, cultural, and institutional factors (Andersson & D'Souza, 2014; Manda *et al.*, 2016). Understanding the factors influencing adoption, as well as the impacts of these practices on farm productivity and resilience, is essential for designing effective interventions and policies.

This study explores the role of sustainable agricultural practices in improving farm productivity, yield, and climate resilience in Zambia. By drawing on existing literature and recent empirical findings, the research aims to provide insights into how SAPs can address the challenges of agricultural sustainability in Zambia while contributing to national and global climate goals.

2. LITERATURE REVIEW

Climate change is one of the most pressing global challenges, with significant implications for agriculture, particularly in regions highly dependent on rain-fed farming, such as Southern Africa. Zambia, like many countries in the region, has witnessed increasingly erratic weather patterns, including prolonged droughts, unpredictable rainfall patterns, and extreme weather events such as floods and droughts in selected areas (Alubi *et al.*, 2024). These changes in climate are posing severe threats to agricultural productivity, food security, and rural livelihoods, especially in areas dominated by smallholder farmers who rely heavily on rain-fed farming, making them particularly vulnerable to climate variability and change (IPCC, 2014; Thornton & Cramer, 2012).

The increasing frequency and intensity of extreme weather events have led to reduced crop yields, livestock losses, and deteriorating soil health, further exacerbating food insecurity and poverty levels in the country (Chomba *et al.*, 2016). Sustainable agricultural practices such as conservation agriculture, agroforestry, and organic farming are increasingly recognized as vital strategies for mitigating the impacts of climate change and enhancing the resilience of agricultural systems (Lal *et al.*, 2023; FAO, 2021).

2.1. Concept of conservation agriculture

Conservation agriculture is a sustainable farming approach that integrates principles of minimal soil disturbance, crop rotation, permanent soil cover, and improved soil fertility practices, offering multiple environmental and agricultural benefits (Muyabe *et al.*, 2024). By reducing soil disturbance, practices like zero tillage and minimum tillage farming help preserve the natural structure of the soil, allowing for better water infiltration and retention, which is particularly beneficial in areas prone to droughts. The practice of crop rotation diversifies the types of crops cultivated, which helps break pest and disease cycles, improves nutrient availability in the soil, and enhances overall farm biodiversity. By maintaining permanent soil cover, such as through crop residues or cover crops, conservation agriculture protects the soil from wind and water erosion, reduces moisture evaporation, sequester carbon and fosters a thriving ecosystem of beneficial organisms that contribute to soil fertility, resulting in higher productivity even under variable climatic conditions (Manda *et al.*, 2016).

2.2. Agroforest technique

Other than conservation farming, agroforest if another sustainable agricultural practice widely used by farmers globally. Agroforestry is a land-use system, which integrates trees with crops and livestock. One essential advantage of agroforest is its ability to enhance biodiversity by creating habitats for various plant and animal species, which in turn supports ecosystem services like pollination and natural pest control. Additionally, the presence of trees in agricultural landscapes contributes to improved soil fertility by fixing nitrogen, cycling nutrients from deeper soil layers, and increasing organic matter through leaf litter decomposition (Kiptot *et al.*, 2014). Trees also help in reducing soil erosion by stabilizing the soil with their roots and reducing the impact of raindrops on bare surfaces, ensuring better soil conservation (Giller *et al.*, 2009). Furthermore, agroforestry plays a significant role in carbon sequestration, as trees act as carbon sinks, absorbing CO_2 from the atmosphere and mitigating climate change effects (Quandt *et al.*, 2023). By combining these benefits, agroforestry enhances farm resilience to extreme weather events like droughts and floods, making it a valuable tool for climate-smart agriculture and sustainable land management (FAO, 2016).

2.3. Organic farming practices

Organic farming, which emphasizes the reduction of synthetic inputs is a sustainable agricultural practice, which promotes ecological balance, enhances biodiversity, and is a cornerstone of sustainable land management (FAO, 2016). In Zambia, smallholder farmers adopting organic soil fertility practices, such as composting and using animal manure, have reported notable improvements in soil health and agricultural productivity. A study by Chikopela *et al.* (2024) highlighted that these practices improve soil structure, enhance water retention, and reduce soil erosion, thereby contributing to higher crop yields and more resilient farming systems. Despite these benefits, however, the adoption of organic farming practices among smallholder farmers remains limited due to systemic barriers, including insufficient access to training, reliable markets, and financial support, which disproportionately affect resource-poor farmers (Giller *et al.*, 2009). In addition, the outcomes of adopting organic practices are not the same for all farmers, as factors such as resource availability, land tenure security, and farmers` willingness to embrace new methods significantly influence their effectiveness. Moyo and Mapfumo (2023) stressed that without tailored interventions to address these disparities, the potential of organic farming to sustainably transform smallholder agriculture in Zambia will remain underutilized.

While the literature highlights the positive impacts of sustainable agricultural practices on farm productivity and yield, several gaps still remain to be explored with the adoption. For example, the majority of existing studies focus on specific individual sustainable agricultural practices, such as conservation agriculture or agroforestry, without exploring the combined impact of these practices on farm productivity, yield and climate resilience. In addition, the adoption of sustainable agricultural practices among Zambian farmers still remains uneven.

3. METHODOLOGY

3.1. Study area – Zambia

Zambia is a land linked country in Southern Africa, with a total land area of approximately 75 million hectares (Ministry of Agriculture, 2024; Zambia Development Agency, 2024).

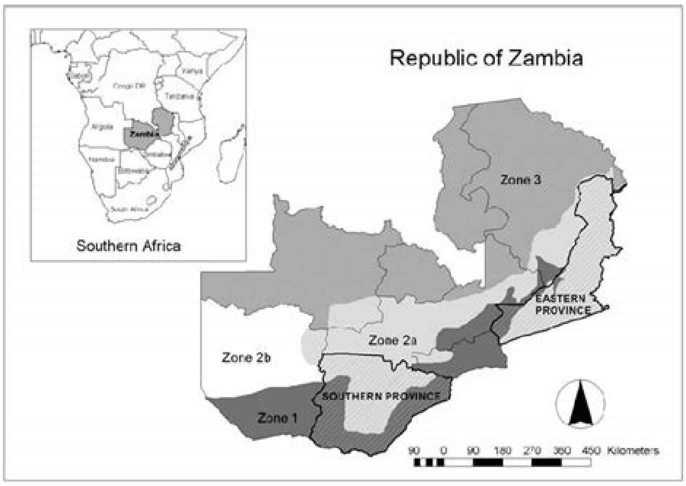

Figure 1. Map of Zambia
(Source: Mtambo et al., 2007)

The country is bordered by eight nations and has a population of around 21.1 million people (United Nations Population Fund, 2024; Zambia Development Agency, 2024), with Lusaka as the capital city (Figure 1). Zambia's climate is tropical, with three main seasons: a rainy season from November to April, a cool dry season from May to August, and a hot dry season from September to October.

The country experiences varying rainfall patterns, with the northern regions receiving an average of 1,000 to 1,500 millimeters of rain annually, while the southern regions, which are more prone to droughts, receive 600 to 800 millimeters (FAO, 2021). The mean annual temperature in Zambia varies from 18°C to 24°C, with hotter temperatures recorded in the lowlands and cooler conditions in the highland areas (ZMD, 2019). Zambia has about 42 million hectares of arable land, of which only about 15% is currently cultivated (Ministry of Agriculture, 2024).

3.2. Methods

The study used a mixed-methods approach, combining quantitative and qualitative data collection methods. The primary data collection tool was a structured questionnaire administered to farmers. The questionnaire consisted of both closed-ended and open-ended questions. The target population consisted of smallholder and medium-scale farmers across various regions in Zambia. Stratified random sampling was used to ensure representation across different age groups, gender mix, farming experience, level of educational attainment, types of farming practices, and farm sizes. The sample size was determined using statistical formulas to ensure representativeness and reliability of the data. A sample of approximately 300 farmers was targeted to provide a robust dataset for analysis. However, only 244 responses were received. Data analysis was done using Microsoft excel.

4. RESULTS AND DISCUSSION

Table 1. Age groups of the respondents

Age bracket	Frequency	Percentage
< 20	8	3.3
20 - 30	23	9.4
31 - 40	121	49.6
41 - 50	64	26.2
> 50	28	11.5
Total	**244**	**100**

Source: Field data

4.1. Demographic profile of respondents

The demographic profile of participants in this study reveals some important insights regarding age, gender, education, and farming experience.

As shown in the table above (Table 1), the majority of the respondents (49.6%) were aged between 31 and 40 years, suggesting that in Zambia, sustainable agricultural practices are mainly adopted by middle-aged farmers. These findings on age distribution are consistent with those from other studies across southern Africa, where middle-aged farmers tend to be more active in agricultural innovation and climate-smart practices.

For example, a study conducted in Zimbabwe by Mujeyi *et al.* (2021) also established that farmers aged between 30 and 45 were the most engaged age group in sustainable farming practices, probably because of their relatively higher levels of experience and access to resources.

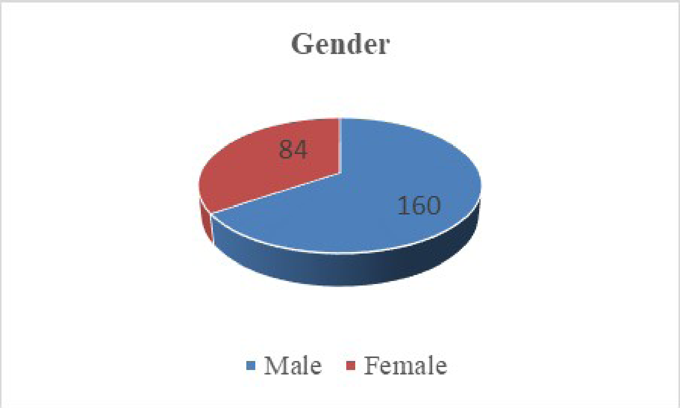

Figure 2. Gender distribution
Source: Field data

The gender distribution shows a male dominance, with 65.6% of respondents being male, compared to 34.4% female (Figure 2). This gender gap reflects patterns seen in other regions of southern Africa, where men tend to have greater access to land, resources, and decision-making power in agriculture. Research conducted by Nchanji *et al.* (2022) in Malawi showed similar gender disparities, with males having more control over farming operations and, therefore, being more likely to adopt new farming techniques. Nevertheless, others studies also suggest that women, though fewer in number, play critical roles in small-scale farming and are key actors in promoting sustainable practices at the household level, as demonstrated by Singh (2014).

Table 2. Farming experience of the respondents

Years of active farming	Frequency	Percentage
<5	13	5.3
5 - 10	58	23.8
11 - 20	77	31.6
21 - 30	90	36.9
> 30	6	2.5
Total	**244**	**100**

Source: Field data

In relation to farming experience of the respondents, the study established significant variations, with 36.9% of farmers having 21 - 30 years of experience (Table 2). This long-term engagement in farming suggests that experienced farmers are more likely to adopt sustainable agricultural practices, as they have witnessed the adverse effects of climate variability on conventional farming. This aligns with findings from Kenya, where Marenya and Barrett (2007) observed that farmers with extensive experience were more inclined to implement sustainable techniques like agroforestry and soil conservation measures due to their deeper understanding of land degradation risks and benefits of long-term strategies.

Table 3. Respondents' level of educational attainment

Level of Education	Frequency	Percentage
No formal education	15	6.1
Primary education	59	24.2
Secondary Education	76	31.1
Tertiary education (College/University)	94	38.5
Total	**244**	**100**

Source: Field data

In terms of educational attainment, 38.5% of the respondents had attained tertiary level of education, and 31.1% had completed secondary education, with only 6% having no formal education (Table 3). The relatively high level of educational attainment among respondents is notable, as previous studies (Manda *et al.*, 2016) have shown that education plays a critical role in the adoption of sustainable agricultural practices. Farmers with higher education levels are often better equipped to understand and implement climate-smart technologies and practices. A study in South Africa found that educated farmers were more likely to use modern irrigation techniques and crop rotation to adapt to climate change (Moyo & Mapfumo, 2023). However, the relatively high level of tertiary education among Zambian farmers in this study contrasts with findings from other regions, such as rural Tanzania, where a majority of farmers had not completed secondary education (Manda *et al.*, 2016). This higher educational attainment may provide Zambian farmers with a unique advantage in adopting sustainable farming methods to combat climate change.

4.2. Farm sizes of the respondents

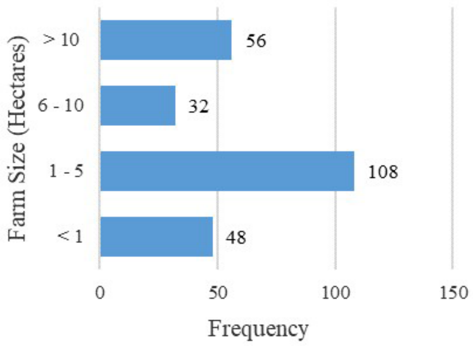

Figure 3. Farm size
Source: Field data

Results on the farm sizes (Figure 3) indicate that the majority of participants in the survey were smallholder farmers, with 108 (44%) farming on plots ranging from 1 to 5 hectares and only (32) 23% farming on land exceeding 10 hectares. This trend of smaller farm sizes is consistent with the broader agricultural landscape in Zambia and much of southern Africa, where smallholder farming dominates. Small-scale farmers play a crucial role in food production and are often the primary adopters of sustainable agricultural practices due to their vulnerability to climate change. These findings align with research conducted by Makate *et al.* (2019), which revealed that smallholder farmers, particularly those with less than 5 hectares of land, are more likely to adopt sustainable agricultural practices such as agroforestry, conservation tillage, and crop rotation. Their limited access to resources, coupled with the high climate variability in southern Africa, compels them to embrace sustainable methods to enhance productivity and climate resilience. A similar study conducted in Malawi by Ngwira *et al.* (2013) also found that smallholder farmers, who typically own less than 2 hectares of land, are more engaged in sustainable agricultural practices as a strategy to cope with erratic rainfall patterns and soil degradation. In contrast, farmers with larger plots often have better access to capital, technology, and resources, allowing them to implement advanced irrigation systems or purchase high-yield seeds without necessarily adopting more sustainable or climate-resilient methods.

The observation that only 23% of the participants in Zambia farmed on land greater than 10 hectares underscores the prevailing structure of land ownership in the region. Research by Hamazakaza *et al.* (2022) shows that landholding patterns in southern Africa remain highly skewed, with the majority of rural households having limited access to large tracts of land. This reflects broader historical and socio-economic challenges affecting land tenure and agricultural productivity in southern Africa.

The dominance of smallholder farmers in Zambia has significant implications for sustainable agricultural practices. Small farms are more likely to adopt low-input, climate-smart practices that prioritize soil health, water conservation, and biodiversity. As Belmin *et al.* (2023) argue, smallholder farming systems are typically more flexible and adaptable, making them key players in the transition to climate-resilient agriculture. However, these farmers often face challenges such as limited access to finance, technology, and extension services, which can hinder their ability to fully benefit from sustainable practices. In comparison to larger farms, smallholders may also face greater constraints in scaling up sustainable techniques.

Studies from South Africa, such as those by Makate *et al.* (2019), highlight that while smallholder farmers are more likely to experiment with sustainable practices, larger farms often benefit from economies of scale, allowing them to implement more sophisticated climate adaptation strategies. Therefore, targeted interventions, including subsidies, training, and access to credit, are essential to help smallholder farmers maximize the benefits of sustainable agriculture.

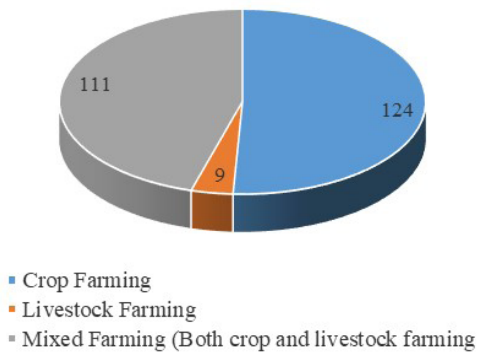

Figure 4. Type of farming systems
Source: Field data

4.3. Farming systems implemented by farmers

Results of the study indicate that the most common farming systems among the respondents were mixed farming (51%) and crop farming (45%). Only 3.7% of the respondents exclusively practiced livestock farming (Figure 4). This dominance of mixed farming systems reflects the broader agricultural landscape in Zambia and southern Africa, where diversified farming approaches are often used to mitigate risks related to climate variability. Mixed farming, combining both crop and livestock production, is widely regarded as a resilient system that allows farmers to diversify income sources, manage natural resources more effectively, and improve food security. The prevalence of mixed farming in this study aligns with findings from similar research across southern Africa. For example, Belmin *et al.* (2021) emphasize that mixed farming systems are more resilient to climate change impacts due to their capacity to integrate various sustainable agricultural practices such as crop rotation, agroforestry, and manure recycling.

The combination of crop and livestock production provides farmers with multiple pathways to buffer against crop failure or livestock loss during adverse climatic events. A study in Malawi by Ngwira *et al.* (2013) also found that mixed farming was a key strategy for smallholder farmers to improve soil fertility, enhance biodiversity, and manage the risks associated with climate change.

In contrast, crop farming, which accounted for 45% of the respondents in this study, is generally more vulnerable to climate change impacts, particularly in regions where rainfall patterns are highly unpredictable. According to Makate *et al.* (2019), crop-based farming systems, especially mono-cropping, are less resilient to extreme weather events such as droughts and floods. As a result, crop farmers in southern Africa have increasingly adopted sustainable practices such as conservation agriculture, intercropping, and the use of drought-resistant crop varieties to enhance resilience. However, the limited flexibility of crop-only farming systems makes them more susceptible to income losses in the face of climate variability.

The fact that only 3.7% of respondents exclusively practiced livestock farming highlights the relatively low prominence of livestock production in the country. This may be due to various factors, including limited access to pastureland, water, and veterinary services, which can hinder livestock farming. However, in other parts of southern Africa, such as Botswana and Namibia, livestock farming plays a more central role in rural livelihoods, especially in arid and semi-arid regions where crop farming is less viable. Studies by Mutengwa *et al.* (2023) in Southern Africa have shown that livestock farmers are increasingly adopting climate-smart practices such as rotational grazing, silvopastoral systems, and improved animal breeding to cope with the changing climate.

The predominance of mixed farming systems among respondents suggests that Zambian farmers are already employing diversification strategies that enhance sustainability and resilience. Mixed farming allows for the efficient use of natural resources, such as the recycling of livestock manure to improve soil fertility in crop production, and provides multiple streams of income.

This system is well-suited to combatting the impacts of climate change in southern Africa, as it helps farmers adapt to variability in rainfall and temperature. Furthermore, mixed farming systems are conducive to the integration of other sustainable practices, such as agroecology and organic farming, which promote ecosystem services and reduce the reliance on external inputs like synthetic fertilizers and pesticides.

However, the significant proportion of farmers engaged in crop-only farming indicates the need for targeted interventions to promote more sustainable farming practices within this group. Crop farmers may benefit from training on climate-smart agriculture, including the adoption of conservation agriculture techniques, such as minimum tillage, crop rotation, and cover cropping, which have been shown to improve soil health and water retention.

4.4. Types of sustainable agricultural practices implemented by farmers

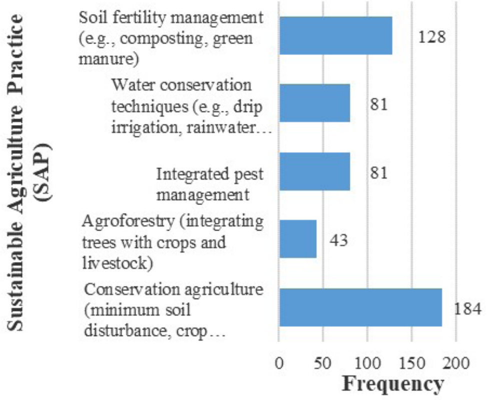

Figure 5. Sustainable agriculture practice being used by farmers
Source: Field data

Findings on the types of sustainable agricultural practices currently being implemented in Zambia (Figure 4) show that the majority of farmers (75%) are adopting conservation agriculture techniques, which include practices such as minimum soil disturbance, crop rotation, and permanent soil cover. Soil fertility management practices, such as composting and the use of green manure, were also widely adopted, with 53% of respondents practicing them. Notably, agroforestry was adopted by only 18% of the respondents, indicating a lower uptake of this particular sustainable agricultural practice compared to others.

The widespread adoption of conservation agriculture in this study aligns with other research findings from southern Africa, where conservation agriculture has been increasingly promoted as a key strategy for enhancing agricultural sustainability and resilience to climate change. For example, a study by Mazvimavi and Twomlow (2020) in Zimbabwe also found that the adoption of conservation agriculture was relatively high, with over 70% of smallholder farmers adopting practices such as minimum tillage and crop rotation. Generally, conservation agriculture is widely recognized for its ability to improve soil health, increase water retention, and reduce vulnerability to extreme weather events, such as droughts and floods, making it an attractive option for farmers in climate-sensitive regions.

Similarly, FAO (2021) has reported that conservation agriculture contributes to sustainable land management by reducing soil erosion and improving soil organic matter. The high percentage of farmers practicing conservation agriculture in Zambia, as indicated by this study, is consistent with the broader trend across southern Africa, where it is promoted by governments and NGOs as part of climate-smart agriculture (CSA) initiatives. These findings suggest that Zambian farmers are actively integrating climate-adaptive strategies into their farming systems to enhance resilience.

Soil fertility management, practiced by 53% of respondents, is another key element of sustainable agriculture. The use of composting, green manure, and organic fertilizers is crucial for maintaining soil health and boosting crop productivity. A more recent study conducted in Zambia by Chikopela *et al.* (2024) similarly found that smallholder farmers adopted organic soil fertility practices, including composting and green manure, to improve soil structure and nutrient content. These practices not only enhance soil health but also reduce reliance on chemical inputs, thereby promoting the sustainability of farming systems.

The lower adoption rate of agroforestry (18%) in this study highlights a gap in the widespread implementation of this sustainable practice in Zambia. Agroforestry, which involves integrating trees with crops or livestock, has been identified as a critical strategy for combating climate change by enhancing carbon sequestration, improving biodiversity, and providing shade and shelter for crops and animals. Studies in other parts of southern Africa Sheppard *et al.* (2020), have reported higher agroforestry adoption rates, with nearly 30% of farmers practicing some form of tree-based farming. The relatively lower adoption rate in Zambia might be attributed to limited awareness, training, or access to agroforestry resources.

Agroforestry has been noted for its long-term benefits, particularly in areas prone to land degradation and erratic rainfall, but it requires a longer time to see results compared to practices like conservation agriculture. According to Kiptot *et al.* (2014), one barrier to the adoption of agroforestry in Africa is the delayed economic benefits and the need for specialized knowledge, which may deter smallholder farmers. This could explain the lower uptake of agroforestry practices in Zambia as established by this study compared to other sustainable agricultural techniques.

Water conservation techniques, such as drip irrigation, are becoming increasingly important in regions facing water scarcity due to climate change. Findings of this study established that about 33% of the farmers practiced water conservation techniques. In southern Africa, Steffen *et al.* (2015) found that farmers using water-saving irrigation techniques could improve water-use efficiency by 50%, leading to better crop yields during periods of drought. In Zambia, the uptake of water conservation techniques like drip irrigation is critical given the frequent droughts experienced in the southern parts of the country.

4.5. Impacts of sustainable agricultural practices on farm productivity, yield, and climate resilience

The results on the impacts of sustainable agriculture practices indicate that the implementation of sustainable agricultural practices has had a broad range of positive effects on farm productivity, yields, and resilience to climate in Zambia. These findings align with other studies in southern Africa that explore the role of sustainable agricultural practices in enhancing agricultural resilience in the context of climate change.

4.5.1. Impacts of sustainable agricultural practices on farm productivity

Table 4. Impacts of sustainable agricultural practices on farm productivity

Impact on farm's productivity	Frequency	Percentage (%)
Improved soil health	213	87.3
Increased water retention	132	54.1
Reduced pest and disease incidence	94	38.5
Enhanced crop and livestock health	39	16.0

Source: Field data

The findings of this study (Table 4) revealed that 87.3% of the respondents experienced improved soil health after adopting sustainable agricultural practices, which are consistent with the finding of Kashe *et al.* (2023) on "opportunities and challenges for conservation agriculture in Botswana" where it was shown that sustainable agricultural practices significantly improves soil structure, increases soil organic matter, and enhances the soil`s capacity to retain moisture, thereby making farms more resilient to droughts. The increased water retention reported by 54.1% of the respondents further supports this, as better soil health directly improves water-holding capacity. These findings also align with the work of Lal *et al.* (2023), which noted that sustainable land management practices, such as mulching and minimum tillage, can boost water infiltration and reduce evaporation losses.

Approximately 38.5% of respondents reported a reduction in pest and disease pressures on their farms, reflecting the benefits of integrated pest management (IPM) techniques. IPM, often a component of sustainable agricultural practices, emphasizes natural pest control methods, including crop diversification and biological control, which are effective in maintaining pest populations at manageable levels. Similar findings have been reported by Parsa *et al.* (2014), who found that sustainable pest management practices lead to long-term reductions in pest populations without harming the environment. This result suggests that SAP, when correctly implemented, reduces reliance on chemical pesticides, contributing to improved ecosystem health, and reduced cost of production.

4.5.2. Impacts of sustainable agricultural practices on yield and livestock

Table 5. Impacts of sustainable agricultural practices on yield and livestock

Impact on Yield and livestock productivity	Frequency	Percentage (%)
Significantly increased	76	31.1
Moderately increased	132	54.1
No change	20	8.2
Moderately decreased	16	6.6

Source: Field data

As a result of implementing sustainable agricultural practices, about 54% of respondents reported a moderate increase in crop yield and livestock productivity, while 31% saw a significant increase (Table 5). These findings are in line with studies by Belmin *et al.* (2023), which show that sustainable agriculture improves productivity over time by enhancing soil fertility, water use efficiency, and reducing yield variability in smallholder farming systems. Sustainable agricultural practices can increase long-term productivity by fostering healthier ecosystems and reducing the risks associated with climatic shocks. However, it is notable that 8.2% of respondents reported no change, and 7% even reported a decrease in productivity. This may be attributed to the lag time required to see the full benefits of sustainable practices, or other variables such as poor soil conditions or limited access to inputs.

Table 6. Impacts of sustainable agricultural practices on resilience to climate change

Impact on farm's resilience to climate change	Frequency	Percentage (%)
Better water management	141	57.8
Improved soil structure/ fertility	197	80.7
Reduced erosion	124	50.8
Increased biodiversity	51	20.9
Level of resilience to climate change	**Frequency**	**Percentage (%)**
Significantly improved	48	19.7
Moderately improved	132	54.1
No change	32	13.1
Moderately decreased	20	8.2
Significantly decreased	12	4.9

Source: Field data

On resilience to climate change, the study found that the majority of farmers (80.7%) experienced improved soil structure and fertility, while 57.8% reported better water management. These improvements contribute directly to enhanced farm resilience to climate variability. Better water management and reduced erosion are key components of climate adaptation, as they protect against the destructive impacts of extreme weather events. Research by Giller *et al.* (2009) supports these findings, showing that practices like conservation agriculture, agroforestry, and cover cropping significantly reduce soil erosion and enhance water retention, thereby improving farm resilience to droughts and floods. It is notable, however, that 13.1% of farmers reported no change in resilience, while 5-8% reported a decrease in resilience. These variations could be due to the uneven application of sustainable agricultural practices, differences in local environmental conditions, or the fact that certain methods of sustainable agricultural practices may not be fully adapted to the specific needs of some farmers. For example, Andersson and D'Souza (2014) found that some farmers in Zimbabwe did not observe immediate benefits from conservation agriculture, leading to slower adoption rates or dissatisfaction.

Further, 21% of respondents reported increased biodiversity as a result of implementing sustainable agricultural practices. This lower percentage indicates that practices specifically aimed at enhancing biodiversity, such as agroforestry are not as widely adopted compared to other methods of sustainable agricultural practices like conservation agriculture (as demonstrated in Figure 4). Studies by Tscharntke *et al.* (2012) suggest that while agroforestry and mixed cropping can improve farm biodiversity and ecosystem services, they require significant knowledge and resource investment, which might explain the relatively lower adoption rates in this study.

5. CONCLUSION

In conclusion, this study has highlighted the impact of various sustainable agricultural practices on farm productivity, yield, and climate resilience among smallholder farmers in Zambia. The findings show that a majority of farmers, particularly those in the middle-aged group (31-40 years), are engaged in various sustainable agricultural practices, with a significant proportion adopting conservation agriculture (75%) and soil fertility management techniques (53%). The study also reveals that smallholder farmers, who predominantly manage small farms (1-5 hectares), are more inclined to implement practices such as crop rotation, minimum tillage, and the use of green manure as part of their efforts to improve soil fertility and cope with climate change. The data indicates that mixed farming systems are the most common (46%), with farmers diversifying their income sources by combining crop and livestock production. This diversified approach helps mitigate the risks associated with climate variability. However, despite the promising adoption of conservation agriculture, agroforestry remains underutilized, with only 18% of respondents incorporating it into their farming systems. The high educational attainment among respondents further supports the likelihood of the adoption of sustainable practices, as more educated farmers are generally better positioned to access information and resources necessary for implementing climate-resilient farming techniques.

REFERENCES

Alubi, T., Tembo, A., & Daka, A. (2024). Access to Agro-Meteorological Information Among Smallholder Farmers in Chongwe District: A Demographic and Socio-Economic Analysis. *Journal of Environment, Climate, and Ecology, 1*(1), 38-45. https://doi.org/10.69739/jece.v1i1.81

Andersson, J. A., & D'Souza, S. (2014). From adoption claims to understanding farmers and contexts: A literature review of Conservation Agriculture (CA) adoption among smallholder farmers in southern Africa. *Agriculture, ecosystems & environment, 187*, 116-132. https://doi.org/10.1016/j.agee.2013.08.008

Belmin, R., Paulin, M., & Malézieux, E. (2023). Adapting agriculture to climate change: Which pathways behind policy initiatives? *Agronomy for Sustainable Development, 43*, 59. https://doi.org/10.1007/s13593-023-00910-y

Chikopela, L., Kalinda, T. H., Ng'ombe, J. N., & Kuntashula, E. (2024). Cultivating sustainability: Adoption and intensity of soil fertility management technologies among rural farms in Zambia. *World Development Sustainability, 5*, 100174. https://doi.org/10.1016/j.wds.2024.100174

Chomba, S. W., Kariuki, J., Lund, J. F., & Sinclair, F. (2016). Roots of inequity: how the implementation of REDD+ reinforces past injustices. *Land Use Policy, 50*, 202-213. https://doi.org/10.1016/j.landusepol.2015.09.021

FAO. (2021). *The state of food and agriculture: Climate-smart agriculture.* Food and Agriculture Organization of the United Nations. http://www.fao.org/state-of-food-agriculture

FAO. (2016). *Sustainable Food and Agriculture: Five Years into the 2030 Agenda.* Rome: Food and Agriculture Organization of the United Nations. https://www.uncclearn.org/wp-content/uploads/library/a-i5499e.pdf

Farm to Market Alliance. (2022). *Making markets work better for smallholder farmers.* Retrieved from https://ftma.org/wp-content/uploads/2022/02/FtMA_Zambia_CountryBrief_Dec-2022.pdf

Giller, K. E., Witter, E., Corbeels, M., & Tittonell, P. A. (2009). Conservation agriculture and smallholder farming in Africa: The heretics' view. *Field Crops Research, 114*(1), 23-34. https://doi.org/10.1016/j.fcr.2009.06.017

Hamazakaza, P., Kabwe, G., Kuntashula, E., Egeru, A., & Asiimwe, R. (2022). Adoption of sustainable agriculture intensification in maize-based farming systems of Katete District in Zambia. *Land, 11*(6), 880. https://doi.org/10.3390/land11060880

IPCC. (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability.* Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the

Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press. https://www.ipcc.ch/report/ar5/wg2/

Kashe, K., Sindel, B. M., Kristiansen, P., & Jessop, R. (2023). Opportunities and challenges for conservation agriculture in Botswana. International *Journal of Agricultural Sustainability, 21*(1). https://doi.org/10.1080/14735903.2023.2270257

Kiptot, E., Franzel, S., & Degrande, A. (2014). Gender, agroforestry and food security in Africa. *Current Opinion in Environmental Sustainability, 6*, 104-109. https://doi.org/10.1016/j.cosust.2013.10.019

Makate, C., Makate, M., Mango, N., & Siziba, S. (2019). Increasing resilience of smallholder farmers to climate change through multiple adoption of proven climate-smart agriculture innovations. Lessons from Southern Africa. *Journal of environmental management, 231*, 858-868. https://doi.org/10.1016/j.jenvman.2018.10.069

Mujeyi, A., Mudhara, M., & Mutenje, M. (2021). The impact of climate-smart agriculture on household welfare in smallholder integrated crop–livestock farming systems: Evidence from Zimbabwe. *Agriculture & Food Security, 10*(4). https://doi.org/10.1186/s40066-020-00277-3

Mutengwa, C. S., Mnkeni, P., & Kondwakwenda, A. (2023). Climate-Smart Agriculture and Food Security in Southern Africa: A Review of the Vulnerability of Smallholder Agriculture and Food Security to Climate Change. *Sustainability, 15*(4), 2882. https://doi.org/10.3390/su15042882

Muyabe, O., Tembo, A., & Musenge, D. C. (2024). An assessment of factors affecting the adoption of conservation agriculture as an approach to mitigate the impact of climate change among smallholder farmers in Zambia: A case of Chikankata District. *International Journal of Advanced Multidisciplinary Research and Studies, 4*(4), 563–568. https://doi.org/10.62225/2583049X.2024.4.4.3071

Nchanji, E. B., Kabuli, H., Nyamolo, V. O., Cosmas, L., Chisale, V., & Matumba, A. (2022). Gender differences in climate-smart adaptation practices amongst bean-producing farmers in Malawi: The case of Linthipe Extension Planning Area. *Frontiers in Sustainable Food Systems, 6*, Article 1001152. https://doi.org/10.3389/fsufs.2022.1001152

Ngwira, A. R., Thierfelder, C., & Lambert, D. M. (2013). Conservation agriculture systems for Malawian smallholder farmers: Long-term effects on crop productivity, profitability, and soil quality. *Renewable Agriculture and Food Systems, 28*(4), 350–363. https://doi.org/10.1017/S1742170512000257

Parsa, S., Morse, S., Bonifacio, A., Chancellor, T. C., Condori, B., Crespo-Pérez, V., ... & Dangles, O. (2014). Obstacles to integrated pest management adoption in developing countries. *Proceedings of the National Academy of Sciences, 111*(10), 3889-3894. https://doi.org/10.1073/pnas.1312693111

Quandt, A., Neufeldt, H., & Gorman, K. (2023). Climate change adaptation through agroforestry: Opportunities and gaps. *Current Opinion in Environmental Sustainability, 60*, 101244. https://doi.org/10.1016/j.cosust.2022.101244

Singh, J. (2014). Role of women in agricultural sector. *The Indian Journal of Political Science, 75*(2), 411–420. http://www.jstor.org/stable/24701148

Sheppard, J. P., Bohn Reckziegel, R., Borrass, L., Chirwa, P. W., Cuaranhua, C. J., Hassler, S. K., ... & Kahle, H. P. (2020). Agroforestry: an appropriate and sustainable response to a changing climate in Southern Africa?. *Sustainability, 12*(17), 6796. https://doi.org/10.3390/su12176796

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., ... & Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science, 347*(6223), 1259855. https://doi.org/10.1126/science.1259855

Thornton, P., & Cramer, L. (eds.). (2012). *Impacts of climate change on the agricultural and aquatic systems and natural resources within the CGIAR's mandate.* CCAFS Working Paper 23. Copenhagen, Denmark: CCAFS. https://hdl.handle.net/10568/21226

Tscharntke, T., Clough, Y., Wanger, T. C., Jackson, L., Motzke, I., Perfecto, I., Vandermeer, J., & Whitbread, A. (2012). Global food security, biodiversity conservation and the future of agricultural intensification. *Biological Conservation, 151*(1), 53–59. https://doi.org/10.1016/j.biocon.2012.01.068

United Nations Population Fund. (2024). *World population dashboard - Zambia.* Retrieved from https://www.unfpa.org/data/world-population/ZM

World Bank. (2012). *Agribusiness Indicators: Zambia.* World Bank, Washington, DC. http://hdl.handle.net/10986/26224 License: CC BY 3.0 IGO.

Zambia Development Agency. (2024). *Agriculture Sector Profile.* Retrieved from https://www.zda.org.zm/wp-content/uploads/2024/09/ZDA-Agriculture-Sector-Profile-2024-Final.pdf

Zambia Meteorological Department (ZMD). (2019). *Annual Climate Report.* Lusaka: ZMD. https://www.mgee.gov.zm/?page_id=708