# The role of trees and the dynamics of tree planting as a climate change adaptation strategy for addressing food and nutrition security challenges in KwaZulu-Natal

**By**

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# DEDICATION

This thesis is dedicated to God Almighty and my lovely family.

# DECLARATION 1: PLAGIARISM

I, **Fortunate Nosisa Zaca**, declare that:

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As the candidate's supervisors, we agree to the submission of this thesis:

Signed: [redacted] Date: 19 December 2024
Professor Mjabuliseni Simon Cloapas Ngidi (Supervisor)

Signed: [redacted] Date: 19 December 2024
Dr Unity Chipfupa (Co-supervisor)

# DECLARATION 2: PUBLICATIONS AND PRESENTATIONS

**Publications**

The following manuscripts form part of the research presented in this thesis:

**Manuscript 1 - Chapter 3 of this thesis**

Zaca, F. N., Chipfupa, U., Ojo, T. O., Managa, L. R. & Ngidi, M. S. C. The benefits and disservices of trees in the rural communities of the KwaZulu-Natal province, South Africa. (Under review: *Forest Policy and Economics*).

**Manuscript 2 - Chapter 4 of this thesis**

Zaca, F. N., Chipfupa, U., Ojo, T. O., Managa, L. R., Slotow, R., Mabhaudhi, T. & Ngidi, M. S. C. The adoption of tree planting as a climate change adaptation strategy among smallholder farmers: A case study of the KwaZulu-Natal province, South Africa. (Under revision: *International Journal of Agricultural Sustainability*).

**Manuscript 3 - Chapter 5 of this thesis**

Zaca, F. N., Chipfupa, U., Ojo, T. O., Managa, L. R. & Ngidi, M. S. C. The effect of fruit trees on food insecurity reduction and nutrition security of rural households: A case study of the KwaZulu-Natal province, South Africa. (Under review: *Journal of Agriculture and Food Research*).

**Manuscript 4 - Chapter 6 of this thesis**

Zaca, F. N., Ngidi, M. S. C., Chipfupa, U., Ojo, T. O. & Managa, L. R. (2023). Factors influencing the uptake of agroforestry practices among rural households: Empirical evidence from the KwaZulu-Natal province, South Africa. *Forests,* 14(10): 2056.

Fortunate Nosisa Zaca conceptualized all the manuscripts. The data collection, data analysis, and writing up of all the manuscripts were also performed by Fortunate Nosisa Zaca. The co-authors contributed guidance and insightful comments.

**Conference contributions (oral presentations)**

Zaca, F.N., Ngidi, M. S. C., Chipfupa, U., Ojo, T. O. & Managa, L. R. (2023). Factors influencing the uptake of agroforestry innovations among rural households: Empirical evidence from the KwaZulu-Natal province, South Africa. *Paper presented at the Annual Young Scientists' Conference, 12 June - 13 June 2023, University of Venda, Limpopo, South Africa*.

Zaca, F.N., Ngidi, M. S. C., Chipfupa, U., Ojo, T. O. & Managa, L. R. (2023). Factors influencing the uptake of agroforestry innovations among smallholder farmers: Empirical evidence from the KwaZulu-Natal province, South Africa. *Paper presented at the 8th BRICS Young Scientist Forum, 31 July - 02 August 2023, Boardwalk Hotel and Conference Centre, Gqeberha, South Africa*.

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Fortunate Nosisa Zaca submitted the abstracts, prepared the PowerPoint presentations, and presented all the papers. The co-authors contributed guidance and insightful comments.

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# ABSTRACT

One of the major environmental problems faced by the modern world is climate change, and its impacts are rapidly escalating. Future predictions indicate that climate change will result in lower rainfall and higher temperatures with increased flooding and drought events in South Africa. Most studies report that the source of livelihood affected mainly by climate change is agriculture, especially crop productivity. Moreover, the agricultural sector is among the most significant contributors to changing climate. Globally, the sector contributes about 20% to greenhouse gas emissions. The effect of climate change on the agricultural sector, combined with the impact of agriculture on greenhouse gas emissions, requires adaptation strategies that will lessen the effects of agricultural production while mitigating climate change. Agroforestry is recognized as the most appropriate adaptation strategy to achieve these objectives due to its high potential for addressing food insecurity, climate change challenges, and ecosystem management. It is defined as a farming system that integrates trees and shrubs with agricultural crops and/or livestock, or both.

Rural communities in South Africa have been planting trees, but what they deem important in trees is not well-known. Hence, identifying the different types of trees currently beneficial to them is essential for tree-planting programs to be successful. Moreover, there is insufficient empirical research on the following: the impact of fruit trees on food and nutrition security; the role and plantation of trees as a long-term and sustainable climate change adaptation strategy; and the role of knowledge, attitudes, perceptions, and extrinsic factors in the uptake of agroforestry practices among rural households. The objectives of the study were: to identify the different types of trees beneficial to rural communities and the main beneficial uses of these trees; to evaluate the potential contribution of trees towards food and nutrition security of rural communities; to investigate tree planting as a climate change adaptation strategy; and to examine the role of knowledge, attitudes, and perceptions in the uptake of agroforestry practices among rural households.

The study was conducted in Swayimane, Umbumbulu, and Richmond, located in the KwaZulu-Natal province, South Africa. The survey used a random sampling method to select and interview a total sample of 317 rural households from the three study locations. However, only 305 questionnaires were valid and used for analysis: Swayimane (92), Umbumbulu (103), and Richmond (110). The data were collected by trained enumerators in person using a structured and pre-tested questionnaire. In addition, focus group discussions were conducted to complement information collected during the household survey. Both descriptive and inferential statistics were employed in this study. Descriptive statistics included percentages, means, standard deviations, and standard errors. For the inferential statistics, a chi-square test, F-test, principal component analysis, binary logistic, multivariate probit, and ordered logit regression models were employed. The International Business Machines (IBM) Statistical Package

for Social Sciences (SPSS) version 28 and STATA SE version 17 were used to analyze the survey data. Moreover, bar charts were created using Microsoft Excel 2019 to organize and summarise data.

The results showed that fruit tree species such as banana, peach, and orange played a vital role in improving food, medicinal, and financial security among rural households. Other tree species, such as *Melia azedarach L.*, were used to adapt to climate change. For example, they function as windbreaks during windy weather. Medicinal tree species were used to treat human illnesses such as toothache, fever, and earache. Therefore, this study recommends the implementation of tree-planting programs and the distribution of fast-growing tree species across rural communities to improve their livelihoods. Improved allocation of resources to tree planting and maintenance by the public and private sectors can be a sound decision based on the benefits provided by trees. Regardless of the benefits of various trees, some respondents mentioned the disservices that result from trees. The results showed that ‘attracting snakes’ and ‘littering the yard’ were the dominant disservices across most fruit trees. It is recommended that rural households involved in tree planting be educated about methods of preventing snake invasion.

Planting trees was the most common adaptation strategy in the study locations. Compared to other strategies, it emerged as a long-term and sustainable strategy. The multivariate probit model results showed that access to training and climate change information, land size, and psychological capital influence the adoption of tree planting as a climate change adaptation. This indicated the importance of agricultural-related training in climate change adaptation. Raising awareness of the benefits of trees through training programs is crucial in encouraging farming rural households to adopt tree planting as an adaptive measure. Moreover, most rural households indicated a lack of access to training on climate change adaptation strategies. It is recommended that extension officers, non-governmental organizations, policymakers, and other stakeholders support local-level knowledge of climate change adaptation and turn it into effective and sustainable action.

The ordered logit regression model findings showed that growing fruit trees and consuming wild fruits influenced household food insecurity and nutrition security. Households practicing fruit farming are more likely to have better access to food and consume acceptable diets. Growing fruit trees was negatively associated with household food insecurity and positively associated with nutrition security. This suggests that households practicing fruit farming are more likely to have better access to food and consume acceptable diets. To improve the plantation of fruit trees in rural households, this study recommends the dissemination of information on the benefits of fruit trees. The level of wild fruits consumption among the sampled rural households was low. This indicates a need for awareness campaigns promoting the utilization and consumption of wild fruits. Encouraging rural households to consume wild fruits may reduce food insecurity through improved dietary diversity. It may also reduce reliance on purchased food items.

Knowledge, attitudes, and perceptions towards agroforestry were found to positively influence the adoption of agroforestry practices. The results showed that the likelihood of adopting agroforestry was higher among knowledgeable household heads than those without knowledge. Thus, educating rural households about trees' economic and environmental benefits could increase tree cover in the agricultural landscape. Implementing training programs with practical demonstration is recommended to increase awareness of the benefits of agroforestry practices and encourage households to protect on-farm trees. Extension officers, climate change champions, researchers, policymakers, and other stakeholders need to join forces in public-private partnerships to collectively participate in distributing adequate knowledge on agroforestry practices and their advantages to rural households. Moreover, addressing institutional and service constraints such as access to tree saplings and agricultural equipment, financial constraints, and water availability is vital to enhance the adoption and expansion of agroforestry practices.

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| | |
|---|---|
| ARC | Agricultural Research Council |
| $CO_2$ | Carbon Dioxide |
| COVID-19 | Coronavirus Disease of 2019 |
| CSA | Climate-smart Agriculture |
| DAFF | Department of Agriculture, Forestry, and Fisheries |
| DCoG | Department of Co-operative Governance |
| eTMM | eThekwini Metropolitan Municipality |
| FAO | Food and Agriculture Organization |
| FCS | Food Consumption Score |
| FANTA | Food and Nutrition Technical Assistance |
| GDP | Gross Domestic Product |
| HFIAP | Household Food Insecurity Access Prevalence |
| HFIAS | Household Food Insecurity Access Scale |
| HLPE | High Level Panel of Experts |
| HSSREC | Humanities and Social Sciences Research Ethics Committee |
| IBM | International Business Machines |
| ICRAF | International Council for Research in Agroforestry |
| IFSPC | Integrated Food Security Phase Classification |
| OLS | Ordinary Least Squares |
| PMT | Protection Motivation Theory |
| PCA | Principal Component Analysis |
| PCs | Principal Components |
| RUT | Random Utility Theory |
| SADC | Southern African Development Community |
| SDGs | Sustainable Development Goals |

| | |
|---|---|
| SPSS | Statistical Package for Social Sciences |
| TPB | Theory of Planned Behaviour |
| uMDM | uMgungundlovu District Municipality |
| USAID | United States Agency for International Development |
| VIF | Variance Inflation Factor |
| WFP | World Food Programme |
| ZAR | South African Rand |

# CHAPTER 1. INTRODUCTION

## 1.1 Background to the study

One of the major environmental problems faced by the modern world today is that climate change and its impacts are rapidly escalating (Vermeulen *et al.*, 2012; Chersich and Wright, 2019; Khan *et al.*, 2020). Future predictions indicate that climate change will result in lower rainfall and higher temperatures with increased flooding and drought events in South Africa (Mathews *et al.*, 2018). The climate change impacts on livelihood include severe livestock deaths, reduction in the yield of crops and marine fish harvests, availability of fuelwood, and rise in human illnesses and natural disasters (Vermeulen, 2014; Msalilwa *et al.*, 2016; Elum *et al.*, 2017; Aniah *et al.*, 2019; Dumtochukwu *et al.*, 2022). Agricultural production risks, such as those posed by climate change, predominate in developing nations, with most farmers experiencing them, even though the major origin and implications might differ across nations (Sultan *et al.*, 2014). Agricultural production activities in Africa (South Africa included) are more susceptible to climate change in comparison with other production constraints (Kurukulasuriya and Mendelsohn, 2008; Adimassu *et al.*, 2014; Campbell *et al.*, 2016; Talanow *et al.*, 2021).

Changing temperature and rainfall patterns expose agricultural production to climate risks, causing crop failure and adversely affecting the livelihoods of rural households that largely depend on farming. Most studies report that the source of livelihood mostly affected by climate change is agriculture, especially crop productivity (Msalilwa *et al.*, 2016; Aniah *et al.*, 2019; Ighodaro *et al.*, 2020; Adeagbo *et al.*, 2021). Thus, if the impacts of climate change are not managed through adaptation strategies, they will lead to low crop yields and reduced food availability. This, in turn, will increase food and nutrition security challenges. Campbell *et al.* (2016) indicated that reducing the risk in food security from climate change is one of the major challenges of the 21st century. Unless the approach to planning and investment for agricultural growth and development is altered, there is a risk of resource misallocation and the generation of agricultural systems incapable of supporting food security and contributing to rising climate variability (Lipper *et al.*, 2014).

According to Newell *et al.* (2019), agricultural production is amongst the most significant contributors to changing climate. Globally, the agricultural sector contributes about 20% to greenhouse gas emissions (Ntinyari and Gweyi-Onyango, 2021; Nyang'au *et al.*, 2021). It contributes directly through agricultural practices and indirectly via land use change from forest to cropland. With rising food demand resulting in the need for increased food production, agriculture is anticipated to be a main source of emissions growth, which threatens future food security (Lipper *et al.*, 2014; Abegunde *et al.*, 2019). The effect of climate change on food security, combined with the impact of agriculture on greenhouse gas emissions requires adaptation strategies that will lessen the impact of agricultural production while mitigating climate change (Newell *et al.*, 2019; Nyang'au *et al.*, 2021). Climate-smart agriculture (CSA) is recognized as the most appropriate adaptation strategy to achieve these objectives (Adesipo *et al.*, 2020; Senyolo *et al.*, 2021; Mthethwa *et al.*, 2022). The concept of CSA was first introduced by the Food and Agriculture Organization (FAO) of the United Nations in 2010 as an approach to achieving food security (Abegunde *et al.*, 2019).

Adesipo *et al.* (2020) defined CSA as a transformative and sustainable agricultural strategy that aims to enhance productivity in food security and production systems, based on combining the pillars of climate change (e.g., adaptation, resilience, and mitigation) in addition to smart and innovative technological knowledge, thereby increasing profit and reducing vulnerability through the reduction of greenhouse gas emissions. That is, CSA aims to support efforts that promote food and nutrition security (Barasa *et al.*, 2021). The notion of CSA aims to mutually address food insecurity, climate change challenges, and ecosystem management (Lipper *et al.*, 2014). The three main objectives of the CSA include: (1) a sustainable rise in farming production to improve income levels and food and nutrition security; (2) climate change adaptation and resilience; and (3) a decrease and/or complete elimination of greenhouse emissions where possible (Newell *et al.*, 2019; Kurgat *et al.*, 2020; Barasa *et al.*, 2021; Riyadh *et al.*, 2021). Therefore, CSA improves the resilience of agricultural systems through balancing the priorities between climate change adaptation, mitigation, and food security (Vermeulen *et al.*, 2012; Lipper *et al.*, 2014; Thornton *et al.*, 2018; Newell *et al.*, 2019). Agricultural interventions that achieve these outcomes are considered "climate-smart" (Kurgat *et al.*, 2020; Senyolo *et al.*, 2021).

Ighodaro *et al.* (2020) described CSA as an agricultural system where several practices are mixed and is dependent on suitable and adaptable elements in a particular local environment. The CSA practices include cultivation of cover crops, rotational cropping, agroforestry, conservation agriculture, crop diversification, use of organic manure, planting drought and heat-resistant crops, rotational cropping, small-scale irrigation farming and mulching (Mango *et al.*, 2018; Abegunde *et al.*, 2020). Agroforestry is one of the few land use strategies that has the capacity to deliver all the three benefits of CSA (Mbow *et al.*, 2014a; Newaj *et al.*, 2015). It is defined as a farming system that integrates trees and shrubs with crops and/or livestock, or both (Mwase *et al.*, 2015; Tokede *et al.*, 2020a). Agroforestry is recognised as a significant element in CSA due to its high potential for building resilience to climate change, sequestering carbon, and strengthening rural livelihoods (Barasa *et al.*, 2021; Riyadh *et al.*, 2021). It improves resilience to changing climate through increased tree cover, carbon sequestration, agricultural productivity and household income thereby improving the livelihood status of rural resource-poor households (Riyadh *et al.*, 2021).

Planting of trees is increasingly being recognized as a long-term and sustainable adaptation strategy because of its numerous benefits such as providing food, additional income, and environmental services (Dawson *et al.*, 2014; Lasco *et al.*, 2014; Msalilwa *et al.*, 2016; Alam *et al.*, 2017; Koffi *et al.*, 2020).

Leaves falling from trees planted in crop fields improve soil fertility and crop yields, thus contributing to household food and nutrition security (Foli *et al.*, 2014; Chivandi *et al.*, 2015). Furthermore, planting trees significantly mitigates the increasing carbon dioxide ($CO_2$) levels in the atmosphere (Campbell *et al.*, 2016; Aba *et al.*, 2017; Hall *et al.*, 2019; Sahoo *et al.*, 2022). Bernet (2021) estimated that an average tree absorbs about 10 kilograms (or 22 pounds) of $CO_2$ per year for the first 20 years. That is, $CO_2$ removed from the atmosphere per year per hectare during the first 20 years of tree growth ranges between 4.5 and 40.7 tons.

By affecting resource availability, climate change alters the context of socio-ecological systems and, as a result, frequently has gendered impacts where women are disadvantaged (Jost *et al.*, 2016; Pearse, 2017). The impact of climate change, particularly at a rural household level, has significant consequences on women as many households are female-headed (Boko *et al.*, 2007). Tibesigwa and Visser (2015) also reported that female-headed rural households tend to be more vulnerable to climate change and food insecurity than male-headed households. As a result of these gendered effects, climate change may also, in turn, indirectly reinforce gender inequality (Eastin, 2018). According to Desai and Mandal (2021), climate change also exposes women and girls to gender-based violence (e.g., sexual assault and harassment, physical and emotional violence, and child or forced marriage). For example, during droughts, women and girls walk far to fetch water for the household, which exposes them to rape. The increase in travel time also decreases the time spent by girls on schoolwork (Allen *et al.*, 2021). Moreover, in some African countries such as Malawi, girls are forced to get married due to food insecurity, which is a result of the changing climate (Desai and Mandal, 2021; van Daalen *et al.*, 2022). The rate of gender-based violence increases when women are displaced and in temporary shelter facilities during and after extreme climate events such as floods (Memon, 2020).

The lack of effective long-term adaptation strategies reduces the likelihood of achieving essential United Nations' Sustainable Development Goals (SDGs) by 2030, such as zero hunger and climate action (van Wijk *et al.*, 2020). Therefore, implementing effective adaptation strategies is vital to secure future agricultural productivity and rural livelihoods (Talanow *et al.*, 2021). The household's level of taking proactive measures to adapt to the effects of climate change is highly associated with their awareness of climate change (Le Dang *et al.*, 2014). That is, households that are aware of changes in climate in terms of temperature and precipitation are more likely to apply vital adaptation strategies. Msalilwa *et al.* (2016) revealed that adaptation to climate change is sometimes constrained by a lack of information. Without environmental education and training, rural households have limited knowledge about climate change and its projected impact on food and nutrition security. Therefore, understanding the role of rural communities' knowledge, how they perceive changes in climate, and what factors shape their adaptive behaviour (i.e., utilization and plantation of trees) is useful for climate change adaptation research.

Despite the potential benefits, adoption of CSA-relevant technologies is still low, especially in sub-Saharan Africa. Adoption processes and decisions are usually hindered by factors such as biophysical and socio-economic constraints, barriers in the political process, and the institutional environment. Therefore, Senyolo *et al.* (2021) emphasized the significance of the government and private sector joining forces in public-private partnerships to improve the adoption and distribution of CSA innovations to address climate change-related risks within rural communities. It has to be a collective effort involving district and extension officers, private entities, traditional leaders, local/regional governments, and networks among community members (Wale *et al*., 2022). It is against this backdrop that this study proposes a unique transdisciplinary approach, anchored on ecosystem restoration and the enhancement of the natural capital, which supports the co-production of knowledge across disciplines, and between expert and local knowledge, the building of social cohesion and good governance.

In the face of these numerous challenges, innovative, systemic, and transformative approaches that take into account food and nutrition insecurity and gender inequalities, are required to help transform developing world landscapes into resilient multi-functional ones (FAO and ARC, 2021; Visser and Wangu, 2021). The landscapes need to be capable of delivering on complex societal and environmental goals. The rising footprint of human activities on unmanaged forest landscapes has changed ecosystem processes under natural conditions, and the impact of climate change on forest landscape dynamics and their management remains a challenge (Li *et al*., 2011). Globally, forest management, especially agroforestry, is recognized as a significant response to the threat of climate change (Canadell and Raupach, 2008; Baker, 2021). According to Dawson *et al.* (2014), improved management of agroforestry systems provides adaptation and mitigation opportunities. These systems bring humankind closer to safe operating spaces across spatial and temporal scales for food systems, in the context of climate change for both its adaptation and mitigation roles (Thorlakson and Neufeldt, 2012; Neufeldt *et al*., 2013).

### 1.2 Research problem

South Africa faces major changes to its climate. In the past five decades, the country’s average annual temperatures have risen by at least 1.5 times more than the noted global average of 0.65°C (Van Der Walt and Fitchett, 2022). This has exposed the health, livelihoods, food security, water supply, human security, and economic growth of the country to climate-related risks. In the previous 50 years, flood events have frequently risen, and these changes are expected to continue. Moreover, unless intensive action is taken to lessen greenhouse gas emissions, temperatures may increase by above 4°C across the southern African interior by 2100 and by above 6°C across the western, central, and northern parts of South Africa (Kapwata *et al*., 2018). Forecasts indicate that many African countries with South Africa included, will be affected by variable climatic conditions. Arable land in developing countries is also expected to decrease by 110 million hectares by 2080 due to moisture constraints (Agathokleous *et al*., 2019). This in turn, threatens food production and access for both rural and urban areas through the decrease of on-farm income, rise in risks, and markets' distortion (Vermeulen, 2014).

Climate change impacts on the agricultural system are accompanied by a rising world's population which is expected to increase from current levels to as high as 10 billion people by 2050, and a high proportion is expected to come from Africa (Harvell *et al.*, 2002; Serdeczny *et al.*, 2017). The agricultural sector in KwaZulu-Natal contributes significantly to the national gross domestic product (GDP), and provides a major source of employment for many rural households (Blunden and Arndt, 2020). Extreme changes in rainfall patterns and increases in temperatures lead to unfavourable conditions in the cropping calendars, thus altering cultivation seasons which subsequently affect the crop productivity (Abegunde *et al.*, 2019; Adeagbo *et al.*, 2021). These changes have the potential to place strain on food and nutrition security in rural areas, where most households are dependent on farming to sustain their livelihoods. According to Hansen *et al.* (2019), there is a strong connection between climate-related risks and high poverty levels in rural areas. The connection of these issues has worsened poverty, food insecurity, and nutrition deficiencies in many African countries (Abegunde *et al.*, 2019). Although South Africa has sufficient food to meet its population's per capita requirements, most households are vulnerable to food insecurity (Altman *et al.*, 2009). Food insecurity persists in the rural areas of KwaZulu-Natal (Maziya *et al.*, 2017). Food security challenges in municipalities such as uMgungundlovu and eThekwini, where three of the case studies in this research are located, are intensified by climate change. This condition calls for a significant transformation in the agricultural sector to ensure adequate food supplies and improved food and nutrition security among the rural communities in South Africa.

Ensuring adequate food supplies has become more critical given the rising poverty levels, widening income gap, and unequal access to opportunities in the country. The poverty level has been on the increase, with more than 50% of South Africa's population, mostly from rural farming communities, still living in poverty (Lehohla, 2017). According to Wight *et al.* (2014), households that suffer from extreme poverty are usually expected to experience food and nutrition insecurity, *ceteris paribus*. Therefore, mitigating climate change demands that long-term and effective adaptative strategies such as tree restoration and/or improved forest management be put in place to support rural households to improve their food and nutrition security. Tree resources need to be an essential part of international and local policies and strategies to address the challenge of food and nutrition insecurity (Maseko *et al.*, 2017). Though there are several studies exploring the contributions of tree resources to food and nutrition security (e.g., McMullin *et al.*, 2019; Koffi *et al.*, 2020), there is insufficient empirical research on the possible contribution of trees in addressing food and nutrition security challenges. Some of the studies known to the author that have attempted to examine the contribution of trees to food and nutrition security are Koffi *et al.* (2020) and Omotayo and Aremu (2020). However, these studies are only based on a comprehensive review of the existing literature. They did not show empirical evidence on the actual contribution of trees. Moreover, the empirical studies (e.g., M'Kaibi *et al.*, 2015; Bellon *et al.*, 2016) combined crops, tree resources, and wild or semi-wild plants in a single independent variable, making it impossible to identify the actual contribution of tree resources to improving dietary diversity. Thus, having tree resources as a standalone variable is important to understand the actual contribution of trees to food and nutrition security.

Numerous types of climate change adaptation strategies are available to rural households, and the extent of their adoption is determined by the level of perception of climate change (Adeagbo *et al.*, 2021). According to Adeagbo *et al.* (2021), the adaptation strategies include changes in crop management practices (e.g., planting dates, planting densities, crop varieties), livestock management practices (e.g., livestock choice, feeding and animal health practices), land utilization and management (e.g., ploughing, tree planting or protection, irrigation and water harvesting, soil and water conservation measures, tillage practices, soil fertility management) and livelihood strategies (e.g., agroforestry, mixture of on-farm and off-farm activities, migration). However, these traditional coping strategies are increasingly becoming inadequate for dealing with the long-term effects of climate change. Previous studies have examined climate change adaptation strategies (Lasco *et al.*, 2014; Adeagbo *et al.*, 2021). However, there has been limited focus on how rural communities perceive planting trees as a climate change adaptation strategy. Rural communities in South Africa have been planting trees, but their role as a climate change adaptation strategy is not well known. Moreover, understanding how such communities perceive planting trees as an adaptation strategy is useful for climate change adaptation research. Therefore, this study also aims to focus on the role of planting trees as a long-term and sustainable adaptation strategy. This will enable policymakers to identify appropriate intervention strategies to mitigate the adverse effects of climate change.

According to Barona (2015), a thorough understanding of what individuals deem important in trees is required for tree-planting programs to be successful. The choice of tree species is crucial as the biophysical performance and social-economic requirements of different communities vary across regions (Akinnifesi *et al.*, 2010; Ndayambaje *et al.*, 2012). It is important to select tree species that are climatically suitable, marketable, and resistant to pests and pathogens to effectively mitigate climate change and address food and nutrition security challenges. Thus, identifying the different types of trees currently beneficial to rural communities is essential in the process of implementing and promoting tree planting programs. This study, therefore, also aims to identify tree types beneficial to rural households and their main uses.

Despite the great potential of agroforestry innovations, the uptake by smallholder farmers in sub-Saharan Africa seems to be low (Meijer *et al.*, 2015; Tokede *et al.*, 2020a). The low uptake of agroforestry programs is due to little emphasis placed on understanding the perceptions of local communities (Zubair and Garforth, 2006). Though knowledge, attitudes, and perceptions studies on the uptake of innovations have been carried out since the 1980s (Meijer *et al.*, 2015), there is a lack of such studies focusing on the decision-making process of agroforestry adoption in rural areas, particularly in South Africa. The limited knowledge of how rural resource-poor households perceive agroforestry innovation presents challenges regarding planning, investments, and formulation of relevant policies that can enhance their resilience to climate change. The analysis conducted by Meijer *et al.* (2015) emphasized that both extrinsic variables (e.g., characteristics of the adopter, characteristics of the innovation, and the external environment) and intrinsic variables (e.g., knowledge, perceptions, and attitudes) influence the decision to adopt agroforestry practices. For example, an individual's characteristics and economic variables may influence adoption indirectly by affecting the knowledge, attitudes, and perceptions, which in turn influence the decision to adopt an innovation.

Research simultaneously focusing on the role of intrinsic and extrinsic factors in the uptake of agroforestry innovations is limited to date. The previous studies are context-specific and focus on part of the subject, and a broader picture is only discovered when all these studies are put together (Meijer *et al.*, 2015). Therefore, this study aims to add to the literature by empirically examining the role of knowledge, attitudes, and perceptions together with extrinsic factors in the uptake of agroforestry innovations among rural households to better understand the adoption process. Understanding the role of rural communities' knowledge and how they perceive agroforestry innovations is important since it is recognized as a significant response to the threat of climate change. Moreover, while numerous studies have examined the adoption of agroforestry innovations among smallholder farmers in other African countries, their findings may not be fully applicable to the South African context due to differences in socio-economic conditions, environmental challenges, and policy frameworks. This study addresses this gap by focusing on rural areas in South Africa, providing localized insights into tree planting as a climate adaptation strategy. As a result, it contributes to a deeper understanding of region-specific dynamics that influence food and nutrition security and climate resilience.

Trees ' various contributions to food and nutrition security depend on their existence, location, type and composition, management, and use rights. Use rights and access are usually a challenge because trees and forests are used for different purposes by a wide range of individuals in rural communities (HLPE, 2017). In many contexts, access, rather than availability, limits the use of tree resources. For example, rural households benefit more from tree resources if they have the right to access them (Ribot and Peluso, 2003). Therefore, this study highlights the importance of considering access to and rights to use tree resources in the nearest forests to ensure food and nutritional security. Moreover, literature on the impacts of climate change on food security focuses on only one component of future food security (quantity of production, and mainly from crops), yet climate change influences all food security dimensions (availability, access, utilization, and stability), food nutrition and the entire food system (Campbell *et al.*, 2016). Therefore, this study's literature review highlights how climate change influences all food security dimensions.

According to Grothmann and Patt (2005), adaptation to climate change refers to the individual's ability to develop practical ways for adapting to the adverse effects of climate change events. This ability depends on factors such as psychological capital, infrastructure, access to finance, and health status (Wuepper et al., 2019). Psychological capital explains why individuals endowed with similar resources and working environment perform differently (Chipfupa *et al.*, 2021). Although studies demonstrating the importance of psychological factors to climate change adaptation have been carried out (e.g., Grothmann *et al.*, 2013; Bechtoldt *et al.*, 2021; Chipfupa *et al.*, 2021), there is still a limitation of empirical studies explaining the role of psychological capital on climate change adaptation behaviour and food and nutrition security. Therefore, this study also evaluated how psychological capital impacts the adoption of climate change adaptation strategies and the improvement of food and nutrition security.

### 1.3 Research objectives

The main research objective of this study is to examine the role of trees and the dynamics of tree planting as a climate change adaptation strategy for addressing food and nutrition security challenges in the KwaZulu-Natal province. The specific objectives of the study are:

1. To identify the different types of trees beneficial to selected resource-poor rural communities and the main beneficial uses and disservices of these trees;
2. To examine the adoption of tree planting as a climate change adaptation strategy among rural households;
3. To evaluate the potential contribution of trees towards food insecurity and nutrition security of resource-poor rural households; and
4. To examine the role of knowledge, attitudes, and perceptions in the uptake of agroforestry innovations among households.

### 1.4 Research questions

The research questions are as follows:

1. What are the main benefits and disservices of different tree species in rural communities;
2. What are the determinants of tree planting as a climate change adaptation strategy among rural households;
3. What is the contribution of trees towards food insecurity and nutrition security among rural households; and
4. What is the role of knowledge, attitudes, and perceptions in the uptake of agroforestry innovations among households?

### 1.5 Study hypotheses

The hypotheses of the study are:

1. The different types of trees have different benefits and disservices;
2. Rural households use tree planting as a climate change adaptation strategy;
3. There is an association between trees and food insecurity and nutrition security; and
4. There is a positive relationship between the socio-psychological factors and the adoption level of agroforestry practices.

### 1.6 Outline of the thesis structure

The remaining part of the thesis is outlined as follows: Chapter 2 presents a literature review on the link between trees, food and nutrition security, and climate change mitigation and adaptation. The key concepts are defined. The chapter also includes discussions on the status of food and nutrition security and climate change from a South African perspective. The thesis is written using the paper format. Hence, chapters 3 to 6 present four papers, each of which answered a specific objective. The analytical methods (econometric models) for data analysis are presented in each chapter (4, 5, and 6). Since all four papers depend on the same data that was collected in three study locations in the KwaZulu-Natal province, there is a degree of repetition of information that is observed. Moreover, some of the literature that identifies research gaps under chapters 1 and 2 is repeated in the four papers. Although the nature of the thesis presentation is such that repetition is inevitable, efforts were made to minimize repetitions. Chapter 3 investigates the beneficial and harmful features of specific tree species planted by rural households. The chapter uses descriptive and inferential statistics to analyze the survey data. Chapter 4 focuses on the adoption of tree planting as a climate change adaptation strategy among smallholder farmers. Chapter 5 examines the impact of fruit trees on food insecurity and nutrition security of rural households. Chapter 6 examines the role of knowledge, attitudes, perceptions, and extrinsic factors in the uptake of agroforestry practices among rural households to better understand the adoption process. Chapter 7 is a concluding chapter that presents the conclusions and recommendations based on the findings of this study. The chapter also indicates the limitations of the study and the suggestions for future research.

# CHAPTER 2. LITERATURE REVIEW

## 2.1 Introduction

This chapter presents a literature review on the link between trees, food and nutrition security, as well as climate change mitigation and adaptation. It begins by defining the key concepts and then discusses the status of food and nutrition security and climate change from a South African perspective. The review indicates that the source of livelihood affected mainly by climate change is agricultural production, thus increasing food and nutrition insecurity. Moreover, the living conditions of most people globally are expected to worsen by 2050, whereby hunger and poverty will be taking the lead, making it significantly challenging to improve food security. To respond to this projected crisis, a global transition to climate-smart agriculture (CSA) has been advocated and endorsed by several international institutions. The CSA is recognized as an approach to addressing agricultural productivity challenges, supporting adaptation strategies, and building resilience to climate change without compromising food security. This chapter also explores the contribution of trees to food and nutrition security and the value of trees for climate adaptation and mitigation.

## 2.2 Key concepts and their broader context

### 2.2.1 Climate change

Global warming, subsequent climate change, and weather volatility are amid the current crucial environmental challenges facing the world. Climate change is defined as "a change of climate which is attributed directly or indirectly to human activity that changes the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods" (Shisanya and Mafongoya, 2016; Adamo *et al*., 2021). Climate change effects have been experienced in the form of widespread flooding, continuous drought, disrupted weather patterns, rising global temperature, storms, and wildfires (Aba *et al.*, 2017; Jandl *et al.*, 2019; Drysdale *et al.*, 2020). The impacts of climate change can be categorized into two parts: (1) biophysical (e.g., rising pests and weed challenges, rising sea temperature) and (2) socio-economic (e.g., declining agricultural production, volatile world market prices, increased food insecurity and hunger, frequent wildfires) (Hof *et al.*, 2017; Aba *et al.*, 2017). Areas extensively affected by the effects of climate-related hazards comprise agriculture, freshwater and energy sources, fisheries, forestry, wildlife, human health, and the sustainable livelihood of rural and peri-urban communities (Vermeulen, 2014; Drysdale *et al.*, 2020; Ogada *et al.*, 2020).

Deforestation is one of the major causes of climate change, followed by pollution and environmental degradation (Dumtochukwu *et al.*, 2022). In sub-Saharan Africa, deforestation rates are twice the world average (Austin *et al.*, 2017). Forests are increasingly disrupted due to exhaustive logging for timber; exploitation for charcoal, firewood, and poles; and urban and industrial expansion (Roland and Oyelana, 2014; Aba *et al.*, 2017). As a result, the ecosystem services provided by forests, such as timber production, protection against natural hazards and biodiversity increasingly diminish. The need for adaptation of forest management to cope with changes in these properties and produce desirable resources in the future is widely recommended. Especially in productive forests that support the bio-economy of rural communities. A proactive management strategy is recommended whereby individuals examine the stability of the existing forests under the conditions of a changing climate and immediately take countermeasures. For example, enriching the diversity of tree species through planting species is expected to better cope with future climatic conditions (Jandl *et al.*, 2019).

### 2.2.2 Food security

Food security is a major development priority in sub-Saharan Africa due to the many malnourished individuals (SADC, 2014; Onyeaka *et al.*, 2022). It exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food that meets their dietary requirements and food preferences for an active and healthy life (FAO, 1996). This definition has four distinct but interrelated pillars of food security: (i) availability of sufficient quantities of food of appropriate quality; (ii) access to adequate resources to acquire appropriate and nutritious food; (iii) utilization of food ingredients appropriately and proportionately; (iv) and stability of the three other pillars over an extended period (HLPE, 2017; Koffi *et al.*, 2020; Fauzan'Azhima *et al.*, 2023). This study adopted an updated definition of food security that incorporates two additional dimensions, namely, agency and sustainability. This expands a four-pillar framework for food security to a six-dimensional one to address increasing inequities within food systems. Such iniquities are characterized by severe climate and ecological shocks and an imbalance of power dynamics (Clapp *et al.*, 2022).

Agency refers to the ability of individuals and communities to exercise their voices and participate in their local food systems (Burchi and De Muro, 2016; Fauzan'Azhima *et al.*, 2023). Moreover, sustainability refers to resilient food systems that maintain natural, social, and economic systems and fulfil the food needs of current and future generations (Fauzan'Azhima *et al.*, 2023). Incorporation of agency and sustainability dimensions into food security policy and analysis frameworks will ensure that all people are food secure all year round and in the long-term (Clapp *et al.*, 2022). Maxwell (2001) broadly indicated that food security exists when the poor and vulnerable, particularly women and children and those living in marginal areas, have secure access to enough food. However, according to Abdulla (2013), reaching food self-sufficiency alone does not certainly indicate the achievement of food security because most countries that were considered self-sufficient in food were found to be food insecure due to a lack of either an efficient food system or access to adequate resources. This signifies that the attainment of macro-level food self-sufficiency does not guarantee the attainment of household food security.

### 2.3 Status of food and nutrition security in South Africa

Achieving food security for all at all times is increasingly becoming difficult as food insecurity remains one of the major challenges faced by the world (Chakona and Shackleton, 2019). South Africa has largely been food secure at the national level but not at the household level (Maziya *et al.*, 2017). While the country has enough food to meet the per capita requirements of its population, most households are vulnerable to food and nutrition insecurity (Altman *et al.*, 2009). They struggle to buy enough food to feed the entire household due to the high level of poverty (Chakona and Shackleton, 2019). In South Africa, about 24% of the country's population was affected by moderate to severe food insecurity, while almost 15% experienced severe food insecurity in 2020 (Stats Stats SA, 2022). KwaZulu-Natal province had the highest percentage (20%) of people facing high levels of acute food insecurity (i.e., classified in crisis), thus requiring urgent action to reduce food gaps and protect livelihoods. This deteriorating food security is mainly driven by the COVID-19 pandemic, economic decline and unemployment, high food prices, and climate change (IFSPC, 2021). Adding to these existing challenges, the current Russia-Ukraine war may severely worsen food insecurity in African countries, including South Africa (Balma *et al.*, 2022). Russia and Ukraine are major providers of essential food commodities such as wheat, maize, and sunflower oil, with Russia being the world's top exporter of fertilizers (FAO, 2022). The conflict affects the capacity of food systems and causes supply chains not to function properly (Behnassi and El Haiba, 2022). Therefore, the disruption in the importation of grains and fertilizers in South Africa decreases the supply of agricultural commodities and causes an increase in food prices and food insecurity (Balma *et al.*, 2022). The higher costs of core staple foods result in the removal of nutritious food from household's plates, thus having a negative effect on health and well-being. Food security is also influenced by factors such as rising demand for food, higher input prices, household size, geographical location, soil degradation, and increasing competition for land and water from non-food uses (Shisanya and Mafongoya, 2016; Maziya *et al.*, 2017; Chakona and Shackleton, 2019).

### 2.4 Status of climate change in South Africa

Like many African countries, South Africa has been identified as being highly vulnerable to the adverse effects of climate change. The country has recorded climate-related disasters (e.g., droughts, floods, storms) that have led to limited food production, immense damage to physical infrastructure, and sometimes deaths (Elum *et al.*, 2017). These climatic challenges and their impacts on household wealth, income streams, and general livelihood sources, together with prevailing challenges in resource-poor rural communities, are overwhelming (Ogada *et al.*, 2020). Table 2.1 presents the climate-related events in South Africa. The 2015/2016 severe El Niño induced drought had a negative impact on the South African agricultural sector, causing about R4.7 billion decline in the sector's exports (Drysdale *et al.*, 2020; Sazib *et al.*, 2020). The agricultural commodities severely affected included maize, wheat, sugar, cattle and sheep. Maize yields were 27.6% lower than the previous season, while sugarcane production decreased by 5 million tons. In KwaZulu-Natal, more than 40,000 cattle died due to drought, and the province was formally declared a disaster area (Agri, 2016; Drysdale *et al.*, 2020).

**Table 2.1.** Climate-related events in South Africa

| Year | Event |
|---|---|
| 2024 | Floods in Eastern Cape, KwaZulu-Natal, and Western Cape |
| | Storms in Western Cape |
| 2023 | Floods in Western Cape and KwaZulu-Natal |
| | Storms in KwaZulu-Natal |
| 2022 | Floods in Eastern Cape, KwaZulu-Natal and Gauteng |
| 2021 | Storms in Eastern Cape, KwaZulu-Natal, Mpumalanga and Limpopo |
| | Floods across the country |
| 2020 | Storms in Eastern Cape, Free State, Gauteng, and KwaZulu-Natal |
| | Floods in Gauteng |
| 2019 | Floods in Eastern Cape, Free State, Gauteng, and KwaZulu-Natal |
| | Storm in KwaZulu-Natal |
| 2017 | Storms in KwaZulu-Natal and Western Cape |
| | Floods in KwaZulu-Natal |
| | Wildfire in Knysna |
| 2016 | Floods in Gauteng, KwaZulu-Natal and Western Cape |
| | Extreme temperature in North West |
| | El Nino drought |
| 2015 | El Nino drought |
| 2014 | Floods in Gauteng, KwaZulu-Natal, Limpopo, Mpumalanga and North West |
| | Earthquake in Orkney |
| 2014 | Storm in Western Cape |
| 2012 | Storms in Limpopo and Mpumalanga |
| | Floods in Eastern Cape |

**Source:** Adapted from Guha-Sapir *et al.* (2022)

In 2017, the Knysna fires burned approximately 15,000 hectares, destroying more than 5,000 hectares of commercial forestry plantations (Kraaij *et al.*, 2018). A survey by the South African Department of Trade Industry and Competition revealed that the recent floods in KwaZulu-Natal (the year 2022) affected more than 800 companies, with the cost of damage estimated at ZAR 6.4 billion. Moreover, a survey conducted by the South African Cane Growers Association among cane growers in rural areas of the province estimated losses at approximately ZAR 223 million. Several local roads and bridges, which are the access routes for farm inputs and farm workers, were washed away, thus threatening food security in the province. After assessing the magnitude and severity of floods occurring in parts of the country that resulted in deaths and damage to property, infrastructure, and the environment, the Head of the National Disaster Management Centre classified these occurrences as a national disaster (DCoG, 2022). Therefore, South Africa requires supportive policies and frameworks to improve the climate change adaptation process, especially for resource-poor rural and peri-urban households.

## 2.5 Climate change and food security

Several risks to the agricultural economy are caused mainly by climate change, such as extreme weather, unexpected temperature, and rainfall fluctuations (Ojo and Baiyegunhi, 2021). According to Kahsay and Hansen (2016), the agricultural sector is expected to be directly influenced by climate change through changes in land and water regimes. This can negatively impact food security through reduced food production and increased food prices. Reduction in food production limits food availability and leads to high food prices, therefore impacting food access. As a result, vulnerable individuals lacking adaptive capacity experience poor food utilization and nutritional status (Drysdale *et al.*, 2020). Greater exposure to climate risk without insurance leads rural resource-poor communities to prefer low-risk and low-return subsistence crops, be less likely to apply fertilizer or other purchased inputs, and choose the adoption of new technologies. These, in turn, result in increased food and nutrition insecurity (Vermeulen, 2014; Matlakala *et al.*, 2021).

The economic elements to be affected by changes in the climate include the reduced contribution of agriculture to the GDP, change in the geographical distribution of trade regimes, and increased number of people vulnerable to hunger, migration, and civil unrest (Ojo and Baiyegunhi, 2021). The number of hungry people globally is expected to rise by 20% by 2050 due to the adverse impacts of climate change on agricultural production and rural households' livelihoods (Arshad *et al.*, 2018; Hossain *et al.*, 2019). Climate variability also affects marine fish harvests, thus negatively affecting the food security of small-scale coastal fisheries through smaller catches and lower incomes (Vermeulen, 2014). Therefore, ensuring long-term food and nutrition security requires integrating complex land utilization systems that improve agriculture and the delivery of ecosystem services (Mbow *et al.*, 2014b).

## 2.6 Climate-smart agriculture

The living conditions of approximately 9 billion people globally are expected to worsen by 2050, whereby hunger and poverty will take the lead, making it significantly challenging to improve food security (Newaj *et al.*, 2015; Barasa *et al.*, 2021). To respond to this projected crisis, a global transition to CSA has been advocated and endorsed by several international institutions, including the Food and Agriculture Organisation (FAO) and the World Bank (Taylor, 2018; Ighodaro *et al.*, 2020). As mentioned in *Section 1.1*, CSA is defined as a transformative and sustainable agricultural strategy that aims to enhance productivity in food security and production systems, based on combining the pillars of climate change (e.g., adaptation, resilience, and mitigation) in addition to smart and innovative technological knowledge, thereby increasing profit and reducing vulnerability through the reduction of greenhouse gas emissions (Adesipo *et al.*, 2020). Agroforestry is considered as one of the few cost-effective strategies that have the capacity to deliver all the three benefits of CSA (Mbow *et al.*, 2014a). The World Agroforestry Centre, previously known as the International Council for Research in Agroforestry (ICRAF), has a long history of agroforestry research and development in Africa (DAFF, 2017). The knowledge produced by the ICRAF enables governments, development agencies, and farmers to use trees to make farming and livelihoods more environmentally, socially, and economically sustainable (Sharma *et al.*, 2016). Between 2007 and 2011, ICRAF implemented the Malawi agroforestry food security project to improve rural communities' livelihood opportunities and food security through accelerated adoption of fertilizer trees, fruit trees, fodder trees, and fuelwood trees (Beedy *et al.*, 2013). Agroforestry experiments conducted by ICRAF indicate that planting the right trees on-farm can improve crop yield (Sharma et al., 2016). Moreover, to better include fruits into homegrown food systems while addressing the seasonality challenge, ICRAF has developed a fruit tree portfolios methodology that selects socio-ecologically suitable and nutritionally significant fruit tree species for on-farm production (McMullin *et al.*, 2019).

The CSA can reduce food and nutrition insecurity by integrating climate variability into the development and implementation of sustainable agricultural strategies (Lipper *et al.*, 2014; Managa and Nkobole-Mhlongo, 2016). Numerous African countries recognize CSA as an approach to addressing agricultural productivity challenges, supporting adaptation strategies, and building resilience to climate change without compromising food security (van Wijk *et al.*, 2020; Barasa *et al.*, 2021). The adoption of CSA practices might be an innovative measure to mitigate climate change for the benefit of resource-poor rural communities dependent on highly climate-sensitive activities such as agriculture (Ighodaro *et al.*, 2020). Resource-poor rural communities are vulnerable to climate change shocks as they often lack the means to improve their adaptive capacity due to factors such as small farmland sizes, inadequate capital, limited access to input and output markets, and lack of credit (Ighodaro *et al.*, 2020; Senyolo *et al.*, 2021). According to Mathews *et al.* (2018), CSA is primarily concerned with adapting to a changing environment and decreasing agricultural losses. Information and evidence on the applicability of CSA practices and individuals' approval and prioritization can assist stakeholders in making strategic decisions that will improve government policies and institutional arrangements to achieve desired results (Abegunde *et al.*, 2020).

### 2.7 Contributions of trees to food and nutrition security

Figure 2.1 shows how trees contribute to food and nutrition security. At the household level, trees play significant roles in livelihood resilience in the presence of climate change, such as safety nets in periods of emergency, sources of products vital for production and income diversification, and employment sources (especially where farming and other rural livelihood strategies are no longer feasible). Investing in planting the right trees can contribute to generating new jobs and opportunities for sustainable development (HLPE, 2017).

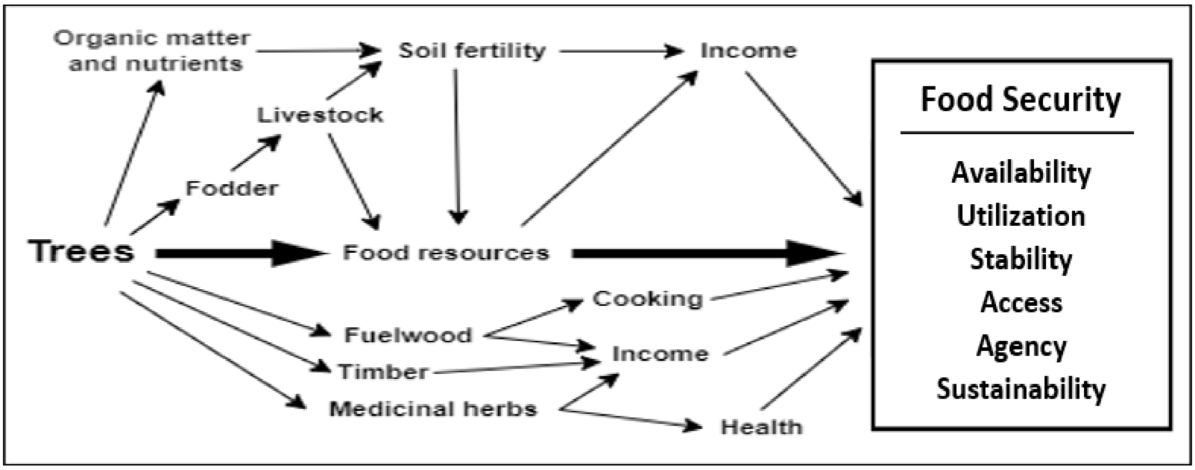


**Figure 2.1.** Contributions of trees to food and nutrition security

**Source:** Adapted from HLPE (2017) and Koffi *et al.* (2020)

According to Koffi *et al.* (2020), tree resources contribute to pillars of food security in the following ways: (i) by providing a supplement to staple food all year long (availability); (ii) in periods of food shortage (stability); (iii) through increased dietary quality (utilization); and (iv) as a source of direct dietary improvement or income to purchase food (access). Trees also contribute to food sustainability as some species are more drought-resistant and pest-tolerant than annual crops (McMullin *et al.*, 2019).

### 2.7.1 Direct contribution

Trees contribute significantly to food and nutrition security through the direct provision of food and energy for cooking (Figure 2.1). Trees' deep and extensive roots make them more drought tolerant than annual crops, thus providing food in dry periods when other food sources are unavailable (Pramova *et al.*, 2012; McMullin *et al.*, 2019). They also tend to be more tolerant of pests (Chivandi *et al.*, 2015). Edible tree resources have been reported to decrease food insecurity through improved dietary diversity (Kepe, 2008) and providing nutritional diets (Fentahun and Hager, 2009), particularly for rural households (Arnold *et al.*, 2011). For example, nuts, fruits, leaves, roots of trees, and tubers are crucial sources of micronutrients in many rural communities because they are easily accessible, inexpensive, and nutritious (Maseko *et al.*, 2017; Hall *et al.*, 2019; Koffi *et al.*, 2020). Their consumption is also motivated by culture, tradition, and dietary preference (Trefry *et al.*, 2014). Food insecurity in vulnerable rural households can be reduced by encouraging them to plant fruit trees and increase their consumption of fruits (Achaglinkame *et al.*, 2019).

Moreover, access to fuelwood ensures proper cooking of foods and sterilization of water, thus preventing food-borne diseases (HLPE, 2017). The majority of the rural communities in most developing countries depend on fuelwood as a source of energy for activities such as cooking and heating (Shackleton and Shackleton, 2006; Shackleton *et al.*, 2007). Globally, more than 2 billion people rely on fuelwood for cooking, with two-thirds of African households reported to use fuelwood as their main fuel for cooking (HLPE, 2017). In resource-poor rural communities, fuelwood is usually preferred over gas, paraffin, electricity, coal, and solar energy, as these and their cooking appliances are expensive (Roland and Oyelana, 2014; HLPE, 2017). The current predictions of future energy usage, proposed renewable energy, and climate change laws indicate that tree biomass energy will be utilized more in the next decades (Sahoo *et al.*, 2022). Trees can play a crucial role in sustainable bioenergy production, thus decreasing wood harvest pressures in forests. They provide feedstocks for the production of different forms of bioenergy: (1) solid biomass can be utilized as fuelwood, charcoal, and for electricity generation; (2) oilseeds can be utilized for the production of liquid biofuels such as biodiesel and lignocellulosic biomass can be utilized for ethanol production; and (3) residues such as leaves and oilseed cake can be utilized for biogas production (Sharma *et al.*, 2016; Sahoo *et al.*, 2022). Well-designed bioenergy production systems can contribute to climate change mitigation and adaptation, increased energy access, job creation, and improved food security (Sharma *et al.*, 2016; Ceccherini *et al.*, 2020).

### 2.7.2 Indirect contribution

Trees indirectly contribute to food and nutrition security through income generation from the sale of tree products and the provision of ecosystem services essential for agricultural production (Figure 2.1). Some households generate a portion of their total income from selling tree products such as fuelwood, timber, and medicinal plants or herbs (Shackleton and Shackleton, 2006; Roland and Oyelana, 2014). Income generated from the sales is often used to purchase food items to supplement the household diet (Koffi *et al.*, 2020). The nature of land rights, resource availability, accessibility of markets, and challenge of underdevelopment remains critical in influencing the benefits rural households obtain from selling the tree resources (e.g., fuelwood, woodcraft, twig broom, marula beer, fruits, nuts, etc.) and their potential to contribute to food and nutrition security (Paumgarten, 2005; Shackleton *et al.*, 2008; Koffi *et al.*, 2020). Trees also provide ecosystem services such as improved soil fertility, organic matter content, and nutrient circulation, which in turn increase crop yields and hence enhance food availability and accessibility (Mbow *et al.*, 2014a; Newaj *et al.*, 2015; McMullin *et al.*, 2019; Koffi *et al.*, 2020).

## 2.8 The value of trees for climate change adaptation and mitigation

Climate change adaptation and mitigation topics have become the subject of intense worldwide discussions, especially in the agricultural sector, which is dependent on climate-sensitive resources (Elum *et al.*, 2017; Abegunde *et al.*, 2019; Dang *et al.*, 2019). Barona (2015) mentioned that the two strategies suggested to address changing climate are mitigation (i.e., decreasing greenhouse gas emissions or enhancing the earth's carbon sinks to limit global warming) and adaptation (i.e., adjusting the system to cope with changing climatic conditions). This is in line with Elum *et al.* (2017), who indicated that the world has responded to changing climate through mitigation and adaptation strategies to moderate the adverse effects of climate change and take advantage of arising beneficial opportunities.

These strategies include planting more trees and enhancing species selection to reduce greenhouse gas emissions and improve atmospheric carbon capture (Msalilwa *et al.*, 2016; Hof *et al.*, 2017; Aniah *et al.*, 2019; Riyadh *et al.*, 2021). It is important to carefully select tree species based on site characteristics and the type of ecosystem service prioritized under specific climatic conditions.

Pramova *et al.* (2012) highlighted five cases in which trees can support adaptation and mitigation: (i) providing goods to communities facing climatic threats; (ii) regulating water, soil, and microclimate for resilient production in agricultural fields; (iii) maintaining watershed hydrology; (iv) protecting coastal areas from climate-related threats; and (v) urban trees regulating temperature and water for resilient cities. Trees hold the soil together, improve drainage, and prevent splash erosion during heavy rains. It is common for rural households, particularly in developing countries, to use tree products as an adaptation strategy during climate shocks. These products constitute significant safety nets and are part of income diversification strategies (Pramova *et al.*, 2012). According to Shackleton *et al.* (2007), there are three forms of safety nets: (i) Use of tree resources not usually used by the affected household (e.g., wood poles for building instead of buying commercial poles or blocks); (ii) substitution of purchased commodities with harvested ones (e.g., a decrease in utilization of paraffin, gas or electricity in favour of fuelwood); and (iii) sale of tree resources.

### 2.9 Role of socio-psychological factors and psychological capital in climate change adaptation

Effective climate change adaptation relies deeply on socio-psychological factors (e.g., knowledge, perceptions, and attitudes) (Meijer *et al.*, 2015; Tokede *et al.*, 2020a; Tokede *et al.*, 2020b; Adeagbo *et al.*, 2021). Knowledge about climate change enables informed decision-making, while perceptions of risk influence the urgency with which adaptation measures are implemented (Villamor *et al.*, 2023). Positive attitudes toward sustainable practices play a significant role in fostering behavioral change and promoting resilience, particularly in resource-poor communities (Amare and Darr, 2022; Ahmad *et al.*, 2023). Moreover, psychological capital, encompassing resilience, optimism, self-efficacy, and hope, is equally crucial in driving successful adaptation (Chipfupa *et al.*, 2021). Studies demonstrating the importance of psychological factors to climate change adaptation (Grothmann *et al.*, 2013; Bechtoldt *et al.*, 2021; Ayal *et al.*, 2021) have been carried out. According to Wuepper *et al.* (2019), psychological capital empower individuals to remain motivated and innovative when faced with the uncertainties and challenges posed by climate change. Therefore, by enhancing psychological capital, vulnerable communities can better withstand the negative effects of climate change, recover quickly, and build adaptive capacity for long-term sustainability (Truelove *et al.*, 2015; Keshavarz and Moqadas, 2021).

# CHAPTER 3. THE BENEFITS AND DISSERVICES OF TREES IN THE RURAL COMMUNITIES OF THE KWAZULU-NATAL PROVINCE, SOUTH AFRICA


## 3.0 Abstract

Trees and tree planting have been identified as one of the pathways rural households can use to improve their livelihoods while addressing the adverse effects of climate change. Trees provide financial, food, nutrition, energy, and medicinal security for rural communities in most African countries. However, some tree species provide disservices. Thus, this study aimed to investigate the benefits and disservices of tree species planted by rural households. This is beneficial to the stakeholders interested or involved in improving the livelihoods of rural communities through tree planting to make informed decisions. A sample of 305 households was randomly selected from Swayimane, Umbumbulu, and Richmond, in the KwaZulu-Natal province. Descriptive and inferential statistics were utilized to analyze the survey data. Most of the respondents (97.4%) indicated that trees play a significant role in the livelihoods of rural households. Fruit tree species such as banana, peach, and orange were used as a source of food, medicine, and income. Some medicinal tree species were used to treat toothache, fever, and earache. This study recommends the implementation of tree-planting programs across rural communities to improve their livelihoods. Since some tree species were perceived as harmful to children, promoting educational programs on trees' benefits and disservices for children is also critical.



**Keywords:** benefits of trees; disservices of trees; forest products; rural livelihoods

## 3.1 Introduction

Trees usually provide financial, food, nutrition, energy, and medicinal security for rural households in most African countries (Holl and Brancalion, 2020; Miller *et al.*, 2020; Pokwana *et al.*, 2021). Trees' deep and extensive roots make them more drought-tolerant than annual crops, thus providing food in dry periods when other food sources are unavailable (McMullin *et al.*, 2019). Trees also tend to be more tolerant of pests (Chivandi *et al.*, 2015). They provide ecosystem services such as improved soil fertility, organic matter content, and nutrient circulation (Koffi *et al.*, 2020; Yadav *et al.*, 2024). For example, leaves falling from trees planted in crop fields improve soil fertility and crop yields (Chivandi *et al.*, 2015). Moreover, about 600 million Africans depend on traditional energy sources such as fuelwood for cooking and heating activities (Adeeyo *et al.*, 2022). Access to fuelwood ensures proper cooking of foods, sterilization of water, and prevention of food and water-borne diseases in most rural households (HLPE, 2017). According to Sahoo *et al.* (2022), current predictions of future energy usage, proposed renewable energy strategies and climate change laws indicate that tree biomass energy will be utilized more in the next decades. This shows the significance of improved investment in tree-planting projects (Brancalion and Holl, 2020).

Globally, tree restoration and improved forest management are recognized as a significant response to the threat of climate change and food insecurity (Smith *et al.*, 2020; Baker, 2021; Hassall *et al.*, 2024). Planting trees plays a huge role in mitigating the increasing carbon dioxide ($CO_2$) levels in the atmosphere (Aba *et al.*, 2017; Hall *et al.*, 2019; Holl and Brancalion, 2020; Sahoo *et al.*, 2022). Bernet (2021) estimated that an average tree absorbs about 10 kilograms (or 22 pounds) of $CO_2$ per year for the first 20 years. That is, the $CO_2$ removed from the atmosphere per year per hectare during the first 20 years of tree growth ranges between 4.5 and 40.7 tons. However, the rising footprint of human activities on unmanaged forest landscapes remains a challenge. For instance, the natural forest cover is declining in South Africa due to deforestation and frequent wildfires. Over the past four decades, the country’s forests have been adversely affected by a rising number of economically damaging wildfires (Xulu *et al.*, 2021). This calls for a need to plant more trees to reduce the pressure put on natural forests and prevent their extinction (Pokwana *et al.*, 2021). According to Brancalion and Holl (2020), reducing deforestation is a central component of the United Nations’ Sustainable Development Goals.

If suitable trees are strategically planted, they can help save endangered species to survive and provide the necessary livelihoods to rural households (Turner-Skoff and Cavender, 2019). Investing in planting the right trees can generate new jobs and opportunities for sustainable development (HLPE, 2017). However, a thorough understanding of what individuals deem important in trees is required for tree-planting programs to be successful (Barona, 2015). The choice of tree species is crucial as different communities' biophysical performance and socio-economic requirements vary across regions (Akinnifesi *et al.*, 2010; Ndayambaje *et al.*, 2012). Thus, it is essential to select tree species that are climatically suitable, marketable, and resistant to pests and pathogens to mitigate climate change and effectively reduce food and nutrition insecurity. Identifying the different types of trees currently beneficial to rural communities is essential in the process of implementing and promoting tree planting programs. This will assist the stakeholders interested in improving the livelihoods of rural communities through tree planting to understand how individuals rely on trees and ensure that the planted tree species benefit rural households (Pokwana *et al.*, 2021). Moreover, a thorough understanding of the disservices associated with trees is required. The literature shows that trees provide disservices such as dropping leaves and flowers, contributing to road accidents, financial costs associated with tree maintenance, and attracting insects (Turner-Skoff and Cavender, 2019; Brancalion and Holl, 2020; Wojnowska-Heciak *et al.*, 2020).

There is limited research simultaneously investigating the benefits and disservices provided by trees to people (Turner-Skoff and Cavender, 2019). The only study known to the authors that has attempted to evaluate tree benefits and disservices is Wojnowska-Heciak *et al.* (2020). However, they did not provide information on tree species. Hence, this study aimed to investigate both the beneficial and harmful features of specific tree species planted by rural households. Furthermore, various contributions of trees depend on their existence, location, type and composition, management, and use rights. Use rights and access are usually a challenge because trees and forests are used for different purposes by a wide range of individuals in rural communities (HLPE, 2017). In many contexts, access, rather than availability, limits the use of tree resources. For instance, rural households benefit more from tree resources if they have the right to access them (Ribot and Peluso, 2003). Therefore, this study also highlighted the importance of considering access to and rights to use tree resources in the nearest forests. Research shows that forests have a significant role in food systems. Unlike a large part of agricultural production which is damaging to the biodiversity and the wider environment (Ntinyari and Gweyi-Onyango, 2021), forest food systems are more ecologically friendly because trees are carbon confiscating (Zaca *et al.*, 2023), utilize less (or no) chemical inputs (Vinceti *et al.*, 2013), and usually rely on rainfall rather than surface water (Goldsmith *et al.*, 2022).

## 3.2 Methodology

### 3.2.1 Study area, sampling strategy, and data collection

The study focused on rural households in Swayimane, Umbumbulu, and Richmond, in the KwaZulu-Natal province, South Africa. Figure 3.1 shows the research study area. The study was conducted in three study areas to facilitate a comparative analysis of the outcomes, mainly for descriptive analysis purposes. This approach allowed for capturing variations across the locations to better understand the observed differences. Swayimane is located in uMshwathi Local Municipality, while Umbumbulu is under eThekwini Metropolitan Municipality. Richmond is situated in Richmond Local Municipality. Most of the households from these study locations practice farming activities such as crop, fruit, and livestock production. Some households are directly dependent on forests. The dependence is through collecting fuelwood, traditional medicine, bush meat, wild fruits, and building poles (Wale *et al.*, 2022). The three study locations were selected based on the presence of forests and various tree species. They were purposively selected to align the study with the South African government's tree and forest restoration initiatives (Mugwedi *et al.*, 2018; Van Staden and Stoffberg, 2021). One such initiative is the 10 Million Tree Programme, a five-year commitment to plant at least two million trees annually, aimed at combating deforestation, restoring degraded ecosystems, and promoting climate resilience (Kabanda and Gumede, 2023).

The survey used a random sampling method to select and interview a total sample of 317 rural households from the study locations. Nevertheless, only 305 questionnaires were valid and used for analysis: Swayimane (92), Umbumbulu (103), and Richmond (110). The data were collected between September 2022 and October 2022 by trained enumerators. All the interviews were conducted face-to-face using a structured and pre-tested questionnaire. Research ethical clearance was granted by the Humanities and Social Sciences Research Ethics Committee (HSSREC) of the University of KwaZulu-Natal (protocol reference number: HSSREC/00003793/2022). The informed consent was also obtained from all the respondents. The questionnaire included questions about socio-economic and demographic characteristics, tree species, the role of trees on household livelihoods, and the use of forest products. In addition, focus group discussions were held to supplement the household survey data.

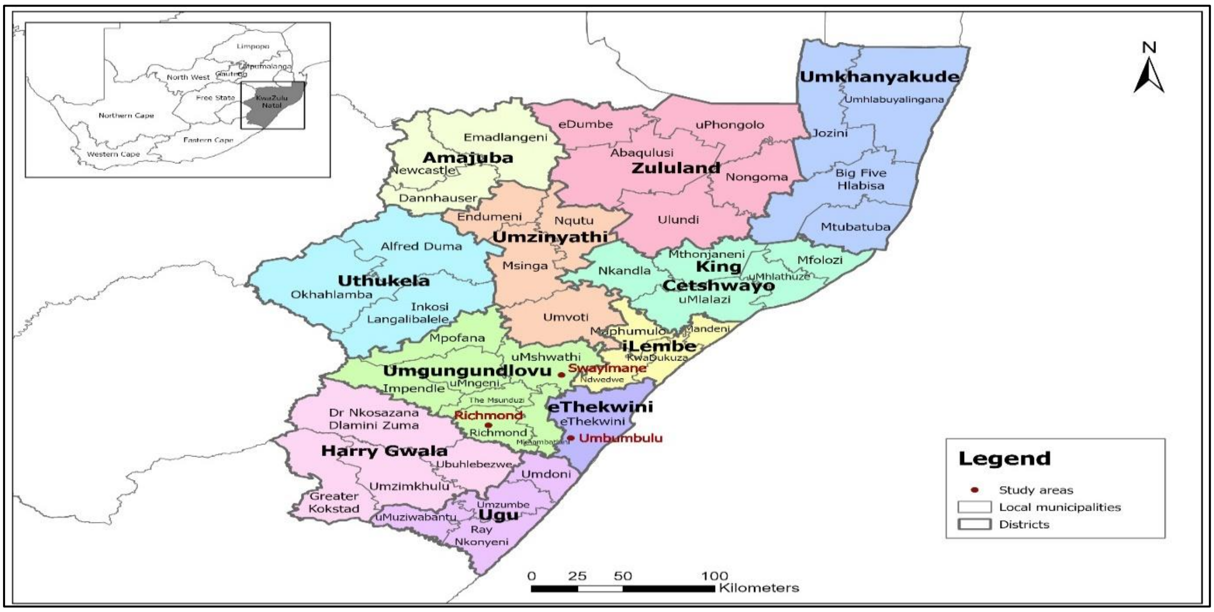


**Figure 3.1.** Map showing the KwaZulu-Natal province of South Africa

**Source:** Authors

### 3.2.2 Data analysis

In this study, both descriptive and inferential statistics were used to analyze the survey data. Descriptive statistics included means, standard deviations (Std. Dev.), and percentages. For the inferential statistics, a chi-square ($Chi^2$) test was used for comparison purposes across the three selected study locations. The data were analyzed using the International Business Machines (IBM) Statistical Package for Social Sciences (SPSS) version 28 and STATA SE version 17. Microsoft Excel 2019 was used to create charts.

## 3.3 Results and discussion

### 3.3.1 Socio-economic and demographic characteristics of sampled households

Table 3.1 shows the descriptive statistics for socio-economic and demographic factors. The average household head age was 61.83, while the average household size was 5.88. The estimated mean market value of physical assets owned by households (e.g., radio, television, wheelbarrow, and water tank) was ZAR 50,452.58, while the average annual on-farm income was ZAR 6,834.72. The results showed that the majority of households were female-headed. Similarly, Simelane *et al.* (2023) found that most of the households in the KwaZulu-Natal province were female-headed. The possible reason is that, in rural areas, males usually migrate to cities for employment opportunities. Moreover, 90.2% of households had at least one tree in their homestead and/or farmland. The majority of households (80.3%) owned livestock such as domestic chickens, goats, and cattle. During the survey, most of the households indicated that they kept livestock for consumption purposes. According to Ekesa *et al.* (2008), domestic chickens are a primary source of protein for rural households. Some households sold their livestock to generate income. On average, they sold goats, cattle, and domestic chickens for about ZAR 1,700, ZAR 9,500, and ZAR 115 each, respectively. This is in line with Tenza *et al.* (2024) who reported that rural households use domestic chickens to sustain their livelihoods. Thus, there is a potential opportunity to improve livestock farming for rural households, which, in turn, will reduce food and nutrition insecurity.

**Table 3.1.** Socio-economic and demographic factors, their means, standard deviations, and percentages

| Variable | Description | Mean | Std. Dev. | % |
|---|---|---|---|---|
| **Continuous variables** | | | | |
| Age | Household head age (Years) | 61.83 | 14.05 | - |
| Household size | Household size (Number) | 5.88 | 2.85 | - |
| Education | Household head education level (Years of schooling) | 5.48 | 4.90 | - |
| Land size | Land size household has access to (Hectares) | 1.33 | 1.22 | - |
| Assets | Total value of physical assets (Rands) | 50452.58 | 171985.20 | - |
| On-farm income | Annual income from on-farm activities (Rands/year) | 6834.72 | 17181.82 | - |
| **Dummy variables** | | | | |
| Gender | Gender of household head (1 = Male; 0 = Otherwise) | - | - | 42.0 |
| Training | Access to agricultural training (1 = Yes; 0 = Otherwise) | - | - | 35.1 |
| Growing trees | Household involved in growing trees (1 = Yes; 0 = Otherwise) | - | - | 90.2 |
| Livestock ownership | Ownership of livestock per household (1 = Yes; 0 = Otherwise) | - | - | 80.3 |
| Crop production | Household involved in growing crops (1 = Yes; 0 = Otherwise) | - | - | 91.5 |
| Irrigation | Access to water for irrigation purposes (1 = Yes; 0 = Otherwise) | - | - | 46.9 |
| Credit | Access to credit (1 = Yes; 0 = Otherwise) | - | - | 23.0 |

**Source:** Survey data (2022)

Furthermore, 91.5% of sampled households grew crops such as maize, amadumbe (*colocasia esculenta*), cabbage, spinach, potato, and beans. Crops were grown for various reasons such as earning income from sales and creating job opportunities. On average, cabbage and spinach were sold for approximately ZAR 13 per head and ZAR 12 per bunch, respectively. The percentage of households with access to water for irrigation purposes was 46.9%. During the interviews, most respondents at Swayimane and Umbumbulu indicated dissatisfaction with water availability in their areas. As a result, they rely on municipality water tankers, rivers, streams, and springs as water sources. According to Sinyolo (2020), most rural households are located in areas with limited access to irrigation due to inadequate water resources and a lack of infrastructure to divert water to their gardens. The results also showed that access to credit was low (23.0%). Deißler *et al.* (2024) reported that limited access to financial and natural resources may have a negative effect on rural households' ability to plant trees.

### 3.3.2 The role of trees on rural households' livelihoods

The results showed that 97.4% of sampled households indicated that trees play a significant role in the livelihoods of rural households (Figure 3.2). Similarly, Olowo *et al.* (2022) reported that most rural households are aware of the potential benefits of their local tree species. Some of the trees' roles identified by respondents were income generation, fuelwood and shade provision, improved soil fertility, fruits and traditional medicine provision, controlling soil erosion during floods, and blocking wind during storms. This is in line with Deißler *et al.* (2024), who indicated that on-farm trees have a significant positive impact on rural households' livelihoods, such as improving food and nutrition security. Moreover, during the survey, some respondents reported that trees take years to reach maturity. This implies the importance of introducing earlier fruiting or fast-growing tree species to encourage tree farming among rural households (Omotayo and Aremu, 2020).

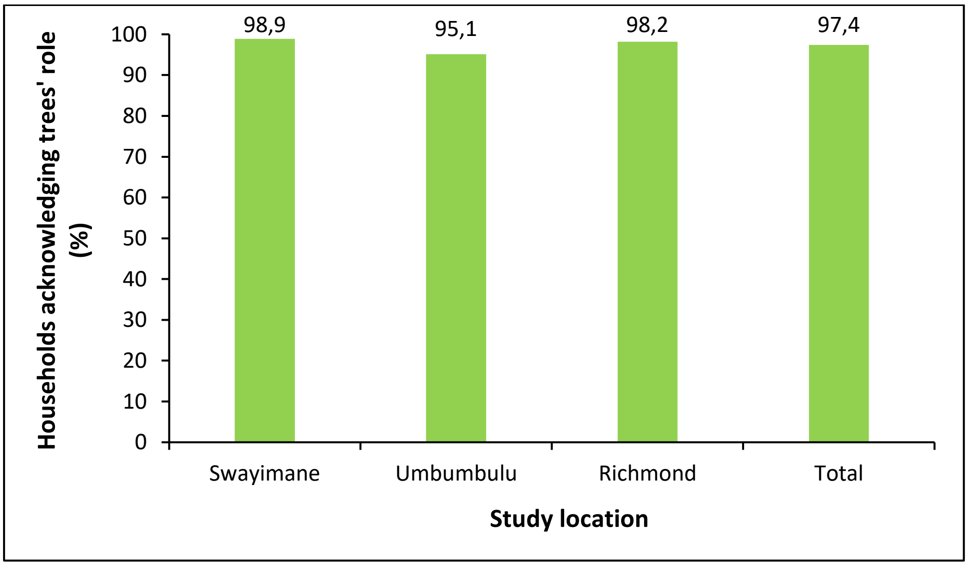

**Figure 3.2.** The role of trees on rural households' livelihoods by study location
**Source:** Survey data (2022)

### 3.3.3 The main uses and disservices of fruit trees

Details on the main uses and disservices of fruit tree species planted by sampled households are shown in Table 3.2. The results show that the fruit trees were used as a source of food, medicine, and income.

Banana, peach, and orange trees contributed in all the three aforementioned use categories, while the majority of other fruit trees had dual contributions (e.g., guava, lemon, mango, etc.). Ojha *et al.* (2022) highlighted the importance of investing in farming systems that improve food-medicine security. Papaya tree was only used for consumption purposes (3.3%). Moreover, 0.7% and 3.6% of households used orange and lemon trees for medicinal reasons, respectively. Respondents reported that they boil lemon or lemon peels in water and drink the liquid to treat colds and influenza. This is in line with Aworh (2023) who reported that fruit trees play a vital role in traditional medicine. A study conducted by Lawal *et al.* (2020) also showed that most respondents used citrus fruits to treat cough.

**Table 3.2.** Benefits and disservices of fruit trees

| Fruit tree type | Scientific name | Main use (%) | | | Disservice |
|---|---|---|---|---|---|
| | | Food | Medicine | Selling | |
| Banana | *Musa × paradisiaca* | 39.7 | 0.7 | 1.0 | Attracts snakes, pests, and insects |
| Guava | *Psidium guajava* | 30.8 | 3.3 | - | Attracts snakes, litters the yard, slippery tree bark, and causes constipation |
| Peach | *Prunus persica* | 58.0 | 1.6 | 0.3 | Attracts snakes and litters the yard |
| Orange | *Citrus × sinensis* | 23.9 | 0.7 | 0.7 | Attracts snakes and litters the yard |
| Lemon | *Citrus limon* | 27.5 | 3.6 | - | Litters the yard and tree has thorns |
| Kei apple | *Dovyalis caffra* | 3.6 | - | - | Litters the yard |
| Mulberry | *Morus* | 14.4 | - | - | Litters the yard and stains hands/fingertips |
| Apple | *Malus pumila* | 9.8 | - | 0.3 | None |
| Mango | *Mangifera indica* | 18.0 | - | 1.0 | Attracts snakes and litters the yard |
| Avocado | *Persea americana* | 24.9 | - | 2.3 | Litters the yard and roots destroy the house |
| Naartjie | *Citrus unshiu* | 3.0 | - | 0.3 | None |
| Papaya | *Carica papaya* | 3.3 | - | - | Litters the yard |

**Note:** Multiple responses were allowed.

**Source:** Survey data (2022)

Regardless of the benefits of various trees, some respondents mentioned the disservices that result from fruit trees. Previous studies also showed that trees can have disservices such as damaging houses (Turner-Skoff and Cavender, 2019; Brancalion and Holl, 2020). The results of this study showed that ‘attracting snakes’ and ‘littering the yard’ were the dominant disservices across most fruit trees. One of the respondents at Swayimane stated that, “*Kei apple fruits and leaves usually fall and litter the yard. Hence, we have to sweep it almost every day*.” Banana trees were reported to attract pests and insects (e.g., mosquitoes). This is consistent with Mahmood and Zubair (2020). Some respondents indicated that children fall and get injured when they climb guava trees to pick fruits because their bark is slippery. Moreover, mulberry fruit stains hands, especially among children. This is in line with Turner-Skoff and Cavender (2019), who found that rural parents perceive trees as dangerous to children. Figure 3.3 shows a child consuming mulberry and another with mulberry stains in Richmond. The findings showed that apple and naartjie trees had no harmful features. According to Turner-Skoff and Cavender (2019), carefully selecting tree species can lessen disservices.

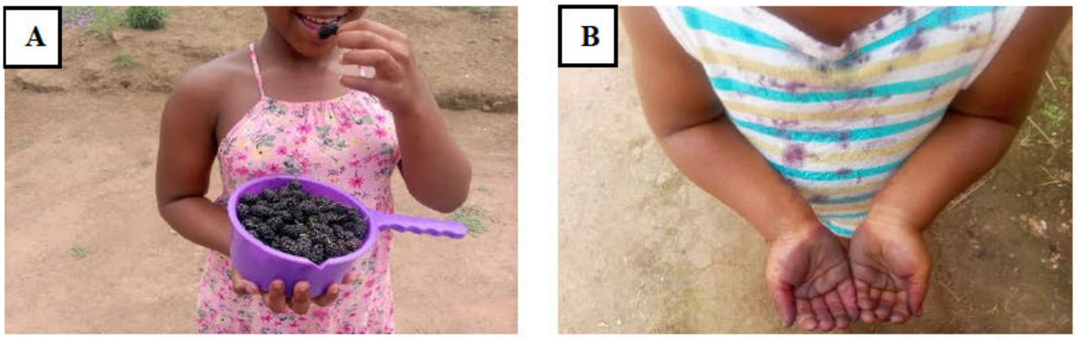


**Figure 3.3.** Child consuming mulberries (A) and child with mulberry stains (B) in Richmond

**Source:** Survey data (2022)

### 3.3.4 The main uses and disservices of medicinal trees

Table 3.3 displays the main uses and disservices of medicinal tree species planted by sampled households. The findings showed that *Clerodendrum glabrum E.Mey* tree treats diarrhoea on cows and goats. This is in line with Cock and Van Vuuren (2020), who reported that some trees treat livestock diseases. Other medicinal tree species were used to treat human illnesses in the study locations. For example, the bark of *Erythrina caffra Thunb.* treats sores. It is also used as an ingredient in the preparation of traditional medicine which is used to hasten the repair of a broken or fractured bone (Mhlongo and Van Wyk, 2019). Moreover, an infusion of leaves is used as eardrops to treat earache. The bark of *Ficus sur Forssk.* treats chickenpox. This is consistent with De Wet *et al.* (2013). Most of the medicinal trees had no disservices. However, some respondents reported that *Erythrina caffra Thunb.* and *Albizia adianthifolia (Schumach.) W.Wight* trees attract insects and snakes, respectively. The milky latex from *Euphorbia tirucalli L.* tree is toxic and may cause blisters on the skin.

**Table 3.3.** Benefits and disservices of medicinal trees

| Family | Scientific name | Vernacular name | Disease condition treated (*tree part used*) | Disservices |
|---|---|---|---|---|
| Lamiaceae | *Clerodendrum glabrum E.Mey.* | *Umqoqonga* | Diarrhoea on cows and goats (*leaves*) | None |
| Fabaceae | *Erythrina caffra Thunb.* | *Umsinsi* | Earache (*leaves*); toothache, sores, and bone repair (*bark*) | Attracts insects |
| Moraceae | *Ficus sur Forssk.* | *Umkhiwane* | Chickenpox (*bark*); sore throat (*milky latex*) | None |
| Euphorbiaceae | *Spirostachys africana Sond.* | *Umthombothi* | Sores (*stem bark*) | None |
| Rutaceae | *Clausena anisata (Willd.) Hook.f. ex Benth.* | *Umnukelambiba* | Fever (*leaves*) | None |
| Fabaceae | *Albizia adianthifolia (Schumach.) W.Wight* | *Umgadankawu* | Lice infestation (*leaves*) | Attracts snakes |
| Solanaceae | *Solanum aculeastrum Dunal* | *Umthuma* | Bone repair (*fruit*) | None |
| Asphodelaceae | *Aloidendron barberae (Dyer)* | *Umpondondo* | Stomach ache (*leaves*) | None |
| Euphorbiaceae | *Euphorbia tirucalli L.* | *Umsululu* | Sores (*stem part*) | Causes blisters on the skin |

**Note:** The language of the vernacular name is IsiZulu.

**Source:** Survey data (2022)

### 3.3.5 The main uses and disservices of other tree species

Table 3.4 shows other tree species planted by sampled households, their main uses, and the tree parts they use. The results showed that some tree species were used to adapt to climate change. For example, they function as windbreaks during windy weather. This is consistent with Agesa *et al.* (2019). The findings also showed that *Melia azedarach L.* is used as a shade tree across the study locations. According to Baral *et al.* (2016), tree planting plays a role in the provision of social benefits such as increasing shade in rural communities. Moreover, *Eucalyptus camaldulensis Dehnh.* tree was used as a source of fencing and building poles. This is in line with Garekae *et al.* (2020). The tree was also used for medicinal purposes. Most rural households steamed with a hot infusion of *Eucalyptus camaldulensis Dehnh.* leaves during the COVID-19 pandemic (El-Shiekh *et al.*, 2024). During the survey, some respondents indicated that they prefer to use fuelwood from *Acacia dealbata Link.* tree because it burns longer and provides more heat than other wood types. Figure 4 shows the delivery of fuelwood and a rondavel roofed with wood poles in two of the sampled households in Richmond. The disservice of *Acacia dealbata Link.* is that it sometimes falls on power lines during storms. This indicates the importance of educating rural communities about the danger of planting trees near power lines.

**Table 3.4.** Benefits and disservices of other tree species

| Family | Scientific name | Vernacular name | Main use (*tree part used*) | Disservices |
|---|---|---|---|---|
| Pinaceae | *Pinus* | *Phayini* | Roofing (*wood*); climate change adaptation (*whole tree*); fencing (*wood*); shade (*whole tree*) | - |
| Myrtaceae | *Eucalyptus camaldulensis Dehnh.* | *Ugamthrini* | Medicine (*leaves*); fuelwood (*wood*); roofing (*wood*); climate change adaptation (*whole tree*); fencing (*wood*) | - |
| Fabaceae | *Acacia dealbata Link.* | *Uwatela* | Medicine (*bark*); fuelwood (*wood*); fencing (*wood*); roofing (*wood*) | Trees fall on power lines |
| Meliaceae | *Melia azedarach L.* | *Umsalinga* | Medicine (*leaves*); fuelwood (*wood*); climate change adaptation (*whole tree*); shade (*whole tree*) | Attracts snakes and the roots destroy the house |
| Arecaceae | *Phoenix reclinata Jacq.* | *Isundu* | Medicine (*spines*); climate change adaptation (*whole tree*); religion (*leaves*) | - |
| Fabaceae | *Vachellia natalitia (E.Mey.)* | *Isangqawe* | Fuelwood (*wood*); soil fertility (*leaves*) | - |
| Bignoniaceae | *Jacaranda mimosifolia D.Don* | *Jakharanda* | Fuelwood (*wood*); shade (*whole tree*) | - |
| Fabaceae | *Vachellia xanthophloea (Benth.)* | *Umkhanyakude* | Shade (*whole tree*) | - |

**Note:** The language of the vernacular name is IsiZulu.

**Source:** Survey data (2022)

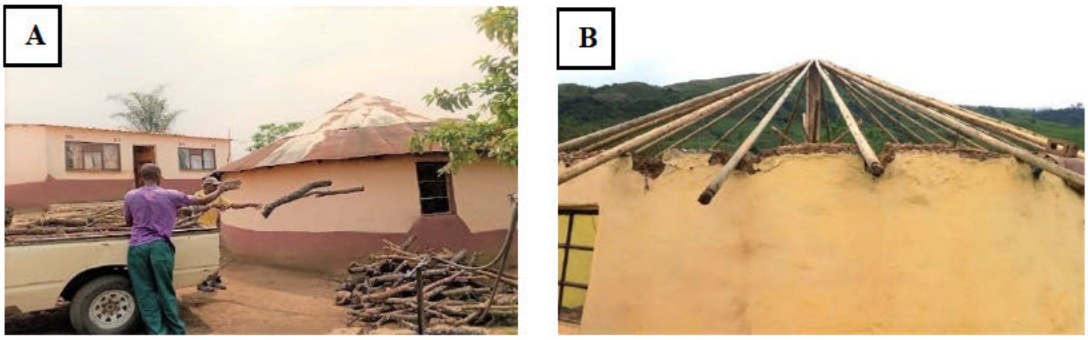


**Figure 3.4.** Fuelwood delivery (A) and a rondavel roofed with wood poles (B) in Richmond

**Source:** Survey data (2022)

### 3.3.6 The use of forest products among sample households

The findings showed that 67.2% of the sampled households received benefits from the nearest forests (Table 3.5). The $Chi^2$ test results indicated that the utilization of forest products was statistically different across the selected study locations at the 1% significance level. Umbumbulu had a higher number of households using forest products (84.5%). The possible reason is that 81.6% of the households in Umbumbulu indicated that the state of ownership for the nearest forest is public. Moreover, 12.6% of the households were involved in small-scale forestry. This implies that rural communities benefit more from forest products when they have the right to access them.

**Table 3.5.** Households using forest products (%)

| Variable | Swayimane | Umbumbulu | Richmond | Total | $Chi^2$ - test |
|---|---|---|---|---|---|
| Using forest products | 67.4 | 84.5 | 50.9 | 67.2 | 27.18*** |
| Forest's state of ownership | | | | | |
| *Owned by household* | 10.9 | 12.6 | - | 7.5 | |
| *Public* | 16.3 | 81.6 | 41.8 | 47.5 | 155.47*** |
| *Private* | 33.7 | 2.9 | 52.7 | 30.2 | |
| *Unknown* | 39.1 | 2.9 | 5.5 | 14.8 | |

**Note**: *** indicates the level of significance at 1%.

**Source:** Survey data (2022)

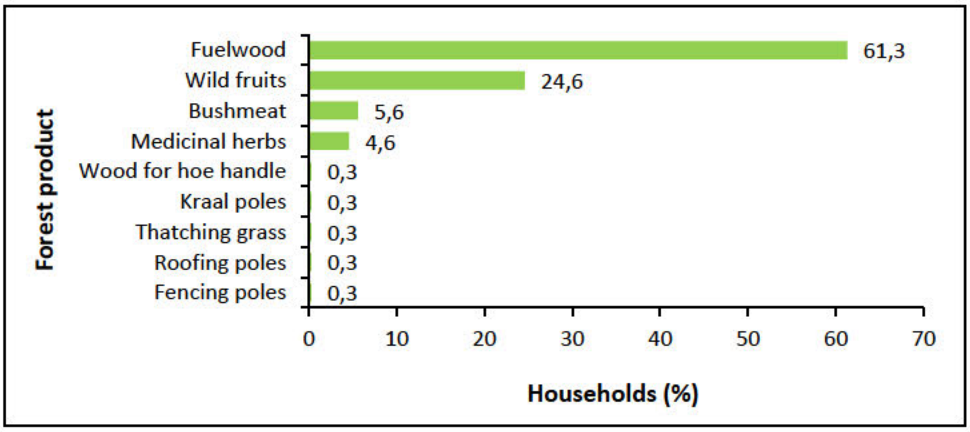


**Figure 3.5.** Forest products collected by sampled households

**Source:** Survey data (2022)

Figure 3.5 shows that the most collected forest product was fuelwood (61.3%), followed by wild fruits (24.6%), bushmeat (5.6%), and medicinal herbs (4.6%). Fuelwood was mainly used for cooking and heating purposes. This is consistent with Garekae *et al.* (2020).

### 3.4 Conclusions and recommendations

This study investigated the benefits and disservices of different tree species planted by the sampled rural households. It also highlighted the importance of considering access and rights to collect forest products. The results showed that fruit tree species such as banana, peach, and orange played a vital role in improving food, medicinal, and financial security among rural households. Other tree species were used to adapt to climate change. However, some respondents indicated that trees do not improve their livelihoods instantly because they take years to reach maturity. Therefore, this study recommends the implementation of tree-planting programs and the distribution of fast-growing tree species across rural communities to improve their livelihoods. Improved allocation of resources to tree planting and maintenance by the public and private sectors can be a sound decision based on the benefits provided by trees. Given that most tree species were reported to attract snakes, it is recommended that rural households involved in tree planting be educated about methods of preventing snake invasion. This study also revealed that some tree species were perceived as harmful to children. Thus, promoting educational programs on trees for children is essential to improve their basic understanding of trees' benefits and dangerous features.

The findings on the medicinal use of *Eucalyptus camaldulensis Dehnh.* leaves during the COVID-19 pandemic provide baseline information for proper clinical testing of rural communities' medicinal trees to validate their utilization and improve rural health systems. Moreover, the results showed that rural households benefit more from forests when they have access rights, especially when the forests are publicly owned, as this allows more people to use the resources. The sampled households collected forest products such as fuelwood, wild fruits, bushmeat, and medicinal herbs. Therefore, reforestation and protecting existing forests need to be crucial parts of international, national, and local policies to address challenges such as food and nutrition insecurity, medicine insecurity, and deforestation. This may also contribute to the sustainable use of forest products in rural communities.

# CHAPTER 4. THE ADOPTION OF TREE PLANTING AS A CLIMATE CHANGE ADAPTATION STRATEGY AMONG SMALLHOLDER FARMERS: A CASE STUDY OF THE KWAZULU-NATAL PROVINCE, SOUTH AFRICA


## 4.0 Abstract

Global warming and subsequent adverse climate change are amid the crucial environmental challenges currently facing the world. Areas extensively affected by climate-related hazards include agriculture, sources of freshwater, wildlife, human health, and the sustainable livelihood of rural communities. Although various climate change adaptation strategies are available to farming rural households, the extent of their adoption is determined by the level of perception of climate change. Hence, this study examined the perceptions of climate change and determinants of climate change adaptation decisions among smallholder farmers in the KwaZulu-Natal province, South Africa. Descriptive statistics results indicated that most smallholder farmers perceived climate change as challenging. Planting trees, changing planting dates, soil conservation, and diversifying crops were the most common adaptation strategies. Multivariate probit model results showed that age, age square, group membership, access to training and climate change information, off-farm income, land size, and psychological capital influence climate change adaptation decisions among smallholder farmers. Prioritizing comprehensible and practical climate change-related training programs is recommended to accommodate illiterate and less experienced farmers and to promote just and equitable development. Moreover, the integration of psychological support services into agricultural extension services, climate adaptation planning, and/or policy is also recommended.



**Keywords:** climate change; perceptions; adaptation strategies; tree planting; protection motivation theory; psychological capital; smallholder farmers

## 4.1 Introduction

Global warming and subsequent adverse climate change (e.g., weather volatility) are amid the crucial environmental challenges currently facing the world (Biswas and Rahman, 2023; Mbhenyane and Tambe, 2024; Tikita and Lee, 2024). Like many African countries, South Africa is highly vulnerable to the impacts of climate change (Sibiya *et al.*, 2023). In the past three decades, the country has recorded 86 climate-related disasters (e.g., droughts, floods, storms), impacting more than 22 million people and damaging infrastructure of over ZAR 113 billion (Igamba, 2023). The disasters have also led to limited food production, deaths, and mental illnesses such as depression (DCoG, 2022; Tomita *et al.*, 2022). Moreover, in the past five decades, the average annual temperature has risen by at least 1.5 times more than the global average of 0.65°C (Van Der Walt and Fitchett, 2022). Unless intensive action is taken to lessen greenhouse gas emissions, temperatures may increase by above 6°C across the western, central, and northern parts of South Africa by 2100 (Kapwata *et al.*, 2018). These climatic challenges and their impacts on household wealth, income streams, and general livelihood sources, together with prevailing challenges in resource-poor rural communities are overwhelming (Ogada *et al.*, 2020).

Climate change is defined by the United Nations Framework Convention on Climate Change as "a change of climate which is attributed directly or indirectly to human activity that changes the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods" (Shisanya and Mafongoya, 2016; Adamo *et al.*, 2021). Climate change effects have been experienced in the form of widespread flooding, continuous drought, disrupted weather patterns, rising global temperature, storms, and wildfires (Aba *et al.*, 2017; Jandl *et al.*, 2019; Drysdale *et al.*, 2020). The impacts of climate change can be categorized into two parts: (1) biophysical (e.g., rising pests and weed challenges, rising sea temperature); and (2) socio-economic (e.g., declining agricultural production, volatile world market prices, increased food insecurity and hunger, frequent wildfires) (Hof *et al.*, 2017; Aba *et al.*, 2017). Areas extensively affected by the effects of climate-related hazards comprise agriculture, freshwater and energy sources, fisheries, forestry, wildlife, human health, and the sustainable livelihood of rural and peri-urban communities (Vermeulen, 2014; Drysdale *et al.*, 2020; Ogada *et al.*, 2020).

Numerous types of climate change adaptation strategies are available to farming rural households, and the extent of their adoption is determined by the level of perception of climate change (Kumar and Sidana, 2018; Ojo and Baiyegunhi, 2020). Adaptation strategies are actions taken by individuals to reduce the adverse effects of climate change and improve opportunities for welfare (Thorn *et al.*, 2015). According to Adeagbo *et al.* (2021), climate change adaptation strategies include changes in crop management practices (e.g., planting dates, planting densities, crop varieties), livestock management practices (e.g., livestock choice, feeding, animal health practices), land utilization and management (e.g., fallowing, irrigation and water harvesting, soil and water conservation measures, tillage practices, soil fertility management), and livelihood strategies (e.g., mixture of on-farm and off-farm activities, migration). However, these traditional adaptation strategies are increasingly becoming inadequate for dealing with the long-term effects of climate change (Antwi-Agyei and Nyantakyi-Frimpong, 2021).

Previous studies have examined climate change adaptation strategies (Ojo and Baiyegunhi, 2020; Adeagbo *et al.*, 2021; Chipfupa *et al.*, 2021; Ojo *et al.*, 2021; Biswas and Rahman, 2023; Jawo *et al.*, 2023; Madamombe *et al.*, 2024). However, there has been limited focus on how farming rural communities perceive planting trees as a climate change adaptation strategy. Rural communities in South Africa have been planting trees for decades, but their role as a climate change adaptation strategy is not well known. Planting trees contributes to the achievement of the United Nations' Sustainable Development Goals 1 (no poverty), 2 (zero hunger), 3 (good health), 5 (gender equality), and 13 (climate action) (Turner-Skoff and Cavender, 2019; Brancalion and Holl, 2020; Bhebhe *et al.*, 2023). Therefore, understanding how rural communities perceive planting trees as an adaptation strategy is helpful for climate change adaptation planning. Based on this motivation, this study focused on the role of planting trees as a long-term and sustainable adaptation strategy in addition to other strategies. This will enable policymakers to identify appropriate intervention strategies to mitigate the adverse effects of climate change.

According to Grothmann and Patt (2005), adaptation to climate change in smallholder farming refers to the farmers' ability to develop practical ways for adapting to the adverse effects of climate change events. This ability depends on factors such as psychological capital, infrastructure, access to finance, and health status (Wuepper *et al.*, 2019). Psychological capital explains why smallholder farmers endowed with similar resources and working environment perform differently (Chipfupa *et al.*, 2021). Hence, Abunyewah *et al.* (2023) emphasized a need for research focusing on psychological factors that trigger farmers' ability to adapt to climate change. Studies demonstrating the importance of non-cognitive (psychological) factors to climate change adaptation (Grothmann *et al.*, 2013; Bechtoldt *et al.*, 2021; Ayal *et al.*, 2021) have been carried out. However, there is still a limitation of empirical studies explaining the role of psychological capital on climate change adaptation behaviour among smallholder farmers (Mortreux *et al.*, 2020).

The only study known to the authors that has attempted to evaluate how psychological capital impacts climate change adaptation is Chipfupa *et al.* (2021). However, they used stated preference-based questions, which are prone to strategic and hypothetical biases (Carlsson, 2010). In contrast, this study adopted a data collection approach that establishes scenarios to generate data that are close to the revealed preference approach. This approach is closely related to behavioural economics, a concept that is gaining momentum in the field of agriculture (Phakathi and Wale, 2018; Chipfupa *et al.*, 2021). The developed scenarios denote adaptation behaviour because climate change adaptation is a behavioural aspect influenced by an individual's decision-making (Feola *et al.*, 2015). The scenarios were designed to represent or mimic real-life farming challenges to capture smallholder farmers' actual decisions or behaviour under those conditions. The research question was: what are the determinants of smallholder farmers' climate change adaptation decisions?

### 4.2 Conceptual framework

Following Chipfupa *et al.* (2021) and Villamor *et al.* (2023), this study used the protection motivation theory (PMT) to describe smallholder farmer's climate change adaptation behaviour. The theory states that individuals facing a threat will adopt behaviours that protect themselves if they deem the risk of the threat to be high and feel capable of coping with the threat (Rippetoe and Rogers, 1987; Truelove *et al.*, 2015). The PMT as a theoretical framework addresses risk and adaptation (Villamor *et al.*, 2023). For example, farmers who perceive the severe negative effects of climate change and feel capable of adopting a new behaviour (e.g., planting drought-tolerant crops and trees) will be more likely to take protective action and adopt that behaviour.

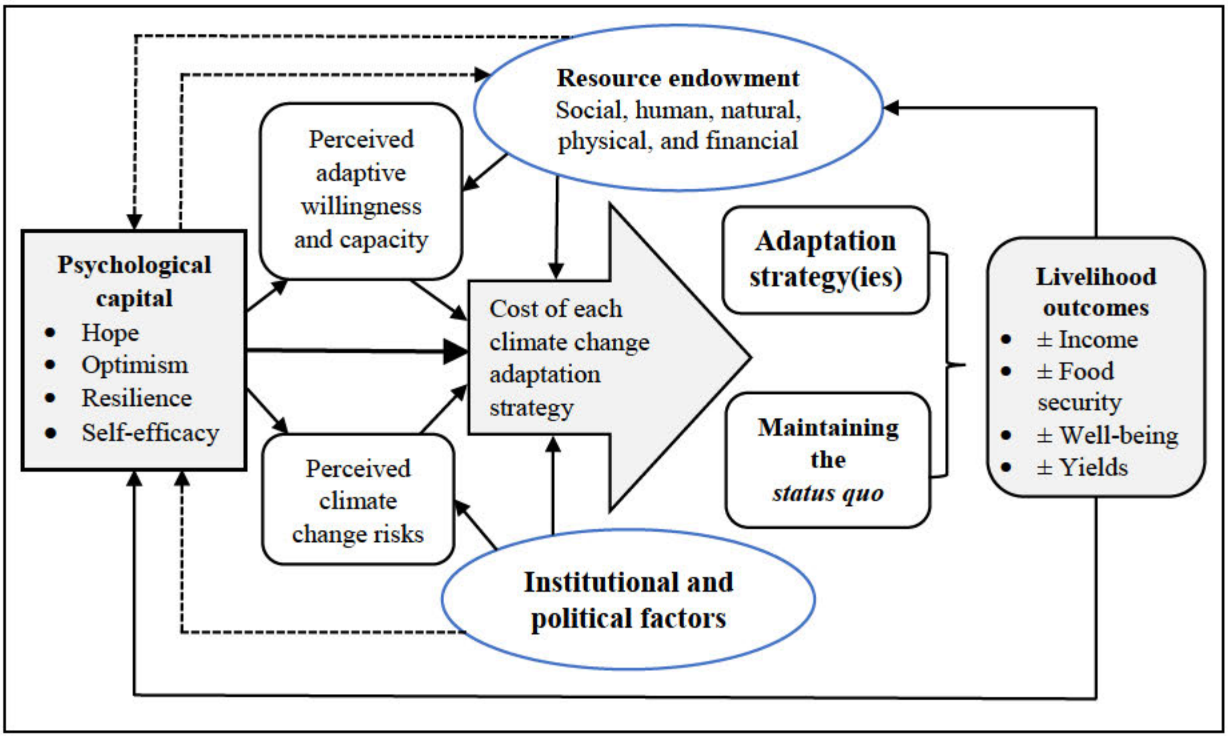


**Figure 4.1.** The modified psychological capital model of adaptive behaviour to climate change

**Source:** Adapted from Chipfupa *et al.* (2021)

Moreover, if the loss due to climate change is below the cost of adapting, smallholder farmers are expected to maintain the *status quo*. Otherwise, they will adopt adaptation strategies. According to Chipfupa *et al.* (2021), there are some similarities between the PMT and the random utility theory (RUT). For example, both theories explain decision-making in the context of adaptation strategies by emphasizing the importance of perceived benefits and individual choice. The RUT states that the choices of adaptation strategies depend on what smallholder farmers prefer and that preference considers the utilities of different options. Random factors can also explain their choices. Although the literature has linked the importance of livelihood assets to agricultural productivity, it is emphasized in this study that the role of psychological capital should be accounted for in explaining climate change adaptation behaviour.

Figure 4.1 adapts the psychological capital model of adaptive behaviour to climate change and presents the conceptual framework. The framework incorporates the dimensions of psychological capital, livelihood assets endowment, cost of each adaptation strategy, perceived risk of maintaining the *status quo*, and livelihood outcomes. The constructs of psychological capital (i.e., hope, optimism, self-confidence, and resilience) affect the smallholder farmers' perceptions of shocks such as climate change (perceived climate change risks) and their adaptive capacity (perceived adaptive willingness and capacity) (Wuepper *et al.*, 2019; Mortreux *et al.*, 2020; Chipfupa *et al.*, 2021; Villamor *et al.*, 2023). The higher the risk of not taking any action, the higher the motivation to adapt and *vice versa*.

The investigation of psychological factors in agricultural research indicates the significance of interdisciplinary research in providing solutions for improving the livelihood of smallholder farmers (Chipfupa and Wale, 2018; Suksod *et al.*, 2019; Chipfupa and Wale, 2020; Chipfupa and Tagwi, 2021; Chipfupa *et al.*, 2021). Moreover, the higher the costs (e.g., financial, time, health, and emotional risks) associated with engaging in protective actions, the lower the motivation to take protective action. Overall, the framework suggests that smallholder farmers who are concerned about the negative effects of climate change, endowed with high positive psychological capital, and with low perceived adaptation costs are expected to make adaptation decisions to achieve better livelihood outcomes, all else being equal (Chipfupa *et al.*, 2021).

The vulnerability of farmers also depends on access to and utilization of livelihood assets (i.e., human, social, physical, natural, and financial capitals) (Chipfupa *et al.*, 2021). Therefore, their propensity to adapt to climate change is a function of their willingness (psychological readiness to face the opportunity cost of adaptation) and their ability (resource endowment). Several studies have shown that institutional and political factors affect smallholder farmers' adaptive decisions (Dang *et al.*, 2019; Mortreux *et al.*, 2020; Chipfupa *et al.*, 2021). The main functions of institutions in smallholder agriculture comprise information provision, capacity building, and facilitating access to finance and markets (Mubaya and Mafongoya, 2017; Chipfupa *et al.*, 2021). The barriers to adaptation include limited political will at the local government level and unfavourable government policies (Bello *et al.*, 2013; Sibiya *et al.*, 2023). Some politicians do not acknowledge climate change adaptation as politically urgent to advance the policy agenda (Preston *et al.*, 2013). This is usually caused by changes in the leadership of political parties, especially after elections, since leaders have different priorities (Sibiya *et al.*, 2023).

Understanding the relationship between climate change adaptation strategies and livelihood assets will enable policymakers, climate change champions, extension officers, and other stakeholders to identify appropriate intervention strategies which improve smallholder farmers' adaptive behaviour and resilience (Alam *et al.*, 2017). Smallholder farmers with similar resources and constraints may respond differently to a climate change threat because their willingness to adapt differs by their psychological capital endowment level. For instance, those with a higher level of internal locus of control are motivated to organize their resources to protect themselves from climate change threats, while those with an external locus of control (dependency syndrome) depend on external support from government and/or other institutions (Phakathi and Wale, 2018; Chipfupa *et al.*, 2021).

## 4.3 Research Methodology

### 4.3.1 Study area

The study was conducted in Swayimane, Umbumbulu, and Richmond, in the KwaZulu-Natal province, South Africa (see Figure 3.1, page 22). The province has the second-highest population of about 12.4 million (Statistics South Africa 2023). Most rural households in the province are involved in small-scale farming and practice numerous agricultural activities such as crop, livestock, and fruit farming (Zaca *et al.*, 2023). However, due to their low adaptive capacity, the changing climate negatively affects their agricultural production (Maziya *et al.*, 2024). Extreme changes in rainfall patterns and temperature increases lead to unfavourable conditions in the cropping calendars, thus, altering cultivation seasons and subsequently affecting crop productivity (Abegunde *et al.*, 2019; Adeagbo *et al.*, 2021). Floods also damage several local roads and bridges, which are the access routes for farm inputs and farm workers, thus threatening food security in the province (Dardagan, 2022). For example, food security challenges in uMgungundlovu District Municipality (uMDM) and eThekwini Metropolitan Municipality (eTMM), where the three study sites are located, are intensified by changing climate (Blunden and Boyer, 2021; Udo and Naidu, 2024).

The province's winter occurs from June to August, while summer occurs from November to March which is the main rainy season. The average temperature rises above 25°C during summer and falls below 20°C in winter. The mean annual precipitation received by uMDM and eTMM is approximately 813 mm and 964 mm, respectively (Ndlovu and Demlie, 2020). Climate change projections indicate that rain-fed agriculture will continue to suffer in the province due to lower annual precipitation and higher temperatures, resulting in the need for effective and sustainable adaptation strategies (Jury, 2022). Moreover, the resource-poor communities in KwaZulu-Natal face other socio-economic challenges such as food insecurity, malnutrition, a high unemployment rate, and low levels of education (Sartorius *et al.*, 2020; Zaca *et al.*, 2023; Cele and Mudhara, 2024; Zondi *et al.*, 2024). They use churches, stokvel clubs, community meetings, and social media applications such as Facebook and WhatsApp to share knowledge and experiences and access support services (Zaca *et al.*, 2023).

### 4.3.2 Sampling strategy and data collection

A multistage sampling technique was employed to select the respondents. The first stage involved a purposive selection of the KwaZulu-Natal province. The province was chosen because its agricultural sector contributes significantly to the national gross domestic product (approximately 4.3%) and provides on-farm job opportunities for numerous rural households (Blunden and Arndt, 2020). The second stage involved identifying municipalities negatively affected by the changing climate and with households involved in agricultural activities. This was done purposively to align the study with the government's climate change adaptation and resilience agenda (Mthembu and Nhamo, 2022). The third stage used random sampling to select and interview a sample of 317 households. However, only 305 questionnaires were valid and used for the analysis. The total number of respondents interviewed per study site was 92, 103, and 110 in Swayimane, Umbumbulu, and Richmond, respectively. A sample size greater than or equal to 50 is considered reasonably large and reliable to produce significant statistics for the regression analysis used in this study (Gujarati and Porter, 2009).

The survey was conducted between September 2022 and October 2022. The data were collected by trained enumerators in person using a structured and pre-tested questionnaire. The study questionnaire and procedures were reviewed and approved by the Humanities and Social Sciences Research Ethics Committee (HSSREC) of the University of KwaZulu-Natal (protocol reference number: HSSREC/00003793/2022). Moreover, the informed consent was obtained from all the respondents. The questionnaire included questions about socio-economic and demographic factors, livelihood assets, perceptions of climate change, effects of climate change on agricultural production, adaptation strategies to changing climate, barriers to adaptation, and access to weather information. Following previous studies (Phakathi and Wale, 2018; Chipfupa *et al.*, 2021), the questionnaire also encompassed five-point Likert scale statements to measure the level of psychological capital endowment among smallholder farmers. As mentioned earlier, contrary to those studies, this study used a set of scenario-based questions to measure psychological capital. Additionally, focus group discussions were conducted to supplement information collected through the questionnaire.

### 4.3.3 Data analysis

The International Business Machines (IBM) Statistical Package for Social Sciences (SPSS) version 28 and STATA SE version 17 were used to analyze the survey data. Both descriptive and inferential statistics were employed in this study. Descriptive statistics included percentages, means, standard deviations (Std. Dev.), and standard errors (Std. Err.). A chi-square ($Chi^2$) test, F-test, principal component analysis, and multivariate probit regression model were employed for the inferential statistics. Moreover, bar charts were created using Microsoft Excel 2019 to organize and summarise data.

### 4.3.4 Multivariate probit model

Following several studies (Yegbemey *et al.*, 2013; Mulwa *et al.*, 2017; Aryal *et al.*, 2018; Ojo and Baiyegunhi, 2020; Chipfupa *et al.*, 2021), a multivariate probit model was used to investigate the factors influencing smallholder farmers' decisions to adapt to climate change. These studies indicated the significance of accounting for the interdependence among the different adaptation strategies. That is, the adaptation strategies can be used simultaneously. Adapting to climate change requires making choices among a set of available adaptation practices. Adopting one practice could be influenced by adoption decisions for other practices (Yegbemey *et al.*, 2013). For example, smallholder farmers may choose to adopt a mix of strategies instead of relying on one strategy to take advantage of complementarities between alternatives (Mulwa *et al.*, 2017; Ojo and Baiyegunhi, 2020). This makes adoption decisions genetically multivariate. Therefore, a multivariate probit model was employed to analyze data. The model estimates multiple binary probit equations simultaneously, allowing the error terms to be correlated. In contrast, univariate logit and probit models assume the independence of error terms and may result in biased estimates and wrong conclusions (Aryal *et al.*, 2018). Thus, they were not appropriate in this study.

Following Lin *et al.* (2005), this study formulated a multivariate probit model with four binary dependent variables, namely, planted trees (PT), changed planting dates (CPD), soil conservation strategies (SCS), and diversified crops (DC) as follows:

$$y_{ik}^{*} = \beta_{ik}x_{ik}' + \varepsilon_{ik} \quad (i = 1,2,3,4 \; and \; k = PT, CPD, SCS, \; DC) \tag{4.1}$$

$$y_{ik} = 1 \; if \; y_{ik}^{*} \; > 0, 0 \; otherwise, \tag{4.2}$$

where $PT, CPD, SCS, and\ DC$ represent the adaptation strategies adopted by smallholder farmers in the study sites, $y_{ik}^{*}$ is the latent variable that denotes observed and unobserved preferences associated with the k[th] climate change adaptation strategy, $\beta_{ik}$ represents estimated conformable parameter vectors, $x_{ik}'$ is a vector of independent variables, and $y_{ik}$ represents the binary dependent variables. Farmers take a value of one if they choose any of the adaptation strategies and zero otherwise. The error terms ($\varepsilon_{ik}$) jointly follow a multivariate normal (MVN) distribution with zero conditional mean and unitary variance, where $\varepsilon_{ik} \approx$ MVN (0, Ω). That is, smallholder farmers can adopt more than one adaptation strategy at any given time. The symmetric covariance matrix (Ω) of equation (1) can be specified as:

$$\Omega = \begin{bmatrix} 1 & \rho PT\_CPD & \rho PT\_SCS & \rho PT\_DC \\ \rho CPD\_PT & 1 & \rho CPD\_SCS & \rho CPD\_DC \\ \rho DC\_PT & \rho DC\_CPD & 1 & \rho SCS\_DC \\ \rho DC\_PT & \rho DC\_CPD & \rho DC\_SCS & 1 \end{bmatrix} \tag{4.3}$$

where $\rho$ denotes the pairwise correlation coefficient of the error terms in the model. The correlation between the error terms of different climate change adaptation strategies adopted is denoted by the off-diagonal elements (e.g., $\rho CPD\_PT$, $\rho PT\_CPD$). This assumption implies that equation (2) gives a multivariate probit model that jointly represents decisions to adopt a particular adaptation strategy (Kassie *et al.*, 2013). The non-zero correlations in the off-diagonal elements justify the application of a multivariate probit model instead of univariate probit (Aryal *et al.*, 2018). Therefore, a multivariate probit model for the adoption of climate change adaptation strategies is specified as follows in this study:

$$y_{ik} = \beta_0 + \sum_{i=1}^{m} \beta_{ik} S_{ik} + \sum_{i=1}^{m} \beta_{ik} A_{ik} + \sum_{i=1}^{m} \beta_{ik} I_{ik} + \sum_{i=1}^{m} \beta_{ik} P_{ik} + \sum_{i=1}^{m} \beta_{ik} O_{ik} + \varepsilon_i, \tag{4.4}$$

$\forall_i = 1 \ldots m$ regressors

where $\beta s$ are coefficients of explanatory variables. $S_i$, $A_i$, $I_i$, $P_i$, and $O_i$ denote variables for socio-economic and demographic characteristics of sampled households, household assets, institutional factors, psychological capital, and other variables such as access to climate change information, respectively. The likelihood ratio and Wald tests were used to evaluate the model's goodness of fit. Statistically significant tests' values indicate that the model fits the data well (Aryal *et al.*, 2018). The joint probability of success and failure was also used to assess smallholder farmers' likelihood of adopting all the adaptation strategies and adopting none. The variance inflation factor (VIF) was used to check for multicollinearity among independent variables. The average VIF above the threshold value of 10 implies the existence of multicollinearity (Gujarati and Porter, 2009).

### 4.3.5 Principal component analysis

The principal component analysis (PCA) was used to create indices for the psychological capital explanatory variables. The PCA is a data reduction method that linearly transfigures an original set of variables into a new set of uncorrelated and orthogonal variables, namely, principal components (PCs) (Jolliffe, 2002; Gujarati and Porter, 2009). Bartlett's test of Sphericity and the Kaiser-Mayer-Olkin (KMO) were used to check if the data were appropriate for the PCA. Furthermore, the Kaiser criterion was used to determine the decision on factor retention. For more details on Bartlett's test of Sphericity, KMO, and Kaiser criterion, see Zaca *et al.* (2023). The varimax rotation technique was used to improve the interpretability of the PCA results. Factor loadings above 0.50 were considered to have a strong influence on the PCs and were included in the interpretation.

## 4.4 Results and discussion

### 4.4.1 Descriptive statistics of variables used in the model

Descriptive statistics for the independent variables are presented in Table 4.1. The average age of sampled household heads was 61.83 years. This is consistent with previous studies (Cele and Wale, 2020; Villamor *et al.*, 2023) which indicated a relatively low involvement of youth in agriculture. This has a negative effect on ensuring continuity and succession planning in small-scale farming. The results showed that 35.1% of smallholder farmers had access to training. Most of them indicated a lack of access to training on climate change adaptation strategies. This is in line with Ubisi *et al.* (2020), who indicated that smallholder farmers rely on indigenous knowledge to adapt to climate variability. Although the local government authorities are aware of climate change risks, the adaptation works are done in fragments, and their effectiveness is not evident in resource-poor communities due to a lack of community engagement (Biswas and Rahman, 2023). According to Alam *et al.* (2017), adaptation strategies occurring at the local level tend to be more effective than those imposed nationally.

**Table 4.1.** Description of independent variables, their means, standard deviations, and percentages

| Variable | Description | Mean | Std. Dev. | % |
|---|---|---|---|---|
| **Continuous variables** | | | | |
| Age | Household head age (Years) | 61.83 | 14.05 | - |
| Age square | Square of the age of household head | 4020.07 | 1777.65 | - |
| Adult equivalence | Household size in adult equivalents | 3.32 | 1.79 | - |
| Land size | Farmland size household has access to (Hectares) | 1.33 | 1.22 | - |
| Total livestock units | Tropical Livestock Units | 1.75 | 3.05 | - |
| Assets | Log of the total value of physical assets | 9.49 | 1.33 | - |
| Off-farm income | Log of the annual income from non-farm activities | 10.88 | 0.86 | - |
| **Dummy variables** | | | | |
| Training | Access to agricultural training (1 = Yes; 0 = Otherwise) | - | - | 35.1 |
| Married | Marital status (1 = Married; 0 = Otherwise) | - | - | 40.7 |
| Group membership | Membership in groups (1 = Yes; 0 = Otherwise) | - | - | 92.5 |
| Gender | Gender of household head (1 = Yes; 0 = Otherwise) | - | - | 42.0 |
| Climate change information | Access to climate change information (1 = Yes; 0 = Otherwise) | - | - | 91.1 |
| Credit | Access to credit (1 = Yes; 0 = Otherwise) | - | - | 23.0 |
| Self-confidence | Psychological capital indices computed using PCA | - | - | - |
| Hope | | - | - | - |
| Optimism | | - | - | - |
| Resilience | | - | - | - |

**Source:** Survey data (2022)

Moreover, the majority of respondents (91.1%) had access to climate change information about potential temperature changes, rainfall predictions, and the occurrence of droughts. The main sources of information were radio and television. This shows the importance of media in raising awareness and information on climate change and adaptation strategies in local languages. A low percentage of smallholder farmers had access to credit (23.0%). Most of them rely on informal money lenders (loan sharks and *stokvels*) because formal credit sources (commercial banks and microfinance institutions) have strict credit requirements (Chipfupa *et al.*, 2021).

### 4.4.2 Perceptions of climate change

The average number of years the respondents had lived in Swayimane, Umbumbulu, and Richmond was 33.61, 31.63, and 27.65, respectively (Table 4.2). This implies that the respondents have accumulated much experience and knowledge on climate change in the study locations. Moreover, the F-test results indicated that the average number of years lived in the area was statistically significant across the study locations at the 5% significance level. Smallholders' perceptions of climate change shape their adaptive behaviour (Bryan *et al.*, 2013; Kumar and Sidana, 2018). The results showed that 93.1% of sampled farming households perceived climate change as a problem. They indicated that changing climate is a challenge due to the following reasons: damaged physical infrastructure and houses; unstable weather conditions; severe floods; decreased edible wild fruits and vegetables; lower crop yields; on-farm job opportunities decline; increased temperatures; water shortage; and changed planting dates. Yield inconsistency caused by varying weather patterns impacts the profitability and livelihoods of smallholder farmers (Thibane *et al.*, 2023). Furthermore, previous studies on the relationship between climate change and employment reported that unfavourable climatic conditions in farming communities raise the unemployment rate (Alam *et al.*, 2017; Fagariba *et al.*, 2018).

**Table 4.2.** Smallholder farmers' perceptions of climate change and average number of years lived in the area

| | Swayimane | Umbumbulu | Richmond | Total | $Chi^2$ - test |
|---|---|---|---|---|---|
| Climate change is a problem (%) | 94.6 | 89.3 | 95.5 | 93.1 | 3.55 |
| Rainfall patterns have changed over the past 20 years (%) | 95.7 | 90.3 | 98.2 | 94.8 | 6.88** |
| *Increasing* | 75.0 | 32.3 | 39.8 | 48.1 | |
| *Decreasing* | 8.0 | 43.0 | 28.7 | 27.0 | 44.47*** |
| *Variable* | 17.0 | 24.7 | 31.5 | 24.9 | |
| Temperature patterns have changed over the past 20 years (%) | 85.9 | 87.4 | 98.2 | 90.8 | 11.32*** |
| *Increasing* | 82.3 | 50.0 | 67.6 | 66.1 | |
| *Decreasing* | 6.3 | 20.0 | 5.6 | 10.5 | 25.36*** |
| *Variable* | 11.4 | 30.0 | 26.9 | 23.5 | |
| Climate change has affected agricultural production (%) | 88.6 | 79.6 | 90.8 | 86.6 | 5.93* |
| | | | | | F-test |
| Average number of years lived in the area | 33.61 | 31.63 | 27.65 | 30.79 | 3.29** |

**Note:** ***, **, and * indicate the level of significance at 1%, 5% and 10%, respectively.

**Source:** Survey data (2022)

Moreover, respondents were asked questions about their observations of the rainfall and temperature patterns over the past 20 years. The $Chi^2$ test results indicated that the differences in perception of changes in rainfall and temperature across the study locations were statistically significant at the 5% and 1% significance level, respectively. The majority of smallholder farmers (66.1%) perceived an increase in temperature over the past 20 years while 24.9% perceived variable rainfall. Respondents in the same area can have different perceptions about climate change due to individual experiences and differences in access to awareness programs and climate information.

### 4.4.3 Perceived causes of climate change

Figure 4.2 shows that most smallholder farmers attributed climate change to pollution (43.6%). This is in line with Perera (2017), who identified air, water, and land pollution as major drivers of climate change. Other identified causes of changing climate were population growth, deforestation, ozone layer depletion, and God.

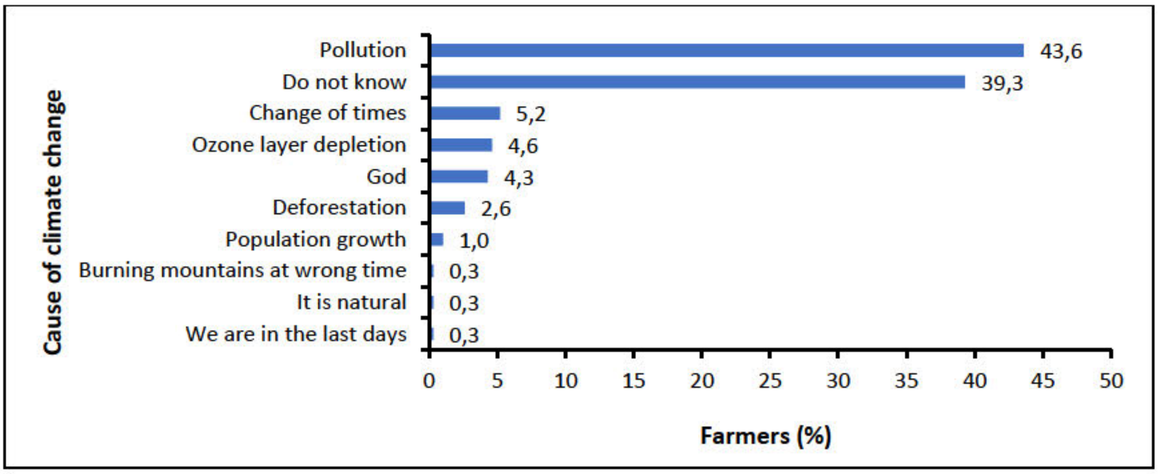


**Figure 4.2.** Smallholder farmers' perceived causes of climate change

**Source:** Survey data (2022)

According to Msalilwa *et al.* (2016), climate change is also caused by human activities such as deforestation. Continuous dependence on the forest for basic needs such as herbs, food, firewood, and shelter affects biodiversity conservation (Fagariba *et al.*, 2018). Nevertheless, some respondents (39.3%) did not know the causes of climate variability. This inconclusiveness can be attributed to smallholder farmers' lack of environmental education (Oliver *et al.*, 2020). This lack of knowledge can be attributed to limited access to climate-related information and poor outreach programs in rural areas. These challenges often hinder smallholder farmers from gaining a clear understanding of environmental issues.

### 4.4.4 Effects of climate change on smallholder farmers' livelihoods

Climate variability has several direct and indirect effects on the individuals' economy, environment, and lives (Fagariba *et al.*, 2018). Table 4.3 shows that the majority of smallholder farmers (71.5%) reported that crop production in their community is mainly affected by climate change. This increases the utilization of fertilizers and improved seeds for yield improvement, which raises farming costs and leads to high food prices. This is in line with previous studies such as Adeagbo *et al.* (2021), who emphasized that the agricultural activity mainly affected by climate change is crop productivity.

**Table 4.3.** Climate change effects on livelihoods (%)

| | Swayimane | Umbumbulu | Richmond | Total | $Chi^2$ - test |
|---|---|---|---|---|---|
| Crop production | 76,1 | 63,1 | 75,5 | 71,5 | 5.35* |
| Livestock farming | 17,4 | 14,6 | 34,5 | 22,6 | 14.13*** |
| Water availability | 16,3 | 38,8 | 19,1 | 24,9 | 16.31*** |
| Health | 27,2 | 7,8 | 20,0 | 18,0 | 12.83*** |
| Firewood availability | 0,0 | 7,8 | 4,5 | 4,3 | 7.22** |
| None | 4,3 | 4,9 | 1,8 | 3,6 | 1.62 |

**Note:** ***, **, and * indicate the level of significance at 1%, 5% and 10%, respectively.
**Source:** Survey data (2022)

The results also showed that livestock farming (22.6%), water availability (24.9%), and the health of rural households (18%) were affected by climate change. Frequent water shortage implies a lack of access to drinkable water for livestock and human beings or irrigation water for crops. Some respondents stated that their goats and cattle usually die due to lack of water. Moreover, excessive changes in temperature patterns escalate human illnesses such as fever and heat exhaustion. According to Talukder *et al.* (2021), climate change affects the health of emerging farmers. However, their health is usually neglected in debates about the future of agriculture and policymaking approaches such as climate-smart agriculture. Poor health of smallholder farmers reduces farm labour and poses a threat to food and nutrition security for households who depend on farming for their livelihood (Combary and Traore, 2021). This implies that measures should be implemented to address climate change's impact on the environment, economy, and humanity. For example, planting on-farm trees can prevent soil erosion during floods and provide shade to protect farm employees who work in open fields under the sun from heat-related diseases (Deißler *et al.*, 2024). A few respondents also mentioned houses (1.3%), roads (0.7%), fruit farming (0.3%), and fisheries (0.3%) as livelihoods affected by changing climate.

### 4.4.5 Effects of climate change on agricultural production

The majority of smallholders (86.6%) indicated that changes in rainfall and temperature patterns have affected their agricultural production (Figure 4.3). Crop pests and diseases, crop failure, reduced quality and quantity of crops, livestock deaths, and reduced soil fertility were some of the effects of climate change identified by respondents.

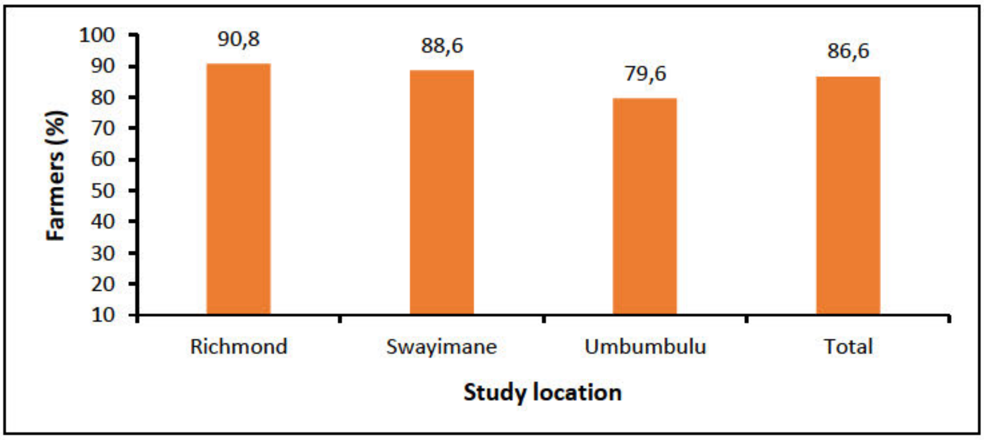


**Figure 4.3.** Impact of climate change on agricultural production

**Source:** Survey data (2022)

During the survey, some smallholder farmers reported that they find it difficult to save seed stocks for the next farming season due to the declining quantity of crops harvested. Moreover, the farmers mainly farm for consumption. Mthethwa *et al.* (2022) asserted that climate change reduces the quality and quantity of crop yields through drought, hailstorms, and floods. Some respondents at Swayimane stated that they had to switch from vegetable to sugarcane farming due to climate change. However, they have limited financial ability to cope with the rising input and labour costs required for sugarcane planting. Furthermore, the impact of the changing climate on soil fertility increases the risk of food insecurity, poverty, and hunger for resource-poor communities (Fagariba *et al.*, 2018).

### 4.4.6 Prevalence of climate change events

To distinguish between responses to perceived long-term climate change and climate shocks, the respondents were also asked about their experience with climate change events. Figure 4.4 illustrates that changing rainfall patterns (94.4%), increasing temperature (86.6%), floods (84.6%), change in season's length (80.3%), and storms (80%) were the common climate change phenomena in the study locations. These results support the finding of Chipfupa *et al.* (2021) in which smallholder farmers reported increasing temperature and rainfall variability in the KwaZulu-Natal province.

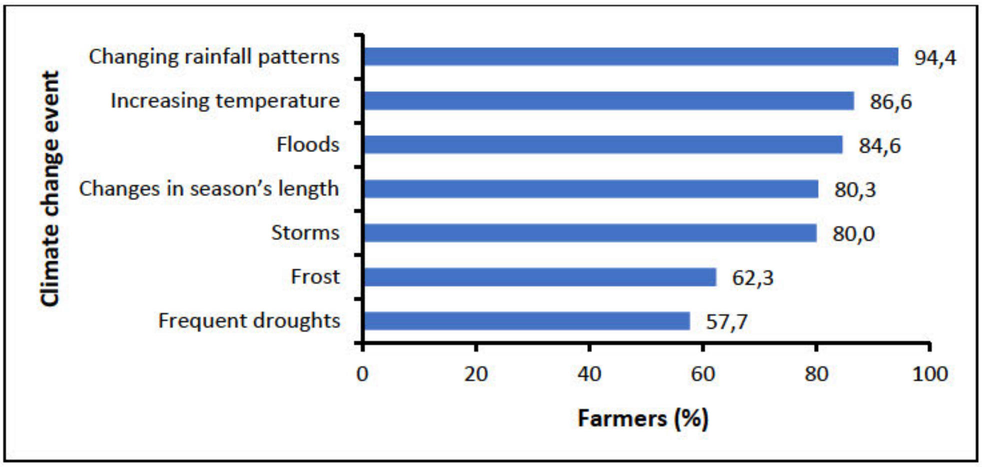


**Figure 4.4.** Climate change events experienced by smallholder farmers

**Source:** Survey data (2022)

After assessing the magnitude and severity of floods occurring in parts of South Africa that resulted in deaths and damage to property, infrastructure, and the environment, the Head of the National Disaster Management Centre classified these occurrences as a national disaster (DCoG, 2022). A survey conducted by the South African Cane Growers Association revealed that the year 2022 floods in KwaZulu-Natal affected sugarcane growers in rural areas, with estimated losses at approximately ZAR 223 million (Dardagan, 2022). Moreover, most respondents indicated that they are experiencing a significant delay in the rainy season due to climate change. For example, they receive rain in September or October instead of August. This leads to delayed planting dates for at least one month because they lack irrigation equipment and irrigable land either near a water source or river or in the irrigation schemes. In line with these results, Talanow *et al.* (2021) also reported that the seasons have moved along with the changing climate in South Africa. Boreholes are identified as a viable method to improve crop production in areas with poor rain and frequent drought (Fagariba *et al.*, 2018; Nguyen *et al.*, 2021).

### 4.4.7 Smallholder farmers' adaptation strategies

Despite the climate change events in the study locations, smallholder farmers applied various adaptation strategies to sustain and improve their livelihoods. The most common strategies were planting trees (84.9%), changing planting dates (67.5%), soil conservation strategies such as crop rotation and mulching (64.3%), and diversifying crops (53.8%) (Figure 4.5). Some smallholder farmers indicated that trees provide shade, block wind during storms, control soil erosion during floods, provide herbal medicine to treat diseases caused by changing climate, improve carbon sequestration, and provide income.

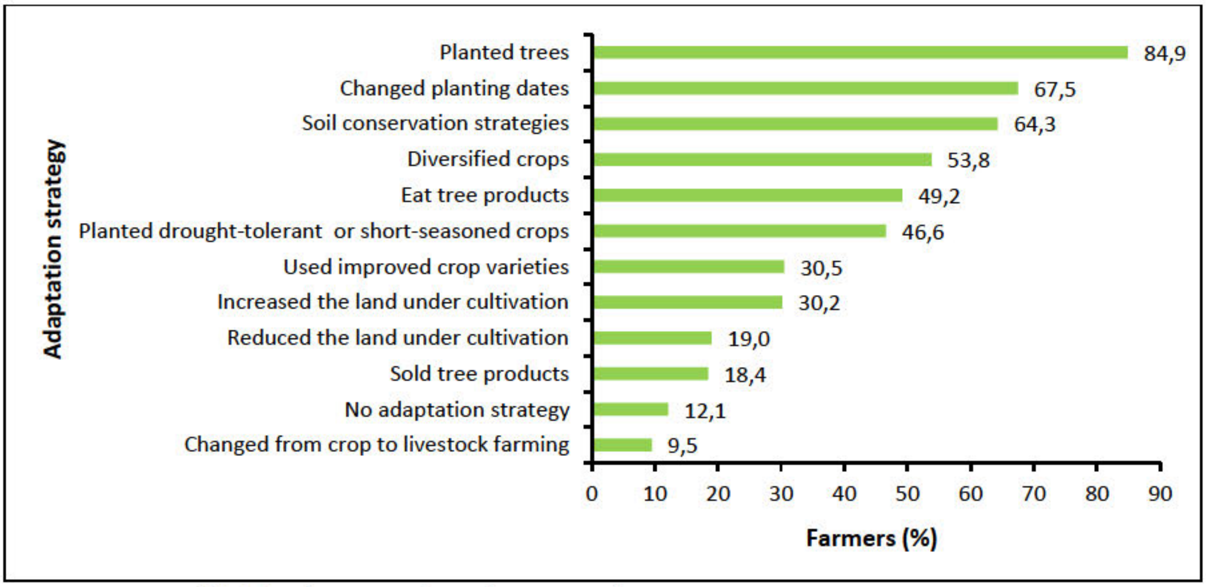


**Figure 4.5.** Smallholder farmers' adaptation strategies

**Source:** Survey data (2022)

Moreover, the results indicated that smallholder farmers employed soil and crop management strategies rather than water management techniques. These findings concur with Nguyen *et al.* (2021), who reported that few smallholder farmers employ water management practices due to financial constraints and lack of knowledge. Adjusting the farming calendar is a widely used strategy because it is simple to implement and requires less input cost. Crop diversification improves food and nutritional security, on-farm income, and employment opportunities. It also promotes sustainable agriculture development (Barman *et al.*, 2022; Douyon *et al.*, 2022). Smallholder farmers in the study locations practiced multiple cropping and/or intercropping as part of their responses to changing climate to reduce production loss. The main crops intercropped included maize, cabbage, sweet potatoes, cassava, beans, potatoes, and spinach. As unfavourable climatic conditions also increase soil erosion, soil conservation strategies have been found to improve soil fertility and moisture (Fagariba *et al.*, 2018). For example, most of the sampled smallholder farmers indicated that they use livestock manure and crop residues as compost because they cannot afford expensive fertilizers.

The results also indicated that trees were used as a solution to food and nutrition insecurity caused by climate change through eating tree products such as fruits (49.2%). For example, some respondents indicated that they spread avocado on bread or eat it with crumbly maize porridge (i.e., use it as a substitute for curry and spreads such as peanut butter and jam). This enables them to save money for other essential household expenditures. However, most smallholder farmers indicated a lack of access to tree saplings as the main barrier to planting more trees on their farmland. According to Alam *et al.* (2017), farming rural households receive relatively little technical and financial support for agricultural adaptation strategies such as tree planting. A relatively low percentage of smallholder farmers (12.1%) did not apply any adaptation strategy. The lack of knowledge, financial constraints, inadequate water, poor soil fertility, shortage of land, and lack of farm inputs were mentioned as critical barriers to climate change adaptation. Strengthening agricultural credit, extension, and training is crucial for effectively transferring technologies to cope with the changing climate (Kumar and Sidana, 2018).

### 4.4.8 Psychological capital indices

**Table 4.4.** Positive psychological capital dimensions for smallholders

| Variables | Principal components | | | |
|---|---|---|---|---|
| | **$PC_1$ – Self-confidence** | **$PC_2$ – Hope** | **$PC_3$ – Optimism** | **$PC_4$ – Resilience** |
| **Hope** | | | | |
| Given the current farming constraints, do you believe that there is a potential to turn things around? | 0.303 | 0.481 | -0.093 | 0.476 |
| Given the current unemployment rate, do you believe that youth have the potential to start businesses and create more jobs? | -0.009 | **0.742** | -0.169 | -0.040 |
| **Resilience** | | | | |
| If your crops are affected by pests, will you seek to raise money to buy effective pesticides or pest-resistant crops in the next season? | 0.024 | -0.101 | 0.069 | **0.927** |
| If your business has been making a loss for the past three years, will you continue with it and consult a business advisor or successful business owner? | 0.186 | **0.652** | 0.222 | -0.024 |
| **Self-confidence** | | | | |
| Do you believe that you are most likely to be nominated by others as a leader in the community? | **0.875** | 0.130 | 0.002 | 0.081 |
| Would you accept the nomination if you were nominated as a committee member in an organization? | **0.879** | 0.057 | 0.001 | 0.031 |
| **Optimism** | | | | |
| When faced with poor yields and struggling to meet basic needs, would you continue farming and see the constraints as temporary? | -0.080 | 0.318 | **0.736** | 0.178 |
| If the government introduces a new land consolidation program, are you most likely going to refuse the compensation and keep your land? | 0.068 | -0.323 | **0.731** | -0.113 |
| *Eigenvalue* | 2.06 | 1.21 | 1.16 | 1.00 |
| *% of variance* | 25.71 | 15.15 | 14.47 | 12.51 |
| *Cumulative % of variance* | 25.71 | 40.86 | 55.33 | 67.84 |

**Note:** Only component loadings greater than |0.50| are included in the interpretation; KMO = 0.61 and Bartlett's Test of Sphericity $Chi^2$ = 257.17, p-value = 0.000.

**Source:** Survey data (2022)

Table 4.4 presents the PCA-derived psychological capital indices. A statistically significant Bartlett's test of Sphericity and the KMO value (0.61) showed that the data were appropriate for PCA. Four PCs accounting for 67.84% of the total variation in the data were retained using the Kaiser criterion. The first PC represented farmers with high levels of self-confidence. The second represented hopeful smallholder farmers. The third and fourth PCs represented optimistic and resilient smallholder farmers, respectively.

### 4.4.9 Determinants of smallholders' choice of adaptation strategies to climate change

This section discusses the results from the multivariate probit model. Table 4.5 shows the pairwise correlation matrix results. All the correlation coefficients of the error terms were positive, indicating complementarity among the adaptation strategies. The highest positive correlation (46.1%) was between SCS and DC, while the lowest (8.7%) was between PT and DC. A statistically significant likelihood ratio test [$Chi^2(6)$ = 94.556; $p$ = 0.000] for the overall correlation of error terms justified the use of the multivariate probit model. The null hypothesis that the error terms across the four adaptation strategies are not correlated was rejected. The joint probability of adopting all the adaptation strategies (success) was 32.8%, while that of adopting none of the strategies (failure) was 3.3%.

**Table 4.5.** Pairwise correlation matrix from the multivariate probit model estimation

| **Variables** | $P_j$ | **CPD** | | **SCS** | | **DC** | | **$Chi^2(6)$** | $p$ |
|---|---|---|---|---|---|---|---|---|---|
| | | **Coef.** | **Std. Err.** | **Coef.** | **Std. Err.** | **Coef.** | **Std. Err.** | | |
| PT | - | 0.119[b] | 0.044 | 0.183[a] | 0.042 | 0.087 | 0.041 | - | - |
| CPD | - | - | - | 0.345[a] | 0.053 | 0.312[a] | 0.051 | - | - |
| SCS | - | - | - | - | - | 0.461[a] | 0.049 | - | - |
| LR test | - | - | - | - | - | - | - | 94.556 | 0.000 |
| Success | 0.328 | - | - | - | - | - | - | - | - |
| Failure | 0.033 | - | - | - | - | - | - | - | - |

**Note:** $P_j$, joint probability; PT, planted trees; CPD, changed planting dates; SCS, soil conservation strategies; DC, diversified crops; LR, likelihood ratio. [a] and [b] indicate the level of significance at 1% and 5%, respectively.
**Source:** Survey data (2022)

The Wald test [$Chi^2(68)$ = 102.66; $p$-value = 0.004] for joint significance of the adaptation strategies was also statistically significant (Table 4.6). This implies that the decisions to adopt the four adaptation strategies are interdependent and, thus, should be estimated mutually. The results showed the absence of multicollinearity since the VIFs had an average of 6.64, which is below the threshold value. Two of the four psychological capital variables (hope and resilience) had a statistically significant relationship with smallholder farmers' climate change adaptation choices. This is in line with previous studies (Wuepper *et al.,* 2019; Mortreux *et al.,* 2020; Chipfupa *et al.,* 2021; Villamor *et al.,* 2023) and indicates the significance of non-cognitive variables in the analysis of climate variability adaptation behaviour. However, the fact that psychological capital variables were only significant in four out of the sixteen possible outcomes emphasizes the importance of assessing the impact of different constructs on farmers' decision-making instead of assuming it.

**Table 4.6.** Determinants of adaptation strategies to climate change: Multivariate probit model results

| Variables | PT | | CPD | | SCS | | DC | |
|---|---|---|---|---|---|---|---|---|
| | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. |
| Age | 0.028 | 0.042 | 0.069[c] | 0.037 | 0.072[c] | 0.037 | 0.075[b] | 0.037 |
| Age square | -0.000 | 0.000 | -0.001[c] | 0.000 | -0.001[c] | 0.000 | -0.001[b] | 0.000 |
| Training | 0.382[c] | 0.228 | 0.344[c] | 0.178 | 0.173 | 0.174 | 0.116 | 0.166 |
| Total livestock units | 0.036 | 0.037 | 0.021 | 0.028 | -0.006 | 0.026 | -0.033 | 0.025 |
| Married | -0.279 | 0.250 | -0.299 | 0.207 | -0.236 | 0.209 | -0.105 | 0.200 |
| Adult equivalence | -0.019 | 0.064 | 0.121[b] | 0.051 | 0.056 | 0.050 | 0.037 | 0.049 |
| Group membership | -0.071 | 0.355 | 1.103[a] | 0.315 | 0.431 | 0.300 | 0.543[c] | 0.314 |
| Assets | 0.056 | 0.086 | 0.010 | 0.069 | 0.117[c] | 0.070 | -0.026 | 0.067 |
| Off-farm income | 0.072 | 0.144 | -0.142 | 0.121 | 0.026 | 0.123 | 0.229[c] | 0.117 |
| Land size | 0.234[b] | 0.110 | -0.067 | 0.065 | -0.027 | 0.064 | 0.082 | 0.065 |
| Gender | 0.384 | 0.252 | 0.206 | 0.205 | 0.416[b] | 0.207 | 0.173 | 0.197 |
| Climate change information | 0.499[c] | 0.292 | -0.172 | 0.294 | 0.079 | 0.284 | -0.485[c] | 0.284 |
| Credit | -0.027 | 0.234 | -0.164 | 0.188 | 0.050 | 0.187 | 0.278 | 0.184 |
| Confidence | 0.058 | 0.093 | -0.017 | 0.080 | 0.063 | 0.077 | 0.039 | 0.076 |
| Hope | -0.236[c] | 0.104 | 0.112 | 0.079 | 0.243[a] | 0.078 | 0.124[c] | 0.075 |
| Optimism | -0.019 | 0.095 | 0.006 | 0.079 | 0.038 | 0.078 | 0.123 | 0.078 |
| Resilience | -0.100 | 0.096 | 0.101 | 0.080 | 0.141[c] | 0.078 | 0.083 | 0.078 |
| Constant | -1.850 | 1.686 | -1.605 | 1.451 | -4.232[a] | 1.505 | -4.693[a] | 1.450 |

**Note:** Wald test $Chi^2(68) = 102.66$; $p$-value = 0.004; Log likelihood = -619.386; Multicollinearity test VIF = 6.64; **[a]**, **[b]**, and **[c]** indicate the level of significance at 1% and 5%, and 10% respectively.
**Source:** Survey data (2022)

The results showed that hopeful smallholder farmers were less likely to adopt PT but more likely to adopt SCS and DC. Being hopeful makes them perceive the changing climate as a temporary challenge. This makes them invest in short-term adaptation strategies such as soil conservation and crop diversification instead of long-term strategies such as planting trees. On the other hand, farmers who have lost hope and stopped planting certain crops due to drought and floods are less likely to adopt crop farming-related adaptation strategies, but are more likely to plant trees due to their multiple benefits. This is in line with Truelove *et al.* (2015), who indicated that farmers negatively affected by climate change are more likely to adopt long-term adaptation strategies. The findings showed a positive and significant relationship between resilience and the adoption of SCS. These results support the conclusions of Keshavarz and Moqadas (2021), who emphasized that resilient individuals can adapt to climate change shocks and stresses. According to Chipfupa *et al.* (2021), resilience depends on mental or emotional strength and ability. Thus, smallholder farmers also require personal assets to translate non-cognitive skills into palpable coping mechanisms and adapt to climate change.

The results also showed that five other explanatory variables had a significant relationship with more than one adaptation strategy (i.e., age, age square, training, group membership, and climate change information). The relationship between the age of the household head and the adoption of CPD, SCS, and DC was positive. This implies that older smallholder farmers are more likely to adopt climate change adaptation strategies than younger ones. They tend to be knowledgeable and utilize their experience to adapt better because they have witnessed more climate change events (Nguyen *et al.*, 2021). Nevertheless, the significant and negative coefficient of the square of age indicates that the relationship is non-linear. That is, adaptive decisions increase with age until a certain point beyond which smallholder farmers become less likely to adopt new adaptation strategies. According to Aryal *et al.* (2018), aging smallholders are reluctant to alter their behaviour, less willing to employ modern technologies or farming practices, less innovative, and prefer traditional methods.

Access to training had a positive and significant impact on the adoption of PT and CPD. This implies that awareness of the benefits of adaptation strategies through training programs is crucial in encouraging smallholder farmers to adopt adaptive measures and improving their knowledge and experience in climate change adaptation. The results are in line with other studies that have indicated the importance of agricultural-related training in climate change adaptation (Aryal *et al.*, 2018; Esfandiari *et al.*, 2020; Pello *et al.*, 2021). Smallholder farmers' climate change adaptation decisions are influenced by what they learn from training programs (Nguyen *et al.*, 2021). Group membership positively and significantly impacted the adoption of CPD and DC. Farmers share information on overcoming the impacts of changing climate and obtain various options for adaptation through membership in groups (Chipfupa *et al.*, 2021). These results are in line with previous studies that have indicated the significance of social networks in climate change adaptation (Ojo and Baiyegunhi, 2020; Nguyen *et al.*, 2021; Pello *et al.*, 2021). Farmers' adaptive behaviour increases if they know that others are also involved in adaptation practices (Truelove *et al.*, 2015; Bechtoldt *et al.*, 2021).

Access to climate change information was positively associated with farmers' decision to adopt PT as an adaptation strategy. This is in line with Sertse *et al.* (2021), who reported that smallholder farmers are more likely to plant trees as a strategy to mitigate the negative effects of climate variability if they have access to climate information services. Adopting climate-smart agriculture techniques such as agroforestry significantly increases among smallholder farmers who receive climate variability information from trusted sources (Nguyen *et al.*, 2021). Contrary to expectation, there was a significant and negative relationship between the farmers' access to climate change information and the adoption of DC. The possible reason is that equipping farmers with the necessary knowledge about climate change improves their decision to invest in sustainable and long-term strategies, such as integrating trees into farming activities to enhance agricultural productivity and on-farm income (Apeh *et al.*, 2023). This signifies that the role of climate change awareness in encouraging resilience to the changing climate among smallholder farmers should be critically evaluated.

Other statistically significant variables included adult equivalence, assets, off-farm income, land size, and gender. However, these variables were associated with only one of the adaptation strategies. The results showed that land size was positively related to the adoption of PT. This is consistent with Sertse *et al.* (2021), who found a significant positive relationship between farmland size and planting trees to cope with changing climate. This implies that PT adoption increases with a rise in land size owned by smallholder farmers. According to Pello *et al.* (2021), a larger farmland size is an incentive for diversification and enables farmers to dedicate part of their land to new and various climate change adaptation strategies. The relationship between off-farm income and the adoption of DC was positive. This is in line with previous studies (Ojo and Baiyegunhi, 2020; Adeagbo *et al.*, 2021) which reported that smallholder farmers with access to off-farm income are likely to invest in climate change adaptation strategies because their involvement in off-farm activities may contribute to addressing financial constraints.

### 4.5 Conclusions and policy implications

This study examined the determinants of adaptation to climate change among smallholder farmers. Climate change adaptation is a two-step process requiring smallholder farmers to first perceive climate change and then respond to the changes. The results showed that most smallholder farmers perceived climate change as challenging and indicated it mainly affects crop production. To adapt to climate change, they applied various adaptation strategies such as planting trees, changing planting dates, soil conservation (crop rotation and mulching), using improved crop varieties, and crop diversification. Planting trees was the most common adaptation strategy in the study locations. It emerged as a long-term and sustainable adaptation strategy compared to other strategies. This suggests an intervention of forestry extension services and addressing the lack of access to tree saplings in smallholder farming. Prioritization of policies on tree planting as a climate change adaptation strategy and raising awareness on the benefits of planting trees is recommended.

Most of the barriers to climate change adaptation were related to infrastructure and institutional factors. Therefore, policy intervention is required to improve institutional services and infrastructural facilities and to deliver effective, affordable, and sustainable adaptation strategies. Increasing access to early warning systems is the key to successful adoption of precautionary measures. Early warnings of climatic events may enable rural households to be prepared and reduce losses that they usually experience during unexpected climate shocks. Multivariate probit model results indicated that age, age square, group membership, access to training and climate change information, off-farm income, land size, and psychological capital (hope and resilience) influence the decisions to adopt climate change adaptation strategies. Most farmers indicated a lack of access to training on climate change adaptation strategies and that they rely on indigenous knowledge. Therefore, extension officers, non-governmental organizations, policymakers, and other stakeholders need to support local-level knowledge of climate change adaptation and turn it into effective and sustainable action. Engaging smallholder farmers strengthens their support of adaptation policies.

Moreover, government leadership at all levels need to prioritize climate change adaptation in their national, provincial, district, and local budgets. Prioritizing climate change-related training programs is recommended to effectively enhance smallholder farmers' capacity to adapt to changing climate. Such programs need to be simple, comprehensible, and practical to accommodate illiterate and less experienced farmers and to promote just and equitable development. For example, local languages can be used in training platforms. Ensuring effective and reliable access to information and improving awareness of the potential benefits of adaptation is also crucial. The findings of this study indicated a relationship between psychological capital and climate change adaptive behaviour of smallholder farmers. Thus, psychological support services need to be integrated into agricultural extension services, climate adaptation planning, and/or policy. This can be done through training workshops and mentorship programs to improve smallholder farmers' resilience and adaptive capacity. It is recommended that future studies adopt a data collection approach that is close to the revealed preference method to measure psychological capital.

# CHAPTER 5. THE EFFECT OF FRUIT TREES ON FOOD INSECURITY REDUCTION AND NUTRITION SECURITY OF RURAL HOUSEHOLDS: A CASE STUDY OF THE KWAZULU-NATAL PROVINCE, SOUTH AFRICA


## 5.0 Abstract

Fruit trees play a key role in supporting food and nutrition security initiatives. However, their contribution is generally not well considered in the various food and nutrition initiatives of the KwaZulu-Natal government in particular and South Africa in general. This study investigated the effect of fruit trees on food insecurity reduction and nutrition security among rural households in KwaZulu-Natal province, South Africa. A sample size of 305 households was obtained from Swayimane, Umbumbulu, and Richmond. Descriptive statistics, household food insecurity access scale, household food insecurity access prevalence, food consumption score, principal component analysis, and ordered logit model were used to analyze the survey data. The results showed that only 29.8% of the households were food secure, while the rest were either mildly (36.4%), moderately (27.9%), or severely (5.9%) food insecure. Only 4.6% of the households consumed poor diets. While 23.0% of the sampled households were at the borderline, 72.5% consumed an acceptable diversity of food groups. The ordered logit model findings showed that growing fruit trees, consumption of wild fruits, household size, off-farm income, access to irrigation, access to training, livestock ownership, and psychological capital significantly influenced household food and nutrition insecurity. The study recommends the implementation of awareness campaigns promoting the plantation of fruit trees and the consumption of wild fruits. The collective participation of the private sector, government, researchers, civil society organizations, policymakers, politicians, and farming rural households in transforming food systems is also suggested. There is a need for nutrition-related training programs and workshops to enhance rural households' confidence in managing food resources.



**Keywords:** food and nutrition insecurity; fruit trees; rural households; ordered logit model; psychological capital

## 5.1 Introduction

High levels of food and nutrition insecurity are prevalent in sub-Saharan Africa, with more than one-third of the population experiencing undernourishment (Onyeaka *et al.*, 2022). About two billion people worldwide lack access to adequate food (FAO *et al.*, 2021). South Africa is no exception to this prevailing challenge as 12.9% of people experienced hunger in 2022 (Stats SA, 2023). Although the country is food secure at a national level, it remains food insecure at the household level. For instance, 19.6% of South African households considered their access to food as inadequate or severely inadequate in 2022 (Stats SA, 2023). Rural households usually experience higher rates of food and nutrition insecurity and different forms of malnutrition than urban households (FAO *et al.*, 2021). According to McMullin *et al.* (2019), malnutrition is mainly caused by a low-quality diet with inadequate consumption of fruits and vegetables. Thus, it is important to ensure that all individuals have access to adequate and nutritious food produced in an environmentally and socio-culturally sustainable way (Vinceti *et al.*, 2013; Omotayo and Aremu, 2020). In the present context of climate change, continuous loss of species and genetic diversity, soil degradation, rising urbanization, social conflict, and extreme poverty, collective and effective action is required to address food and nutrition insecurity.

The world has been struggling to achieve the United Nations' Sustainable Development Goals (SDGs) targets of eradicating hunger, ensuring constant access to safe, nutritious, and sufficient food for all people, and eliminating all forms of malnutrition (Ekwebelem *et al.*, 2021). Challenges such as the COVID-19 pandemic, economic instability, and international conflicts (e.g., the Russia-Ukraine war) have put the world off track to eradicating food insecurity and malnutrition in all its forms by 2030 (FAO *et al.*, 2021; Balma *et al.*, 2022). Such challenges affect the capacity of food systems and cause supply chains to not function properly in African countries, including South Africa (Behnassi and El Haiba, 2022). The Southern African Development Community (SADC) plans to significantly decrease food and nutrition insecurity in selected African countries by 2025 (SADC, 2014). Hence, food and nutrition insecurity reduction is one of the top agenda items for the South African government. For example, the country's National Policy on Food and Nutrition Security of 2013 aims to utilize a multi-sectored approach to combat food and nutrition insecurity (Maziya *et al.*, 2017).

According to Smith *et al.* (2020), tree restoration and improved forest management are key strategies to reduce food and nutrition insecurity. Hence, tree resources need to be incorporated into policies because they contribute to attaining the six pillars of food security (availability, access, utilization, stability, agency, and sustainability). They contribute significantly to food and nutrition insecurity reduction through the direct provision of food and energy for cooking. Edible tree resources have been reported to decrease food insecurity through improved dietary diversity (Kepe, 2008) and providing nutritional diets (Fentahun and Hager, 2009), particularly for rural households (Arnold *et al.*, 2011). For example, nuts and fruits harvested from trees are crucial sources of micronutrients in many rural communities because they are easily accessible, inexpensive, and nutritious (Maseko *et al.*, 2017; Hall *et al.*, 2019; McMullin *et al.*, 2019). Tree products also contribute indirectly through income provision (Vinceti *et al.*, 2013; Koffi *et al.*, 2020).

Though several studies explored the role of tree resources in addressing food and nutrition insecurity (e.g., McMullin *et al.*, 2019; Koffi *et al.*, 2020), there is insufficient empirical research on the impact of fruit trees on food insecurity and nutrition security. Some of the limited studies known to the authors that have attempted to examine the contribution of trees to food and nutrition insecurity are Koffi *et al.* (2020), Omotayo and Aremu (2020), and Bhebhe *et al.* (2023). The first two studies are based on a comprehensive review of the existing literature. The authors did not use primary data on the actual contribution of trees. Using detailed data (collected utilizing a pre-tested and structured questionnaire) is essential to understand the actual effect of trees. Moreover, although Bhebhe *et al.* (2023) used an empirical model in their study, the authors did not include the contribution of fruit trees to food groups consumed by each household in their analysis. Therefore, this study aimed to investigate the impact of fruit trees on food insecurity and nutrition security among rural households. It hypothesized an association between fruit trees and household food insecurity and nutrition security status.

Another novel aspect of this study is that it adopted a definition of food security with six pillars. Including agency and sustainability dimensions expands a four-pillar framework for food security to a six-dimensional one to address rising inequities within food systems. A six-pillar framework was proposed by the High Level Panel of Experts on Food Security and Nutrition (HLPE) and accepted by the Food and Agriculture Organization and other United Nations agencies in the State of Food Security and Nutrition in the World 2021 report (Fauzan'Azhima *et al.*, 2023). Agency refers to the ability of individuals and communities to exercise their voices and participate in their local food systems (Burchi and De Muro, 2016; Fauzan'Azhima *et al.*, 2023). Agency can be improved through equitable access to practical trainings, agricultural inputs, extension services, and arable land and through collective participation in shaping food systems and institutional frameworks (e.g., involvement of farmers), especially in vulnerable communities. Sustainability refers to resilient food systems that maintain natural, social, and economic systems and fulfil the food needs of current and future generations (Fauzan'Azhima *et al.*, 2023). Policy initiatives such as the SDGs also emphasize the significance of adopting sustainable food systems such as climate-smart agriculture.

### 5.2 Conceptual framework

Figure 5.1 presents the conceptual framework with its dimensions and impact pathways. It is argued that the role of livelihood assets must be accounted for in explaining the contribution of fruit trees in addressing food insecurity and improving nutrition security. Thus, the framework assumes that rural households pursue a wide range of agricultural activities such as planting trees conditional on their endowments (human, financial, physical, natural, social, and psychological capitals) and external factors (e.g., climate change and extension support). The endowments include psychological capital (Chipfupa and Wale, 2018; Phakathi and Wale, 2018), which defines an individual's mindset, perceptions, and behaviour (Luthans *et al.*, 2015). The asset comprises four constructs, i.e., self-confidence, hope, optimism, and resilience. Despite the difficulties, confident farming rural households believe in their capacity to grow and nurture fruit trees. Hope affords such households the willpower to persevere and proactively devise alternative solutions when facing challenges. Optimism enables them to have positive expectations about the future of agroforestry.

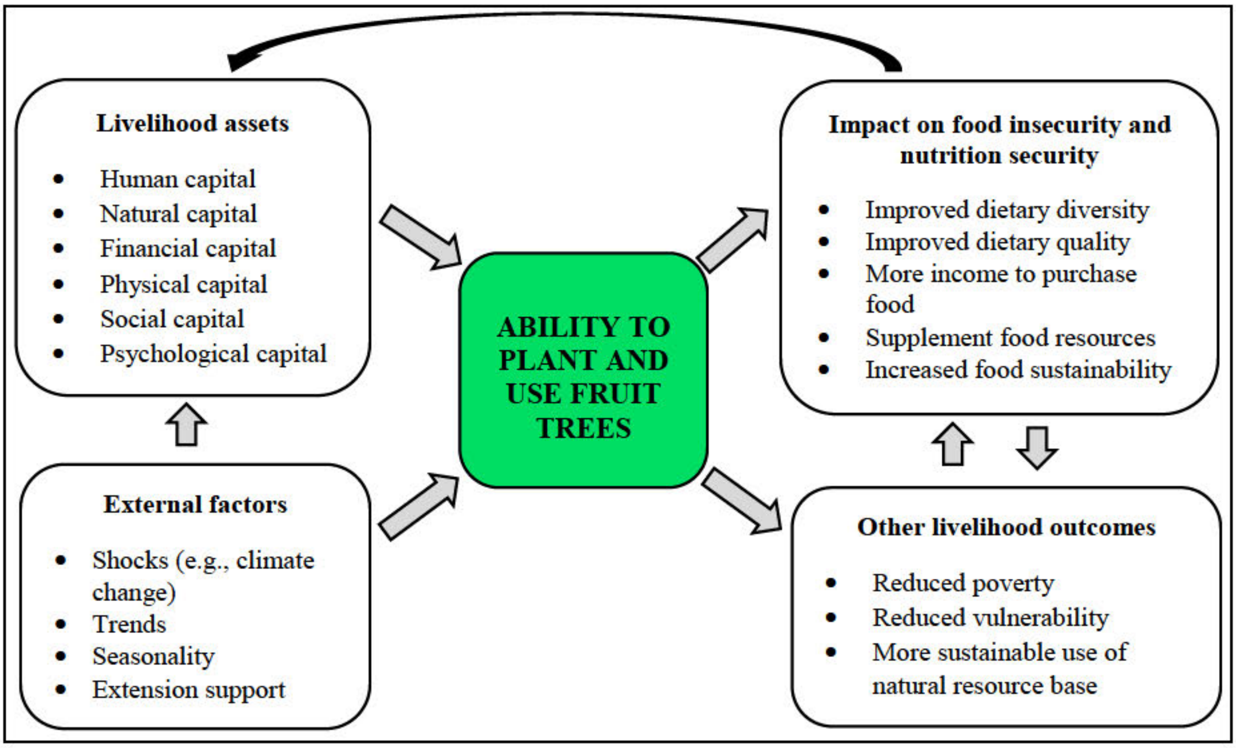


**Figure 5.1.** The conceptual link: impact of fruit trees on food insecurity and nutrition security

**Source:** Authors compilation

As a venture, setbacks or failures in planting fruit trees are common due to several adverse conditions. The households' resilience in the face of such adversities will thus be critical. If a household does not possess or have access to these assets, the result is failure to plant and use fruit trees to address food and nutrition security challenges (Phakathi and Wale, 2018). External factors such as climate change and extension support directly affect households' ability to plant and use fruit trees. However, they can also impact an individual's ability to possess livelihood assets, thus, indirectly affecting their agroforestry activities. Understanding these factors helps to appreciate how planting and utilizing fruit trees impacts rural households' food insecurity and nutrition security status. This is important for identifying and supporting sustainable development trajectories (Manlosa *et al.*, 2019). As mentioned earlier, two plausible pathways of tree products have been advocated to reduce food and nutrition insecurity. When consumed, they can improve dietary diversity (direct contribution). Income generated from their sales can also be utilized to buy food items to supplement the household diet (indirect contribution) (HLPE, 2017; McMullin *et al.*, 2019; Koffi *et al.*, 2020). According to Koffi *et al.* (2020), tree resources contribute to the attainment of food security pillars in the following ways: by providing a supplement to staple food all year long (availability), in periods of food shortage (stability), through increased dietary quality (utilization); and as a source of direct dietary improvement or income to purchase food (access). Fruit trees also contribute to food sustainability as some species are more drought-resistant and pest-tolerant than annual crops, thus, provide food in dry periods when other food sources are not available (McMullin *et al.*, 2019).

## 5.3 Research Methodology

### 5.3.1 Study area, sampling strategy, and data collection

The study focused on rural households in the KwaZulu-Natal province, South Africa (see Figure 3.1, page 22). The province has the second-highest population of approximately 12.4 million (Statistics South Africa, 2023). The province's average temperature increases above 25°C in summer and falls below 20°C during winter. Moreover, the average annual rainfall is about 800mm. The survey was conducted in three study sites: Swayimane, Umbumbulu, and Richmond. Swayimane and Richmond are in the uMgungundlovu District Municipality, while Umbumbulu is in the eThekwini Metropolitan Municipality. Most households in the study sites are involved in various farming activities such as crop, fruit, and livestock production. The majority of household members rely on social grants as their source of income (Simelane *et al.*, 2023).

A multistage sampling approach was employed to carry out the survey. The first stage involved the purposive selection of the KwaZulu-Natal province. The province was selected for the study due to its high levels of unemployment, poverty, and food insecurity, particularly among rural households (Simelane et al., 2023). This was done purposively to align the study with the South African government's plan to reduce poverty and improve food security. The second stage was the identification of municipalities with households engaged in small-scale farming activities. The municipalities were also chosen based on the presence of homestead and wild fruit trees. The third stage was the random selection of 317 rural households from the three study sites for interviews. However, only 305 questionnaires were valid and utilized for the analysis. According to Gujarati and Porter (2009), this sample size is reasonably large and deemed acceptable to conduct significant statistics.

The data were collected from September 2022 to October 2022 by trained enumerators who spoke the local language (IsiZulu). Research ethical clearance was obtained from the Humanities and Social Sciences Research Ethics Committee (HSSREC) of the University of KwaZulu-Natal (protocol reference number: HSSREC/00003793/2022). Moreover, all the ethical requirements such as informed consent and confidentiality, were observed throughout the study. The data collection took place during the fruiting season of the following trees: banana, peach, lemon, kei apple, mulberry, mango, and papaya Households grew different types of fruit trees, ensuring fruits were produced throughout different seasons. This diversity allowed for consistent fruit availability across households, which justified their inclusion in the analysis and aligned with the food security indicators assessed during the 30-day recall period. A structured and pre-tested questionnaire was used to collect data. The questionnaire encompassed questions about socio-economic and demographic characteristics, livelihood assets, fruit trees, food insecurity, food consumption, and agricultural production. In addition, focus group discussions were conducted to complement information collected during the household survey.

### 5.3.2 Data analysis

Descriptive statistics such as percentages, means, standard deviations (Std. Dev.), and standard errors (Std. Err.) were used to analyze data. A chi-square ($Chi^2$) test was conducted to determine whether there were statistically significant differences between the three study sites. Food insecurity status was measured using the household food insecurity access scale (HFIAS) and household food insecurity access prevalence (HFIAP). The food consumption score (FCS) was used to assess dietary intake or nutritional status. The principal component analysis (PCA) was employed to create psychological capital indices (see results in Table 4.4, page 44). These indices (i.e., self-confidence, hope, optimism, and resilience) were then included as independent variables in the regression model. The impact of fruit trees on food and nutrition insecurity was evaluated using the ordered logit model. The International Business Machines (IBM) Statistical Package for Social Sciences (SPSS) version 28 and STATA SE version 17 were used to perform statistical data analysis. Moreover, bar charts were done on Microsoft Excel 2019 to organize and summarise data.

#### 5.3.2.1 Food insecurity measurement

The HFIAS was used to evaluate the status of food insecurity among rural households. It has been widely used to determine the household food insecurity status (e.g., M'Kaibi *et al.*, 2015; Shisanya and Mafongoya, 2016; Maziya *et al.*, 2017; Manlosa *et al.*, 2019; Ndlovu *et al.*, 2022). The HFIAS is a self-reported measure of food insecurity based on a methodology developed by the Food and Nutrition Technical Assistance (FANTA) Project, which was funded by the United States Agency for International Development (USAID). Its aim is to categorize households into different food security levels (D'Haese *et al.*, 2013; Maziya *et al.*, 2017). The validity and reliability of the HFIAS in measuring household food insecurity were confirmed by Knueppel *et al.* (2009) and Becquey *et al.* (2010). The HFIAS comprises nine frequency-of-occurrence questions capturing the three dimensions of household food insecurity: anxiety and uncertainty about food access, insufficient food quality (includes dietary diversity, nutritional adequacy, and preferences), and insufficient food intake and the physical consequences or hunger (Coates *et al.*, 2007). The household food insecurity level is determined by the HFIAS score. According to Coates *et al.* (2007), the score is a continuous measure of the degree of food insecurity (access) in the past four weeks (i.e., 30 days). The HFIAS score variable was calculated for each household by adding the codes for each frequency-of-occurrence question about food access at the household level. Each of the nine questions has a maximum score of three. Therefore, the minimum score for a household is zero and the maximum score is 27. While a higher score indicates a more food insecure household, a lower score indicates a more food secure household (Coates *et al.*, 2007). The average HFIAS score is calculated using the following equation:

$$Average\ HFIAS\ score = \frac{Sum\ of\ HFIAS\ scores\ in\ the\ sample}{Total\ number\ of\ HFIAS\ scores\ in\ the\ sample\ (i.e., households)} \tag{5.1}$$

Moreover, the HFIAP indicator was used to illustrate the prevalence of household food insecurity. It categorizes the households into four levels of household food insecurity, namely, food secure, mildly food insecure, moderately food insecure, and severely food insecure (Coates *et al.*, 2007). These four categories were used as a dependent variable in this study. For more details on the computation of HFIAP and the definition and calculation of each household food insecurity (access) category see Coates *et al.* (2007:19-21).

#### 5.3.2.2 Nutritional adequacy measurement

According to D'Haese *et al.* (2013), the HFIAS and HFIAP measurements do not give a complete picture of the food security and nutrition status of households and individuals. Therefore, the FCS was also used in this study as an indicator of dietary intake. Previous studies have shown that the FCS is significantly associated with nutritional status indicators and can be used as a proxy for nutritional adequacy (Hasanah *et al.*, 2017; Isaura *et al.*, 2018; Toiba *et al.*, 2020; Rahman *et al.*, 2021; Hlatshwayo *et al.*, 2023). The FCS is based on dietary diversity, food frequency, and the relative nutritional importance of various food groups consumed by a household over a seven-day recall period (WFP, 2008). Thus, it is preferred to other indicators solely focusing on food diversity (Hasanah *et al.*, 2017). The nine food groups are main staples, pulses, vegetables, fruit, meat and fish, milk, sugar, oil, and condiments. Each food group is multiplied by its weight. The FCS is then calculated by summing the nine weighted food groups consumed by each household in the past seven days before the survey (WFP, 2008). While a higher score indicates nutrition security, a lower score indicates nutrition insecurity. For more details on the food items included in each food group see WFP (2008:8). Following Hasanah *et al.* (2017) and Isaura *et al.* (2018), this study used the FCS to categorize households into three food consumption groups depending on the score value: poor (0 to 21), borderline (21.5 to 35), and acceptable (greater than 35). These three categories were used as a dependent variable in this study. The number of meals consumed by a household per day was also used as an indicator of food consumption status (D'Haese *et al.*, 2013).

#### 5.3.2.3 Ordered logit model

The ordered logit model was used to examine the impact of fruit trees on household food insecurity and nutrition security. The dependent variable of this model is categorical and ordered (Winship and Mare, 1984). The model is used when the regressand has more than two ordered categories, and the value of each category is higher than the previous one (Otekunrin *et al.*, 2021; Otekunrin, 2022; Bahta and Musara, 2023). The dependent variable used to measure food insecurity in this study has four ordered categories (i.e., 1 = food secure; 2 = mildly food insecure; 3 = moderately food insecure; and 4 = severely food insecure). Moreover, the dependent variable measuring nutrition security has three ordered categories (i.e., 1 = poor; 2 = borderline; and 3 = acceptable). Therefore, following previous studies with a similar dependent variable (Cordero-Ahiman *et al.*, 2020; Otekunrin *et al.*, 2021; Maseko *et al.*, 2022; Otekunrin, 2022), the ordered logit model was selected for regression analysis. Although both ordered logit and probit models are the most appropriate for analyzing ordinal survey data, it is argued that selecting between the two models is a matter of choice because they both usually give the same results (Nkegbe *et al.*, 2017; Acheampong *et al.*, 2022; Danso-Abbeam *et al.*, 2022).

The difference between the two models is that the ordered logit assumes a logistic distribution of the error term, while the ordered probit assumes a normally distributed error term (Kolog *et al.*, 2023). Moreover, the multinomial logit or probit models were inappropriate for the analysis in this study because they fail to account for the ordinal nature of the dependent variable (Greene, 2002). In the ordered logit model there is an observed ordinal variable $(Y)$ which is a function of an unobserved latent variable $(Y^*)$. The latent variable has numerous threshold points and its properties are useful and intuitive (Chiphang and Singh, 2020; Otekunrin, 2022). In this study, the ordered logit model is constructed on an unobservable latent random variable as follows (Greene, 2002; Otekunrin *et al.*, 2021; Otekunrin, 2022):

$$Y_i^* = X_i'\beta + \varepsilon_i \quad (i = 1, 2, 3, \ldots, n) \tag{5.2}$$

where $Y_i^*$ is the unobservable latent random variable with more than two ordered categories and denotes the level of food insecurity in household $i$, $X_i'$ is a vector of explanatory variables affecting food insecurity in household $i$, $\beta$ is a vector of parameters to be estimated, and $\varepsilon_i$ is a random error term which is assumed to be logistically distributed. The relationship between the observed ordinal variable $(Y_i)$ and unobserved latent variable $(Y_i^*)$ is described from the food insecurity model as follows:

$$\begin{aligned} &Y_i = 1 \; if \; 0 < Y_i^* \le \mu_1 \quad (Food\ secure) \\ &Y_i = 2 \; if \; \mu_1 < Y_i^* \le \mu_2 \quad (Mildly\ food\ insecure) \\ &Y_i = 3 \; if \; \mu_2 < Y_i^* \le \mu_3 \quad (Moderately\ food\ insecure) \\ &Y_i = 4 \; if \; Y_i^* > \mu_3 \quad (Severely\ food\ insecure) \end{aligned} \tag{5.3}$$

where $\mu_1$ to $\mu_3$ are unknown parameters or threshold points to be estimated with $\beta$. The relationship between the observed ordinal variable $(Y_i)$ and unobserved latent variable $(Y_i^*)$ is described from the nutrition security model as follows:

$$\begin{aligned} &Y_i = 1 \; if \; 0 < Y_i^* \le \mu_1 \quad (Poor) \\ &Y_i = 2 \; if \; \mu_1 < Y_i^* \le \mu_2 \quad (Borderline) \\ &Y_i = 3 \; if \; Y_i^* > \mu_2 \quad (Acceptable) \end{aligned} \tag{5.4}$$

where $\mu_1$ to $\mu_2$ are unknown parameters or threshold points to be estimated with $\beta$. The probability of observing a particular response ($j$) for a household $i$ is expressed as follows (Cordero-Ahiman *et al.*, 2020):

$$
\begin{aligned}
Prob(Y_i = j) &= Prob\left(\mu_{j-1} < Y_i^* \leq \mu_j\right) \\
&= Prob\left(\mu_{j-1} - X_i'\beta < \varepsilon_i \leq \mu_j - X_i'\beta\right) \\
&= F\left(\mu_j - X_i'\beta\right) - F\left(\mu_{j-1} - X_i'\beta\right) \\
&= \frac{e^{(\alpha_j + X_i'\beta)}}{1 + e^{(\alpha_j + X_i'\beta)}}
\end{aligned}
\tag{5.5}
$$

where $j$ denotes the ordered categories of the dependent variable (e.g., 1, 2, 3, and 4), $F$ denotes the standard logistic cumulative distribution function, and $\alpha_j$ is the intercept for $j$ logit. The Hosmer-Lemeshow, Lipsitz, and likelihood ratio tests were used to evaluate the goodness of fit of the ordered logit model in this study. The statistically insignificant Hosmer-Lemeshow and Lipsitz test values ($p$-value > 0.10) indicate a good fit of the model (Fagerland and Hosmer, 2017). On the contrary, a statistically significant likelihood ratio Chi$^2$ test value ($p$-value < 0.05) indicates a good fitting ordered logit model (Moawed and El-Aziz, 2022).

**Table 5.1.** Description of explanatory variables, their means, standard deviations, and percentages

| Variable | Description | Mean | Std. Dev. | % |
|---|---|---|---|---|
| **Continuous variables** | | | | |
| Age | Household head age (Years) | 61.83 | 14.05 | - |
| Household size | Household size (Number) | 5.88 | 2.85 | - |
| Education | Household head education level (Years of schooling) | 5.48 | 4.90 | - |
| Off-farm income | Log of the annual income from non-farm activities | 10.88 | 0.86 | - |
| **Dummy variables** | | | | |
| Growing fruit trees | Household involved in growing fruit trees (1 = Yes; 0 = Otherwise) | - | - | 89.8 |
| Wild fruits consumption | Consumption of wild fruits per household (1 = Yes; 0 = Otherwise) | - | - | 34.8 |
| Gender | Gender of household head (1 = Male; 0 = Otherwise) | - | - | 42.0 |
| Training | Access to agricultural training (1 = Yes; 0 = Otherwise) | - | - | 35.1 |
| Irrigation | Access to water for irrigation purposes (1 = Yes; 0 = Otherwise) | - | - | 46.9 |
| Livestock ownership | Ownership of livestock per household (1 = Yes; 0 = Otherwise) | - | - | 80.3 |
| Self-confidence | Psychological capital indices computed using PCA | - | - | - |
| Hope | | - | - | - |
| Optimism | | - | - | - |
| Resilience | | - | - | - |

**Source:** Survey data (2022)

Moreover, the Durbin-Wu-Hausman test was performed to detect the presence of endogeneity between the following variables: education, off-farm income, gender, training, irrigation, livestock ownership, and hope. A statistically insignificant Chi$^2$ test value ($p$-value > 0.10) indicates the absence of endogeneity. The Approximate Likelihood-Ratio test of proportionality of odds was performed to assess whether the proportional odds assumption holds. A statistically insignificant Chi$^2$ test value ($p$-value > 0.10) indicates that the proportional odds assumption is not violated. The variance inflation factor (VIF) was also calculated to test for multicollinearity among explanatory variables. The average VIF below the threshold value of 10 implies the absence of multicollinearity (Gujarati and Porter, 2009). Table 5.1 shows the description of explanatory variables used in the ordered logit model.

## 5.4 Results and discussion

### 5.4.1 Household fruits production

The results showed that most rural households planted fruit trees (Table 5.2). The $Chi^2$ test results indicated that the production of lemons was statistically different across the selected study locations at the 10% significance level.

**Table 5.2.** Fruits produced by sampled households (%)

| Variable | Swayimane | Umbumbulu | Richmond | Total | $Chi^2$ - test |
|---|---|---|---|---|---|
| Households producing fruits | 88.0 | 94.2 | 87.3 | 89.8 | 3.24 |
| Type of fruit produced | | | | | |
| *Banana* | 29.3 | 65.0 | 24.5 | 39.7 | 42.33*** |
| *Guava* | 42.4 | 12.6 | 38.2 | 30.8 | 24.57*** |
| *Peach* | 55.4 | 44.7 | 72.7 | 58.0 | 17.57*** |
| *Orange* | 22.8 | 21.4 | 29.1 | 24.6 | 1.94 |
| *Lemon* | 35.9 | 29.1 | 20.9 | 28.2 | 5.61* |
| *Kei apple* | 7.6 | 1.9 | 1.8 | 3.6 | 6.07** |
| *Mulberry* | 9.8 | 8.7 | 23.6 | 14.4 | 11.87*** |
| *Apple* | 12.0 | 9.7 | 8.2 | 9.8 | 0.81 |
| *Mango* | 5.4 | 37.9 | 10.9 | 18.4 | 40.47*** |
| *Avocado* | 32.6 | 38.8 | 6.4 | 25.2 | 33.50*** |
| *Naartjie* | 6.5 | 1.0 | 1.8 | 3.0 | 6.00** |
| *Papaya* | 1.1 | 5.8 | 2.7 | 3.3 | 3.61 |
| Main reason for producing fruits | | | | | |
| *Earn income* | 5.4 | 4.9 | 0.9 | 3.6 | 3.65 |
| *Consumption* | 87.0 | 94.2 | 87.3 | 89.5 | 3.61 |
| *Medicinal* | 13.0 | 7.8 | 7.3 | 9.2 | 2.37 |

**Note**: ***, **, and * indicate the level of significance at 1%, 5%, and 10%, respectively; Multiple responses were allowed.

**Source:** Survey data (2022)

The most common fruit type at Richmond was peach (72.7%). A few rural households reported that they produced kei apple (3.6%), papaya (3.3%), and naartjie (3.0%). Some households (3.6%) generated income from the sale of fruits. According to Bhebhe *et al.* (2023), encouraging rural households to plant more trees on their homesteads and sell tree products can sustain their household income and improve food security. The findings showed that 9.2% of the sampled households used fruit trees for medicinal purposes. During the survey, some respondents indicated that they use peach and guava leaves to treat stomach ache and diarrhoea, respectively. This is in line with Omotayo and Aremu (2020), who reported that fruit trees play a crucial role in the healthcare system of rural communities which still rely on traditional medicine. Ojha *et al.* (2022) also emphasized the importance of awareness of agriculture systems that improve food-medicine security and avoid malnutrition among rural households.

### 5.4.2 Household food insecurity access scale (HFIAS) results

The results showed that 59.3% of the interviewed households experienced anxiety and uncertainty about food access (Table 5.3). This is in line with Bhebhe et al. (2023), who reported that more than 50.0% of households in KwaZulu-Natal were worried they would not have enough food in the past four weeks. The percentage of households who ate a limited variety of foods and some non-preferred foods often was 11.5% and 11.1%, respectively. Moreover, 15.4% of households rarely ate a smaller meal than required. Fewer households (3.9%) indicated that they sometimes went to sleep hungry due to inadequate quantities of food.

**Table 5.3.** Food insecurity conditions of sampled households in the past 30 days (%)

| Variable | Yes | Frequency-of-occurrence | | |
|---|---|---|---|---|
| | | Rarely | Sometimes | Often |
| Worried that the household would not have enough food | 59.3 | 24.6 | 25.9 | 8.9 |
| Unable to eat preferred kinds of foods because of a lack of resources | 63.0 | 21.6 | 29.8 | 11.5 |
| Ate a limited variety of foods due to a lack of resources | 59.3 | 23.9 | 23.9 | 11.5 |
| Ate some non-preferred foods due to a lack of resources to obtain other food types | 58.4 | 19.0 | 28.2 | 11.1 |
| Ate a smaller meal than needed because there was not enough food | 42.0 | 15.4 | 18.7 | 7.9 |
| Ate fewer meals in a day because there was not enough food | 36.4 | 14.1 | 16.4 | 5.9 |
| No food to eat of any kind because of a lack of resources to get food | 19.7 | 8.2 | 7.5 | 3.9 |
| Went to sleep at night hungry because there was not enough food | 10.2 | 4.3 | 3.9 | 2.0 |
| Spent the whole day and night without eating anything because there was not enough food | 7.2 | 3.3 | 3.0 | 1.0 |

**Source:** Survey data (2022)

Table 5.4 shows that the households in Richmond had a higher average HFIAS score (7.01), followed by those in Swayimane (6.95) and then Umbumbulu (5.26). The average score for the total sample was 6.40, indicating that most households in the study area were mildly food insecure.

**Table 5.4.** The average household food insecurity access scale (HFIAS) score

| Variable | Swayimane | | Umbumbulu | | Richmond | | Total | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. |
| Average HFIAS score | 6.95 | 6.44 | 5.26 | 5.55 | 7.01 | 6.76 | 6.40 | 6.31 |

**Source:** Survey data (2022)

### 5.4.3 Household food insecurity access prevalence (HFIAP) results

The results of HFIAP categories are shown in Figure 5.2. The findings showed that 70.2% of the households were food insecure, while 29.8% were found to be food secure. The food secure households rarely worried about not having enough food and experienced none of the other food insecurity conditions in the past four weeks. The mildly food insecure households (36.4%) worried about not having enough food sometimes or often, or were unable to eat preferred foods, or rarely consumed a monotonous diet and undesirable foods. The moderately food insecure households (27.9%) ate a monotonous diet and some non-preferred foods sometimes or often and/or reduced the size and number of meals rarely or sometimes. That is, they sacrificed the quality and quantity of foods consumed. Moreover, the severely food insecure households (5.9%) had to reduce the meal size or number of meals consumed often, and/or experienced the three most severe conditions (i.e., ran out of food, went to bed hungry, or spent a whole day and night without eating anything). The overall results indicate that most of the sampled households were food insecure.

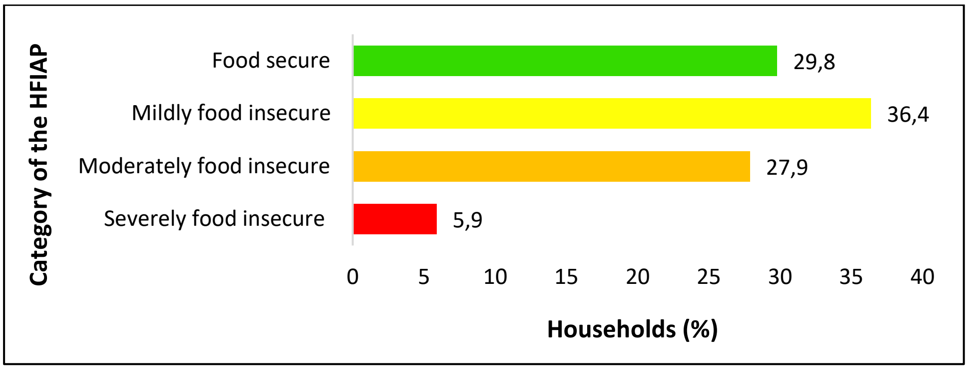


**Figure 5.2.** Household food insecurity access prevalence categories

**Source:** Survey data (2022)

### 5.4.4 Food consumption score (FCS) results

Table 5.5 shows that the food groups consumed by most households in the past seven days before the survey were condiments (100.0%), main staples (99.7%), oil (99.0%), vegetables (98.7%), and meat and fish (93.4). The consumption of milk and other dairy products was relatively low (16.1%). Most households indicated that they consumed milk in small amounts (i.e., added to tea or coffee). Following WFP (2008), small amounts of milk were treated as condiments in this study. The results also showed that households obtained their food items in various ways. For example, 42.0% of the households indicated that some vegetables consumed in the week were produced from their own farmland, while 89.8% reported that they purchased some.

These results illustrate that agricultural production is a source of livelihood for some rural households. A few households sourced meat and fish from the forest through hunting (0.7%) and river through fishing (2.6%). This indicates that forests and fisheries provide a limited contribution to the food groups consumed by rural households. Only 0.3% of the sampled households reported that they obtained milk and/or maas from their own cattle. This is in line with Xulu and Naidoo (2023) who indicated that fewer rural households are involved in small-scale dairy farming in KwaZulu-Natal. Moreover, 11.8% of households obtained fruits from other sources such as events (e.g., funerals and weddings) and donations or gifts. The average FCS in Swayimane, Umbumbulu, and Richmond was 45.16, 44.27, and 43.36, respectively (Table 5.6). The overall average FCS was 43.36, implying that most households consumed acceptable diets. The results also showed that the sampled households commonly consumed 2.98 meals per day on average. According to Ibe *et al.* (2016), the standard number of meals per day recommended by nutrition experts is three (i.e., breakfast, lunch, and dinner).

**Table 5.5.** Food groups consumed by sampled households in the past seven days and their sources (%)

| Food group | Yes | Source food obtained from | | | | |
|---|---|---|---|---|---|---|
| | | Own production | Purchased | Forest | River | Other sources |
| Main staples | 99.7 | 17.7 | 98.7 | - | - | 1.6 |
| Pulses | 63.6 | 8.5 | 54.4 | - | - | 1.3 |
| Vegetables | 98.7 | 42.0 | 89.8 | - | - | 3.0 |
| Fruit | 73.8 | 14.4 | 63.9 | - | - | 11.8 |
| Meat and fish | 93.4 | 14.4 | 90.2 | 0.7 | 2.6 | 6.6 |
| Milk | 16.1 | 0.3 | 15.7 | - | - | - |
| Sugar | 89.8 | - | 87.9 | - | - | 3.3 |
| Oil | 99.0 | - | 99.0 | - | - | 0.3 |
| Condiments | 100.0 | - | 100.0 | - | - | 0.3 |

**Note:** Multiple responses were allowed.

**Source:** Survey data (2022)

**Table 5.6.** The average household food consumption score and number of meals consumed per day

| Variable | Swayimane | | Umbumbulu | | Richmond | | Total | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. |
| Average FCS | 45.16 | 16.94 | 44.27 | 11.36 | 40.99 | 12.02 | 43.36 | 13.58 |
| Average number of meals eaten per day | 2.96 | 0.63 | 3.07 | 0.60 | 2.91 | 0.46 | 2.98 | 0.56 |

**Source:** Survey data (2022)

The results showed that 72.5% of the rural households consumed an acceptable diversity of food groups in the past seven days (Figure 5.3). Simelane *et al.* (2023) also found the same. Their study showed that about 75.9% of households in the KwaZulu-Natal province consumed an acceptable number of food groups. While 23.0% of households were at the borderline, 4.6% consumed poor diets. This shows a need for food consumption educational programmes among rural households to improve the consumption of acceptable diets. It is also important to investigate the underlying reasons for inadequate consumption of food groups, as constraints related to availability or access would require interventions focused on addressing these structural barriers, alongside educational initiatives, to ensure a comprehensive solution.

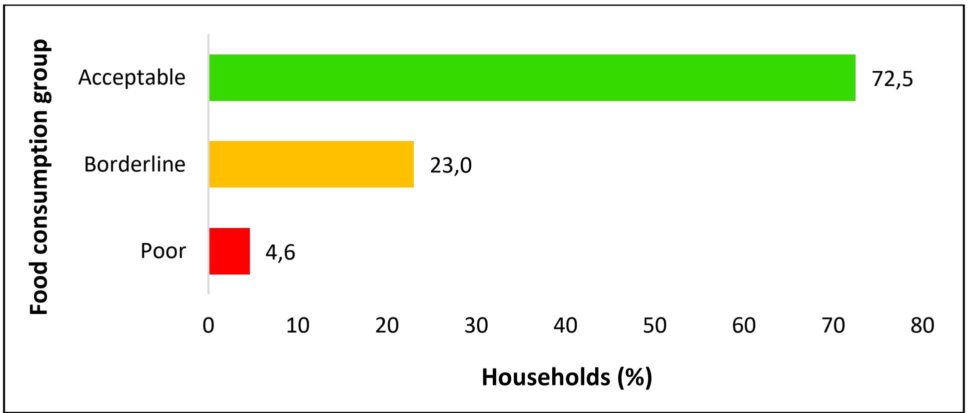


**Figure 5.3.** Household food consumption group categories

**Source:** Survey data (2022)

### 5.4.5 Ordered logit model results

The ordered logit model was used to investigate the impact of fruit trees on food insecurity and nutrition security of rural households (Table 5.7). The likelihood ratio $Chi^2$ test value supported the existence of a relationship between the dependent variable and independent variables in both regression models ($p$-value = 0.000). The statistically insignificant Hosmer-Lemeshow ($p$-value = 0.732) and Lipsitz ($p$-value = 0.200) test values indicated a good fit of the model. Thus, this study accepted the null hypothesis that the ordered logit model fits the data well. The Durbin-Wu-Hausman test results ($p$-value = 0.988) indicated no evidence of endogeneity. Hence, this study accepted the null hypothesis that the variables are exogenous. The statistically insignificant Approximate Likelihood-Ratio test value ($p$-value= 0.138) indicated that the proportional odds assumption was not violated, confirming the appropriateness of the ordered logit model. Moreover, the average VIF was 1.20, indicating the absence of multicollinearity among the explanatory variables.

The direction of the relationship between the explanatory variable and dependent variable was indicated by the sign of the estimated coefficient. For instance, a positive coefficient implied that an increase in a certain explanatory variable would increase food insecurity and nutrition security as measured by the HFIAP and FCS, *ceteris paribus*. A negative coefficient implied that an increase in a variable would lead to a decrease in household food insecurity and nutrition security. However, the estimated coefficient of the ordered logit model only provides the direction of the impact of the explanatory variable on the dependent variable and does not represent the actual magnitude of change or likelihood (Baiyegunhi, 2023). Hence, the marginal effects were also reported to show the expected change in the likelihood of being food secure, mildly, moderately, and severely food insecure, and of being in the poor, borderline, and acceptable food consumption group for a one-unit change in the explanatory variable.

The results showed that two explanatory variables capturing the impact of fruit trees on food insecurity and nutrition security were statistically significant. The relationship between growing fruit trees and household food insecurity was negative (-1.077). The marginal effects' results showed that those who grow fruit trees had a 19% higher probability of being food secure than those who did not grow fruit trees. The probability of being moderately and severely food insecure was 14.0% and 5.5% lower, respectively, for those who grow fruit trees. The relationship between growing fruit trees and household nutrition security was positive (1.008). The probability of consuming acceptable diets increased by 17.1%, while the probability of being at the borderline and consuming poor diets decreased by 12.9% and 4.2%, respectively. This implies that households involved in fruit farming are more likely to have better access to food and nutrition. During the survey, some respondents indicated that they consume fruits produced in their farmland. For instance, they spread home-produced avocado on bread instead of store-bought spreads such as peanut butter. According to Omotayo and Aremu (2020), nutritionally sufficient or healthy diets include fruits. Similarly, Bhebhe *et al.* (2023) mentioned that tree resources contribute to households' diverse diets. In the study locations, some households produced multiple fruit types with different fruiting seasons. This improves food sustainability due to the availability of fruits in various seasons of the year. Trees are also adaptable to different climate conditions. Moreover, fruit trees contribute to food insecurity reduction through income generation. Some households also use the income generated from the sale of tree resources to buy food items.

The findings also showed a significant relationship between the consumption of wild fruits and food insecurity. The probability of being food secure decreased by 15.8% for households consuming wild fruits, while the probability of being moderately and severely food insecure increased by 11.6% and 4.6%, respectively. That is, household food insecurity increases with a rise in the consumption of wild fruits. This is in line with Chakona and Shackleton (2019), who found that households who consumed wild foods had a higher HFIAS score in their study. They argued that the consumption of wild foods tends to be high among low-income households who cannot afford to purchase enough food. Ngidi (2023) also reported that consumption of wild foods is a coping strategy for households with low dietary diversity and who struggle to access food due to increasing food prices.

The other four independent variables also had a significant relationship with both food insecurity and nutrition security (i.e., household size, off-farm income, access to irrigation, and self-confidence). The marginal effects' results showed that an additional member of the household decreased the probability of being food secure and consuming acceptable diets by 3.0% and 2.5%, respectively. That is, an increase in the household size results in the likelihood of being in the higher categories of food and nutrition insecurity, *ceteris paribus*. This is in line with previous studies which reported that a larger family size leads to food and nutrition insecurity (Maziya *et al.*, 2017; Sani and Kemaw, 2019; Hlatshwayo *et al.*, 2022). Cele and Mudhara (2024) indicated that larger families usually experience higher food demand which, in turn, increases the risk of food insecurity. Another possible reason is that most rural households have many young and unemployed family members, thus, struggle to achieve food and nutrition security due to financial constraints (Maziya *et al.*, 2017; Bhebhe *et al.*, 2023).

**Table 5.7.** The impact of fruit trees on household food insecurity and nutrition security: Ordered logit model results

| | Food insecurity model | | | | | | Nutrition security model | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Marginal effects | | | | | | Marginal effects | | |
| **Variables** | **Coef.** | **Std. Err.** | **FS** | **Mildly FI** | **Moderately FI** | **Severely FI** | **Coef.** | **Std. Err.** | **Acceptable** | **Borderline** | **Poor** |
| Growing fruit trees | -1.077*** | 0.386 | 0.190*** | 0.005 | -0.140*** | -0.055** | 1.008** | 0.431 | 0.171** | -0.129** | -0.042** |
| Wild fruits consumption | 0.892*** | 0.258 | -0.158*** | -0.004 | 0.116*** | 0.046*** | 0.031 | 0.313 | 0.005 | -0.004 | -0.001 |
| Age | -0.004 | 0.010 | 0.001 | 0.000 | 0.000 | 0.000 | -0.007 | 0.012 | -0.001 | 0.001 | 0.000 |
| Gender | -0.303 | 0.232 | 0.054 | 0.001 | -0.039 | -0.016 | 0.042 | 0.293 | 0.007 | -0.005 | -0.002 |
| Household size | 0.169*** | 0.045 | -0.030*** | -0.001 | 0.022*** | 0.009*** | -0.146*** | 0.056 | -0.025*** | 0.019*** | 0.006** |
| Education | -0.017 | 0.026 | 0.003 | 0.000 | -0.002 | -0.001 | 0.050 | 0.033 | 0.008 | -0.006 | -0.002 |
| Off-farm income | -0.888*** | 0.166 | 0.157*** | 0.004 | -0.115*** | -0.046*** | 0.780*** | 0.217 | 0.132*** | -0.099*** | -0.033*** |
| Training | -0.045 | 0.258 | 0.008 | 0.000 | -0.006 | -0.002 | 0.792** | 0.343 | 0.134** | -0.101** | -0.033** |
| Irrigation | -0.428* | 0.237 | 0.076* | 0.002 | -0.055* | -0.022* | 0.912*** | 0.314 | 0.154*** | -0.116*** | -0.038** |
| Livestock ownership | -0.207 | 0.288 | 0.037 | 0.001 | -0.027 | -0.011 | 0.635* | 0.355 | 0.108* | -0.081* | -0.027* |
| Self-confidence | -0.188* | 0.112 | 0.033* | 0.001 | -0.024* | -0.010 | 0.263* | 0.150 | 0.045* | -0.034* | 0.011 |
| Hope | -0.003 | 0.109 | 0.001 | 0.000 | 0.000 | 0.000 | 0.345** | 0.141 | 0.058* | -0.044* | -0.014* |
| Optimism | 0.055 | 0.109 | -0.010 | 0.000 | 0.007 | 0.003 | 0.106 | 0.134 | 0.018 | -0.013 | -0.004 |
| Resilience | -0.364*** | 0.110 | 0.064*** | 0.002 | -0.047*** | -0.019*** | 0.099 | 0.136 | 0.017 | -0.013 | -0.004 |
| /cut1 | -11.194 | 1.685 | | | | | 5.293 | 2.104 | | | |
| /cut2 | -9.316 | 1.647 | | | | | 7.579 | 2.118 | | | |
| /cut3 | -6.920 | 1.627 | | | | | | | | | |
| Pseudo $R^2$ | 0.11 | | | | | | 0.11 | | | | |
| Log likelihood | -340.081 | | | | | | -192.447 | | | | |
| Likelihood ratio test | $Chi^2(14) = 83.43$, $p$-value = 0.000 | | | | | | $Chi^2(14) = 49.83$, $p$-value = 0.000 | | | | |
| Hosmer-Lemeshow test | $Chi^2 = 18.460$, $p$-value = 0.732 | | | | | | $Chi^2 = 13.818$, $p$-value = 0.539 | | | | |
| Lipsitz test | $Chi^2 = 11.026$, $p$-value = 0.200 | | | | | | $Chi^2 = 11.548$, $p$-value = 0.173 | | | | |
| Durbin-Wu-Hausman test | $Chi^2(1) = 0.000$, $p$-value = 0.988 | | | | | | $Chi^2(1) = 0.132$, $p$-value = 0.717 | | | | |
| Approximate Likelihood-Ratio test | $Chi^2(28) = 36.17$, $p$-value = 0.138 | | | | | | $Chi^2(14) = 19.10$, $p$-value = 0.161 | | | | |
| Multicollinearity test | Mean VIF = 1.20 | | | | | | Mean VIF = 1.20 | | | | |

**Note**: ***, **, and * indicate the level of significance at 1%, 5%, and 10%, respectively; FS, food secure; FI, food insecure.

**Source:** Survey data (2022)

The results showed that households generating higher income from off-farm activities are less likely to be food and nutrition insecure. These findings are consistent with Maziya *et al.* (2017). An increase in off-farm income decreased the likelihood of being moderately and severely food insecure by 11.5% and 4.6%, respectively. Moreover, the likelihood of consuming poor diets and being at the borderline decreased by 3.3% and 9.9%, respectively. The high-income households are more likely to purchase preferred, diverse, and nutritious food items and consume acceptable diets (Sani and Kemaw, 2019). According to Anang *et al.* (2020), access to off-farm income enables farming rural households to stabilize household income and reduce food insecurity associated with declining agricultural production due to climate change. Bhebhe *et al.* (2023) also reported that higher income improves food access and availability.

The probability of being moderately and severely food insecure for households with access to irrigation decreased by 5.5% and 2.2%, respectively, while the probability of consuming poor diets decreased by 3.8%. This implies that households with access to water for irrigation purposes were more likely to be in the lower categories of food and nutrition insecurity than those who had no irrigation access, *ceteris paribus*. These results are consistent with several studies that indicated the importance of access to water in reducing food insecurity, especially in rural communities where most households depend on farming for food consumption and income generation (Sani and Kemaw, 2019; Sinyolo, 2020; Ndlovu *et al.*, 2022). A study by Nounkeu and Dharod (2020) revealed that limited water access raises the risk of food insecurity because it negatively impacts food availability, access, and utilization. Other studies also mentioned that access to reliable sources of water enhances the year-round productivity of livelihood strategies such as growing crops, raising livestock, and planting trees, and reduces the undernourishment levels (Chikozho *et al.*, 2020; Mbhenyane and Tambe, 2024).

The results showed that the psychological capital variable (self-confidence) had a statistically significant association with household food insecurity and nutrition security. An increase in self-confidence is associated with an increased probability of being food secure and consuming acceptable diets by 3.3% and 4.5%, respectively. That is, confident individuals were less likely to experience food and nutrition insecurity. This is consistent with Jomaa *et al.* (2020), who found that caregivers with high self-confidence had lower odds of household food insecurity. They reported that caregivers in food insecure households were less confident in their abilities to choose best priced vegetables and fruits, purchase and cook healthy foods for their families on a budget, and stick to their grocery list compared to those in food secure households. This suggests that increased confidence in managing food resources among rural households is associated with a lower risk of food and nutrition insecurity. Armstrong *et al.* (2021) also demonstrated the essential role that confidence plays in improving household food and nutrition security.

An increase in access to agricultural training was associated with an increased probability of consuming acceptable diets by 13.4%. According to Bahta and Musara (2023), access to training programs equips individuals with agricultural and financial management skills which can positively impact food-related decision-making within the household and reduce food and nutrition insecurity. The findings also showed that a unit rise in the number of livestock owned was associated with a lower likelihood of consuming poor diets by 2.7%. This is in line with Cele and Mudhara (2024), who reported that livestock ownership contributes to food and nutrition insecurity reduction through the direct provision of eggs, milk, and meat. It also contributes indirectly through income provision. During the survey, some respondents indicated that they kept livestock such as goats and domestic chickens for consumption purposes. The marginal effects' results showed that the probability of consuming poor diets and being at the borderline for hopeful individuals decreased by 1.4% and 4.4%, respectively. Hopeful individuals have the ability to identify different ways to reduce nutrition insecurity even when facing difficult life events (Younginer *et al.*, 2015).

The relationship between resilience and household food insecurity status was negative and statistically significant. The probability of being moderately and severely food insecure decreased by 4.7% and 1.9%, respectively. These findings are in line with Egamberdiev *et al.* (2023), who reported that resilient households are less likely to suffer from food insecurity. In the context of food insecurity, resilience refers to the household's capacity to bounce back from shocks and stresses such as crop failure, high food and agricultural inputs prices, job loss, death of the family breadwinner, livestock theft, floods, drought, and storm (Boukary *et al.*, 2016; Dhraief *et al.*, 2019; Alhassan, 2020). According to Chipfupa *et al.* (2021), resilience is associated with ability or possession of agricultural and non-agricultural assets. Several studies (Boukary *et al.*, 2016; Smith and Frankenberger, 2018) have found a positive relationship between access to assets and rural household's resilience to food insecurity. This implies that rural households also require physical assets such as tractors, water tanks, and watering cans, among others, to be resilient to food insecurity.

### 5.5 Conclusions and recommendations

This study investigated the impact of fruit trees on food insecurity and nutrition security of rural households. It was conducted in the KwaZulu-Natal province, South Africa. The results showed that two explanatory variables capturing the impact of fruit trees on food insecurity and nutrition security (i.e., growing fruit trees and consumption of wild fruits) were statistically significant. Growing fruit trees reduced household food and nutrition insecurity. Based on these findings, the study recommends the dissemination of information about the benefits of fruit tree cultivation in rural households. Promoting the practice of growing fruit trees can help improve household access to food and enhance the likelihood of consuming acceptable diets. Educational programs and outreach efforts should focus on the potential advantages of fruit farming, including its positive impact on food and nutrition security.

The level of wild fruit consumption among the sampled rural households was low, suggesting that wild fruits are underutilized as a food source. This indicates a need for awareness campaigns promoting the utilization and nutritional benefits of consuming wild fruits. It is also important to investigate the underlying reasons for the inadequate consumption of food groups, as factors such as access, knowledge, or seasonal availability may play a role. Encouraging rural households to consume wild fruits may reduce food insecurity through improved dietary diversity. It may also reduce reliance on purchased food items. Moreover, encouraging them to sell wild fruits may improve their household income and food security.

The findings also showed that access to irrigation and off-farm income reduced food and nutrition insecurity. Therefore, this study recommends the establishment, rehabilitation, and revitalization of irrigation projects in rural communities to enhance food and nutrition security. Given the rising water scarcity, training programs focusing on using irrigation water productively and managing small-scale irrigation schemes are also required. Moreover, creating opportunities for off-farm income-generating activities is recommended. This could include training programs and improved investment in entrepreneurship, particularly for the rural youth. Confident, hopeful, and resilient individuals were less likely to experience household food and nutrition insecurity. These results indicate that psychological capital plays a vital role in food and nutrition insecurity reduction. Nutrition-related training programs and workshops are recommended to enhance self-confidence in managing food resources. These programs can cover topics such as shopping strategies, budgeting, food selection, food preparation, and consumption of wild foods. This may also improve the consumption of acceptable food groups and the quality of food utilization in resource-poor communities.

Strategies related to improving rural households' access to physical assets such as tractors, water tanks, and watering cans are suggested to enhance resilience to food insecurity. This study also recommends the collaboration of government, research and academia, private sector, civil society organizations and non-state actors, policymakers, politicians, and farming rural households to transform food systems and reduce food and nutrition insecurity. The involvement of politicians such as ward councillors is important because they play a vital role in the mobilization of resources at a local level. Moreover, the involvement of farming rural households may improve their ability to exercise their voices and participate in shaping local food systems. That is, it may contribute to the attainment of food agency. The future studies need to apply the theory of psychological capital in its wholesome to household food consumption research. Moreover, these studies should use a data collection method that is close to a revealed preference approach to measure the four constructs of psychological capital.

# CHAPTER 6. FACTORS INFLUENCING THE UPTAKE OF AGROFORESTRY PRACTICES AMONG RURAL HOUSEHOLDS: EMPIRICAL EVIDENCE FROM THE KWAZULU-NATAL PROVINCE, SOUTH AFRICA


## 6.0 Abstract

Agroforestry is recognized as a significant element in climate-smart agriculture due to its high potential for addressing food insecurity, climate change challenges, and ecosystem management. However, despite the potential benefits of agroforestry practices, the adoption by rural households in Sub-Saharan Africa is low. Adopting agroforestry practices requires understanding rural households' socio-economic and socio-psychological factors. Hence, this study empirically examined the role of knowledge, attitudes, and perceptions in the uptake of agroforestry practices among rural households to better understand the adoption process. A sample of 305 households was obtained from three communities, namely, Swayimane, Umbumbulu, and Richmond, in KwaZulu-Natal province. Principal component analysis and a binary logistic regression model were employed to analyze the data. Knowledge, attitudes, and perceptions towards agroforestry were found to positively influence the adoption of agroforestry practices. The results also revealed that age, farming experience, education level, and land size were determinants of agroforestry adoption. Therefore, the study recommends that policymakers, extension officers, and climate change champions consider rural households' socio-economic characteristics, knowledge, attitudes, and perceptions when designing agroforestry projects. Implementing training programs with practical demonstration is also recommended to increase awareness of the benefits of agroforestry practices and encourage rural households to protect on-farm trees and shrubs.



**Keywords:** agroforestry practices; climate-smart agriculture; climate change; adoption; theory of planned behaviour; rural households

## 6.1 Introduction

One of the key environmental challenges faced by the modern world currently is that climate change and its effects are rapidly mounting (Chersich and Wright, 2019; Khan *et al.*, 2020). Future predictions indicate that changing climate will result in lower rainfall and higher temperatures with increased flooding and drought events in South Africa (Mathews *et al.*, 2018). Most studies report that the source of livelihood affected mainly by climate change is agriculture, especially crop productivity (Aniah *et al.*, 2019; Ighodaro *et al.*, 2020; Adeagbo *et al.*, 2021). Agricultural production activities in Africa (South Africa included) are more vulnerable to climate change than other production constraints (Campbell *et al.*, 2016; Talanow *et al.*, 2021). This adversely affects rural households who largely depend on farming. For example, the number of hungry people globally is expected to rise by 20% by 2050 due to the adverse impacts of climate change on agricultural production and the lives of rural households (Hossain *et al.*, 2019).

According to Newell *et al.* (2019), the agricultural sector is among the most substantial contributors to changing climate. Globally, the sector contributes approximately 20% to greenhouse gas emissions directly through agricultural practices and indirectly via land use alteration (Ntinyari and Gweyi-Onyango, 2021; Nyang'au *et al.*, 2021). With rising food demand resulting in the need for increased food production, agriculture is projected to be a primary source of emissions growth, which threatens future food security (Lipper *et al.*, 2014; Abegunde *et al.*, 2019). The impact of changing climate on the agricultural sector, combined with the impact of agriculture on greenhouse gas emissions necessitates adaptation strategies that will lessen the negative impact of agricultural production while mitigating climate change (Newell *et al.*, 2019; Nyang'au *et al.*, 2021). Climate-smart agriculture (CSA) is recognized as the most suitable adaptation strategy to accomplish these objectives. It is defined as a transformative and sustainable agricultural strategy that aims to jointly address food insecurity, climate variability challenges, and ecosystem management (Adesipo *et al.*, 2020; Senyolo *et al.*, 2021; Mthethwa *et al.*, 2022).

The CSA practices include cultivation of cover crops, rotational cropping, agroforestry, conservation agriculture, crop diversification, use of organic manure, planting drought and heat-resistant crops, small-scale irrigation farming, and mulching (Mango *et al.*, 2018; Abegunde *et al.*, 2020). Agroforestry is one of the few land use strategies with the capacity to deliver all three benefits of CSA (Mbow *et al.*, 2014a; Newaj *et al.*, 2015). It is defined as a farming practice that integrates trees and shrubs with agricultural crops and/or livestock, or both (Mwase *et al.*, 2015; Tokede *et al.*, 2020a). Moreover, it is recognized as a significant element in CSA due to its high potential for building resilience to climate change, carbon sequestration, and strengthening rural livelihoods (Barasa *et al.*, 2021; Riyadh *et al.*, 2021). Resilience to changing climate is improved through increased tree cover, carbon sequestration, agricultural productivity, and household income (Riyadh *et al.*, 2021). According to Nair (1985), agroforestry practices are categorized into *agrisilvicultural* (trees/shrubs and crops), *silvopastoral* (trees/shrubs and livestock), and *agrosilvopastoral* (trees/shrubs, crops and livestock). Therefore, households with trees/shrubs around their farm land (e.g. windbreaks and fences), combinations of trees, crops, and livestock around homesteads, and who used trees/shrubs as shelterbelts for livestock were considered to be involved in agroforestry practices in this study (Köthke *et al.*, 2022).

Regardless of the potential benefits of agroforestry practices, adoption by small-scale farmers in Sub-Saharan Africa is low (Meijer *et al.*, 2015; Tokede *et al.*, 2020a). Following Mwase *et al.* (2015), in this study, adoption is defined as a decision to make full use of an agroforestry practice. Low adoption of agroforestry programs is due to minimal emphasis placed on understanding local communities' knowledge, attitudes, and perceptions (Mwase *et al.*, 2015). Though knowledge, attitudes, and perceptions studies on the adoption of innovations have been carried out since the 1980s (Meijer *et al.*, 2015), there is a lack of such studies focusing on the decision-making process of agroforestry adoption in rural areas, particularly in South Africa. This, in turn, presents challenges regarding planning, investments, and formulation of relevant policies that can enhance resilience to changing climate. One possible reason for the lack of research in this field may be the methodological challenges associated with measuring individual's perceptions of agricultural practices (Meijer *et al.*, 2015).

The analysis conducted by Meijer *et al.* (2015) emphasized that both extrinsic variables (e.g., characteristics of the adopter, characteristics of the innovation, and the external environment) and intrinsic variables (e.g., knowledge, perceptions, and attitudes) influence the decision to adopt new agroforestry technologies. The theoretical literature also justifies that both variables have a key influence on rural households' decision to adopt agroforestry practices. For example, an individual's characteristics and economic variables may influence adoption indirectly by affecting the knowledge, attitudes, and perceptions, which in turn influence the decision to adopt an innovation. Moreover, socio-economic and demographic factors such as the household head's age, education level, farming experience, employment status, and access to agricultural extension services are drivers of individuals' decisions to adopt agroforestry in most resource-poor communities (Ahmad *et al.*, 2023). According to Cahyono *et al.* (2020), the adoption of agroforestry is positively related to adequate knowledge, a positive attitude, and perceived low implementation constraints.

Research simultaneously focusing on intrinsic and extrinsic factors' role in the uptake of agroforestry practices is limited to date. Some studies known to the authors that have attempted to simultaneously assess the effect of extrinsic and intrinsic variables on agroforestry practices adoption include Ahmad *et al.* (2023) and Tokede *et al.* (2020b). However, these studies did not focus on all three intrinsic variables, and a broader picture is only discovered when they are put together. Therefore, this study aims to add to the literature by empirically examining the role of knowledge, attitudes, perceptions, and extrinsic factors in the uptake of agroforestry practices among rural households to better understand the adoption process. Understanding the role of rural communities' knowledge and how they perceive agroforestry practices is essential since it is recognized as a significant response to the threat of climate change. Given this motivation, the research question is: what is the nature and the extent of the relationship between socio-psychological factors (knowledge, attitudes, and perceptions) and the adoption of agroforestry practices among rural households? The study hypothesized a positive relationship between the socio-psychological factors and agroforestry practices' adoption level in the study area.

The remainder of this paper is structured into five sections. The following section presents the theoretical framework. This is followed by the research methodology, results, and discussion sections. The final section presents the conclusions and recommendations based on the empirical results.

### 6.2 Theoretical framework

Figure 6.1 shows a modified theory of planned behaviour (TPB) framework. The TPB is a theoretical framework widely employed to describe and predict an individual's behaviour. Conscious decision-making and goal-oriented behaviour of an individual are the main focus aspects of TPB (Amare and Darr, 2022). Various studies have applied the theory to explain factors affecting the adoption of agroforestry practices (Meijer *et al.*, 2015; Amare and Darr, 2022; Ahmad *et al.*, 2023). It states that the intention to adopt the practices is influenced by attitudes, social norms, and perceived behavioural control (Ajzen, 1991).

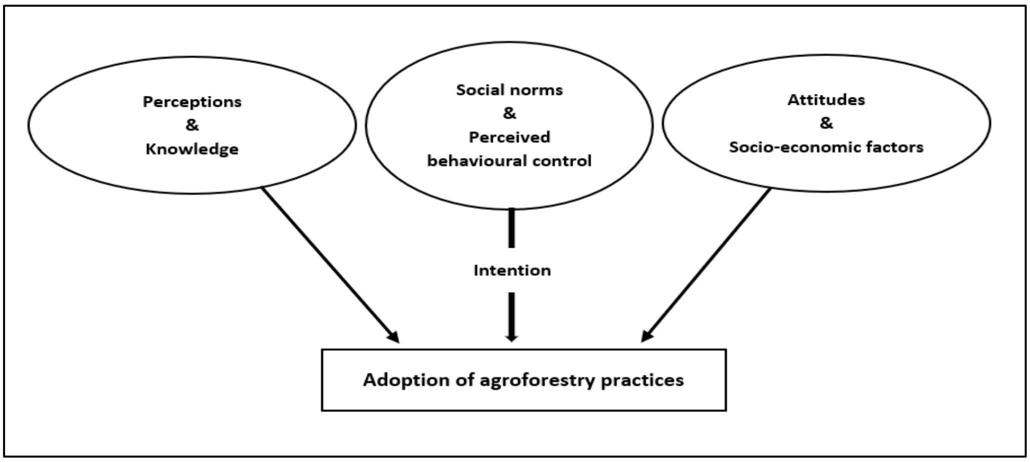


**Figure 6.1.** Theoretical research framework

**Source:** Rezaei *et al.* (2018); Amare and Darr (2022); and Ahmad *et al.* (2023)

According to Ahmad *et al.* (2023), the literature on agroforestry practices confirms the adoption of agroforestry (behavioural intention) is significantly and positively associated with the acceptance of support from family, relatives, cooperative members, and friends (social norms), having a positive opinion (attitude), and believing in having the capability to successfully engage in these practices (perceived behavioural control). In the context of agroforestry, behavioural control is associated with the beliefs about the existence of factors that may enhance (e.g., skills and opportunities) or hinder (e.g., financial constraints and inadequate farming assets) the household's ability to adopt the practice (Rezaei *et al.*, 2018). Following Ahmad *et al.* (2023) and Rezaei *et al.* (2018), the framework also incorporates knowledge, perceptions, and socio-economic characteristics to explain the adoption of agroforestry practices. According to Rezaei *et al.* (2018), knowledgeable individuals are more confident in adopting new technologies. Individuals' adoption decisions are also influenced by their perceptions of the advantages and disadvantages of agroforestry practices. Moreover, understanding the agroforestry adoption process also requires an analysis of socio-economic factors (Ahmad *et al.*, 2023).

## 6.3 Research methods

### 6.3.1 Study area description

The study was conducted in Swayimane, Umbumbulu, and Richmond, located in the KwaZulu-Natal province, South Africa (see Figure 3.1, page 22). Swayimane is located in uMshwathi Local Municipality under the Gcumisa Traditional Authority. The area comprises good precipitation (500 to 800 mm $yr^{-1}$), fertile soils, and a population of 6 856 (Mthethwa et al., 2022). Umbumbulu is in ward 100 under eThekwini Metropolitan Municipality. The area is characterized by small-scale subsistence farming. Richmond is located in Richmond Local Municipality and comprises seven wards. The area's population is approximately 65 793 (Mncube et al., 2023). The province was selected for the study due to its immense potential for agroforestry practices. Its agricultural sector contributes significantly to the national gross domestic product and provides a major source of employment for many rural households (Blunden and Arndt, 2020). However, extreme changes in rainfall patterns and increases in temperatures negatively affect crop productivity (Adeagbo *et al.*, 2021). This condition calls for a significant transformation in the province's agricultural sector to ensure adequate food supplies and improved food and nutrition security among rural households in South Africa.

The choice of the three study sites was based on the presence of agricultural land uses, which integrate trees and shrubs with agricultural crops and/or livestock, or both. Most of the households are involved in homestead agroforestry practices, demonstrating an immense potential for sustainable agricultural activities. The commonly grown crops include maize, cabbage, sweet potatoes, cassava, and beans. Fruit trees such as bananas, oranges, peaches, avocados, and guava are also grown. The common livestock owned by households are domestic chickens, cattle, and goats. Stokvel clubs, churches, community meetings, and social media applications such as WhatsApp and Facebook are used as platforms for sharing knowledge, experiences and learning, and for accessing support services. Moreover, the study sites have limited economic and job opportunities.

### 6.3.2 Sampling method

Both purposive and stratified random sampling methods were applied to select the respondents. The study purposively selected municipalities with households involved in some form of farming. For the purpose of stratifying, the households were classified into three groups, namely, *agrisilvicultural*, s*ilvopastoral*, and *agrosilvopastoral*. The sampling approach for the study was driven by two deliberations. Firstly, the existence of different types of agroforestry practices adopted by rural households in the KwaZulu-Natal province. Secondly, to align the study with the government's goal of promoting the farming sector as a key contributor to job creation and rural development. Prior to the household survey, focus group discussions were held. The quantitative survey randomly selected and interviewed a sample of 317 households. However, twelve incomplete questionnaires were discarded. This yielded a total of 305 questionnaires valid for analysis: Swayimane (92), Umbumbulu (103), and Richmond (110). According to Gujarati and Porter (2009), a sample size greater than or equal to 50 is considered reasonably large and adequate to conduct significant statistics.

### 6.3.3 Data collection

The survey was conducted between September to October 2022 by trained enumerators. The data collection instrument and procedures were approved by the Humanities and Social Sciences Research Ethics Committee (HSSREC) of the University of KwaZulu-Natal (protocol reference number: HSSREC/00003793/2022). A structured and pre-tested questionnaire was utilized to collect data. The questionnaire encompassed questions about socio-economic and demographic factors (e.g., age, household size, gender, farming experience, education level, access to agricultural extension services, etc.), livelihood assets, and the household's involvement in agroforestry practices. The household's physical assets were used as indicators of their resource availability and status of wealth (Chipfupa *et al.*, 2021). Following previous studies (Zubair and Garforth, 2006; Munthali *et al.*, 2019) the questionnaire also included five-point Likert scale statements to measure respondents' knowledge, attitudes, and perceptions toward agroforestry practices.

The questionnaire was pre-tested for two reasons: to inspect the validity, cultural sensitivity, flow, and questions' consistency, and to facilitate and refine the translation of questions to the local language. For consistency motives, a similar questionnaire was utilized for all the respondents. Moreover, semi-structured interviews with open-ended questions were administered via focus group discussions to complement information captured through the use of a questionnaire. All the interviews were conducted in-person to control respondents' unfamiliarly to complete the questionnaire and lessen non-response error.

### 6.3.4 Statistical data analysis

The survey data were analyzed using the International Business Machines (IBM) Statistical Package for Social Sciences (SPSS) version 28 and STATA SE version 17. The descriptive statistics of socio-economic and demographic characteristics of households were reported in terms of percentages, means, and standard deviations (Std. Dev.). Statistical analysis by means of principal component analysis and a binary logistic regression model was also conducted to determine factors linked with the adoption of agroforestry practices by rural households.

#### 6.3.4.1 Principal component analysis

The principal component analysis (PCA) was used to create indices for the independent variables designed to represent rural households' knowledge, perceptions, and attitudes toward agroforestry practices. PCA is a widely used multivariate data analysis technique that linearly transforms an original set of variables into a new set of uncorrelated and orthogonal variables called principal components (PCs) (Gujarati and Porter, 2009; Jolliffe, 2002). The objective is to reduce the number of variables to a few factors without losing most of the original information. The PCs can be related to the original variables as:

$$PC_1 = a_{11}X_1 + a_{12}X_2 + \ldots + a_{1n}X_n$$

$$PC_m = a_{m1}X_1 + a_{m2}X_2 + \ldots + a_{mn}X_n \quad (6.1)$$

where $a_{mn}$ denotes the weight for the $m^{th}$ PC and the $n^{th}$ variable, $\chi_n$ denotes the $n^{th}$ variable. The Bartlett’s test of Sphericity was applied to check if the observed correlation matrix diverges significantly from the identified matrix. A statistically significant value ($p < 0.10$) meant that there was sufficient correlation and the data were appropriate for PCA. Moreover, the Kaiser-Mayer-Olkin (KMO) measure of sampling adequacy was also applied, with a value > 0.5 implying PCA could be performed. The Kaiser criterion which recommends retaining factors with eigenvalues > 1 was used for the factor retention decision. The varimax rotation method was used to enhance the interpretability of the PCA results. Factor loadings greater than 0.50 were considered to have a strong influence on the PCs and were interpreted.

#### 6.3.4.2 Binary logistic regression model

The econometric models that are usually utilized to examine the adoption of innovative systems comprise logistic regression (logit and probit) and linear regression models. The regression models’ response variable is a linear function and follows a normal distribution (Bandi *et al.*, 2022). Logistic regression models are non-linear and have a binary response variable. In this study, the response variable is binary (i.e., 1 for adoption and 0 for non-adoption). Therefore, following several studies (Sanou *et al.*, 2019; Awe *et al.*, 2021; Ahmad *et al.*, 2023; Jahan *et al.*, 2022), a binary logistic regression model was utilized to examine the determinants of agroforestry adoption among rural households. This model is a maximum likelihood estimation technique used to calculate the relationship between a binary dependent variable and a set of independent variables. It estimates the likelihood that a feature is present, or otherwise. That is, the probability of adopting agroforestry practices is specified by $P_i$, while that of not adopting is specified by $1 - P_i$. The odds ratio is expressed as $P_i/(1 - P_i)$. The log of odds ratio which is projected by the logit technique is derived from the natural logarithm of the odds ratio (Liliane *et al.*, 2020; Awe *et al.*, 2021).

The model is more realistic, robust to outliers, and assumes a logistic distribution of errors, contrary to the probit model which is sensitive to outliers and assumes normally distributed errors (Sankalpa *et al.*, 2020; Zerihun, 2020; Ahmad *et al.*, 2023). Moreover, the logit model has two practical advantages, namely, simplicity and interpretability. Its inverse linear transformation can be construed directly as a logarithm of likelihoods, while the probit's inverse transformation does not have a direct interpretation (Klieštik *et al.*, 2015). It also incorporates the natural logarithm of an odds ratio to overcome difficulties of the ordinary least squares (OLS) regression in treating binary outcomes (Peng *et al.*, 2002). Unlike OLS, the logistic regression model accommodates a non-linear relationship between the response and explanatory variables. For more details on the features of the logistic regression model see (Gujarati and Porter, 2009) (pp. 553-555). In this study, a binary logistic regression model characterizing the adoption of agroforestry practices is denoted as follows:

$$\ln[P_i/(1 - P_i)] = \beta_0 + \beta_1\chi_{1i} + \beta_2\chi_{2i} + \cdots + \beta_n\chi_{ni} + \varepsilon_i \quad (6.2)$$

where $\ln[P_i/(1 - P_i)]$ denotes log odds ratio, $P$ is the probability of the outcome (i.e., 1 if the household practices agroforestry and 0 otherwise), $i$ is observation in the $i^{th}$ sample, $\beta_0$ is the constant, $\beta_1$, $\beta_2$,… $\beta_n$ are coefficients of independent variables $\chi_1$, $\chi_2$,… $\chi_n$, and $\varepsilon$ is the normally distributed error term. The coefficients of independent variables and the odds ratio of the regression model were used to interpret the relationship between the independent and explanatory variables. Marginal effects were also calculated to show how a dependent variable (outcome) changes if a specific explanatory variable varies.

The Hosmer-Lemeshow and likelihood ratio tests were utilized to evaluate the goodness of fit of the model. A statistically insignificant Hosmer-Lemeshow test value ($p$-value > 0.05) indicates a good fit of the model (Hosmer and Lemesbow, 1980). In contrast, a statistically significant likelihood ratio chi-square ($Chi^2$) test value ($p$-value < 0.05) supports the existence of a relationship between the dependent variable and independent variables. Wald test was used to test the significance of individual logistic regression coefficients for each variable. A classification table showing the percentage of all cases correctly predicted was also used to assess the model's overall accuracy (El-Habil and El-Jazzar, 2013; Abdulqader, 2017). Moreover, the variance inflation factor (VIF) was calculated to check for multicollinearity in the outcome equation. The average VIF below the critical value of 10 indicates the absence of multicollinearity (Gujarati and Porter, 2009).

## 6.4 Results and discussion

### 6.4.1 Socio-economic and demographic characteristics of sampled households

Descriptive statistics for socio-economic and demographic variables are presented in Table 6.1. The average age of sampled household heads and farming experience were 61.83 and 19.99 years, respectively. Sampled household heads had low levels of education. This is consistent with the literature, which indicated that most household heads in KwaZulu-Natal attained a primary level of education. The estimated mean of the log of physical assets' total value (e.g., radio, television, tractor, and water tank) was 9.49. Sampled households had access to small land sizes with an average of 1.33 hectares and owned livestock such as cattle, goats, and domestic chickens. About 92.5% of household heads were members of different social groups. Moreover, the results showed that access to agricultural extension was low (17.4%). Most rural households complained about inadequate and ineffective extension services. The results also showed that 42% of households were male-headed.

**Table 6.1.** Socio-economic factors, their means, standard deviations, and percentages

| Variable | Description | Mean | Std. Dev. | % |
|---|---|---|---|---|
| **Continuous variables** | | | | |
| Age | Household head age (Years) | 61.83 | 14.05 | - |
| Experience | Household head farming experience (Years) | 19.99 | 15.36 | - |
| Education | Household head education level (Years of schooling) | 5.48 | 4.90 | - |
| Land size | Land size household has access to (Hectares) | 1.33 | 1.22 | - |
| Total livestock units | Tropical livestock units | 1.75 | 3.05 | - |
| Assets | Log of the total value of physical assets | 9.49 | 1.33 | - |
| Off-farm income | Log of the annual income from non-farm activities | 10.88 | 0.86 | - |
| **Dummy variables** | | | | |
| Group membership | Membership in groups (1 = Yes; 0 = otherwise) | - | - | 92.5 |
| Extension | Agricultural extension (1 = Yes; 0 = otherwise) | - | - | 17.4 |
| Gender | Household head gender (1 = Male; 0 = otherwise) | - | - | 42.0 |

**Source:** Survey data (2022)

### 6.4.2 Agroforestry practices involvement and willingness to expand and adopt

Table 6.2 shows the agroforestry practices status of sampled rural households. Umbumbulu had a higher number of households involved in agroforestry practices (95.1%), followed by Richmond (89.1%) and then Swayimane (85.9%). A dominant agroforestry type was the combination of trees/shrubs with agricultural crops and livestock (79.6%). The results showed that 88% of interviewed households were willing to expand their practices if an opportunity arose. For example, they were willing to have more livestock and plant more trees to increase the size of their agroforestry practices. However, land scarcity, access to agricultural inputs and equipment, financial constraints, and water availability were barriers to their ability to expand. Moreover, 83.3% of households in Richmond were willing to adopt agroforestry. Inadequate knowledge about tree planting and respondents' age were among the factors contributing to the unwillingness to adopt agroforestry practices.

**Table 6.2.** Agroforestry practices status of sampled households

| | Swayimane | Umbumbulu | Richmond | Total |
|---|---|---|---|---|
| Households involved in agroforestry (%) | 85.9 | 95.1 | 89.1 | 90.2 |
| Agroforestry types households involved in | | | | |
| *Trees/shrubs and agricultural crops (%)* | 34.2 | 10.2 | 5.1 | 15.3 |
| *Tress/shrubs and livestock (%)* | 3.8 | 1.0 | 10.2 | 5.1 |
| *Trees/shrubs with agricultural crops and livestock (%)* | 62.0 | 88.8 | 84.7 | 79.6 |
| Households willing to expand agroforestry (%) | 91.1 | 88.8 | 84.7 | 88.0 |
| Households willing to adopt agroforestry (%) | 69.2 | 100.0 | 83.3 | 80.0 |

**Source:** Survey data (2022)

### 6.4.3 Principal component analysis (PCA) results

The PCA-derived agroforestry practices knowledge indices are presented in Table 6.3. Three PCs accounting for 65.952% of the total variation in the data were retained. The first component ($PC_{K1}$) was closely related to knowing agroforestry practices. The second component ($PC_{K2}$) was found to be closely associated with maximized land usage. This is in line with previous studies which indicated that agroforestry maximizes land usage. The third component ($PC_{K3}$) was closely related to agroforestry being against animal grazing. Some respondents indicated that planting trees on farm land reduces grazing land for livestock.

**Table 6.3.** Households' knowledge of agroforestry practices

| Variables | Principal components | | |
|---|---|---|---|
| | $PC_{K1}$ – Agroforestry knowledge | $PC_{K2}$ – Land utilisation | $PC_{K3}$ – Against animal grazing |
| Before this interview, I knew about forestry farming | 0.636 | 0.411 | 0.014 |
| I have always known about agroforestry innovations although I did not know the exact wording | 0.751 | -0.115 | -0.159 |
| I have always known and understood what agroforestry innovations are | 0.760 | 0.003 | 0.230 |
| Agroforestry is against the practice of animal grazing | 0.030 | 0.036 | 0.946 |
| Agroforestry maximises land usage | 0.011 | 0.818 | -0.150 |
| Agroforestry guarantees consistent supply to the markets | 0.046 | 0.695 | 0.220 |
| *Eigenvalue* | 1.74 | 1.18 | 1.01 |
| *% of variance* | 28.91 | 19.71 | 16.91 |
| *Cumulative % of variance* | 28.91 | 48.62 | 65.52 |

**Note:** Only component loadings greater than |0.50| are included in the interpretation; KMO = 0.60 and Bartlett's Test of Sphericity $Chi^2 = 121.93$, $p$-value = 0.000.
**Source:** Survey data (2022)

The PCA-derived agroforestry practices perception indices are presented in Table 6.4. Four PCs accounting for 55.49% of the total variation in the data were retained. The first component ($PC_{P1}$) represents households who perceive agroforestry as expensive and labour intensive. Rural households often lack the ability to attain optimal levels of financial capital which hinders their potential to uptake agroforestry practices. Achieving the long-term benefits of agroforestry requires high initial investment which could be expensive for these households. Moreover, agroforestry practices may have high labour requirements such as digging a hole to plant a tree or shrub. The second component ($PC_{P2}$) was closely related to hindering the use of modern farm implement. The third component ($PC_{P3}$) was found to be closely related to profitability. Agroforestry systems are more profitable because they create various income streams through tree products, crops, and livestock sales. The fourth component ($PC_{P4}$) was found to be closely related to the technicality of agroforestry systems. Most sampled households indicated that agroforestry practice is not properly understood due to its technicality. This indicates a lack of information and skills which may be due to a lack of access to agroforestry extension officers.

**Table 6.4.** Households' perceptions towards agroforestry practices

| **Variables** | **Principal components** | | | |
|---|---|---|---|---|
| ***Agroforestry practice is*:** | **$PC_{P1}$ – Expensive and labour intensive** | **$PC_{P2}$ – Incompatibility to modern farm equipment** | **$PC_{P3}$ – Profitable** | **$PC_{P4}$ – Technical** |
| Difficult to practice | 0.613 | 0.190 | -0.031 | 0.233 |
| A common practice in this area | -0.088 | 0.335 | 0.637 | -0.214 |
| Can increase farm productivity | 0.003 | -0.124 | 0.651 | 0.277 |
| Not properly understood because of its technicality | -0.040 | 0.144 | -0.018 | 0.829 |
| Time consuming | 0.673 | -0.036 | 0.119 | 0.086 |
| Not profitable | -0.036 | 0.141 | -0.670 | 0.004 |
| Expensive to practice | 0.750 | 0.078 | -0.153 | 0.141 |
| Labour intensive | 0.804 | 0.057 | 0.013 | -0.135 |
| Cannot be practiced on small piece of land | 0.278 | 0.669 | -0.002 | 0.246 |
| Hinders the use of modern farm implement | -0.004 | 0.829 | -0.093 | -0.010 |
| Not meant for low-income/smallholder farmers | 0.221 | 0.009 | 0.076 | 0.528 |
| *Eigen value* | 2.45 | 1.35 | 1.26 | 1.04 |
| *% of variance* | 22.26 | 12.28 | 11.48 | 09.47 |
| *Cumulative % of variance* | 22.26 | 34.55 | 46.02 | 55.49 |

**Note:** Only component loadings greater than |0.50| are included in the interpretation; KMO = 0.66 and Bartlett's Test of Sphericity $Chi^2$ = 389.27, $p$-value = 0.000.
**Source:** Survey data (2022)

The PCA-derived agroforestry practices attitudes indices are presented in Table 6.5. This measures the intention levels of households to plant trees on their farm land. Three PCs accounting for 52.73% of the total variation in the data were retained. The first component ($PC_{A1}$) showed that households viewed agroforestry as a worthwhile investment. It was found to be closely related to fuel and furniture wood provision. Most respondents considered planting trees vital because they provide fuelwood as a source of energy for heating, boiling water, and cooking. The second component ($PC_{A2}$) was found to be closely related to reduced crop yields. This may result from the presence of trees on a limited amount of farm land which interferes with crop production. For example, some sampled rural households indicated that tree shading reduced crop yields. The third component ($PC_{A3}$) was closely related to controlling air pollution. This is in line with the literature which reported that planting trees greatly reduces greenhouse gas emissions and improves atmospheric carbon dioxide capture.

**Table 6.5.** Households' attitudes towards agroforestry practices

| Variables | Principal components | | |
|---|---|---|---|
| ***Planting trees on my land will*:** | **$PC_{A1}$ – Positive attitudes** | **$PC_{A2}$ – Negative attitudes** | **$PC_{A3}$ – Environmental contribution** |
| Increase household income | 0.600 | -0.241 | 0.247 |
| Provide fuelwood and furniture wood | 0.719 | 0.030 | 0.093 |
| Control soil erosion | 0.203 | -0.082 | 0.797 |
| Control air pollution | 0.062 | 0.182 | 0.837 |
| Cause hindrance in agricultural operations | -0.042 | 0.631 | -0.060 |
| Cause shade that will reduce the yield of crops | 0.126 | 0.722 | 0.245 |
| Incur more cost | 0.193 | 0.678 | -0.212 |
| Provide harbor to insects, pests and diseases | -0.206 | 0.581 | 0.182 |
| Provide shade for human beings and animals | 0.671 | 0.050 | 0.188 |
| Be a long-time land utilization | 0.618 | 0.094 | -0.106 |
| *Eigen value* | 2.22 | 1.81 | 1.25 |
| *% of variance* | 22.18 | 18.07 | 12.48 |
| *Cumulative % of variance* | 22.18 | 40.25 | 52.73 |

**Note:** Only component loadings greater than |0.50| are included in the interpretation; KMO = 0.64 and Bartlett's Test of Sphericity $Chi^2$ = 408.83, $p$-value = 0.000.
**Source:** Survey data (2022)

### 6.4.4 Binary logistic regression model results

A binary logistic regression model was used to examine the determinants of agroforestry practices adoption (Table 6.6). Post-estimation diagnostic tests were conducted to check the model's goodness of fit. A statistically insignificant Hosmer-Lemeshow test value ($p$-value = 0.667) indicated a good fit of the model. The likelihood ratio $Chi^2$ test value indicated that the model was statistically significant and had a strong explanatory power ($p$-value = 0.000). Therefore, this study rejected the null hypothesis that the model without explanatory variables and the model with explanatory variables were similar. According to Cox and Snell $R^2$, Nagelkerke $R^2$, and McFadden $R^2$ values, the dependent variable defines 19%, 40%, and 32.7% of the variance in independent variables, respectively. Moreover, the model correctly classified 91.80% of the cases and had a statistically significant Wald test ($p$-value = 0.000). Multicollinearity was not a challenge since the VIFs had an average of 1.31, well below the threshold.

This study looked at the socio-psychological factors (knowledge, attitudes, and perceptions) and their role in the adoption of agroforestry practices among rural households. The binary logistic regression model results showed a positive relationship between these three factors and adoption of the practices. According to the argument in the introduction of this paper, focusing on all three intrinsic variables is essential to better understand the adoption process for agroforestry practices among rural households. Therefore, the findings of this study confirm that including knowledge, perceptions, and attitudes variables in one analysis improves the understanding of adoption decisions. This demonstrates the novelty of this study that all these variables are crucial. Other countries can benefit from this study by ensuring that they include all intrinsic factors in their future adoption studies and policy formulation.

**Table 6.6.** Determinants of agroforestry practices adoption: Binary logistic regression model results

| Variables | Coef. | Sig. | Std. Err. | Wald | Odds ratio | Marginal effect |
|---|---|---|---|---|---|---|
| Age | 0.055** | 0.046 | 0.028 | 3.984 | 1.057 | 0.001 |
| Experience | 0.038* | 0.080 | 0.021 | 3.057 | 1.038 | 0.001 |
| Education | 0.122* | 0.076 | 0.069 | 3.150 | 1.130 | 0.003 |
| Extension | -0.779 | 0.325 | 0.790 | 0.971 | 0.459 | -0.023 |
| Gender | -0.272 | 0.599 | 0.517 | 0.277 | 0.762 | -0.006 |
| Land size | 1.677*** | 0.000 | 0.437 | 14.744 | 5.351 | 0.038 |
| Total livestock units | -0.016 | 0.866 | 0.093 | 0.028 | 0.984 | -0.000 |
| Assets | -0.269 | 0.207 | 0.214 | 1.592 | 0.764 | -0.006 |
| Group membership | -1.517 | 0.153 | 1.062 | 2.038 | 0.219 | -0.020 |
| Off-farm income | 0.456 | 0.178 | 0.339 | 1.811 | 1.577 | 0.010 |
| Agroforestry knowledge ($PC_{K1}$) | 0.548** | 0.039 | 0.266 | 4.251 | 1.730 | 0.012 |
| Land utilisation ($PC_{K2}$) | -0.425 | 0.159 | 0.301 | 1.988 | 0.654 | -0.010 |
| Against animal grazing ($PC_{K3}$) | 0.369 | 0.211 | 0.295 | 1.563 | 1.447 | 0.008 |
| Expensive and labour intensive ($PC_{P1}$) | -0.020 | 0.949 | 0.307 | 0.004 | 0.980 | -0.000 |
| Incompatibility to modern farm equipment ($PC_{P2}$) | 0.134 | 0.650 | 0.295 | 0.206 | 1.143 | 0.003 |
| Profitable ($PC_{P3}$) | 0.934*** | 0.002 | 0.306 | 9.333 | 2.544 | 0.021 |
| Technical ($PC_{P4}$) | -0.452 | 0.140 | 0.307 | 2.173 | 0.636 | -0.010 |
| Positive attitudes ($PC_{A1}$) | 0.633** | 0.021 | 0.275 | 5.311 | 1.883 | 0.014 |
| Negative attitudes ($PC_{A2}$) | 0.409 | 0.179 | 0.305 | 1.804 | 1.506 | 0.010 |
| Environmental contribution ($PC_{A3}$) | -0.013 | 0.957 | 0.246 | 0.003 | 0.987 | -0.000 |
| Constant | -4.045 | 0.212 | 3.242 | 1.556 | 0.018 | |
| Multicollinearity test | 1.31 | | | | | |
| Number of cases correctly classified | 91.80% | | | | | |

**Note**: ***, ** and * indicate the level of significance at 1%, 5% and 10%, respectively; Hosmer-Lemeshow test $Chi^2$ = 5.825, $p$-value = 0.667; -2 Log likelihood = 131.935; Likelihood ratio $Chi^2$ = 64.159, $p$-value = 0.000; Wald test = 132.778, $p$-value = 0.000; Cox and Snell $R^2$ = 0.190; Nagelkerke $R^2$ = 0.400; McFadden $R^2$ = 0.327.

**Source:** Survey data (2022)

Household heads who were more knowledgeable about agroforestry practices had a higher adoption capability. This is consistent with studies from Nigeria (Tokede *et al.*, 2020b) and Pakistan (Ahmad *et al.*, 2023) which emphasized that adequate knowledge promotes adopting agroforestry practices. The marginal effects' results showed that a one-unit increase in the knowledge score of household heads increased the likelihood of adopting agroforestry practices by 0.012 percentage points. Therefore, educating rural households about trees' economic and environmental benefits could increase tree cover in the agricultural landscape. Sampled households who perceived agroforestry as a profitable practice were more likely to adopt agroforestry practices. This is consistent with Ahmad *et al.* (2023), who reported a positive relationship between perceptions and agroforestry adoption. According to Saha *et al.* (2018), most rural households perceive agroforestry as a profitable practice compared to a monoculture production system. The results also showed that sampled households who agreed that planting trees provides fuelwood and furniture wood (i.e., positive attitude) had a greater likelihood of adopting the agroforestry practices, *ceteris paribus*. Households using firewood as an energy source tend to plant more trees on their farm land than those using electricity, paraffin, and gas (Kinyili, 2022; Ahmad *et al.*, 2023). Moreover, tree species such as teak provide the raw material for furniture.

In this study, a distinction between age and farming experience was made because a 50-year-old household head, for instance, might have commenced farming at the age of 40 and another of the similar age might have commenced at the age of 30. Thus, their knowledge, skills, and motives for farming might differ based on their age and experiences (Cele and Wale, 2020). The results indicated a positive and significant relationship between the age of the household head and the adoption of agroforestry practices. That is, a one-year rise in household head’s age would increase the probability of adopting agroforestry by 5.5%, *ceteris paribus*. This is in line with previous studies (Tokede *et al.*, 2020a; Bandi *et al.*, 2022) which indicated that older household heads are more likely to adopt agroforestry practices than younger ones. Younger individuals perceive agroforestry practice as a long-term method due to the slow growth rate of tree species compared to cash crops (Ahmad *et al.*, 2023). This calls for a need to promote fast-growing species in farm lands. Adoption of agroforestry practices was also found to be positively associated with the farming experience. This is consistent with Awe *et al.* (2021), who reported that more experienced households have the knowledge and skills to manage their on-farm activities effectively.

The relationship between household heads’ education level and agroforestry practices adoption was positive and significant. Increasing household head’s education by one year increases the probability that they would adopt agroforestry by 12.2%, *ceteris paribus*. This is because education improves access to knowledge, understanding of technologies, and opportunities’ identification. Previous studies, such as Jahan et al. (2022), also asserted that educated individuals tend to have the capacity to adopt agroforestry practices. The results indicated that the estimated coefficient of land size was positively related to the adoption of agroforestry practices, *ceteris paribus*. The odds of adopting agroforestry practices were 5.351 times higher among households with larger land sizes than those with smaller land sizes. Bigger land sizes enable rural households to accommodate trees, shrubs, agricultural crops, and livestock for optimal benefits. This is in line with numerous studies (Liliane *et al.*, 2020; Awe *et al.*, 2021) that reported a positive relationship between land size and agroforestry adoption. According to Moronge and Nyamweya (2019), agroforestry practices are less likely to be economically feasible on small land sizes. The results regarding the marginal effect indicated that a one-unit increase in land size increases the likelihood of adopting agroforestry practices by 3.8%.

### 6.5 Conclusions and recommendations

This study empirically investigated the determinants of agroforestry practices adoption among rural households. It emphasized the importance of incorporating socio-psychological factors, such as households' perceptions and attitudes, to effectively design and implement agroforestry projects. Knowledge, attitudes, and perceptions towards agroforestry were found to impact the adoption of the practice positively. These findings support the hypothesis that socio-psychological factors have a positive impact on the adoption of agroforestry practices among rural households. The results also showed that agroforestry adoption was significantly affected by age, farming experience, education level, and land size. Therefore, the study concludes that socio-economic and socio-psychological factors are associated with agroforestry adoption. Considering rural households' socio-economic characteristics, knowledge, attitudes, and perceptions when designing agroforestry projects is recommended.

Extension officers, climate change champions, researchers, policymakers, and other stakeholders need to join forces in public-private partnerships to collectively participate in distributing adequate knowledge on agroforestry practices and their advantages to rural households. The use of media to raise awareness and information on the impact of changing climate and the benefits of agroforestry in locally understood languages and the implementation of training programs with practical demonstration is essential in promoting the level of adoption and encouraging rural households to protect on-farm trees and shrubs. Moreover, addressing institutional and service constraints such as land scarcity, access to tree saplings and agricultural equipment, financial constraints, water availability, and inadequate knowledge is vital to enhance the adoption and expansion of agroforestry practices. Actively involving rural households in the design of agroforestry programs is also important to develop programs that meet households' needs and preferences, improve food and nutrition security, and address climate change related risks within rural communities.

Moreover, as mentioned earlier, one possible reason for the lack of research on understanding the relationship between intrinsic factors and agroforestry adoption may be methodological challenges associated with measuring individual's perceptions of farming systems. This study then used five-point Likert scale statements to measure respondents' knowledge, attitudes, and perceptions. Using numerous statements to measure each factor, rather than one statement generated a wealth of knowledge from the analysis. The results showed that certain aspects of knowledge, perceptions, and attitudes were significant and critical to rural households' agroforestry adoption decisions, while others were not. For example, agroforestry knowledge, perceptions of profitability, and positive attitudes affected adoption decisions. Therefore, it is recommended that other studies use a similar approach to measure intrinsic variables for better results.

# CHAPTER 7. CONCLUSIONS, RECOMMENDATIONS, AND FUTURE RESEARCH DIRECTIONS

## 7.1 Recapping the purpose of the research

South Africa faces major changes to its climate. In the past five decades, the country's average annual temperatures have risen by at least 1.5 times more than the noted global average of 0.65°C. This has exposed the health, livelihoods, food security, water supply, human security, and economic growth of the country to climate-related risks. In the previous 50 years, flood events have frequently risen, and these changes are expected to continue. Moreover, unless intensive action is taken to lessen greenhouse gas emissions, temperatures may increase by above 4°C across the southern African interior by 2100 and by above 6°C across the western, central, and northern parts of South Africa. These climatic challenges and their impacts on household wealth, income streams, and general livelihood sources, together with prevailing challenges in resource-poor rural communities are overwhelming. Extreme changes in rainfall patterns and increases in temperatures lead to unfavourable conditions in the cropping calendars, thus altering cultivation seasons, which subsequently affect crop productivity. These changes have the potential to place strain on food and nutrition security in rural areas, where most households are dependent on farming to sustain their livelihoods. Therefore, mitigating climate change demands that long-term and effective adaptative strategies be put in place to support rural households to improve their food and nutrition security.

Tree restoration and/or improved forest management is a crucial strategy to co-deliver food security and climate change mitigation. Without tree resources, global and national levels of food and nutrition insecurity would be significantly higher. The literature indicated that tree resources need to be an essential part of international and local policies and strategies to address the challenge of food and nutrition insecurity. Hence, the general research objective of this study was to examine the role of trees and the dynamics of tree planting as a climate change adaptation strategy for addressing food and nutrition security challenges in the KwaZulu-Natal Province, South Africa. The specific objectives have been to (1) identify the different types of trees beneficial to selected resource-poor rural communities and the main beneficial uses and disservices of these trees; (2) investigate tree planting as a climate change adaptation strategy among rural households; (3) evaluate the potential contribution of trees towards food insecurity and nutrition security of resource-poor rural households; and (4) examine the role of knowledge, attitudes, and perceptions in the uptake of agroforestry innovations among households.

## 7.2 Conclusions

The fruit tree species such as banana, peach, and orange played a vital role in improving food, medicinal, and financial security among rural households. Some of the trees' roles identified by respondents were fuelwood and shade provision, improved soil fertility, controlling soil erosion during floods, and blocking wind during storms. However, some respondents indicated that trees do not improve their livelihoods instantly because they take years to reach maturity. However, the attraction of snakes and yard littering were the most common disservices associated with most fruit trees. Based on these findings, this study concludes that, regardless of the benefits of various trees, there are disservices that result from some trees.

Despite the climate change events in the study locations, smallholder farmers applied various adaptation strategies to sustain and improve their livelihoods. Planting trees was the most common adaptation strategy. Compared to other strategies, it emerged as a long-term and sustainable strategy. Trees were used as a solution to food and nutrition insecurity caused by climate change through eating tree products such as fruits. The age, age square, group membership, access to training and climate change information, off-farm income, land size, and psychological capital (hope and resilience) influenced the decisions to adopt climate change adaptation strategies. Hopeful smallholder farmers were less likely to plant trees but more likely to adopt soil conservation strategies and crop diversification. Moreover, access to training had a positive and significant impact on the adoption of tree planting. This study concludes that trees play a crucial role in climate change adaptation.

Most of the households were food insecure. The severely food insecure households had to reduce the meal size or number of meals consumed often, and/or experienced the three most severe conditions (i.e., ran out of food, went to bed hungry, or spent a whole day and night without eating anything). However, most households consumed an acceptable number of food groups. The level of wild fruit consumption among the sampled rural households was low. Two explanatory variables capturing the impact of fruit trees on food insecurity and nutrition security (i.e., growing fruit trees and consumption of wild fruits) were statistically significant. Growing fruit trees reduced household food and nutrition insecurity. This study concludes that fruit trees play a crucial role in improving food and nutrition security among rural households.

Most of the interviewed households were willing to expand their agroforestry practices if an opportunity arose. However, land scarcity, access to agricultural inputs and equipment, financial constraints, and water availability were barriers to their expansion. There is a positive association between the socio-psychological factors (knowledge, attitudes, and perceptions) and the adoption of agroforestry practices. Agroforestry adoption was also significantly affected by age, farming experience, education level, and land size. Therefore, the study concludes that socio-economic and socio-psychological factors are associated with agroforestry adoption. Including knowledge, perceptions, and attitudes variables in one analysis improves the understanding of adoption decisions.

### 7.3 Policy recommendations

Based on the findings of this study, the following recommendations are made:

- The implementation of tree-planting programs and the distribution of fast-growing tree species across rural communities to improve their livelihoods. Improved allocation of resources to tree planting and maintenance by the public and private sectors can be a sound decision based on the benefits provided by trees. This can also be achieved through the intervention of forestry extension services.
- Prioritization of policies on tree planting as a climate change adaptation strategy and raising awareness on the benefits of planting trees, especially fruit trees.
- Implementation of awareness campaigns promoting the utilization and consumption of wild fruits.
- The proper clinical testing of rural communities' medicinal trees to validate their utilization and improve rural health systems.
- Reforestation and protection of existing forests need to be crucial parts of international, national, and local policies to address challenges such as food and nutrition insecurity, medicine insecurity, and deforestation.
- Some tree species were perceived as harmful to children. Hence, promoting educational programs on trees for children is essential to improve their basic understanding of trees' benefits and dangerous features.
- Extension officers, non-governmental organizations, policymakers, and other stakeholders need to support local-level knowledge of climate change adaptation and turn it into effective and sustainable action. This needs to include the prioritization of simple**,** comprehensible, and practical change-related training programs to accommodate illiterate and less experienced farmers and to promote just and equitable development.
- Government leadership at all levels needs to prioritize climate change adaptation in their national, provincial, district, and local budgets.
- Integration of psychological support services into agricultural extension services, climate adaptation planning, and/or policy.
- Creating opportunities for off-farm income-generating activities. This could include training programs and improved investment in entrepreneurship, particularly for rural youth.

- Nutrition-related training programs and workshops are recommended to enhance self-confidence in managing food resources. These programs can cover topics such as shopping strategies, budgeting, food selection, food preparation, and consumption of wild foods.
- The collaboration of government, research and academia, private sector, civil society organizations and non-state actors, policymakers, politicians, and farming rural households to transform food systems and reduce food and nutrition insecurity.
- Consideration of rural households' socio-economic characteristics, knowledge, attitudes, and perceptions when designing agroforestry projects. It is important to actively involve rural households in the design to develop programs or projects that meet their needs and preferences.
- Extension officers, climate change champions, researchers, policymakers, and other stakeholders need to join forces in public-private partnerships to collectively participate in distributing adequate knowledge on agroforestry practices and their advantages to rural households.
- Addressing institutional and service constraints such as land scarcity, access to tree saplings and agricultural equipment, financial constraints, water availability, and inadequate knowledge is vital to enhance the adoption and expansion of agroforestry practices.
- Given the rising water scarcity, training programs on using irrigation water productively and managing small-scale irrigation schemes are also required. Establishing, rehabilitating, and revitalizing irrigation projects in rural communities is suggested.

### 7.4 Limitations of the study and suggestions for future research

Due to financial and time limitations, this study was conducted in one of nine South African provinces. Although the sample size of 305 households from the KwaZulu-Natal province is considered reasonably large and adequate to conduct significant statistics, the data is not nationally representative. Therefore, future similar research should include rural households from other provinces to produce more comprehensive results comparable across the different provinces. Moreover, this study only collected data for one season (i.e., spring). The results would have been more robust if the study had been conducted in more than one season to compare the household food and nutrition security status in four different seasons of the year (i.e., spring, summer, autumn, and winter). Future studies should consider the following:

- Adopt a data collection approach that is close to the revealed preference method to measure psychological capital. This approach would involve observing actual behavior or choices made by individuals to infer their levels of psychological capital. This method moves beyond self-reported surveys by relying on real-life decisions that reflect the four psychological traits (i.e., hope, resilience, optimism, and self-confidence). For example, actions such as saving patterns, investments in long-term projects, and participation in community activities could serve as observable proxies for psychological capital.

- Apply the theory of psychological capital in its wholesome form to household food consumption research. This comprehensive approach entails integrating all four dimensions of psychological capital (i.e., hope, resilience, optimism, and self-confidence) into the analysis of household decision-making processes and assessing how they collectively influence household consumption behaviors (e.g., spending on nutritious versus non-nutritious foods, frequency of meals, and food diversity). Understanding how psychological capital shapes spending on food under various socio-economic constraints could provide valuable insights and support the development of more targeted and effective policies.
- This study used five-point Likert scale statements to measure respondents' knowledge, attitudes, and perceptions. Using numerous statements to measure each factor, rather than one statement generated a wealth of knowledge from the analysis. Therefore, it is recommended that future studies use a similar approach to measure intrinsic variables for better results.

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# APPENDICES

## Appendix A: Ethical clearance

UNIVERSITY OF KWAZULU-NATAL™
INYUVESI YAKWAZULU-NATALI

28 January 2022

**Fortunate Nosisa Zaca (211504046)**
**School Of Agri Earth & Env Sc**
**Pietermaritzburg Campus**

**Dear FN Zaca,**

**Protocol reference number:** HSSREC/00003793/2022
**Project title:** The role of trees in and the dynamics of tree planting as a climate change adaptation strategy for addressing food and nutrition security challenges in KwaZulu-Natal
**Degree:** PhD

**Approval Notification – Expedited Application**

This letter serves to notify you that your application received on 20 January 2022 in connection with the above, was reviewed by the Humanities and Social Sciences Research Ethics Committee (HSSREC) and the protocol has been granted **FULL APPROVAL**.

**Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number. PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.**

This approval is valid until 28 January 2023.
To ensure uninterrupted approval of this study beyond the approval expiry date, a progress report must be submitted to the Research Office on the appropriate form 2 - 3 months before the expiry date. A close-out report to be submitted when study is finished.

All research conducted during the COVID-19 period must adhere to the national and UKZN guidelines.

HSSREC is registered with the South African National Research Ethics Council (REC-040414-040).

Yours sincerely,

[redacted]

-----------------------------------------------
**Professor Dipane Hlalele (Chair)**

**/dd**

**Humanities and Social Sciences Research Ethics Committee**
**Postal Address:** Private Bag X54001, Durban, 4000, South Africa
**Telephone:** +27 (0)31 260 8350/4557/3587 **Email:** hssrec@ukzn.ac.za **Website:** http://research.ukzn.ac.za/Research-Ethics

Founding Campuses: Edgewood Howard College Medical School Pietermaritzburg Westville

INSPIRING GREATNESS

## Appendix B: Questionnaire used for data collection

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

The information to be captured in this questionnaire is strictly confidential and will be used for research purposes by staff and a post-graduate student at the University of KwaZulu-Natal. It is meant to address a PhD study entitled **"The role of trees and the dynamics of tree planting as a climate change adaptation strategy for addressing food and nutrition security challenges in KwaZulu-Natal"**. There are no wrong or right answers to these questions. You are free to be or not part of this survey. However, your cooperation is greatly appreciated.

| | | | |
|---|---|---|---|
| Date | | Respondent name | |
| Questionnaire No. | | Respondent ID/age | |
| Village name | | Cell No. | |
| Ward No. | | Enumerator name | |

### A. HOUSEHOLD DEMOGRAPHICS

**1.** What is the total number of your household members? (*Please include only those who stay in the household for **3 or more days per week and eat together***) ___________________________

**Please complete table below (*Record household head* details in the first row*).**

| **a.** Household member name | **b.** Relationship to household head[1] | **c.** Age | **d.** Gender[2] | **e.** Marital status[3] | **f.** Main occupation[4] | **g.** Years of Education level completed (specify, e.g., Grade 7) |
|---|---|---|---|---|---|---|
| | 1 | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

**Key**

| **Relation to household head[1]** | **Gender[2]** | **Marital status[3]** | **Main occupation[4]** |
|---|---|---|---|
| 1=Household head*<br>2=Spouse<br>3=Son<br>4=Daughter<br>5=Grand son<br>6=Grand daughter<br>7=Other (specify e.g., in-law) | 1=Male<br>0=Female | 1=Single<br>2=Married<br>3=Divorced<br>4=Widowed<br>5=Co-habiting | 1=Fulltime farmer<br>2=Regular salaried job<br>3=Temporary job [e.g., public works (Zibambele), domestic worker, etc.]<br>4=Self-employed<br>5=Student<br>6=Retired<br>7=Unemployed<br>8=Pensioner |

### B. HUMAN CAPITAL

**B1.** How many years of experience in farming do you have? ________________________________________

**B2.** Have you ever received any form of training? *1= Yes 0= No*

**If yes, please complete the table for at most 3 important trainings received.**

| | **B3.** Training 1 | **B4.** Training 2 | **B5.** Training 3 |
|---|---|---|---|
| a. Kind of the training received **(Code A)** | | | |
| b. Who offered the training? **(Code B)** | | | |

**Code A:** *1= Agricultural related 2= Environmental related 3= Financial related 4= Nutrition/health related 5= Agroforestry or forest farm (tree plantation) 6= If other (please specify)* ___________________________

**Code B:** *1= Extension officer 2= Private company 3= Non-governmental organizations (NGOs) 4= Local municipality 5= self-taught 6= Other (please specify)* ________________________________________

**C. SOCIAL CAPITAL**

**C1.** Are you a member of any group (s) in the community?

| Group | Membership ***1= Yes 0= No*** |
|---|---|
| a. Any business cooperative | |
| b. Credit and/or savings association (e.g., stokvel) | |
| c. Church | |
| d. School (governing body) | |
| e. Social media (WhatsApp, Facebook, Twitter, Instagram etc.) | |
| f. Other (specify): | |
| **C2.** If No to all of the above groups, why not? | |

**Please complete the table for at most 3 information sources used in the past.**

| | **C3.** Source 1 | **C4.** Source 2 | **C5.** Source 3 |
|---|---|---|---|
| a. Information source **(Code C)** | | | |
| b. Rank information source **(Code D)** | | | |

**Code C:** *1= Extension officers 2= Non-governmental organizations (NGOs) 3= Community meetings 4= Media (newspapers, radio, TV) 5= Cooperative leaders 6= Traditional leaders 7= Phone (SMS, social media) 8= Other (please specify)* ____________________

**Code D:** *1= Very unimportant 2= Unimportant 3= Neutral 4= Important 5= Very important*

**D. PSYCHOLOGICAL CAPITAL (Read each statement separately and get a response for each)**

**HOPE**

**D1.** As rural households, you often face challenges with poverty, food insecurity, financial instability, water availability, market access constraints, etc.

| Given the possibility of any of these constraints existing, to what extent do you believe that: | **Response*** |
|---|---|
| a. There is no possibility of resolving these constraints | |
| b. You still have the potential to turn things around | |
| c. The government, other sectors or a relative can address the issues | |
| d. Any other (please specify) | |
| Any reason(s) for your responses? | |

**1= Strongly disagree 2= Disagree 3= Neutral 4= Agree 5= Strongly agree*

**D2.** Unemployment is a challenge in South Africa for young people. Given the recent COVID-19 pandemic, most people have lost their jobs.

| Given this challenge of unemployment, to what extent do you believe that: | **Response*** |
|---|---|
| a. The unemployment problem will decrease in the future | |
| b. The unemployment problem will increase in the future | |
| c. The young people have the potential of starting businesses and create more jobs | |
| d. Any other (please specify) | |
| Any reason(s) for your responses? | |

**1= Strongly disagree 2= Disagree 3= Neutral 4= Agree 5= Strongly agree*

**D3.** Suppose you are running a business and realize new equipment or technology that will minimize costs and increase your profit in the long-run. However, buying this equipment/technology will result in you forgoing your short-run profits.

| To what extent are you most likely to: | **Response*** |
|---|---|
| a. To adopt the new technology and forgo the short-term profits | |
| b. Not buy the equipment and forgo the long-term profits | |
| c. Search for other cheaper equipment or technology | |
| d. Any other (please specify) | |
| Any reason(s) for your responses? | |

**1= Strongly disagree 2= Disagree 3= Neutral 4= Agree 5= Strongly agree*

**RESILIENCE**

**D4.** Suppose you are involved in farming, and your crop(s) are affected by a pest this season and you harvest almost nothing.

| In the next season, to what extent are you most likely to: | **Response*** |
|---|---|
| a. Raise money to buy effective pesticides or pest resistant crops | |
| b. Consult other smallholder farmers not affected by the pest to find out what have they done | |
| c. Change the composition of crop enterprises | |
| d. Any other (please specify) | |
| Any reason(s) for your responses? | |

**1= Strongly disagree 2= Disagree 3= Neutral 4= Agree 5= Strongly agree*

**D5.** Making profit is one of the reasons why people start businesses. Suppose you are running a business and you have been making losses for the past three years?

| In the following year, to what extent are you most likely to: | **Response*** |
|---|---|
| a. Give up and forget about the business | |
| b. Continue with the business and consult a business advisor or a successful business owner | |
| c. Continue with the business and change the way you run your daily business activities | |
| d. Any other (please specify) | |
| Any reason(s) for your responses? | |

**1= Strongly disagree 2= Disagree 3= Neutral 4= Agree 5= Strongly agree*

**D6.** Suppose a certain organisation introduces training/skills development project to empower people in your area and you are selected as a one of the participants. However, you all end up not completing the training because organisers decide to cancel some of the training sessions due to some challenges.

| In the future, to what extent are you most likely to: | **Response*** |
|---|---|
| a. Attend the training again when the same organisation offers it | |
| b. Only attend the training if it is offered by a different organisation | |
| c. Stop attending trainings offered by any organisation in your area | |
| d. Any other (please specify) | |
| Any reason(s) for your responses? | |

**1= Strongly disagree 2= Disagree 3= Neutral 4= Agree 5= Strongly agree*

**SELF-EFFICACY / SELF-CONFIDENCE**

**D7.** Suppose you are a member of an organisation (e.g., stokvel club or cooperative) and they are nominating a committee for the organisation (e.g., chairperson, secretary, etc.).

| To what extent are you most likely to: | **Response*** |
|---|---|
| a. Be nominated by others | |
| b. Accept the nomination if you are nominated | |
| c. Nominate yourself if you are allowed to do so | |
| d. Any other (please specify) | |
| Any reason(s) for your responses? | |

**1= Strongly disagree 2= Disagree 3= Neutral 4= Agree 5= Strongly agree*

**D8.** Suppose you are a member of a stokvel club or cooperative in your area and you attend monthly meetings. In these meetings you do not always agree with some of the decisions taken by the leadership.

| You are in one such meeting and wish to oppose some ideas raised by the leaders, to what extent are you mostly likely to: | **Response*** |
|---|---|
| a. Oppose the leader's opinions that are not aligned with your beliefs | |
| b. Agree with the leader to avoid conflict | |
| c. Agree with the leader to show respect for their position | |
| d. Any other (please specify) | |
| Any reason(s) for your responses? | |

**1= Strongly disagree 2= Disagree 3= Neutral 4= Agree 5= Strongly agree*

**D9.** Suppose you have a farming business and on a normal harvest season, you usually receive at most 5 orders per week. Suppose on a particular week, you receive 10 orders and need to attend a compulsory community meeting.

| To what extent are you most likely to: | **Response*** |
|---|---|
| a. Work longer hours than usual including in the evening to meet all orders | |
| b. Cancel some orders to minimise workload | |
| c. Hire someone to assist you to meet all the orders | |
| d. Any other (please specify) | |
| Any reason(s) for your responses? | |

**1= Strongly disagree 2= Disagree 3= Neutral 4= Agree 5= Strongly agree*

**OPTIMISM**

**D10.** Suppose you have been farming for a certain period of time and you are familiar with the responsibilities of the farming business. Lately, however, you have been facing low yields, struggling to accomplish basic tasks and to make profit.

| To what extent are you most likely to: | **Response*** |
|---|---|
| a. Invest less of your time on farming and seek off-farm opportunities | |
| b. Continue farming and see these failures and setbacks as temporary | |
| c. Quit farming and find something else to do | |
| d. Any other (please specify) | |
| Any reason(s) for your responses? | |

**1= Strongly disagree 2= Disagree 3= Neutral 4= Agree 5= Strongly agree*

**D11.** Suppose you have use rights to some land in your area and the government introduces a new land consolidation programme. People who give up their land to this programme will be compensated with huge sums of money.

| To what extent are you most likely to: | **Response*** |
|---|---|
| a. Give up all of the land | |
| b. Give up part of the land | |
| c. Refuse the compensation and keep the land | |
| d. Any other (please specify) | |
| Any reason(s) for your responses? | |

**1= Strongly disagree 2= Disagree 3= Neutral 4= Agree 5= Strongly agree*

**D12.** Financial constraint is one of the major challenges facing most of rural households. Suppose there is an investment introduced to you with two options.

| To what extent are you most likely to: | **Response*** |
|---|---|
| a. Choose an investment with 50% chance of losing everything and 50% chance that your money will be doubled | |
| b. Choose an investment with 100% guarantee that your money will generate a 15% return | |
| c. Choose none of the investment options and save your money in a normal savings account | |
| d. Any other (please specify) | |
| Any reason(s) for your responses? | |

**1= Strongly disagree 2= Disagree 3= Neutral 4= Agree 5= Strongly agree*

## E. PHYSICAL CAPITAL

**Complete the following table on ownership and access to assets**

| Assets | **E1.** Number of assets | **E2.** Current market value per unit (s) (**Rand**) | **E3.** Own the asset individually ***1= Yes 0= No*** |
|---|---|---|---|
| a. Cell phone | | | |
| b. Radio | | | |
| c. Television | | | |
| d. Stove | | | |
| e. Fridge/freezer | | | |
| f. Generator | | | |
| g. Trailer/cart | | | |
| h. Water tank | | | |
| i. Motor vehicle | | | |
| j. Plough (igeja) | | | |
| k. Planter, harrow or cultivator | | | |
| l. Wheelbarrow | | | |
| m. Tractor | | | |
| n. Other (specify) | | | |

**Complete table below on livestock ownership**

| Type of livestock | **E4.** Number owned | **E5.** Number sold in the previous six months | **E6.** Current value per unit (**Rand**) | **E7.** Main market livestock sold **(Code E)** |
|---|---|---|---|---|
| a. Goats | | | | |
| b. Cattle | | | | |
| c. Sheep | | | | |
| d. Domestic chickens | | | | |
| e. Poultry (broilers) | | | | |
| f. Poultry (layers) | | | | |
| g. Pigs | | | | |
| h. Other (specify) | | | | |

**Code E**: *1= Local butchery 2= Supermarket 3= Community/Neighbors 4= Livestock auctions 5= Hawkers 6= Other (please specify)*____________________

| | |
|---|---|
| **E8.** What is your main purpose of keeping livestock? 1= *Sales (income) 2= Consumption 3= Wealth 4=Draught power (ukulima) 5= Cultural reasons 6 =Other (please specify)* (***multiple answers possible***) | |

**E9.** Are you satisfied with the state of the following infrastructure in your area?

**1= Strongly dissatisfied 2= Dissatisfied 3= Neutral 4= Satisfied 5= Strongly satisfied*

| Infrastructure | **Response*** |
|---|---|
| a. Road accessibility | |
| b. Electricity | |
| c. Water availability or supply | |
| d. Transport availability | |
| e. Health care facilities | |
| Any reason(s) for your responses? | |

## F. NATURAL CAPITAL

**Land ownership and tenure issues**

| **F1.** Land type | **F2.** Type of ownership **(Code F)** | **F3.** Total area **(ha)** | **F4.** Area under use **(ha)** | **F5.** Plot quality **(Code G)** |
|---|---|---|---|---|
| a. Homestead garden | | | | |
| b. Rainfed (field crops) | | | | |
| c. Community garden (your portion) | | | | |

**Code F:** *1= Owned (have title deeds); 2= Traditional (allocated by chief); 3= Rented; 4= Borrowed; 5= Other (please specify)*____________________

**Code G:** *1= Very bad 2= Bad 3=neutral 4= Good 5= Very good*

**F6.** If means of ownership is leasing or renting, how much do you pay per ha per year? ______________**(Rand)**

**F7.** Do you find it difficult to make long-term land use decisions due to the current land ownership system?

*1= Yes   0= No*

**F8.** If **Yes** to **F7**, why? Please give details ______________________________________________

**Complete the following questions regarding interest to plant trees (i.e., agroforestry innovations)**

**F9**. In the last 12 months (**2021**), did you have any fallow land? *1= Yes   0= No*

**F10**. If **Yes** to **F9**, how many hectares of fallow land? _________________**(ha)**

**F11**. If an opportunity arises, are you interested in using your land to plant trees beneficial to your household or community (e.g., fruit trees, timber, etc.)? *1= Yes   0= No*

**F12**. If **Yes** to **F11**, how many hectares of your total land would you like to use to grow trees? _____________**(ha)**

**F13**. If **No** to **F11**, why? ______________________________________________

**F14.** If **Yes** to **F11**, what type of trees beneficial to your household or community would you be interested in planting?

*1= Fruit trees 2= Timber/Firewood 3= Medicinal 4= Boundary wall trees (for fencing/ukubiya) 5= Climate change adaptation trees 6= None 7= Other (please specify)* ____________________(***multiple answers possible***)

**F15**. If you are interested and willing to plant trees, what factors, if any, would likely hinder you? (***For those who said Yes to F11 and did not select none for F14***)

*1= Financial constraints 2= Land availability constraints 3= Lack of access to inputs and machinery 4= Water availability constraints 5= Local and political constraints 6= Other (please specify)* ______________________

(***multiple answers possible***)

**F16**. If None to **F14**, why? ______________________________________________

**F17.** Do you agree that trees play an important role in your household livelihood? *1= Yes   0= No*

**F18.** Please justify your answer in **F17**. ______________________________________________

**F19.** Do you consider tree planting as a one of the solutions to food and nutrition insecurity? *1= Yes   0= No*

**F20.** Please justify your answer in **F19**. ______________________________________________

**F21.** Based on your knowledge on trees, what types of trees would you recommend that would be beneficial in when planted (e.g., improve food and nutrition security, provide income, improve soil fertility, etc.)?

| Purposes | Tree types or names |
|---|---|
| a. Fruit trees | |
| b. Firewood | |
| c. Roofing | |
| d. Medicinal | |
| e. Boundary plantation | |
| f. Climate change adaptation | |
| g. Any other (please specify) | |

## G. FINANCIAL CAPITAL

**G1.** Are any of your household members receiving a government social grant? *1= Yes 0= No*

If **Yes** to **G1**, complete the table below

| Grant type | **G2.** Number of people receiving grant | **G3.** Do all grant receivers live in the household? ***1=Yes 0= No*** | **G4.** If **G3** = 0, they receive money for how many beneficiaries? | **G5.** If **G3** = 0, do they send money home? ***1=Yes 0= No*** | **G6.** If **G5** = 1, how much do they send? **(Rand)** |
|---|---|---|---|---|---|
| a. Child grant | | | | | |
| b. Old persons grant | | | | | |
| c. Disability grant | | | | | |
| d. Foster child grant* | | | | | |
| e. Care dependency grant** | | | | | |
| f. Grant in aid*** | | | | | |
| g. Military veteran grant | | | | | |
| h. COVID-19 SRD grant**** | | | | | |

****Foster child grant**: given to a family that is looking after a child not theirs, in their home. ****Care dependency grant**: received by someone taking care of a person with a disability under the age of 18. *****Grant in aid**: given to someone taking care of a social grant recipient above the age of 18 who cannot take care of themselves. **** COVID-19 social relief of distress (SRD) grant: given to unemployed person above the age of 18 (R350)*

**Complete table below on sources of household income**

| Source of household income | **G7.** Source of income ***1=Yes 0= No*** | **G8.** Number of times you received this income in year 2021? **E.g.,** *once, 2 or 3 times/year, monthly, bi-monthly, etc.* | **G9.** Average income each time **(Rand)** |
|---|---|---|---|
| a. Remittances | | | |
| b. Arts and craft | | | |
| c. Permanent employment | | | |
| d. Temporary employment | | | |
| e. Social grants | | | |
| f. Crop income | | | |
| g. Livestock | | | |
| h. Tree resources (e.g., fuelwood, fruits) | | | |
| i. Self-employment | | | |
| j. Other (please specify) | | | |

**Savings and access to credit**

**G10.** Do you have any form of savings? *1= Yes 0= No*

**G11.** If **Yes** to **G10**, which type of savings? *1= Formal 2= informal (i.e. stokvel) 3= both*

**G12.** Have you ever taken credit or used any loan facility in the past 12 months? *1= Yes 0= No*

If **Yes to G12,** complete the table below, if **No,** proceed to **G16**

| | **G13.** Credit 1 | **G14.** Credit 2 | **G15.** Credit 3 |
|---|---|---|---|
| a. Type of credit **(Code H)** | | | |
| b. Indicate source of credit **(Code I)** | | | |
| d. Interest rate (%) | ________/ month<br>/ year | ________/ month<br>/ year | ________/ month<br>/ year |
| e. Were you able to pay back the loan/credit in time? *1= Yes 0= No* | | | |

**Code H:** *1= Consumption (food, clothes, etc.) 2= Agricultural production (inputs, agricultural equipment, livestock, etc.) 3= Other investment credit (building materials, etc.)*

**Code I:** *1= Relative or friend 2= Money lender 3= Savings club (e.g., stokvel or internal savings and lending schemes) 4= Input supplier 5= Output buyer 6= Banks 7= Government 8= Microfinance institutions 9= Other (please specify)*________________________

**G16.** If **No** to **G12,** please specify the reason(s) for not taking and/or using credit (***multiple answers possible)***
*1= The interest rate is high 2= I couldn't secure the collateral (isibambiso) 3= I have got my own sufficient money 4= It isn't easily accessible 5= I do not want to be indebted 6= Other (please specify)*______________________

## H. FOOD SECURITY

**Complete the table below using a recall period of four weeks (30 days). That is, in the past four weeks.**

| | Questions | **Response** |
|---|---|---|
| **H1.** | Did you worry that your household would not have enough food? *1= Yes 0= No* | |
| **H2.** | If **Yes**, how often did this happen? *1= Rarely (once or twice) 2= Sometimes (three to ten times) 3= Often (more than ten times)* | |
| **H3.** | Were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources? *1= Yes 0= No* | |
| **H4.** | If **Yes**, how often did this happen? *1= Rarely (once or twice) 2= Sometimes (three to ten times) 3= Often (more than ten times)* | |
| **H5.** | Did you or any household member have to eat a limited variety of foods due to a lack of resources? *1= Yes 0= No* | |
| **H6.** | If **Yes,** how often did this happen? *1= Rarely (once or twice) 2= Sometimes (three to ten times) 3= Often (more than ten times)* | |
| **H7.** | Did you or any household member have to eat some foods that you really did not want to eat because of a lack of resources to obtain other types of food? *1= Yes 0= No* | |
| **H8.** | If **Yes,** how often did this happen? *1= Rarely (once or twice) 2= Sometimes (three to ten times) 3= Often (more than ten times)* | |
| **H9.** | Did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food? *1= Yes 0= No* | |
| **H10.** | If **Yes,** how often did this happen? *1= Rarely (once or twice) 2= Sometimes (three to ten times) 3= Often (more than ten times)* | |
| **H11.** | Did you or any household member have to eat fewer meals in a day because there was not enough food? *1= Yes 0= No* | |
| **H12.** | If **Yes,** how often did this happen? *1= Rarely (once or twice) 2= Sometimes (three to ten times) 3= Often (more than ten times)* | |
| **H13.** | Was there ever no food to eat of any kind in your household because of lack of resources to get food? *1= Yes 0= No* | |
| **H14.** | If **Yes,** how often did this happen? *1= Rarely (once or twice) 2= Sometimes (three to ten times) 3= Often (more than ten times)* | |
| **H15.** | Did you or any household member go to sleep at night hungry because there was not enough food? *1= Yes 0= No* | |
| **H16.** | If **Yes,** how often did this happen? *1= Rarely (once or twice) 2= Sometimes (three to ten times) 3= Often (more than ten times)* | |
| **H17.** | Did you or any household member go a whole day and night without eating anything because there was not enough food? *1= Yes 0= No* | |
| **H18.** | If **Yes**, how often did this happen? *1= Rarely (once or twice) 2= Sometimes (three to ten times) 3= Often (more than ten times)* | |

**H19.** How many meals do you normally have per day? ______________________

## I. FOOD CONSUMPTION

| | ***Ask about the food consumption of household members*** | **I1.** Did household members eat this food group yesterday [24 hours recall]? *1=Yes 0= No* | **I2.** How often is this food group usually eaten in the household? Think of the past 7 days. *Number of times in the past 7 days* | **I3.** Where was the food obtained from (source)? **(Code J)** |
|---|---|---|---|---|
| a. | Cereals: maize, rice, wheat, sorghum, millet, and any other foods made from cereals such as porridge, bread, and noodles | | | |
| b. | White roots and tubers (potatoes, white sweet potato, and cassava) | | | |
| c. | Orange-flesh vegetables (pumpkin, carrot, butternut, or sweet potato) | | | |
| d. | Dark green leafy vegetables, including wild/indigenous vegetables | | | |
| e. | Other vegetables (tomato, onion, green beans, gem squash, eggplant, including wild/indigenous vegetables) | | | |
| f. | Orange-coloured fruit (e.g., ripe mango, apricot, spanspek, papaya, dried peach and 100% fruit juice made from these) | | | |
| g. | Other fruit (e.g., oranges, banana, apple, pear, etc.), including wild/indigenous fruits | | | |
| h. | Organ meat (liver, kidney, heart or other organ meats or blood-based foods) | | | |
| i. | Meat (e.g., beef, goat, sheep, poultry, pork, fish, insects) | | | |
| j. | Eggs from any animal | | | |
| k. | Fish and seafood (fresh, tinned or dried and shellfish) | | | |
| l. | Legumes, nuts and seeds (dried beans, dried peas, lentils, nuts, peanuts, seeds) or foods made from these (e.g., peanut butter) | | | |
| m. | Milk and milk products (milk, sour milk, cheese, yogurt, custard, or any other milk products, or any drinks made with milk) | | | |
| n. | Oils and fats (e.g., sunflower, rama, lard, butter added to food or used for cooking) | | | |
| o. | Sugars and sweets (e.g., Sugar, sweets, chocolates, cake and sweetened biscuits, honey, jam, sugar sweetened drinks e.g., cold drinks, sugary foods, sweetened condensed milk) | | | |
| p. | Spices (e.g., salt, pepper, etc.) and condiments (e.g., chutney, tomato sauce, peri peri sauce, etc.) | | | |
| q. | Drinks (Coffee, tea, cocoa) | | | |

**Code J:** *1= Produced (e.g., from own garden) 2= In kind/donations (e.g., food parcel/voucher) 3= Event (e.g., funeral) 4= Food bank/school feeding 5= Bought in cash 6= Bought on credit 7= Forest (e.g., hunting/ukuzingela) 8= River (e.g., fishing)*

**J. AGRICULTURAL PATTERNS / CROP PRODUCTION**

**J1.** Are you involved in farming (i.e., growing crops)? *1= Yes 2= No/Never 3= Used to grow, but have stopped*

**J2.** If *3* to **J1**, when did you stop growing crops (**year**)? ___________________

**J3.** If *3* to **J1**, why did you stop growing crops? ___________________________________________________

**J4.** If **Yes** to **J1**, what form of farming do you practice?

*1= Homestead food gardening 2= Rain-fed farming 3= Community food gardening (independent) 4= Community food gardening (cooperative) 5= Other (please specify)* ___________________ ***(multiple answers possible)***

**J5.** If **Yes** to **J1,** what are your main reasons for farming?

*1= Have sufficient food to feed my family 2= Earn an income from sale of crops 3= Create employment for myself and family members 4= Create employment for people in the community 5= Leisure 6= Other (please specify)* ______________________________________ ***(multiple answers possible)***

**Complete the table below for crops grown in 2021** (Please indicate units of produce for each crop)

| **Crop** | **J6.** Water source *1= Irrigation 2= Rain-fed* | **J7.** Area under production (ha) | **J8.** Quantity harvested (units/ha) | **J9.** Total quantity sold | **J10.** Quantity consumed | **J11.** Unit of sale (kg/5 litre, etc.) | **J12.** How many times did you sell? | **J13.** Price sold per unit | **J14.** Market outlet **(Code K)** |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

**Code K:** *1= Farm gate 2= Hawkers 3= Local shops 4= Shops in town 5= Van traders 6= Roadside 7= Other (please specify)* ___________________________________

**K. CLIMATE CHANGE AND ADAPTATION STRATEGIES**

**K1.** For how long have you been living in this area? ___________**(years)**

**K2.** Do you think that climate change is a problem? *1= Yes 0= No*

**K3.** Please justify your response to **K2** ___________________________________________________

**K4.** Do you think that the rainfall patterns have changed over the past 20 years? *1= Yes 0= No*

**K5.** If **Yes** to **K4**, how are rainfall patterns changing? *1= Increasing 2= Decreasing 3= Variable*

**K6.** Do you think that the temperature patterns have changed over the past 20 years? *1= Yes 0= No*

**K7.** If **Yes** to **K6**, how are temperature patterns changing? *1= Increasing 2= Decreasing 3= Variable*

**K8.** If **Yes** to **K4** and/or **K6**, what is the impact of these changes to your livelihoods? ______________________

**K9.** If **Yes** to **K4** and/or **K6**, have these changes affected your agricultural production (crops and livestock)? *1= Yes 0= No*

**K10.** If **Yes** to **K9**, how have these changes affected your agricultural production? ______________________

**K11.** Which economic activities or livelihood resources are mostly affected by climate change in your area (e.g., crop production, livestock farming, water availability, firewood availability, wellbeing (diseases), etc.)?________

**K12.** What is the main cause(s) of climate change?_____________________________________________

**K13.** Please indicate if you have experienced the following climate change events in your area.

***1= Yes 0= No*

| | **Response*** |
|---|---|
| a. Frequent droughts | |
| b. Increasing Temperature | |
| c. Changing rainfall patterns | |
| d. Floods | |
| e. Storms | |
| f. Frost | |

| | | |
|---|---|---|
| g. | Changes in season's length (e.g., autumn, winter, spring and summer) | |
| h. | Any other (please specify) | |

**K14.** Please indicate if you have applied the following climate change coping or adaptation strategies.
******1= Yes* *0= No*

| | | Response* |
|---|---|---|
| a. | Changed planting dates (i.e., planting late or early) | |
| b. | Planted drought resistant or short seasoned crops | |
| c. | Soil conservation strategies (e.g., crop rotation, fertiliser application, mulching, etc.) | |
| d. | Changed from crop to livestock farming | |
| e. | Diversified your crops (i.e., planting various crops at different times) | |
| f. | Planted trees | |
| g. | Sold tree products (e.g., fruits, timber or woods) | |
| h. | Used improved seeds | |
| i. | Eat tree products (e.g., fruits, nuts) | |
| j. | Increased the land under cultivation | |
| k. | Reduced the land under cultivation | |
| l. | Any other (please specify) | |

**K15.** Do you consider tree planting as a significant climate change adaptation strategy? *1= Yes* *0= No*

**K16.** Please justify your answer in **K15**. ____________________

**K17.** What are the factors holding you up to adapt to climate change (i.e., barriers to adaptation)? ____________________

**K18.** Have you received information or training on the strategies you can apply to cope with and mitigate the impacts of climate change? *1= Yes* *0= No*

**K19.** If **Yes** to **K18**, where did you source this information? ____________________

**K20.** Do you have access to weather and climate information from multiple sources? *1= Yes* *0= No*

**K21.** If **Yes** to **K20**, where do you source this information? ____________________

**L. SOURCE OF ENERGY**

**L1.** What type of energy do you use for cooking?

*1= Firewood* *2= Electricity* *3= Gas* *4= Solar* *5= Biofuels* *6= Paraffin (primus or panda stove)* *7= Other (please specify)* ____________________ ***(multiple answers possible)***

**L2.** If more than one response to **L1**, which one do you use more frequently? ____________________

**L3**. If **firewood** to **L1**, do you use firewood for other purposes, other than cooking (e.g., boiling water/heating)?*1= Yes 0= No*

**L4.** If you use firewood, how does your household source them? *1= Collect from the forest* *2= Buy from wood sellers*

**If answer to L4 is 2 please proceed to L8, otherwise continue**

**L5.** If you collect firewood, what is the distance to the forest? __________**(hours) OR** __________**(minutes)**

**L6.** If you collect firewood, how many times do you collect them from the forest per week? __________**(times)**

**L7.** When collecting firewood, do you plant trees at a later stage to replace the trees that have been cut? *1= Yes* *0= No*

**L8.** If you buy firewood, how much? __________**(Rand)**/ van or truck or tractor.

**L9.** If you buy firewood, how many times do you purchase them per month? __________**(times)**

**L10.** When last did you or one of household members visit the forest? *1= Last week* *2= Last month* *3= Last 6 months* *4= Last 12 months* *5= Above a year* *6= Never visited forest* *7= Other (please specify)*____________________

**L11.** What was the reason of that forest visit?____________________

**L12.** What is the state of ownership for the nearest forest? *1= Public* *2= Private* *3= Unknown* *4= Own*

**L13.** Are you free to collect or use tree resources from nearest forest(s)? *1= Yes* *0= No*

**L14.** Do you or any one in your household sell firewood? *1= Yes* *0= No*

**L15.** If **Yes** to **L14**, how much? __________**(Rand)**/ van or truck or tractor.

**L16.** If **Yes** to **L14**, Do you collect sold firewood from your own forest? *1= Yes* *0= No*

**Complete the table below for types or names of trees planted or available in your area**

| **L17.** Agroforestry practice | **L18.** Tree types or names | **L19.** Number of trees/ total area (ha)? | **L20.** Beneficial features (i.e., use) **(Code L)** | **L21.** Tree part(s) used **(Code M)** | **L22.** Harmful features |
|---|---|---|---|---|---|
| a. Homestead agroforestry (fruits) | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| b. Wild fruits | | | | | |
| | | | | | |
| | | | | | |
| c. Homestead agroforestry (medicinal)<br>***Please indicate the sickness used for under L20*** | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| d. Other homestead trees<br>(***NOT fruits and medicinal trees***) | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| f. Woodlot (forest) | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

**Code L:** *1=Food 2=Medicinal/health 3=Firewood 4= Soil fertility 5=Roofing 6= Climate change adaptation 7= Boundary/fencing 8=Selling 9= Other (please specify)* (***multiple answers possible***)

**Code M:** *1= Fruit 2= Leaves 3= Roots 4=Stem 5= Seeds 6= Bark 7= Flowers 8= Other (please specify)*______________________________ (***multiple answers possible***)

## M. THE KNOWLEDGE, ATTITUDES AND PERCEPTIONS TOWARDS AGROFORESTRY INNOVATIONS

***Agroforestry*** *is the combination of trees/shrubs with agricultural crops or domestic animals, or both.*

**M1.** Are you involved in agroforestry practice? *1= Yes 0= No*

**If answer to M1 is 0 please proceed to M5, otherwise continue**

**M2.** If **Yes** to **M1**, which agroforestry type(s) are you involved in?

*1= Trees and agricultural crops 2= Tress and domestic animals 3= Trees with agricultural crops and domestic animals*

**M3.** If **Yes** to **M1**, would you be interested in expanding your agroforestry practice if an opportunity arises?

*1= Yes 0= No*

**M4.** If **Yes** to **M3**, what are the factors holding you up? ______________________________

**M5.** If **No** to **M1**, would you be interested in adopting agroforestry practice if an opportunity arises?

*1= Yes 0= No*

**M6**. If **No** to **M5**, why? ______________________________

**Complete the following table by indicating to what extent do you agree/disagree with the following statements:**

| **Agroforestry innovations knowledge** | **M7: Response*** |
|---|---|
| a. Before this interview, I knew about forestry farming | |
| b. Before this interview, I did not know I can combine trees, crops and livestock businesses | |
| c. I have always known about agroforestry innovations although I did not know the exact wording | |
| d. I have always known and understood what agroforestry innovations are | |
| e. Agroforestry is against the practice of animal grazing | |
| f. Agroforestry maximizes land usage | |
| g. Agroforestry guarantees consistent supply to the markets | |
| **Perceptions towards agroforestry innovations** | **M8: Response*** |
| a. Agroforestry is difficult to practice | |
| b. Agroforestry is a common practice in this area | |
| c. Agroforestry practice can increase farm productivity | |
| d. Agroforestry practice is not properly understood because of its technicality | |
| e. Agroforestry is a common practice among local farmers. | |
| f. Agroforestry practice is time consuming | |
| g. Agroforestry practice is not profitable | |
| h. Agroforestry is expensive to practice | |
| i. Agroforestry practice is labour intensive | |
| j. Agroforestry practice cannot be practiced on small piece of land | |
| k. Agroforestry practice hinders the use of modern farm implement | |
| l. Agroforestry practice is not meant for low-income / smallholder farmers | |
| **Beliefs underpinning attitude toward farm forestry: "Planting trees on my land will…":** | **M9: Response*** |
| a. Increase household income | |
| b. Provide fuel wood and furniture wood | |
| c. Control soil erosion | |
| d. Control air pollution | |
| e. Improve soil conservation | |
| f. Cause hindrance in agricultural operations | |
| g. Cause shade that will reduce the yield of crops | |
| h. Incur more cost | |
| i. Provide harbor to insects, pests and diseases | |
| j. Provide shade for human beings and animals | |
| k. Be a long-time land utilization | |

**1= Strongly disagree 2= Disagree 3= Neutral 4= Agree 5= Strongly agree*

**SIYABONGA / THANK YOU**

**Appendix C: Focus group discussion checklist**

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The information to be captured in this discussion is strictly confidential and will be used for research purposes by staff and a post-graduate student at the University of KwaZulu-Natal to examine **the role of trees and the dynamics of tree planting as a climate change adaptation strategy for addressing food and nutrition security challenges in KwaZulu-Natal**.

**FOCUS GROUP DISCUSSION AND KEY INFORMANT CHECKLIST QUESTIONS**

**Community leaders/Households/Other actors**

1. Do you think that climate change is a problem?
2. What is the impact of these changes to your livelihoods?
3. Which economic activities or livelihood resources are mostly affected by climate change in your area (e.g., crop production, livestock farming, water availability, firewood availability, wellbeing (diseases), etc.)?
4. What needs to be done to reduce the climate change challenge?
5. Which climate change coping or adaptation strategies have you applied?
6. Are there any crops you have stopped planting in the area due to climate change?
7. Do you think planting trees will be beneficial to your household or community? How or why?
8. Do you consider tree planting as a one of the solutions to food and nutrition insecurity?
9. What types of trees would you recommend that would be beneficial in terms of food and nutrition security (through diet or sales) and climate change adaptation?
10. What are the key problems that face households when it comes to water?
11. What is the role of community leadership in climate change challenge? How have community leadership been playing this role?
12. What is the role of community leadership in food and nutrition security challenges? How have community leadership been playing this role?
13. Do you think agroforestry practice can increase farm productivity? Why?
14. Do you think agroforestry is difficult to practice? Why?