The Nexus of Underutilised Crops Production Systems and Value Chains: Implication for Food Security in KwaZulu-Natal, South Africa

by

Thobani Cele

Submitted in fulfilment of the requirements of the degree of

Doctor of Philosophy

School of Agricultural, Earth and Environmental Science

University of KwaZulu-Natal

Pietermaritzburg

South Africa

December 2023

UNIVERSITY OF KWAZULU-NATAL™

INYUVESI YAKWAZULU-NATALI

Abstract

Utilising underutilised crops can help with food and nutrition security and rural development, but production, consumption, and value chain challenges still need to be addressed. Due to a variety of socioeconomic barriers, smallholder farmers—who are crucial to the production and selling of underutilised crops—are unable to adopt resilient and sustainable production systems or participate in the value chains. The intertwined relationship between crop production systems, value chains, and their implications for food security in the KwaZulu-Natal Province of South Africa holds significant insights for sustainable development. This study aimed to explore the nexus, with a focus on understanding the dynamics and interdependencies between smallholder farmers' crop production practices and the value chains they engage in. The central objective is to unravel the multifaceted effects of this interplay on household food security within the context of KwaZulu-Natal. The study focuses on underutilised crops, specifically sweet potato, and taro roots, which have the potential to contribute significantly to household food security and nutrition in the country. The specific objectives of the study were (i) To analyse the socio-economic determinants of production systems of underutilised crops. (ii) To investigate factors influencing smallholder farmers' decisions to consume underutilised crops. (iii) To evaluate determinants of smallholder farmers' participation in crop value chains, and (iv) To explore the relationship between crop production systems and value chains and their implication in household food insecurity in KwaZulu-Natal, South Africa. The study used primary data, which was collected from a total of 300 smallholder farmers who were selected through simple random sampling. The study focused on two rural areas (Umbumbulu and Swayimana) in the Province of KwaZulu-Natal, South Africa, based on the predominance of underutilised crops by smallholder farmers.

While analysing the socio-economic factors influencing the choice of crop production systems, the multivariate probit analysis reveals that use of credit, farm size, education, and extension services significantly influence farmers' decisions to adopt underutilised crop production systems. Moreover, the study identifies challenges related to credit availability and land access that hinder the adoption of more sustainable and economically viable production systems. This study also investigated the factors affecting the decision of smallholder farmers to consume underutilised crops. The binary logistic regression model found that farmers' perception on production ($p<0.01$), perception on awareness of underutilised crops ($p<0.1$), membership to farmers' group ($p<0.05$), willingness to buy underutilised crops ($p<0.01$), and gender of the household head ($p<0.05$), and off-farm income ($p<0.05$) had a negative impact on the decision to consume underutilised crops. On the other hand, government grants ($p<0.05$), perception on taste ($p<0.1$), household size ($p<0.05$), education level of a household head ($p<0.1$), and marital status ($p<0.01$) had a positive impact on the decision to consume underutilised crops.

The study further evaluated the factors influencing value chain intensity of participation among smallholder farmers. The double hurdle results show that market channels, produce wasted, access to credit, pest and disease management practices, and access to irrigation system are key factors determining farmers' decision to participate in the value chain and the intensity of their participation.

The study explored the relationship between crop production systems and value chains and its implications for household food insecurity. Principal Component Analysis transformed the correlated variables into three distinct domains: modern agro-production practices, sustainable market integration, and traditional knowledge. The Household Food Insecurity Access Scale (HFIAS) showed that in the overall sampled population, 33% of smallholder farmers were food secure, mildly food insecure (36%), 22% were moderately food insecure, and lastly, 9% of smallholder farmers were severely food insecure. Ordered probit results show that sustainable market integration (PC2) ($p<0.01$), traditional knowledge focus (PC3) ($p<0.1$), education ($p<0.01$), and livestock owned ($p<0.01$) significantly and negatively impact household food insecurity. Household size ($p<0.01$), household food expenditure ($p<0.01$), floods ($p<0.1$), and cash credit ($p<0.1$) significantly and positively affect household food insecurity.

This study reveals a complex association between crop production systems, value chains, and household food security, highlighting the critical role of sustainable market integration and traditional agricultural practices in shaping agricultural dynamics and food security outcomes. Incorporating these insights into policy and practice can foster sustainable agricultural development and improve food security outcomes.

Keywords: Nexus, Underutilised Crops, Taro Roots, Sweet Potatoes, Crop Production Systems, Value Chains, Principal Component Analysis, HFIAS, Conventional, Organic, Traditional

Declaration 1

I, **Thobani Cele,** declare that:

• The research reported in this dissertation, except where otherwise indicated, is my original research.

• This dissertation has not been submitted for any degree or examination at any other university.

• This dissertation does not contain other persons' data, pictures, graphs, or other information unless expressly acknowledged as being sourced from those persons.

• This dissertation does not contain other authors' writing unless expressly acknowledged as being sourced from other authors. Where other written sources have been quoted:

> *Their words have been rewritten, but the general information attributed to them has been referenced.
>
> *Where their exact words have been used, their writing has been placed inside quotation marks and referenced.

• This dissertation does not contain text, graphics or tables copied and pasted from the internet unless expressly acknowledged, and the source is detailed in the dissertation and the references section.

Signed **Date**

[redacted] 16 April 2024

Thobani Cele

As Research Supervisor, I agree to the submission of this dissertation for examination.

Signed **Date**

[redacted] 17/4/2024

Prof. Maxwell Mudhara

Declaration 2: Publications

The following papers are part of this doctoral dissertation and are planned for publication:

Publication 1: Paper in preparation

Cele, T., and Mudhara, M.Socio-economic Factors Influencing Choice of Crop Production Systems: Multivariate Probit Approach.

Publication 2: Paper in preparation

Cele,T., and Mudhara,M..Factors Affecting the Decision of a Smallholder Farmer to Consume Underutilised Crops in South Africa: A Study of Swayimana and Umbumbulu Local Communities.

Publication 3: Paper in preparation

Cele,T., and Mudhara,M..Factors Influencing Intensity of Participation in Underutilised Crops Value Chain among Smallholder Farmers: A Case Study of Taro Roots and Sweet Potatoes in Kwazulu-Natal, South Africa.

Publication 4: Published

Cele, T. and Mudhara, M., 2024. Impacts of Crop Production and Value Chains on Household Food Insecurity in Kwazulu-Natal: An Ordered Probit Analysis. Sustainability, 16(2), p.700. **https://doi.org/10.3390/su16020700**

Acknowledgements

I want to express my sincere gratitude to the following people who contributed to making this study possible:

First and foremost, I am immensely grateful to my advisor, **Professor Maxwell Mudhara**, for his unwavering support, guidance, and mentorship. Your expertise, constructive feedback, and encouragement have been instrumental in shaping this research and have challenged me to grow as a researcher. Your passion for knowledge and dedication to academic excellence have been an inspiration throughout this process.

African Centre for Food Security for granting me the opportunity to carry out this study.

I am grateful to the National Research Foundation and the University of KwaZulu-Natal for providing me with the funds for my tuition and subsistence.

To all the respondents in eThekwini District and uMgugundlovu District Municipality who took their time to answer all the questions I had, I am thankful. Your contribution made it possible for me to compile this dissertation; it would have been impossible without your willingness to cooperate.

For data collection, I would like to extend my gratitude to my data collectors, Mhlengi Cele, Philisiwe Ntinga, Aphiwe Dladla, and Andile Hadebe.

I extend my heartfelt appreciation to my family and friends for their unconditional love and unwavering belief in my abilities. Your constant support, encouragement, and understanding have been a driving force behind my academic achievements. I am forever indebted to you for instilling in me a passion for learning and for always being my pillars of strength.

I want to thank God, who gave me the strength to believe in myself and dream beyond my imagination.

I WANT TO THANK MYSELF! MY DEDICATION AND CONSISTENCY, I AM PROUD OF YOU, Mntwana ka Gogo!

Dedications

I dedicate this thesis to my mother and little sister, who have been my pillars of strength and inspiration throughout this academic journey. Their unwavering love, support, and encouragement have been the driving force behind my pursuit of knowledge and academic achievements.

To my mother, A.B Cele, you have been my rock, always there to lift me and guide me with your wisdom and unconditional love. Your sacrifices and belief in my potential have been the foundation upon which I have built my dreams. Your constant encouragement and prayers have given me the strength to persevere through challenges and strive for excellence.

To my little sister, A.P Cele, as you embark on your academic journey, I dedicate this thesis to you as a symbol of hope and a reminder that you, too, can achieve greatness. Your determination and enthusiasm for learning have been a source of inspiration to me. I am proud of the remarkable young woman you are becoming, and I believe in your boundless potential.

This thesis is a testament to the love and support of my family, especially my mother and sister. Your presence in my life has filled it with joy and purpose, and I am deeply grateful for the sacrifices you have made to see me succeed. I dedicate this achievement to you both with heartfelt gratitude and love. May this thesis be a tribute to our shared values of perseverance, resilience, and the pursuit of knowledge.

With all my love,

Thobani Melokuhle Cele

Table of Contents

List of Tables

List of Figures

List of Acronyms and Abbreviations

Covid-19	Coronavirus Disease 2019
CPS	Conventional Production System
DAFF	Department of Agriculture, Forestry and Fisheries
DST	Department of Science and Technology
FA	Factor Analysis
FAO	Food and Agriculture Organization
GHK	Geweke, Hajvassilion, and Keane
GMO	Genetical Modified Organisms
HFIAS	Household Food Insecurity Access Scale
KMO	Kaiser-Meyer-Olkin
KMO	Kaiser-Meyer-Olkin
KZN	KwaZulu-Natal
MVP	Multivariate Probit
NASA	National Aeronautics and Space Administration
NGO	Non-Governmental Organisation
NPFNS	National Policy on Food and Nutrition Security
OPS	Organic Production System
PCA	Principal Component Analysis
PMCA	Participatory Market Chain Approach
PROTA	Plant Resources of Tropical Africa
R and D	Research and Development
SA	South Africa
SSA	Sub-Saharan Africa
TPS	Traditional Production System
UDM	UMgugundlovu District Municipality
VCA	Value Chain Analysis
VIF	Variance inflation factor
WRC	Water Research Commission

Chapter 1: Introduction

1.1 Background

Food security is a critical global concern with profound implications for developed and developing nations (Ruel *et al*., 2017). Food security refers to everyone having access to enough food to maintain an active and healthy lifestyle (Food and Agriculture Organization, 1996). According to Fróna *et al*. (2019), ensuring access to sufficient, safe, and nutritious food resources becomes increasingly complex as the world's population grows. This challenge is particularly pronounced in regions facing socio-economic disparities and agricultural constraints, such as South Africa. According to the Food and Agriculture Organization (2022), approximately 9.8% of the world's population was undernourished in 2021. Despite advancements in agricultural technology and improved access to markets, millions of individuals across the globe still need help to meet their basic dietary needs (Musa and Basir, 2021). The intricate interplay between climate change, market volatility, economic inequalities, and geopolitical factors exacerbates food insecurity worldwide (Müller *et al*., 2020)

Within the African continent, South Africa stands as a nation with unique challenges concerning food security. According to Amelework *et al*. (2021), despite having a reasonably well-developed agricultural sector, unbalanced land distribution, rural-urban mobility, and restricted resource access result in unequal access to food from different population segments. In 2021, South Africa's undernourishment prevalence was 6.9% (Yingi and Hlungwani, 2022). South Africa has made substantial progress in addressing food security challenges at the national level. The country has established policies and programs such as Fetsa Tlala and Operation Phakisa, prioritising agricultural production, trade, and food distribution (Hebinck *et al*., 2023). Even though South Africa is considered a food-secure nation on a national level, there is still room for improvement in both this category and household food security. Household-level food insecurity remains a pressing concern, with a substantial portion of the population needing help to access adequate and nutritious food consistently (Mabhaudhi *et al*., 2019). The household-level food insecurity challenge underscores the need to address limited access to food due to lack of purchasing power and production to ensure comprehensive food security.

The main factors driving food production include human resources, sufficient arable land, and access to water, as well as farm inputs such as fertilisers, pesticides, seeds with good genetic material, and technical knowledge (Chable *et al*., 2020; Prabhat, 2019; Reddy, 2022). In the past, humanity has relied chiefly on a minimal number of the varied range of crops that are accessible around the world. While the plant kingdom offers an extensive variety of edible crops, a handful of staples have consistently dominated global food production and consumption (Chable *et al*., 2020). Crops like wheat, rice, maize (corn), and others have been the linchpin of conventional food systems, providing the most calories and sustenance to populations worldwide (Mabhaudhi *et al*., 2016, Mabhaudhi *et al*., 2019). This limited focus on a select group of crops, often called the "Big Four," has played a crucial role in meeting the world's food requirements. However, this conventional approach, though successful in addressing basic caloric needs, has raised concerns about dietary diversity, nutritional adequacy, and resilience to environmental and market shocks (Wijerathna-Yapa and Pathirana, 2022). Considering this, there is an increasing awareness of the unrealised potential of underutilised crops, which constitute a substantial and untapped resource for improving food security, nutrition, and agricultural sustainability (Mabhaudhi *et al*., 2018). Utilising indigenous or underutilised crops can help to increase food production and enhance food security in the country (Shembe *et al*., 2023).

Underutilised crops offer a valuable alternative by diversifying the available food sources, and they are highly nutritious, often rich in vitamins, minerals, and other essential nutrients that may be lacking in diets heavily reliant on staples like wheat, rice, and maize (Rahmatov and Lazarte, 2023). Underutilised crops include oil crops, root crops, ornamental plants, leafy vegetables, fruits, cereals, and pulses (Chandra *et al*., 2020; Omotayo and Aremu, 2020; Tanimonure *et al*., 2021). (Motsa *et al*., 2015b) state that root and tuber crops are crucial to food security. South Africa produces several root and tuber crops, including potato, taro, sweet potato, indigenous potato, and cassava (Motsa *et al*., 2015a). Due to the country's food insecurity at the household level, increasing the production and productivity of root and tuber crops is a critical alternative.

Root and tuber crops have many practical reasons for being promoted in South Africa. Firstly, they are adaptable staples that can address food security for millions of people and produce more food per unit of land (Yimer and Babege, 2018). Secondly, they are nutritious and provide protein, vitamins (A and C), zinc, and iron to the population's dietary needs. Malnutrition and vitamin A deficiency are problems in South Africa (Sokhela *et al*., 2023). Third, root and tuber crops are suitable for double-cropping, like sweet potato, which has a short cropping cycle of three to four months and can be grown twice in rain-fed systems (Sanginga Nteranya and Mbabu Adiel, 2015). Lastly, these crops ensure sustainable food availability throughout the year, especially the longer cropping cycle crops like taro roots and sweet potatoes, which play a significant role in the annual cycle of food availability, and both these crops are known for their climate resilience (Olango *et al*., 2015).

Rahmatov and Lazarte (2023) stated that underutilised crops are more environmentally sustainable, better adapted to local climates and require fewer inputs like pesticides and fertilisers. Exploring underutilised crops enhances dietary diversity and nutrition and strengthens agricultural resilience, making food systems more robust in climate change and market fluctuations (Mabhaudhi *et al*., 2018). Therefore, considering underutilised crops is vital to achieving a more sustainable, diverse, and resilient global food system.

Underutilised crops face considerable obstacles to adoption despite their promise to improve food and nutrition security. Consumer and agriculture stakeholder awareness is a significant factor in the low demand and investment for underutilised crops (Munoko *et al*., 2023). The underutilisation of these crops is also influenced by factors such as market constraints favouring conventional crops, deeply ingrained cultural preferences, and the need for further research and development initiatives (Tanimonure *et al*., 2021). Underutilised crops require assistance finding their position in this environment because globalisation and trade mostly favour commodities with established international markets (Omotayo and Aremu, 2020). To overcome these obstacles, concerted efforts must be made to increase awareness, support research and development projects, create market connections, and adapt policies to encourage the cultivation and use of underutilised crops, thereby realising the full potential of these crops to improve food security and dietary diversity.

The research gap relates to the nexus of underutilised crop production systems and value chains and its impact on household food security in KwaZulu-Natal, South Africa. There is a need for research on the potential of underutilised crops' contribution to food security at the household level and their market opportunities. While Motsa *et al*. (2015b) and Mabhaudhi *et al*. (2016) have examined the contribution of underutilised crops to food security, there is a need for research that focuses specifically on the factors that influence the adoption of underutilised crop production systems, value chain, and consumption by smallholder farmers in KZN. Understanding the factors that influence smallholder farmers' decisions to adopt underutilised crop production systems, markets, and consumption can help to identify the most effective strategies to promote their cultivation and utilisation and to improve the income and food security of smallholder farmers.

1.2 Problem Statement

There exists a significant gap in the literature regarding underutilised crops, as previous studies have primarily focused on either the production system or the value chain separately, rather than examining both aspects in conjunction. For instance, while Sugri et al. (2017) analysed farmers' involvement in the value chain of sweet potatoes in Ghana, they did not investigate smallholder farmers' preferences and utilisation of crop production systems, such as traditional, conventional, or non-conventional. Similarly, Truong et al. (2018) explored sweet potato production and nutritional quality but overlooked value chain participation. This lack of a comprehensive approach hinders understanding of the interplay between crop production systems and value chains in the context of underutilised crops.

Recognising the complementary roles of value chain analysis and crop production systems in achieving sustainable food security is paramount. While value chain analysis primarily focuses on economic improvement, crop production systems directly incorporate sustainable production considerations. However, the current research lacks a comprehensive approach that considers both economic and production factors. Farmery et al. (2021) argue that a joint review of crop production systems and value chains is necessary to enhance food security by incorporating both production-building and income-enhancing elements. Neglecting one aspect of this nexus can result in the omission or diminishment of essential components contributing to sustainable food security.

Examining and understanding the interplay between crop production systems and value chains in enhancing food security is crucial. Therefore, this research aims to investigate the relationship between crop production systems and value chains for underutilized crops and their implications for household food security in KwaZulu-Natal, South Africa. By adopting a comprehensive approach, this study seeks to provide a foundation for informed policy decisions that can promote sustainable household food security in the region.

1.3 Objectives

The main objective of the study is to comprehensively examine the nexus between crop production systems, value chains, and their implications for household food security in KwaZulu-Natal, South Africa. The specific objectives are as follows:

- To analyse the smallholder farmers' socio-economic determinants of underutilised crop production systems.
- To investigate factors influencing smallholder farmers' consumption of underutilised crops.
- To evaluate the determinants of smallholder farmers' participation intensity in underutilised crop value chains.
- To explore the impact of the relationship between crop production systems and value chains on household food insecurity in KwaZulu-Natal, South Africa.

1.4 Research Questions

- What are the socio-economic determinants of production systems of underutilised crops?
- What are the factors that influence smallholders' decision to consume underutilised crops?
- What are the determinants of farmers' value chain participation and intensity?
- What is the relationship between crop production systems and value chains, and how do they jointly impact household food insecurity?

1.5 Benefits of the Study

This study delves into the nexus of crop production systems and value chains, with a specific focus on underutilised crops such as sweet potato and taro roots, holding significant implications for rural household food security in South Africa. Through its investigation, the study aims to uncover innovative strategies that simultaneously enhance food and nutrition security, stimulate economic growth, and foster rural development. By bridging the knowledge gap in value chain analysis of these underutilised crops, the study sheds light on their pivotal role in bolstering nutrition and economic opportunities for rural households throughout the production process. Its findings will equip policymakers, researchers, and practitioners with actionable insights to address challenges within the smallholder agrarian sub-sector, empowering rural households to overcome the triple burdens of unemployment, poverty, and food insecurity. Furthermore, this research might contributes to Sustainable Development Goals (SDGs), directly supporting SDG 2 (Zero Hunger) by promoting food security and aligning with SDG 1 (No Poverty) and SDG 8 (Decent Work and Economic Growth) through its focus on economic empowerment and rural development. Ultimately, the study's outcomes not only inform future research in agricultural development and food security but also contribute to the global agenda for sustainable development outlined by the United Nations, benefiting rural households in South Africa and beyond.

1.6 Structure of the Thesis

This thesis is presented in the form of a paper. The results of the studies are provided in separate publications that will be sent to journals for publication. The thesis is divided into an introductory chapter (Chapter 1), a chapter reviewing the literature (Chapter 2), four chapters using empirical data (Chapters 3,4,5 and 6), and a chapter summarising the findings (Chapter 7). Chapter 1 presents the introduction, giving the background material that inspired it. The literature review examines relevant research covering production systems, underutilised crop value chains, and household food security. Chapter 3 analyses the socioeconomic factors that affect the production methods of underutilised crops. The decision of smallholder farmers to consume underutilised crops is examined in Chapter 4. Chapter 5 discussed the determinants of the value chain and intensity of participation. Chapter 6 examines the impact of crop production systems and value chains on household food security. The policy implications, limitations, and research proposal ideas are all presented in Chapter 7.

References

Amelework, A. B., Bairu, M. W., Maema, O., Venter, S. L., and Laing, M., 2021. Adoption and Promotion of Resilient Crops for Climate Risk Mitigation and Import Substitution: A Case Analysis of Cassava for South African Agriculture. *Frontiers in Sustainable Food Systems*, *5*, pp. 1–14. https://doi.org/10.3389/fsufs.2021.617783

Chable, V., Nuijten, E., Costanzo, A., Goldringer, I., Bocci, R., Oehen, B., Rey, F., Fasoula, D., Feher, J., Keskitalo, M., Koller, B., Omirou, M., Mendes-Moreira, P., van Frank, G., Naino Jika, A. K., Thomas, M., and Rossi, A., 2020. Embedding cultivated diversity in society for agroecological transition. *Sustainability*, *12*(3), pp. 1–34.

Chandra, S., Naresh, R., Thenua, O., Singh, R., and Geethanjali, D., 2020. Improving resource conservation, productivity and profitability of neglected and underutilised crops in the breadbasket of India: A review. *The Pharma Innovation Journal*, *9*(3), pp.685–696. http://www.thepharmajournal.com

Farmery, A. K., Brewer, T. D., Farrell, P., Kottage, H., Reeve, E., Thow, A. M., and Andrew, N. L., 2021. Conceptualising value chain research to integrate multiple food system elements. *Global Food Security*, *28*,pp. 100500. https://doi.org/10.1016/j.gfs.2021.100500

Food and Agriculture Organization., 1996. Rome Declaration on World Food Security and World Food Summit Plan of Action. World Food Summit 13-17 November 1996. Rome.

Food and Agriculture Organization., 2022. *The state of food security and nutrition in the world 2022*. Food and Agriculture Organization.

Fróna, D., Szenderák, J., and Harangi-Rákos, M., 2019. The challenge of feeding the world. In *Sustainability*, 11(20), pp. 1–18. MDPI. https://doi.org/10.3390/su11205816

Hebinck, P., Smith, L., and Aliber, M., 2023. Beyond technocracy: The role of the state in rural development in the Eastern Cape, South Africa. *Land Use Policy*, *126*, pp.1–14. https://doi.org/10.1016/j.landusepol.2022.106527

Mabhaudhi, T., Chibarabada, T., and Modi, A., 2016. Water-Food-Nutrition-Health Nexus: Linking water to improving food, nutrition and health in Sub-Saharan Africa. *International Journal of Environmental Research and Public Health*, 13(1), pp. 1-19.MDPI. https://doi.org/10.3390/ijerph13010107

Mabhaudhi, T., Chibarabada, T. P., Chimonyo, V. G. P., Murugani, V. G., Pereira, L. M., Sobratee, N., Govender, L., Slotow, R., and Modi, A. T., 2019. Mainstreaming underutilised indigenous and traditional crops into food systems: A South African perspective. *Sustainability* , 11(1),pp 1–22. MDPI. https://doi.org/10.3390/su11010172

Mabhaudhi, T., Mpandeli, S., Nhamo, L., Chimonyo, V., Nhemachena, C., Senzanje, A., Naidoo, D., and Modi, A., 2018. Prospects for Improving Irrigated Agriculture in Southern Africa: Linking Water, Energy and Food. *Water*, *10*(12),pp.1881. https://doi.org/10.3390/w10121881

Motsa, N. M., Modi, A. T., and Mabhaudhi, T., 2015a. Sweet potato (Ipomoea batatas L.) is a drought-tolerant and food security crop. *South African Journal of Science*, *111*(12), pp.8–12. https://doi.org/10.17159/sajs.2015/20140252

Motsa, N. M., Modi, A. T., and Mabhaudhi, T., 2015b. Sweet potato response to low-input agriculture and varying environments of KwaZulu-Natal, South Africa: implications for food security strategies. *Acta Agriculture Scandinavica, Section B — Soil and Plant Science*, *65*(4), pp.329–340. https://doi.org/10.1080/09064710.2015.1011222

Müller, B., Hoffmann, F., Heckelei, T., Müller, C., Hertel, T. W., Polhill, J. G., van Wijk, M., Achterbosch, T., Alexander, P., Brown, C., Kreuer, D., Ewert, F., Ge, J., Millington, J. D. A., Seppelt, R., Verburg, P. H., and Webber, H., 2020. Modelling food security: Bridging the gap between the micro and the macro scale. *Global Environmental Change*, *63*,pp.1–15. https://doi.org/10.1016/j.gloenvcha.2020.102085

Munoko, K. M., Kombat, R., Kofi, K. A., Ramid, S. P., and Fatunbi, A. O.,2023. Reflection on Africa's Underutilised Foods Towards a Sustainable Food System, *Journal of Sustainable Development*, *15*(5), pp.1–57.

Musa, S. F. P. D., and Basir, K. H., 2021. Smart farming: towards a sustainable agri-food system. *British Food Journal*, *123*(9), pp.3085–3099. https://doi.org/10.1108/BFJ-03-2021-0325

Olango, T. M., Tesfaye, B., Pagnotta, M. A., Pè, M. E., and Catellani, M., 2015. Development of SSR markers and genetic diversity analysis in enset (Ensete ventricosum (Welw.) Cheesman), an orphan food security crop from Southern Ethiopia. *BMC Genetics*, *16*(1), pp.98. https://doi.org/10.1186/s12863-015-0250-8

Omotayo, A. O., and Aremu, A. O., 2020. Underutilised African indigenous fruit trees and food–nutrition security: Opportunities, challenges, and prospects. *Food and Energy Security*, *9*(3), pp.1–16. https://doi.org/10.1002/fes3.220

Prabhat, K.T., 2019. *Strategic planning for an agricultural farm start-up in Nepal*. Centria university of applied sciences.

Rahmatov, M., and Lazarte, C. E., 2023. Role of Neglected Plant Foods in Achieving Dietary Diversity, Zero Hunger and Good Health. In Tariq Ismail, Saeed Akhtar, and Claudia E. Lazarte (Eds.), *Neglected Plant Foods of South Asia*. Springer, pp. 29–49.

Reddy, S. J., 2022. Pros and Cons of Farming Systems-Practices in Agriculture: A Discussion. *Journal of Agricultural Research Pesticides and Biofertilizers*, *4*(1), pp. 1–18.

Ruel, M., Garrett, J., Sivan, Y., and Meghan, O.,2017. Urbanisation, Food Security and Nutrition. *Nutrition and Health in a Developing World*, pp. 705–735.

Sanginga, N., and Mbabu, A., 2015. Root and Tuber Crops (Cassava, Yam, Potato and Sweet Potato). *An Action Plan for Agricultural Transformation Conference*, pp.21–23.

Shembe, P. S., Ngobese, N. Z., Siwela, M., and Kolanisi, U., 2023. The potential repositioning of South African underutilised plants for food and nutrition security: A scoping review. *Heliyon*, *9*(6), pp.1–13. https://doi.org/10.1016/j.heliyon.2023.e17232

Sokhela, H., Govender, L., and Siwela, M., 2023. Complementary Feeding Practices and Childhood Malnutrition in South Africa: The Potential of Moringa Oleifera Leaf Powder as a Fortificant: A Narrative Review. *Nutrients*, *15*(8),pp. 1–17. https://doi.org/10.3390/nu15082011

Sugri, I., Maalekuu, B. K., Gaveh, E., and Kusi, F.,2017. Sweet Potato Value Chain Analysis Reveals Opportunities for Increased Income and Food Security in Northern Ghana. *Advances in Agriculture*, pp 1–14. https://doi.org/10.1155/2017/8767340

Tanimonure, V. A., Naziri, D., Codjoe, S. N. A., and Ayanwale, A. B.,2021. Underutilised Indigenous Vegetables for Household Dietary Diversity in Southwest Nigeria. *Agriculture*, *11*(11), pp.1-13. https://doi.org/10.3390/agriculture11111064

Truong, V. D., Avula, R. Y., Pecota, K. V., and Yencho, G. C., 2018. *Sweet potato Production, Processing, and Nutritional Quality*.

Wijerathna-Yapa, A., and Pathirana, R.,2022. Sustainable Agro-Food Systems for Addressing Climate Change and Food Security. *Agriculture,*12(10). https://doi.org/10.3390/agriculture12101554

Yimer, S., and Babege, T., 2018. Evaluation of constraints in the production of root and tuber crops in Ethiopia: Overview of policy neglected climate-resilient food security crops. *Journal of Plant Breeding and Crop Science*, *10*(8), pp.210–217.

Yingi, E., and Hlungwani, P. M., 2022. Agenda 2030 in the Context of the COVID-19 Pandemic in South Africa and Zimbabwe. *African Renaissance*, *19*(4), pp.5

Chapter 2: Literature Review

2.1. Introduction

Food insecurity and poverty remain a global challenge, particularly in developing countries, including South Africa. Approximately 9.34 million people in South Africa have been reported to have experienced chronic food insecurity and have required immediate action to combat food gaps and protect their livelihoods (Stats S.A., 2021). Much like most developing and underdeveloped countries, South Africa strongly relies on agriculture as a gross domestic product (GDP) driver, ensuring food and income security (Mabhaudhi *et al*., 2017; Bandula, 2020). Therefore, in strengthening the economic and social development of the country, and with the Sustainable Development Goal (SDG) 2 of achieving Zero hunger by providing critical solutions for hunger and poverty reduction, there is a recognised need for more robust, efficient, and sustainable agricultural production systems to ensure that food security is achieved at both national and individual levels. Production, value chain. and consumption of underutilised crops have been identified as one of the strategies to address food insecurity in rural areas (Mabhaudhi *et al.*, 2017).

The Plant Resources of Tropical Africa (PROTA) notes a significant number of useful underutilised plants, with a portion dedicated to root and tuber crops like taro roots and sweet potatoes. Sweet potatoes and taro roots have different names depending on the region and cultural value they hold; in Zulu, taro roots are known as "*amadumbe"* while sweet potatoes are known as "*ubhatata"* (Mdluli *et al.,* 2013). Sweet potatoes and taro roots are classified as plant species that are either native to a particular area or were imported and allowed to change over time because of farmer selection or natural processes (Adula *et al.,* 2023).

Despite their nutritional benefits, these root crops often need to be utilised beyond current levels. Scott (2021) highlights the historical importance of traditional root crops, emphasising their role in nutrition and dietary practices. Taro roots and sweet potatoes have been essential ingredients in various diets, this introduction sets the stage for exploring the value chain of these root crops.

This literature review systematically explores the diverse facets of underutilised crops and agricultural production systems and their impact on global and South African food security. It encompasses case studies from various regions, delves into the complexities of the value chain, scrutinises different production systems. The review identifies the escalating challenges in the current food security landscape and underscores the potential of underutilised crops in addressing these issues. By meticulously examining each aspect, the review contributes to a holistic understanding of the subject, identifies gaps in existing literature, and lays the groundwork for future research endeavours.

2.2 Background of Underutilised Crops in South Africa

Rainfed subsistence agriculture is commonly undertaken by rural communities in South Africa (SA), resulting in low economic returns from farming activities (Mabhaudhi *et al.*, 2017). These areas face a disproportionate prevalence of poverty, unemployment, and food and nutrition insecurity. Moreover, these populations grapple with a triple burden of malnutrition, encompassing undernutrition, overnutrition, and micronutrient deficiencies (Christian and Dake, 2022). This complex scenario has led to the belief that expanding agricultural initiatives in these communities could alleviate youth unemployment, enhance food and nutrition security, reduce household poverty, and promote rural development. However, despite these expectations, productivity remains low due to challenges such as inadequate water supply, the geographical location of farmers in marginal agricultural zones, the impact of a changing climate, and limited adaptability among farmers (Arora *et al*., 2023). Critics argue that the existing farming practices in these communities are excessively conventional and need more innovation to foster rural economic growth (Christian and Dake, 2022; Arora *et al*., 2023).

Underutilised crops such as taro roots and sweet potatoes possess characteristics that make them well-suited for cultivation in low-input agricultural systems and marginal production areas, which are prevalent in South Africa's rural landscape (Mabhaudhi *et al.*, 2017). In the context of South Africa's current climate challenges, these underutilised crops emerge as crucial resources for climate change adaptation. Nevertheless, a lack of information pertaining to their agronomy, water usage, and the absence of production guidelines has been identified as hindrances to their widespread promotion (Mabhaudhi *et al.*, 2017).

According to Mabhaudhi *et al.* (2017), in an effort to address this knowledge gap, the Water Research Commission of South Africa has actively invested in the research and development of underutilised crops. Their initiatives encompass screening for drought tolerance in various indigenous underutilised crops, outlining the agronomy, determining drought tolerance, and assessing water usage of selected indigenous crops, as well as evaluating the nutritional water productivity of underutilised crops (Mabhaudhi *et al.*, 2017). More attention has been directed towards underutilised cereals and legume food crops, and more attention should be paid to roots and tubers. Therefore, this study focuses on roots and tubers. While commendable, current efforts have primarily been driven by the realisation of the potential of underutilised crops and the need to address existing knowledge gaps. Despite their sectorial value, predominantly benefiting marginal communities or serving as a health-conscious choice for the elite, information regarding these crops remains to be limited (Mabhaudhi *et al.*, 2017).

The past and current research efforts have generally explored a wide range of underutilised crops. Still, there needs to be a greater gap in focusing on individual crops and their unique potential to address global challenges like food insecurity. Much of the existing research primarily concentrates on the early stages of the value chain, such as cultivation and basic processing. More attention needs to be given to the crucial supporting activities required for the comprehensive utilisation of these underutilised crops. This emphasis on the initial stages often leaves a significant knowledge void in the literature. As a consequence, there needs to be a complete understanding of the full potential and benefits that these crops could offer. The oversight in research attention results in a need for comprehensive models for transforming these underutilised crops into fully utilised resources. In other words, the current research landscape needs to provide a holistic view of how these crops can be integrated into various sectors and industries to maximise their impact on addressing global challenges. Therefore, there is a need for more focused and thorough research that considers the entire value chain and supporting activities to unlock the full potential of underutilised crops.

2.3 Overview of Underutilised Crops and their Characteristics

The role of roots and tubers in contributing to global food security and economic growth within different populations exhibits variation among countries. This significance is underscored by their annual global production, amounting to approximately 836 million tonnes (Sethuraman *et al*., 2021; Hossain *et al*., 2021). Asia takes the lead as the primary producer, trailed by Africa, Europe, and America. Notably, Asian, and African regions contribute 43% and 33%, respectively, to the global production of roots and tubers (Scott, 2021; Chauhan *et al.,* 2022). While various species and varieties are consumed, cassava, potatoes, and sweet potatoes collectively constitute 90% of the global production of root and tuber crops (Chauhan *et al.,* 2022).

From a nutritional standpoint, roots and tubers hold considerable potential as cost-effective sources of dietary energy in the form of carbohydrates (Chauhan *et al.,* 2022). Despite the moisture content in tubers resulting in their energy being one-third of that in an equivalent weight of rice or wheat, their high yields offer greater energy per land unit per day compared to cereal grains (Sajeev *et al*., 2023). According to Sajeev *et al*. (2023), the protein content in roots and tubers is low, ranging from 1 to 2% on a dry weight basis. Notable exceptions include potatoes and yams, which exhibit higher protein levels than other tubers. Sulphur-containing amino acids, particularly methionine and cystine, pose limitations in root crop proteins (Arogundade and Mu, 2012). Certain varieties of sweet potatoes particularly those of yellow colour, contain vitamin C and β-carotene, as shown in Figure 2.1.

Figure 2.1: Purple, Yellow, and Orange sweet potatoes (Source: DeLorenzo, 2021)

Taro stands out as a rich source of potassium. While roots and tubers may lack several vitamins and minerals, they do contain significant amounts of dietary fibre. As with other crops, the nutritional value of roots and tubers varies based on factors such as variety, location, soil type, and agricultural practices (Mabhaudhi *et al*., 2017). Plants producing starchy roots, tubers, rhizomes, corms, and stems play a crucial role in nutrition and health (Arogundade and Mu, 2012). They serve as essential components in the diets of populations in developing countries, and beyond consumption, they find utility in animal feed, as well as in the production of starch, alcohol, and fermented foods and beverages.

Roots and tuber crops rank as vital cultivated staple energy sources, second only to cereals, particularly in tropical regions globally. This category encompasses potatoes, cassava, sweet potatoes, yams, and aroids, belonging to different botanical families but grouped due to their commonality in producing underground food (Chauhan *et al.,* 2022; Siqueira *et al*., 2023). A significant agronomic advantage of these crops as staple foods lies in their adaptability to diverse soil and environmental conditions, as well as their suitability for various farming systems with minimal agricultural inputs (Siqueira *et al*., 2023). However, the inherent bulkiness and high moisture content of roots and tubers, ranging from 60–90%, contribute to challenges such as elevated transportation costs, short shelf life, and limited market margins, particularly in developing countries where they are predominantly cultivated (Chandrasekara and Kumar, 2016). Liu et al. (2014) state that when it comes to annual output volume, potatoes, sweet potatoes, cassava, and yams are some of the most significant food crops in the world. Three of the top ten food crops grown in developing nations are sweet potatoes, potatoes, and cassava. Refer to Table 2.1 for a compilation of commonly consumed starchy tuber and root crops worldwide.

Table 2.1: Commonly consumed starchy tuber and root crops worldwide

Tuber and root crops	Botanical name	Family	Common name
Potatoes	Solanum tuberosum	Solanaceae	Amazambane (SA,KZN)
Country Potato	Solenostemon rotundifolius	Lamiaceae (mint family)	Innala, ratala (Sri Lanka)
Taro roots (Colocasia esculenta)	Xanthosoma sagittifolium	Araceae	Amadumbe (SA, KZN) Keladi (Malaysia) Phueak (Thailand)
Yam	Dioscorea alata	Dioscoreaceae	Purple yam; greater yam Guyana; water yam
Sweet potatoes	Ipomoea batatas	Convolvulaceae	Sanate batata
Cassava	Manihot esculenta	Euphorbiaceae	Yuxco; mogo; manioc mandioca

2.3.1 Sweet Potatoes (*Ipomoea batatas* L.)

The sweet potato (as shown in Figure 2.2), originating from Central America, has become a widely cultivated crop in numerous tropical and subtropical regions across the globe. It thrives in tropical, subtropical, and warm temperate climates (Motsa *et al*., 2015). Its adaptability allows for year-round cultivation under favourable conditions, and instances of complete crop loss due to adverse climatic conditions are uncommon, rendering it a dependable "insurance crop." Particularly significant in Southeast Asia, Oceania, and Latin America, sweet potatoes boast China as the major contributor, claiming around 90% of the total world production (Motsa *et al*., 2015). Recognised as a crucial food security crop, sweet potatoes offer a gradual and extended harvesting period, making them valuable for disadvantaged populations (Motsa *et al*., 2015).

Figure 2.2: Sweet Potatoes (*Ipomoea batatas L*.) (Source: Brandenberger *et al.,* 2022)

The National Aeronautics and Space Administration (NASA) has designated sweet potatoes as a candidate crop for cultivation and inclusion in the diets of astronauts during space missions, owing to their distinctive attributes and nutritional value. The consumption of 125 g of orange-fleshed sweet potatoes, renowned for their carotenoid content, proves effective in enhancing the vitamin A status of children, particularly in developing countries (Przybył *et al*., 2022). Moreover, sweet potatoes are abundant in dietary fibre, minerals, vitamins, and bioactive compounds such as phenolic acids and anthocyanins, contributing to the vibrant colouration of the flesh (Przybył *et al*., 2022).

2.3.2 Taro (*Colocasia esculenta*)

Taro (*Colocasia esculenta (L.) Schott*) (as shown in Figure 2.3), a tropical root crop with an extensive history, belongs to the Araceae family and encompasses a diverse array of over 10,000 landraces (Ravi *et al*., 2021). Cultivated globally in tropical and subtropical regions, taro is found in Africa, China, New Guinea, various Pacific islands, all Caribbean islands, parts of Central and South America, as well as specific regions in the United States (Ferdaus *et al*., 2023). As one of the oldest known crops, taro's domestication is believed to have occurred more than 10,000 years ago, with archaeological evidence from the Solomon Islands suggesting utilisation dating back nearly 28,000 years. However, pinpointing a singular centre of origin for taro has proven challenging (Ferdaus *et al*., 2023). Various theories suggest South Central Asia, specifically India or Malaysia, as potential origins. Matthews (2014) proposed an origin between Myanmar and Bangladesh in the Indo–Malayan region. Despite these hypotheses, a definitive determination of the crop's origin awaits comprehensive genetic analysis of cultivars or wild taro materials from these dispersed regions (Ferdaus *et al*., 2023).

Figure 2.3: Taro (*Colocasia esculenta (L.) Schott*) (Source: Beukes, 2019)

2.4 Current Status of Underutilised Crops in South Africa

South Africa's population is projected to reach 70 million by 2035, with an anticipated increase in the proportion of the population experiencing malnutrition (Statssa, 2022). According to Muzigaba *et al*. (2016), to address this challenge, a substantial 50% increase in food production is deemed necessary. Various strategies have been proposed to enhance agricultural production, including the (i) expansion of cultivated land, (ii) the development of new high-yielding varieties through breeding, and (iii) the implementation of measures to enhance resource efficiency (Mabhaudhi *et al*., 2017).

Despite the presence of underutilised land, predominantly in marginal areas, agricultural potential could be improved by water availability in South Africa. Consequently, efforts have been directed towards improving water use efficiency as a key aspect of resource utilisation (Mabhaudhi *et al*., 2017). Introducing a potential fourth option, a focus on Underutilised crops (underutilised crops), could significantly contribute to improving agricultural production. Underutilised crops have the potential to expand cultivated land, diversify germplasm for future crop improvement, and enhance resource use efficiency, both in terms of land and water (Mabhaudhi *et al*., 2017). The underutilisation of underutilised crops presents an opportunity for the development of new value chains, supporting rural agricultural development and promoting food security. This can be realised through various stages of the research value chain, encompassing breeding/crop improvement, production, agro-processing, and marketing (Mabhaudhi *et al*., 2017).

2.5 Unveiling the Potential: Exploring Underutilised Crop Value Chains from Production to Consumption

This section provides a comprehensive exploration of the value chain concept, elucidating its significance in the realm of underutilised crops. Through an in-depth analysis, it delves into the intricate stages from production to consumption, emphasising the pivotal roles of both primary and supporting activities. The narrative further navigates the specific challenges encountered in establishing underutilised crops value chains, shedding light on the imperative role of research and development in unlocking the full potential of these crops.

2.5.1 What is the Value Chain?

According to the Food and Agriculture Organization (2010), a value chain in agriculture is "the set of actors and activities that bring a basic agricultural product from production in the field to final consumption, where at each stage value is added to the product". The value chain describes the full range of activities which are required to bring a product or service from conception through the different phases of production (involving a combination of physical transformation and the input of various producer services), delivery to final consumers, and final disposal after use (Ndlovu *et al*., 2021). Value chain analysis is a powerful tool to identify the key activities and actors within the whole supply system that form that product's value chain. For smallholder farmers, the most important value chain actors are input suppliers, cultivators, harvesters, consolidators, and processors. However, other actors offer various services, such as technical assistance and advice (FAO, 2010). Value chains are complex because there are more than one channel and actors, as shown in Figure 2.4.

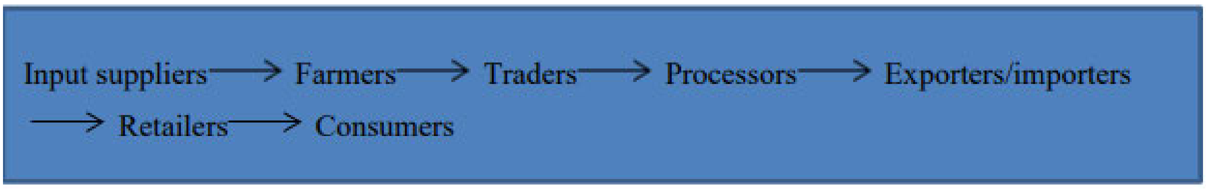

Figure 2.4: Simplified agricultural value chain (Source: Ndlovu *et al*., 2020)

2.5.2 Underutilised Crops Value Chain

Any agricultural product needs to pass through a number of stages from the producer through to the consumer. In between, there are a variety of primary and supportive activities to add value. According to Mabhaudhi *et al*. (2017), products and markets are the focus of primary activities, whereas infrastructure, technology, Research and Development (R & D), and human resources are the areas of support activities. The cluster and order of activities engaged in a product's manufacture up to its marketing, from conception through various stages of manufacturing distribution to end users and ultimate disposal after use, is referred to as the "value chain" (Mabhaudhi *et al*., 2017). underutilised crops are easily identified and improved by analysing the data both upstream and downstream along the value chain.

In understanding the dynamics of scaling up Underutilised crops (underutilised crops) value chains, a fundamental food value chain is depicted in Figure 2.5. This figure outlines the critical "who," "when," and "how" factors that need consideration in the process. Highlighting the importance of support activities, it emphasises the essential role these activities play in determining and enhancing the added "value." This, in turn, encourages a broader participation of stakeholders in the value chain (Mabhaudhi *et al*., 2017). The term "R & D value chain" is used to categorise these tasks, underlining the significance of research and development in the overall process (Mabhaudhi *et al*., 2017).

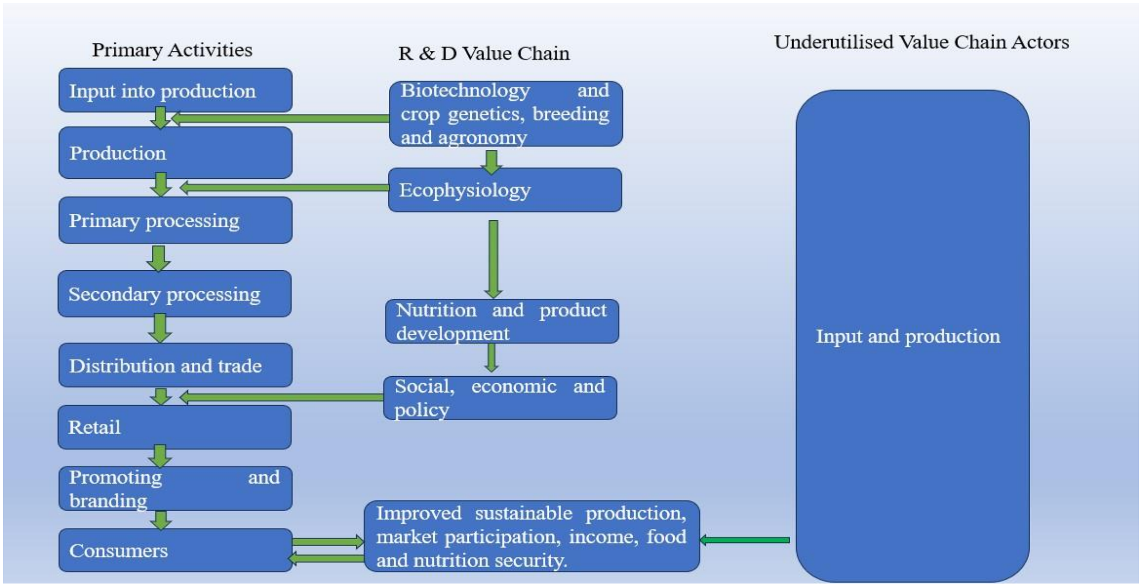

Figure 2.5: Value chain of underutilised crops indicating primary and support activities and actors involved during the primary activities. (Source: Mabhaudi *et al*., 2017)

The slower progress in establishing underutilised crops value chains can be attributed, at least in part, to the need for a clear focus on the supplementary role of research and development (Akinola *et al*., 2020). Mabhaudi *et al*. (2017) stated that research and development are particularly crucial because a substantial amount of knowledge is still embedded in indigenous knowledge systems. A well-defined and targeted research and development plan holds the potential to unlock the full capabilities of underutilised crops. To achieve this, the application of methodologies similar to those used in advancing major crops becomes essential. These methodologies encompass various areas, including biotechnology, crop genetics and breeding, agronomy, and agro-processing (Mabhaudi *et al*., 2017).

2.5.3 Challenges and Opportunities in Underutilised Crops Value Chains

This section embarks on a comprehensive exploration of the intricacies within underutilised crop value chains, unravelling both the promising opportunities and formidable challenges that shape their integration into agricultural systems.

2.6.3.1 Opportunities

The development of the country is greatly influenced by the food and agricultural policies of South Africa, especially when it comes to the inclusion of underutilised crops in national planning (Mabhaudhi *et al.,* 2017; Mabhaudhi *et al*., 2018). Although the main objective has been to boost the yield of the major cereal crops, there has been a discernible shift in the scope of the policy to acknowledge and support underutilised crops as a necessary component for attaining greater nutritional diversity.

The National Policy on Food and Nutrition Security (NPFNS), which vigorously promotes the study, promotion, and use of underused crops, is one important policy in this respect. This approach integrates underutilised crops into farming systems that are mostly focused on cereal crops in an effort to promote and diversify food production (Mabhaudhi *et al.,* 2017; Mabhaudhi *et al*., 2018). These neglected crops are increasingly acknowledged as important supplements to important food crops, helping to avoid malnutrition, especially in rural areas where poverty is prevalent (Mabhaudhi *et al.,* 2017). An important component of the NPFNS and other agricultural development programs is their recognition of the value of diversifying the diet as a means of enhancing nutrition and health (Mabhaudhi *et al.,* 2018).

Moreover, the cultivation and marketing of underutilised crops present opportunities to connect rural farmers with both national and international niche markets. A case in point is the success story of taro (*amadumbe*), an underutilised crop specifically targeted for research and promotion in KwaZulu-Natal, South Africa. The focused efforts on this crop have resulted in its availability in major retail outlets, providing a source of income for rural farmers engaged in organic cultivation for these outlets (Mabhaudhi *et al.,* 2017).

The integration of modern technologies, such as biotechnology and innovative agro-processing techniques, holds the potential to transform underutilised crops into diverse products, enhancing their palatability and extending their shelf-life (Mabhaudhi *et al.,* 2017; Mabhaudhi *et al*., 2018). Taking taro as an example, this could involve the development of new, higher-yielding varieties, the establishment of appropriate post-harvest handling and storage protocols, and the creation of various taro-based products. Such technological advancements open up new opportunities for smallholder communities to actively participate in the value chains of underutilised crops (Mabhaudhi *et al.,* 2017; Mabhaudhi *et al*., 2018).

Furthermore, the promotion of drought-tolerant and nutrient-dense underutilised crops aligns with broader sustainable development goals (SDGs), contributing to the achievement of multiple objectives as outlined in Table 2.2. Overall, South Africa's strategic emphasis on underutilised crops in its policies reflects a holistic approach toward enhancing food security, economic opportunities for rural communities, and sustainable agricultural practices.

Table 2.2: Sustainable Development Goals (SDGs) addressed by underutilised crops.

Focus Area	**Related SDGs**
Achieving Dietary Diversity	SDG 1: End poverty in all forms everywhere. SDG 2: End hunger, achieve food security and improved nutrition, and promote sustainable agriculture. SDG 3: Ensure healthy lives and promote well-being for all ages.
Employment Creation	SDG 1: End poverty in all forms everywhere. SDG 8: Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all.
Mitigating Drought and Water Scarcity	SDG 15: Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and biodiversity loss.

2.6.3.2 Challenges

According to Gruère *et al.* (2012), the effective promotion and utilisation of underutilised crops face challenges stemming from the absence of well-established and supported value chains. Creating sustainable food value chains requires empirical information, which, in the case of underutilised crops, is often anecdotal and inconsistent (Mabhaudhi *et al.,* 2017; Mabhaudhi *et al*., 2018). A considerable literature gap exists concerning these crops due to limited, focused research and development initiatives, along with inadequate infrastructure for upscaling and marketing underutilised crops. Consequently, formulating strategies for scaling up underutilised crops production within smallholder farming communities becomes challenging. To achieve a larger production scale, it is imperative to develop efficient technologies for manufacturing, storage, and processing (Mabhaudhi *et al.,* 2017; Mabhaudhi *et al*., 2018).

Social perceptions surrounding underutilised crops contribute to their low adoption of existing cropping systems. They are often viewed as "low status," "backwards," "old-fashioned," or "poor man's" crops, leading younger generations involved in smallholder farming to avoid them (Mabhaudhi *et al.,* 2017; Mabhaudhi *et al*., 2018). The lack of information accessibility on the benefits of underutilised crops adds to the social barriers. Modern technologies need to be promoted to incentivise and raise awareness among younger generations, addressing the negative perceptions associated with this crop (Mabhaudhi *et al.,* 2017; Mabhaudhi *et al*., 2018).

The need for robust empirical and comparable information on basic aspects of underutilised crops, such as agronomy and ecophysiology, relies heavily on anecdotal evidence. This absence acts as a disincentive for governments and major funders to invest in the research and development of underutilised crops.

According to Padulosi (2013), key agronomic challenges hindering the promotion of underutilised crops include:

- Lack of propagation material and seeds due to informal seed market systems.
- Human resources need to be more trained with technical knowledge of underutilised crops production.

- Poor support from research and development in identifying the best management options for crops, soil, fertiliser, pests, and weeds.

This analysis aligns with the status of underutilised crops in South Africa, highlighting the need for focused efforts to overcome these challenges and promote the sustainable integration of underutilised crops into agricultural systems.

2.6 Promotion of the Underutilised Crops Production

The cultivation and trade of underutilised crops have played a crucial role in promoting food security and diversifying food sources. The sale of these crops has also been recognised as a potential income source for impoverished communities in rural areas of developing countries (Adula *et al.,* 2023). Various policies and frameworks are being proposed and adapted to improve the supply and demand dynamics of underutilised crops.

Horna *et al.* (2007) conducted a study focusing on value chains for underutilised crops in Ghana, specifically examining the case of garden eggs. The research analysed the marketing chain of these crops in Ghana, identifying market constraints and proposing specific policies to address them. The aim was to enhance the economic potential of underutilised crops through improved exploitation.

In another study by Gotor *et al*. (2013), interventions were examined for their impact on the conservation and adaptation of underutilised plant species in rural communities, particularly in Yemen. The interventions involved collaborative efforts between farmers and experts to improve crop varieties, introduce value-added technologies, develop a seed supply system, and conduct fertilisation trials. The results indicated a positive correlation between these interventions and increased yields of underutilised crops, leading to higher income for farmers. The study suggests that interventions such as precision agriculture and value-added technologies, including broadband technology, can significantly boost income for local farmers.

Ravi *et al*. (2021) discussed mobilising underutilised crops in India, starting with a benchmark survey to understand the socio-economic status of impoverished communities. Based on this, a series of agronomic interventions were proposed to promote the cultivation of underutilised crops, utilising genetic diversity, improved agronomic practices, and strategic marketing.

Unlike many frameworks, this project actively incorporates technologies such as precision agriculture, broadband services for improved marketing, and renewable energy systems to optimise crop cultivation. This leads to increased yields and reduced costs, ultimately generating more income for rural communities.

Gruère *et al*. (2012) defined underutilised crops based on three characteristics: local production in restricted rural areas, limited scientific knowledge (with practical knowledge known by local farmers), and a relatively low current economic value compared to their potential. Successful commercialisation, as outlined in the paper, is characterised by profits distributed sufficiently to primary producers for continuous crop production and the sustainability of the market over time in terms of price and profit margin as demand increases.

Based on the economic factors identified, the conditions that affect the successful commercialisation of underutilised crops for people in rural areas are identified as demand expansion, increase in efficiency of supply and supply control mechanism.

2.7 Crop Production Systems of Underutilised Crops

In examining crop production systems for underutilised crops, three distinct approaches emerge conventional production, unconventional (organic) production, and traditional production. Each method carries its unique characteristics, impacts, and considerations, shaping the landscape of agricultural practices globally.

2.7.1 Conventional Production System

For many years, the rise of the green revolution and industrialisation meant that farmers could shift from subsistence methods of crop production to commercial production through land use intensification and the use of inputs to increase crop yields, which thus became the conventional way of production from around the late 20th century (Schrama *et al*., 2018; Durham and Mizik, 2021). Conventional agriculture is complex and has been used in various contexts in different literature (Durham and Mizik, 2021). Durham and Mizik (2021) proffer three discourses on the use of conventional agriculture/production. Firstly, it is used in a counter-current sense towards alternative agricultural practices, where there is a comparison of different production methods, such as conventional production versus conservation or organic production versus conventional production. Secondly, it is used as a discourse construct as an alternative approach. In this case, an alternative to conventional production has been implicitly associated with industrialisation ills like unsustainability, environmental degradation, mechanisation, capitalism, and greenhouse gas emissions (Durham and Mizik, 2021). The implication of this discourse thus leads to the call for 'transformative' change within conventional agriculture. Thirdly, it is used in a normative manner, making it seem homogenous, static, and conservative, making the term devoid of meaning outside of alternative production contexts (Durham and Mizik, 2021). Understanding and classifying the concept is crucial for better structures and policy implementations in future production systems.

Kremen and Miles (2012) define conventional production as a production system that relies on monoculture, inorganic fertilisers, and synthetic chemical pest control inputs. They further mention that, theoretically, since such systems produce greater yields, they provide sufficient food to sustain the population. Similarly, in their definition, Schrama *et al*. (2018) emphasise conventional production systems as increasing agricultural (crop) yields through improved crop varieties and inputs such as pesticides and mineral fertilisers. Durham and Mizik (2021) define conventional production as a large-scale system operating at a large scale dependent on inputs (fertilisers and agro protectants) and highly mechanised. Therefore, it is evident that the consensus on what conventional production systems entail is using inputs to maximise yield outputs. However, studies have noted the adverse impacts of conventional production approaches. Schrama *et al.* (2018) note that land use intensification as a result of the conventional production approach leads to a loss of soil organic matter, which then reduces the soil's barrier against adverse weather conditions, ultimately leading to the soil losing its nutrients over time and having a boomerang effect back on the yield (reducing output).

In this case, Durham and Mizik (2021) suggest organic production as an alternative and solution to the challenges of using conventional production approaches. However, the problem posed by the former approach then becomes that yields in organic production have been reported to be lower than in conventional production, a difference often set off by prices when marketing and selling the end products, i.e., organic products prices tend to be higher, to offset production costs, which thus becomes an issue, particularly to developing and underdeveloped communities in need of affordable, nutritious food. Similarly, Kremen and Mile's (2012) study concur on the benefits of diverting from conventional production approaches and suggests organic production as the suitable production system, noting the ecological benefits its biological diversification provides, as well as its ability to mitigate environmental externalities, therefore, being able to contribute to global food security in a socially equitable and ecologically sustainable manner.

2.7.2 Unconventional (Organic) Production Systems

Unconventional production systems are a newer, dynamic, and much-contested concept. Unconventional production methods are diversified from classical conventional methods of production, which require more significant inputs such as fertilisers and agro protectants (Durham and Mizik, 2021). Some of the synonyms cited in the literature include Organics production/agriculture (Durham and Mizik, 2021), diversified production (Kremen and Miles, 2012), and non-conventional production (Mabhaudi *et al*., 2017). The use of unconventional methods in production has been used in response to mitigate the environmental externalities of conventional production as well as to ensure the agricultural sector becomes more sustainable (Kremen and Miles, 2012; Shrama *et al*., 2018), for example, organic agriculture avoids the use of chemical fertilisers and synthetic pesticides, therefore having no greenhouse gas emissions and no negative impact on soil nutrients (Shrama *et al*., 2018).

Despite the ecological benefits associated with unconventional production, there are still contradictions within the literature on conventional versus organic yield gaps (Kremen and Miles, 2012). There have been many concerns about the yield from non-conventional production methods needing to produce the required amount to sustain the ever-growing population (Schrama *et al*., 2018). The FAO (2020) report noted Italy (16%), Sweden (20%), and Austria (24%) as the countries with the highest share of organic agricultural area in their total area utilised for agriculture. Furthermore, 14 of the top 20 countries with high organic agriculture areas are in Europe. This indicates the state of production methods in developed and developing countries, including South Africa, with developing countries being yield-driven instead of environment and sustainability, thus tilting towards the conventional approach.

2.7.3 Traditional Production Systems

While unconventional production systems focus on diversifying production methods and mitigating environmental externalities, traditional production systems have a rich history rooted in intergenerational knowledge and local ecological understanding. Traditional production systems are methods of farming that have been used for generations, passed down from one generation to the next. These systems are often based on a deep understanding of local ecology, natural resources, and local, low-cost inputs to produce food (Bajjou *et a*l., 2017). Traditional production systems are an essential part of many communities' cultural heritage and a necessary means of food production, particularly in developing countries.

Hirpo (2016) notes that traditional production systems often have farmers relying on diverse and complex cropping systems, including annual and perennial crops, trees, and livestock. These systems are often adapted to local conditions, such as soil type, rainfall patterns, and temperature. They often include using organic and natural fertilisers, intercropping, crop rotation, and soil conservation techniques to maintain soil health and fertility. One of the main advantages of traditional production systems is their ability to maintain a high level of biodiversity (Béné and Obirih-Opareh, 2009). This is due to traditional farmers often growing various crops, including indigenous varieties, adapted to local conditions and can better withstand pest and disease outbreaks. This diversity helps to maintain soil health, prevent erosion, and reduce the need for expensive external inputs such as fertilisers and pesticides.

Traditional production systems are more resilient to climate change and other environmental stresses (Durham and Mizik, 2021). The diverse cropping systems and soil conservation techniques used in traditional farming help maintain soil moisture and reduce the impact of droughts and floods (Béné and Obirih-Opareh, 2009). Traditional farmers also usually have an intimate knowledge of the local environment, allowing them to adapt to changing conditions and make the most of available resources. However, traditional production systems have challenges (Béné and Obirih-Opareh, 2009). Many traditional farmers need help accessing markets and obtaining credit, which limits their ability to invest in their farms and improve their productivity. Additionally, using traditional farming practices can be time-consuming and labour-intensive, limiting farmers' ability to expand their production and generate income.

To address these challenges, many organisations and governments are promoting the adoption of sustainable agriculture practices, which build on the strengths of traditional farming systems while incorporating new technologies and techniques (Chivenge *et al*., 2015). For example, agroforestry systems that combine trees and crops have been shown to improve soil health and provide farmers with a source of income from tree products. Additionally, appropriate technologies, such as low-cost irrigation systems and improved seed varieties, can help increase yields and enhance the resilience of traditional farming systems.

2.8 Determinants of Production Systems of Underutilised Crops

Various crucial elements determine and affect farmers' decision-making and the adoption of land use practices or technologies in selecting which production system to utilise, including biological and geophysical factors. Mabhaudhi *et al*. (2017) mention crops, animals, weeds, pests, and diseases as biological factors that could affect a production system. On the other hand, climate (solar radiation, rainfall, temperature, relative humidity, wind, droughts, and floods) and soils (soil aeration and soil structure, soil reaction, soil fertility, supply of mineral nutrients, absence of growth-restricting substances), among other geophysical factors, influence the choice of production system used (Bowman and Zilberman, 2013; Stevenson *et al*., 2014).

Among other crucial elements influencing farmers' decisions about their production systems are socio-economic factors, which can then be classified into endogenous and exogenous factors. Endogenous factors include variables like family structure, health and nutrition, education, dietary preferences, economic uncertainty, and gender dynamics of smallholder farmers or the rural population that can have an impact on the choice of production system used (Herrero *et al*., 2014; Mabuza *et al*., 2016). Linnes *et al*. (2022) stated that the decision of production systems that emerge in response to changing market demands is also influenced by farmers' attitudes and willingness to pay (i.e., the highest price a consumer would be willing to pay for a good or attribute) for differentiated crops or specific attributes, such as organic or local production or pesticide-free varieties.

According to Norman (1978) and Norman and Gilbert (2019), exogenous factors include events that take place outside of rural regions and are not affected by the rural populace directly, such as input and output markets, pricing, tenure, off-farm activities, infrastructure, credit, policies, and technological adoption. The dynamics of seasonal and local labour availability may mean that growing a crop with a tiny harvest window in a month is unprofitable, where the region's overall demand for agricultural labour is high (Bowman and Zilberman, 2013). This is just one example of how input market conditions influence farmer production system decisions. Farmers' choice of crop production system can also be affected by input price volatility and economies of scale with regard to inputs or technologies (Riar *et al*., 2021). Similar to input market conditions, farmers' profitability in growing a crop depends on factors such as prices, price volatility, transportation costs, and supply chain transaction costs (Bowman and Zilberman, 2013).

Policies and regulations can influence the economic viability and development of different production systems by facilitating or hindering trade in specific types of agricultural products, influencing farmer decisions about what crops to grow or how much land to farm via policies such as price supports or set-aside programs, or making different types of production or land-use relatively more or less "expensive" via regulations, taxes and subsidies, or standards (van Eijck *et al.*, 2014; Mukherjee, 2020). Furthermore, many policies that do not mainly target agriculture, such as labour and immigration rules or water policies, substantially impact agricultural production costs (Bowman and Zilberman, 2013). Laws that govern pesticide usage and application or that limit water consumption, for example, might make it more expensive to produce using synthetic pesticides or inefficient irrigation methods (Bowman and Zilberman, 2013). While such laws may have a detrimental impact on farmer welfare in the short run, they also help spur innovation and the adoption of new technology to comply with regulations and lower production costs (Bowman and Zilberman, 2013).

2.9. Implications for Food Security

This section explores the multifaceted implications for food security, beginning with an in-depth analysis of the global status of food and nutrition security, highlighting the exacerbated challenges faced during the COVID-19 pandemic and beyond. The examination extends to the specific context of South Africa, elucidating the intricate dynamics at both national and household levels. Subsequently, the discussion delves into the evaluation of how underutilised crops can impact food security, considering their potential to address challenges associated with the overreliance on staple crops and their role in promoting sustainable agricultural practices on a global scale.

2.9.1 Status of Food and Nutrition Security in the World

The prevalence of moderate or severe food insecurity, one of the official Sustainable Development Goal (SDG) indicators, offers further information on people who do not regularly have access to wholesome food, even if they are not absolutely hungry. An additional 1.3 billion people, or 16.2 %of the world's population, were predicted to be moderately food insecure in 2019 (Fagbemi, 2021). The estimated number of individuals who experienced moderate or severe food insecurity in 2019 was 2 billion, or 25.9 %of the global population (World Health Organization, 2019). Fan and Zhang (2020) iterate this notion of food insecurity, particularly in the African context, noting that more than half of the population in Africa experienced moderate to severe food insecurity in 2019, far more significant than anywhere else in the globe.

2.9.2 Status of Food and Nutrition Security in Africa

Following a significant increase in 2020 during the COVID-19 pandemic, there was an even more substantial increase in global hunger in 2021 (Swinnen and Vos, 2021; Kent *et al*., 2022). According to Fagbemi (2021), the pandemic's longevity and its long-lasting effects, which worsened already-existing inequities, have contributed to more setbacks in 2021 in the effort to meet the Zero Hunger objective by 2030. Several studies have revealed that the prevalence of undernourishment (PoU) increased from 8% in 2019 to over 9.3 % in 2020 and continues to rise in 2021 after remaining largely stable since 2015 (African Union Commission, 2021). After decades of reduction, the PoU has been rising globally since 2014. In 2019, around 9% people worldwide experienced hunger (Kent *et al*., 2022). The PoU is highest among all regions and has steadily increased since 2014 in Africa, where the situation is most concerning. African Union Commission (2021) stated that nearly 20% of Africans were undernourished as of 2019. On the other hand, between 2000 and 2019, the number of hungry people in Africa rose by 51 million, or 26%.

2.9.3 Current Food Security Status in South Africa

Recent impactful events, including the COVID-19 pandemic, Russia's war in Ukraine, and the devastating KZN floods, have significantly compromised food security in South Africa. While the nation is deemed food secure at the national level, according to Stats S.A., the scenario shifts at the household level, with nearly 20% of households grappling with food insecurity. In 2023, approximately 20% (1 in 5) of South Africans faced food insecurity (Stats S.A., 2023).

Within the realms of moderate and severe food insecurity, the female and black population groups emerged as the most affected. A multitude of factors contribute to this predicament, including poverty, unemployment, income inequality, climate change, the cost of living, unstable food production, past spatial imbalances, and the capacity to produce food (Ngcuka, 2022). A study by the Integrated Food Security Phase Classification (IFSPC) body underscores the COVID-19 pandemic mitigation measures, escalating food prices, drought, and the country's economic decline as primary causes of food insecurity in South Africa.

The escalating climate crisis poses a substantial threat to food security, evident in dwindling water resources, intensified droughts, and rising temperatures that jeopardise the moderate climate essential for food production. The overreliance on a handful of crops like rice, wheat, and maize by the majority of humankind makes the food supply chain vulnerable to disruptions. This vulnerability was underscored in the context of the Russia-Ukraine war, which impacted wheat supplies and underscored the interconnectedness of geopolitical events and food security (Ngcuka, 2022).

2.9.4 Evaluating the Impact of Underutilised Crops on Food Security

Several studies have demonstrated that only 30 plant species produce 95% of the world's food (Borlaug, 2002; Meyer *et a*l., 2012; Al-Khayri *et al*., 2019). Over 50% of the world's consumption is already in three significant crops: maize, wheat, and rice (Shiferaw *et al*., 2013). These three crops—maize, wheat, and rice—are anticipated to gradually dominate the market and consumer demand due to the economic benefits they give (Shiferaw *et al*., 2013). However, rice is susceptible to heat stress, rising sea levels, and flooding, whereas wheat is particularly heat-sensitive (Hossain and Teixeira da Silva, 2013).

Dependence on main crops carries long-term risks related to agronomy, ecology, nutrition, and economics, particularly considering the issue of global climate change and global warming (Shiferaw *et al*., 2013). If alternatives are not considered, it is thought that this would endanger the productivity and crop sustainability of important staple crops, directly harming global food security. This is just one function of underutilised crops in maintaining food security. Many underutilised species can survive in extremely harsh and challenging locations since some are abundantly cultivated in unfavourable conditions. As was already indicated, to secure food security, using underutilised crops is most favourable to withstand the effects of climate change and global warming (Shiferaw *et al*., 2013).

Most underutilised agricultural species have a significant untapped global resource. The world's food supply is dependent on a small number of plant species, as shown by the fact that more than half of the world's food needs are met by just three major staple crops (rice, maize, and wheat), and nearly 95% of those needs are met by just thirty plant species (Shiferaw *et al*., 2013). Meanwhile, because of climate change and poor soil, staple crops are encountering significant difficulties. Moving away from staple crops and toward new crop types is crucial for establishing food production security. Underutilised crops are best suited to address this issue with hereditary attributes, including physical appearance, flavour, nutritional values, cultivation methods, processing capabilities, and possible financial rewards (Al-Khayri *et al*., 2019).

Underutilised crops require comparatively fewer inputs than main crops, which is crucial for sustainable agricultural production. Researchers have discussed the potential for underutilised crops to promote food security (Al-Khayri *et al*., 2019). They emphasised the untapped potential of underutilised crops to help people in need with revenue and subsistence. Underutilised species are crucial for food production in low-income nations with food shortages. There is such a wide variety of crop resources throughout Africa, Asia, and the Pacific, there is a chance to use that variety to enhance the region's environment and way of life sustainably. On the other side, underutilised crops encourage the growth of specialised markets for international commerce in an environment where competition is rising. As a result, the significance of sustainable production systems using fewer common crops and animals to enhance human wellness is receiving growing support nationally and worldwide.

The possible benefits of underutilised crops include improving human health, preserving biodiversity, managing natural resources, empowering women and marginalised groups in society, and increasing food production (Al-Khayri *et al*., 2019). The ability to harness underutilised crops' various applications globally rather than using conventional single-use improvement techniques is the key to realising their full potential. However, due to their incapacity to compete with the primary crops that predominate most agricultural systems, the cultivation of underutilised crops has consistently decreased (Al-Khayri *et al*., 2019).

2.10 Research Gap and Conclusions

2.10.1 Research Gap

In the comprehensive exploration of the literature on underutilised crops, agricultural production systems, and their implications for food security, certain notable research gaps have surfaced. First, there needs to be more focus on the socio-economic and cultural dimensions influencing the adoption of underutilised crops and alternative production systems, particularly in diverse geographic and cultural contexts. Understanding the intricate interplay of local practices, gender dynamics, and indigenous knowledge systems in the cultivation of underutilised crops could provide valuable insights for sustainable agricultural development. Additionally, while the literature highlights the potential of underutilised crops to enhance food security, there needs to be more studies evaluating the long-term ecological and economic sustainability of these crops within diverse agroecosystems. Further research is needed to assess the resilience of underutilised crops in the face of changing climatic conditions, market dynamics, and evolving consumer preferences. Moreover, more attention should be given to the role of digital technologies and innovative farming practices in optimising the value chain of underutilised crops. Exploring the integration of precision agriculture, digital marketing strategies, and renewable energy solutions could unlock new avenues for boosting the productivity and marketability of these crops. Addressing these research gaps would not only enrich our understanding of underutilised crops but also contribute valuable insights for devising inclusive and sustainable agricultural policies on a global scale.

2.10.2 Conclusion

In summary, this literature review sheds light on the multifaceted landscape of underutilised crops, emphasising their pivotal role in addressing contemporary challenges related to food security and sustainable agriculture. The exploration of case studies from Ghana, Yemen, and India underscores the economic potential of these crops and the need for targeted interventions. The value chain analysis illuminates the intricate dynamics involved in bringing agricultural products from production to consumption, stressing the importance of sustainable practices. Discussions on different production systems—conventional, unconventional, and traditional—underscore the significance of considering environmental impacts and climate resilience in agricultural approaches. The determinants influencing farmers' choices, encompassing biological, geophysical, and socio-economic factors, highlight the complexity of decision-making. The review underscores the global and South African food security status, elucidating challenges, and the potential of underutilised crops to offer nutritional benefits and climate change resilience. Moreover, the role of these crops in diverse diets and their superior nutritional content compared to staple crops emerges as a critical aspect system.

References

Adula, D.M., Tefera, M.M. and Ayana, B., 2023. Role of Underutilised Crops in Improving Food Security and Livelihoods of the Households: A Case Study in GutoGida District, Ethiopia. *World*, *1*(4), pp.83-97.

African Union Commission., 2021. Africa regional overview of food security and nutrition 2020: Transforming food systems for affordable healthy diets (Vol. 1). Food and Agriculture Org.

Akinola, R., Pereira, L.M., Mabhaudhi, T., De Bruin, F.M. and Rusch, L., 2020. A review of indigenous food crops in Africa and the implications for more sustainable and healthy food systems. *Sustainability*, *12*(8), p.3493.

Al-Khayri, J.M., Jain, S.M. and Johnson, D.V., 2019. Advances in Plant Breeding Strategies: Industrial and Food Crops. Springer.

Arogundade, L.A. and Mu, T.H., 2012. Influence of oxidative browning inhibitors and isolation techniques on sweet potato protein recovery and composition. *Food Chemistry*, *134*(3), pp.1374-1384.

Arora, S., Bhatt, R., Sharma, V. and Hadda, M.S., 2023. Indigenous practices of soil and water conservation for sustainable hill agriculture and improving livelihood security. *Environmental Management*, *72*(2), pp.321-332.

Bajjou, M.S., Chafi, A. and En-Nadi, A., 2017. A comparative study between lean construction and the traditional production system. *International Journal of Engineering Research in Africa*, *29*, pp.118-132.

Bandula, A. and Nath, T.K., 2020. Underutilised Crops in the Agricultural Farms of Southeastern Sri Lanka: farmers' knowledge, preference, and contribution to the household economy. *Economic Botany*, *74*, pp.126-139.

Béné, C. and Obirih-Opareh, N., 2009. Social and economic impacts of agricultural productivity intensification: the case of brush park fisheries in Lake Volta. *Agricultural Systems*, *102*(1-3), pp.1-10.

Beukes, L., 2019. *The magic of Amadumbe (Madumbi)*. [online] Southlands Sun. Available at: https://southlandssun.co.za/97339/magic-amadumbe-madumbi/ [Accessed 29 Nov. 2023].

Borlaug, N.E., 2002. The green revolution revisited and the road ahead. Stockholm: Nobelprize. Org.

Bowman, M.S. and Zilberman, D., 2013. Economic factors affecting diversified farming systems. *Ecology and Society*, *18*(1).

Brandenberger, L., Hu, B., Rebek, E. and Damicone, J., 2022. *Sweet Potato Production - Oklahoma State University*. [online] extension.okstate.edu. Available at: https://extension.okstate.edu/fact-sheets/sweet-potato-production.html [Accessed 29 Nov. 2023].

Chandrasekara, A. and Kumar, T.J., 2016. Roots and Tuber Crops as Functional Foods: A Review on Phytochemical Constituents and Their Potential Health Benefits. *International Journal of Food Science*, pp.1–15. doi: https://doi.org/10.1155/2016/3631647

Chauhan, V.B.S., Mallick, S.N., Pati, K., Arutselvan, R. and Nedunchezhiyan, M., 2022. Status and Importance of Underexploited Tuber Crops in Relation to Nutritional Security and Economic Prosperity. *Compendium for winter school on "Unexpected Vegetables: Unexplored Treasure Trove for Food, Nutritional and Economic Security". Published by ICAR-Indian Institute of Vegetable Research, Varanasi-221305, Uttar Pradesh*, pp.246-264.

Chivenge, P., Mabhaudhi, T., Modi, A.T. and Mafongoya, P., 2015. The potential role of neglected and underutilised crop species as future crops under water-scarce conditions in Sub-Saharan Africa. *International Journal of Environmental Research and Public Health*, *12*(6), pp.5685-5711.

Christian, A.K. and Dake, F.A., 2022. Profiling household double and triple burden of malnutrition in sub-Saharan Africa: prevalence and influencing household factors. *Public Health Nutrition*, *25*(6), pp.1563-1576.

DeLorenzo, J., 2021. *Vegan Sweet Potato Casserole*. [online] A Life Well Planted. Available at: https://alifewellplanted.com/20758/vegan-sweet-potato-casserole/ [Accessed 29 Nov. 2023].

Durham, T.C. and Mizik, T., 2021. Comparative economics of conventional, organic, and alternative agricultural production systems. *Economies*, *9*(2), p.64.

Fagbemi, F., 2021. COVID-19 and sustainable development goals (SDGs): An appraisal of the emanating effects in Nigeria. *Research in Globalization*, 3, pp.100047.

Fan, S., Si, W. and Zhang, Y., 2020. How do you prevent a global food and nutrition security crisis under COVID-19? China Agricultural Economic Review.

Ferdaus, M.J., Chukwu-Munsen, E., Foguel, A. and da Silva, R.C., 2023. Taro Roots: An Underexploited Root Crop. *Nutrients*, *15*(15), pp.3337.

Food and Agriculture Organization (2010). *Agricultural value chain development: Threat or opportunity for women's employment?* [online] Available at: https://www.fao.org/3/i2008e/i2008e04.pdf [Accessed 29 Sep. 2023].

Food and Agriculture Organization of the United Nations (2020). *The State of World Fisheries and Aquaculture 2020*. [online] FAO. Doi: https://doi.org/10.4060/ca9229en.

Gotor, E., Caracciolo, F., Canto, G.M.B. and Al Nusairi, M., 2013. Improving rural livelihoods through the conservation and use of underutilised species: Evidence from a community research project in Yemen. *International Journal of Agricultural Sustainability*, *11*(4), pp.347-362.

Gruère, G., Giuliani, A. and Smale, M., 2012. *Marketing underutilised plant species for the benefit of the poor: a conceptual framework*. Intl Food Policy Res Inst.

Herrero, M., Thornton, P.K., Bernués, A., Baltenweck, I., Vervoort, J., van de Steeg, J., Makokha, S., van Wijk, M.T., Karanja, S., Rufino, M.C. and Staal, S.J., 2014. Exploring future changes in smallholder farming systems by linking socio-economic scenarios with regional and household models. *Global Environmental Change*, *24*, pp.165-182.

Hirpo, C.L.A., 2016. Current Ecological Scenario of Rift Valley Lakes of Ethiopia: A review. *E.C. Agriculture*, *3*, pp.570-580.

Horna, D., Timpo, S. and Gruère, G., 2007. Marketing underutilised crops: the case of the African garden egg (Solanum ethiopicum) in Ghana.

Hossain, A. and Teixeira da Silva, J.A., 2013. Wheat production in Bangladesh: its future in the light of global warming. AoB Plants, 5.

Hossain, A., Islam, M.T., Maitra, S., Majumder, D., Garai, S., Mondal, M., Ahmed, A., Roy, A., Skalicky, M., Brestic, M. and Islam, T., 2021. Neglected and Underutilised Crop Species: Are They Future Smart Crops in Fighting Poverty, Hunger and Malnutrition Under Changing Climate? *Neglected and underutilised crops-towards nutritional security and sustainability*, pp.1-50.

Kent, K., Murray, S., Penrose, B., Auckland, S., Horton, E., Lester, E. and Visentin, D., 2022. The new normal for food insecurity? A repeated cross-sectional survey over 1 year during the COVID-19 pandemic in Australia. *International Journal of Behavioral Nutrition and Physical Activity*, 19(1), pp.1-13.

Kremen, C. and Miles, A., 2012. Ecosystem services in biologically diversified versus conventional farming systems: benefits, externalities, and trade-offs. *Ecology and Society*, *17*(4).

Linnes, C., Weinland, J.T., Ronzoni, G., Lema, J. and Agrusa, J., 2022. The local food supply, willingness to pay and the sustainability of an island destination. *Journal of Hospitality and Tourism Insights*, (ahead-of-print).

Liu, Q., Liu, J., Zhang, P. and He, S., 2014. Root and tuber crops. *Encyclopedia of agriculture and food systems*, pp.46-61.

Mabhaudhi, T., Chibarabada, T.P., Chimonyo, V.G.P., Murugani, V.G., Pereira, L.M., Sobratee, N., Govender, L., Slotow, R. and Modi, A.T., 2018. Mainstreaming underutilised indigenous and traditional crops into food systems: A South African perspective. *Sustainability*, *11*(1), pp.172.

Mabhaudhi, T., Chimonyo, V.G. and Modi, A.T., 2017. Status of underutilised crops in South Africa: opportunities for developing research capacity. *Sustainability*, *9*(9), pp.1569.

Mabuza, M.L., Ortmann, G.F., Wale, E. and Mutenje, M.J., 2016. The effect of major income sources on rural household food (in) security: Evidence from Swaziland and implications for policy. *Ecology of Food and Nutrition*, 55(2), pp.209-230.

Matthews, P.J., 2014. Part 3: The Origins, Dispersal, and Domestication of Taro. *Senri Ethnological Studies*, *88*, pp.94-261.

Mdluli, F., Thamaga-Chitja, J. and Schmidt, S., 2013. Appraisal of hygiene indicators and farming practices in the production of leafy vegetables by organic small-scale farmers in uMbumbulu (Rural KwaZulu-Natal, South Africa). *International Journal of Environmental Research and Public Health*, *10*(9), pp.4323-4338.

Meyer, R.S., DuVal, A.E. and Jensen, H.R., 2012. Patterns and processes in crop domestication: a historical review and quantitative analysis of 203 global food crops. *New Phytologist*, 196(1), pp.29-48.

Motsa, N.M., Modi, A.T. and Mabhaudhi, T., 2015. Sweet potato (Ipomoea batatas L.) is a drought-tolerant and food security crop. *South African Journal of Science*, *111*(11-12), pp.1-8.

Mukherjee, A., 2020. Examination and Empirical Forecast of Wheat Yield in Northwest India Based on Climate and Socio-Economic Factors (Doctoral dissertation, Utah State University).

Muzigaba, M., Puoane, T. and Sanders, D., 2016. The paradox of undernutrition and obesity in South Africa: A contextual overview of food quality, access, and availability in the new democracy. *Food poverty and insecurity: International food inequalities*, pp.31-41.

Ndlovu, P.N., 2020. *Factors influencing the level of vegetable value chain participation and implications on smallholder farming and food security in Swayimane, KwaZulu-Natal* (master's dissertation).

Ndlovu, P.N., Thamaga-Chitja, J.M. and Ojo, T.O., 2021. Factors influencing the level of vegetable value chain participation and implications on smallholder farmers in Swayimane KwaZulu-Natal. *Land Use Policy*, *109*, pp.105611.

Ngcuka, O., 2022. *S.A. needs subsistence farming for food security*. [online] Food for Mzansi. Available at: https://www.foodformzansi.co.za/sa-needs-subsistence-farming-for-food-security/ [Accessed 29 Nov. 2023].

Norman, D.W. and Gilbert, E., 2019. A general overview of farming systems research, pp.17-30. Routledge.

Norman, D.W., 1978. Farming systems research to improve the livelihood of small farmers. *American Journal of Agricultural Economics*, 60(5), pp.813-818.

Padulosi, S., Thompson, J. and Rudebjer, P.G., 2013. Fighting poverty, hunger, and malnutrition with neglected and underutilised species: needs, challenges, and the way forward.

Przybył, K., Adamski, F., Wawrzyniak, J., Gawrysiak-Witulska, M., Stangierski, J. and Kmiecik, D., 2022. Machine and Deep Learning in the Evaluation of Selected Qualitative Characteristics of Sweet Potatoes Obtained under Different Convective Drying Conditions. *Applied Sciences*, *12*(15), pp.7840.

Ravi, V., Pandey, V., Devi, A. and Giri, N.A., 2021. Prospects of Underutilised Taro (Colocasia esculenta) for Sustainable Biodiversity and Nutritional Security in India. *Promotion of*

Underutilised Taro for Sustainable Biodiversity and Nutrition Security in SAARC Countries, *281*, pp.61.

Riar, A., Mandloi, L.S., Poswal, R.S., Messmer, M.M. and Bhullar, G.S., 2017. A diagnosis of biophysical and socio-economic factors influencing farmers' choice to adopt organic or conventional farming systems for cotton production. *Frontiers In Plant Science*, 8, pp.1289.

Sajeev, M.S., Padmaja, G., Jyothi, A.N., Krishnakumar, T. and Pradeepika, C., 2023. Tropical Tuber Crops: Nutrition and Entrepreneurial Opportunities. *Vegetables for Nutrition and Entrepreneurship* (pp. 409-438). Singapore: Springer Nature Singapore.

Schrama, M., De Haan, J.J., Kroonen, M., Verstegen, H. and Van der Putten, W.H., 2018. Crop yield gap and stability in organic and conventional farming systems. *Agriculture, Ecosystems and Environment*, *256*, pp.123-130.

Scott, G.J., 2021. A review of root, tuber, and banana crops in developing countries: past, present, and future. *International Journal of Food Science and Technology*, *56*(3), pp.1093-1114.

Sethuraman, G., Nizar, M., Nadia, F., Syaheerah, T., Jahanshiri, E., Gregory, P. and Azam-Ali, S., 2020. Nutritional Composition of Black Potato (*Plectranthus rotundifolius (Poir*.) Spreng.) (Synonym: Solenostemon rotundifolius). *The International Journal of Scientific and Engineering Research*, *11*, pp.1145-1150.

Shiferaw, B., Smale, M., Braun, H.J., Duveiller, E., Reynolds, M. and Muricho, G., 2013. Crops that feed the world 10. Past successes and future challenges to the role played by wheat in global food security. *Food Security*, 5(3), pp.291-317.

Siqueira, M.V.B.M., do Nascimento, W.F., Pereira, D.A., Cruz, J.G., de Castro Vendrame, L.P. and Veasey, E.A., 2023. Origin, domestication, and evolution of underground starchy crops of South America. In *Starchy Crops Morphology, Extraction, Properties and Applications*, pp. 17-42. Academic Press.

Statistics South Africa (2023). *Food Security and Hunger*. [online] Available at: https://www.statssa.gov.za/?cat=28 [Accessed 30 Nov. 2023].

Statistics South Africa (2022). *The world at 8 billion*. [online] Available at: https://www.statssa.gov.za/?p=15918 [Accessed 21 Jan. 2024].

Statistics South Africa, 2021. *Mid-year population estimates 2021* . [online] Available at: http://www.statssa.gov.za/publications/P0302/P03022021.pdf [Accessed 30 Nov. 2023].

Stevenson, K.T., Rader, H.B., Alessa, L., Kliskey, A.D., Pantoja, A., Clark, M., Smeenk, J. and Giguère, N., 2014. Sustainable agriculture for Alaska and the circumpolar North: Part II. Environmental, geophysical, biological, and socio-economic challenges. Arctic, pp.296-319.

Swinnen, J. and Vos, R., 2021. COVID-19 and impacts on global food systems and household welfare: Introduction to a special issue. *Agricultural Economics*, *52*(3), pp.365-374.

Van Eijck, J., Romijn, H., Smeets, E., Bailis, R., Rooijakkers, M., Hooijkaas, N., Verweij, P. and Faaij, A., 2014. Comparative analysis of key socio-economic and environmental impacts of smallholder and plantation-based jatropha biofuel production systems in Tanzania. *Biomass and Bioenergy*, 61, pp.25-45.

World Health Organization, 2019. The state of food security and nutrition in the world 2019: safeguarding against economic slowdowns and downturns (Vol. 2019). Food and Agriculture Org.

Chapter 3: Socioeconomic Factors Influencing Choice of Crop Production Systems: A Multivariate Probit Approach

Abstract

The world's main challenge today is how to maintain the welfare of an exponentially increasing population while also dealing with the depletion of resources and negative effects on the environment. Information on farmers' decisions on the use of sustainable practices is needed so that they can be promoted. This study uses a multivariate probit regression model to investigate the factors influencing smallholder farmers' choices of crop production systems. The research is based on data collected from 300 randomly selected farmers. The study finds that farmers' group membership, gender, age, farm size, and use of credit influence the use of the traditional production system. Farmers' group membership, gender, farm size and age influenced the use of the organic production system. Lastly, farmers' group membership, farming years, storage access, and credit use influenced the adoption of the conventional production system. These findings provide valuable insights for policymakers and stakeholders seeking to support smallholder farmers and promote sustainable and diverse crop production systems. Considering these factors, interventions and programs can be tailored to influence farmers' choices and improve the sustainability of agricultural outcomes.

Keywords: Production system, multivariate probit, traditional, conventional, organic

3.1 Introduction

The predominant global challenge entails preserving the well-being of an exponentially growing populace while grappling with the dwindling availability of resources and the damaging repercussions on the environment (Bello *et al*., 2022). This challenge encompasses two aspects of food safety and security, with food safety being a concern for developed and developing countries. In contrast, food security is mainly an issue in developing nations (Vågsholm *et al*., 2020). Agriculture is the key to addressing these issues, combining science and art, and serving an economic purpose. According to Fróna *et al.* (2019) and Kopittke *et al.* (2019), agriculture aims to produce more food, fibre, and fuel safely and securely to meet the increasing demand for these resources. However, this goal is often criticised as incompatible with environmental protection and human health (Kopittke *et al.*, 2019). Hence, agriculture is frequently scrutinised and requires careful evaluation to develop a sustainable, effective, and responsive system.

Agriculture is crucial in providing most of the world's food (Ulian *et al.,* 2020). The three main types of farmers' crop production systems are traditional, conventional, and organic/non-conventional farming (Deb *et al.,* 2021). Therefore, researching factors affecting traditional production systems, organic production systems, and conventional production systems of smallholder farmers in South Africa can provide valuable insights into different motivations for their use.

Several studies, such as Deb *et al*. (2016), Altieri *et al*. (2018), and Bisht *et al*. (2018), defined traditional production systems (TPS) as systems that are characterised by their reliance on traditional knowledge, practices, and techniques that have been passed down through generations. These systems are typically small-scale, labour-intensive, and rely on locally available resources. Organic production systems (OPS) are characterised using organic farming practices, which aim to produce food in a way that is environmentally friendly and sustainable (Jouzi *et al*., 2017). OPS uses natural fertilisation methods, pest and disease control and management, and avoids synthetic chemicals and genetically modified organisms (GMOs) (El-Shafie, 2019). Gould *et al*. (2019) stated that organic production systems use crop rotations, mixed cropping, and other agroecological practices to enhance soil health and maintain biodiversity.

Conventional production systems (CPS), on the other hand, are characterised using inputs such as synthetic fertilisers, pesticides, and genetically modified organisms (GMOs) (Mendoza and Villegas, 2018). Furthermore, CPS often are more profitable but at the cost of the environment and human health (Oladimeji *et al.*, 2020).

According to the author's knowledge, no studies have examined the socioeconomic factors that influence the choice of production system among smallholder farmers in South Africa or studies that have compared the three production systems (organic, conventional, and traditional). Many studies look at individual factors but do not investigate the interplay between them (Ramírez-Rivera *et al.*, 2019), leading to a lack of understanding of how different factors interact and influence the choice of production systems at the farm level. Examining socioeconomic factors influencing production system choices among South African smallholder farmers and conducting comparative studies between different systems is pivotal for policy formulation, resource allocation, sustainability, food security, economic viability, cultural preservation, market access, rural development, and academic progress. These studies can inform holistic approaches to address the country's complex challenges facing smallholder agriculture.

This paper aims to identify and evaluate the socioeconomic factors that determine the choice of production system among smallholder farmers in South Africa, using a multivariate probit model. The study focuses on the farmers' decision to adopt traditional, organic and conventional production systems. The study also looks at the interaction between socioeconomic factors in determining the choice of production system.

3.2 Analytical Framework

As rational economic agents, smallholder farmers are assumed to be utility maximisers (Donkoh *et al.*, 2019). Hence, the decision to use a particular crop production system is made when the perceived utility or net benefit from using the system is significantly greater than would be the case without the system. While utility is not directly observed, households' actions are monitored through their choices. Suppose that $\mathbf{U_j}$ and $\mathbf{U_k}$ represent a household's perceived utility for two options, *j* and *k*, respectively, in the context of smallholder farmers acting as utility maximisers, with the utility determined by the linear random utility model specified in equation 3.1. Suppose also that $\boldsymbol{X_j}$ and $\boldsymbol{X_k}$ are vectors of explanatory variables that influence the perceived desirability of crop *j* and *k*. Following Green (2010), the linear random utility model could be specified as:

$$U_j = \beta' X_j + \varepsilon_j \; and \; U_k = \beta' X_k + \varepsilon_k \qquad (3.1)$$

Where β_j and β_k are parameters to be estimated and ε_j and ε_k are the error terms, assumed to be independently and identically distributed. It follows the perceived utility or benefit for the ith household from option *j* if the household adopts the j option. depicted as:

$$U_{ij}\left(\beta_j' X_i + \varepsilon_j \right) > U_{ik} \left(\beta_k' X_i + \varepsilon_k \right) k \neq j \qquad (3.2)$$

Supposing that Y is the decision to adopt crop production system j where Y takes the value of 1 if adopted and 0 otherwise, the probability that a household will adopt the crop production system of the jth crop conditional on X could then be defined as:

$$\begin{aligned} P(Y = 1|X) &= P\left(U_{ij} > U_{ik}\right) \\ &= P\left(\beta_j' X_j + \varepsilon_j \; - \; \beta_k' X_i + \varepsilon_k \; > 0 \middle| X\right) \\ &= P\left(\beta_j' X_i - \; \beta_k' X_i + \varepsilon_j \; - \varepsilon_k \; > 0 \middle| X\right) \\ &= P(\beta^* X_i - \; \varepsilon^* > 0|X = F\;(\beta^* X_i) \qquad (3.3) \end{aligned}$$

Where P is a probability function, Uij, Uik and Xij are as defined above, $\varepsilon^* = \varepsilon_j - \varepsilon_k$ is a random disturbance term, $\beta^* = (\beta_j' - \beta_k')$ is a vector of unknown parameters which can be interpreted as the net influence of the vector of independent variables influencing the choice of the production system, and $F(\beta^* X_i)$ is the cumulative distribution function of ε^* evaluated at $\beta^* X_i$. F's exact distribution depends on the random disturbance term ε^*distribution.

3.3 Methods and Material

3.3.1 Study Area

In KwaZulu-Natal Province, two rural areas (Swayimana and Umbumbulu) were selected for this study. These two rural areas were chosen because they are typical of KwaZulu-Natal's socioeconomic, biological, and demographic characteristics. Swayimana is at uMgungundlovu District Municipality (UDM) under Mshwati Local Municipality, and Umbumbulu is at eThekwini Metropolitan Municipality.

The uMgungundlovu District Municipality is in the KwaZulu-Natal and comprises seven local municipalities connected to different towns (Mbatha, 2021). This study focused on Swayimana based on its bioresources, socioeconomic, and demographic categories. The region receives an average of 600 to 1200 mm of rain annually, with Swayimana specifically receiving 600 to 1100 mm (Ndlovu *et al.*, 2021). It is considered part of the humid midlands in the mist belt. The average temperature ranges from 11.8°C to 24.0°C, with Swayimana having an average temperature of 17°C. The midlands have dry winters and warm, wet, and cold summers (Ndlovu *et al*., 2021). The soil is a productive type of clay loam.

The Umbumbulu region is part of the eThekwini Metropolitan Municipality in the coastal area of KwaZulu-Natal. The annual rainfall in Umbumbulu is 956 mm (Ngcobo, 2019), which is abundant for agriculture, with most rain falling between November and March. Smallholder farming in the region starts in September or October before the start of the rainy season. The maximum and minimum temperatures in Umbumbulu are 24.0°C and 13.4°C, respectively (Ngcobo, 2019). According to Hawkins *et al*. (2022), 15% of Umbumbulu has a good potential for annual agriculture, while 9% is fertile but less suitable. The climate in Umbumbulu is ideal for a wide range of crops, including taro and sweet potatoes, and farming can be done all year round, with most smallholder agriculture relying on rainfall.

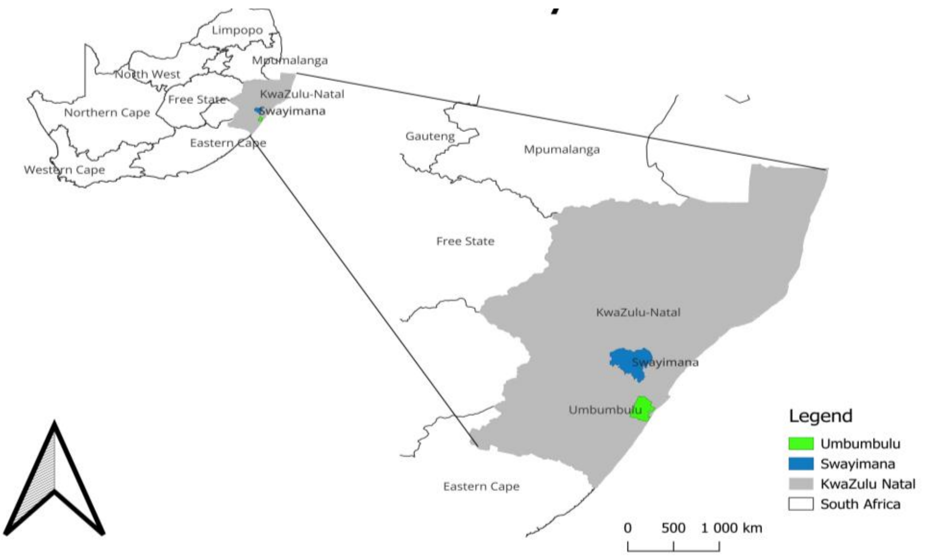

Figure 3.1 : Location of study sites in KwaZulu-Natal province of South Africa.

3.3.2 Data Collection and Sampling

The study used a questionnaire pretested among 30 smallholder farmers in June 2022, carried out by expert enumerators proficient in Zulu. This was to check whether farmers comprehended the questionnaire. Pretesting also ensured that the questionnaire captured all the necessary information and improved its translation into Zulu. The study used a questionnaire pretested among 30 smallholder farmers in June 2022. Pretesting ensured that the questionnaire captured all the necessary information and improved its translation into Zulu.

The list of 1365 households were obtained from the Department of Agriculture KZN, all of whom were engaged in farming underutilised crops in Swayimana and Umbumbula. Using Raosoft's sample size calculator (2004) with a 95% confidence level and a 5% margin of error, a sample size of 300 households was determined for the study. The distribution of this sample across traditional areas was calculated proportionally. Consequently, the sample sizes for Swayimana and Umbumbulu were established at 150 households each. To ensure unbiased representation, the study employed simple random sampling within each traditional area, allowing for a fair and random selection of households.

3.3.3 Empirical Model: Multivariate Probit Model

The multivariate probit econometric method was employed to examine the factors affecting the choice of crop production systems. The multivariate probit models the impact of the set of explanatory variables on each of the crop production systems simultaneously. A multivariate probit model (MVP) is used in this study to assess smallholder farmers' adoption decision behaviour. In the MVP model estimated here, the choice of crop production system corresponds to a binary option (yes/no). The choices are modelled simultaneously while accounting for the correlation among disturbances. Model estimates from the multivariate specification improve over those from univariate specifications when the error correlations significantly differ from zero. Otherwise, the two modelling frameworks would lead to comparable results.
Following Mussida and Zanin (2020), the MVP model used for this study is characterised by a set of n binary dependent variables y (with observation subscripts suppressed), such that:

$$Y^*_{Imi} = x'_m \beta_{im} + \varepsilon_{im}$$

$$y_i \quad = 1\, Y * im > 0\, , and\ 0\ otherwise, \qquad (3.4)$$

ε_{im} ,, $m = 1 \ldots \ldots \ldots M$ *are error* terms distributed as multivariate normal, each with a mean of zero, and variance-covariance matrix V, where V has values of 1 on the leading diagonal and correlations pjk = pkj; as off-diagonal elements. If we assume that ε_{im} , is distributed independently and identically with a univariate normal distribution, equation (3.4) defines M univariate probit models. The assumption of the independence of the error terms means that information about a household's choice of production system does not affect the prediction of the same household's probability of adopting another crop production system. If the unobserved correlations among outcomes are ignored, the whole set of M equations in (3.4) could be estimated separately as univariate probit models. However, neglecting correlations leads to inefficient and biased estimates.

The maximum likelihood estimation maximises the sample likelihood function, which is the product of the probabilities (2) across the sample observations. Calculating the maximum likelihood function using a multivariate normal distribution requires multidimensional integration. Several simulation methods have been proposed to approximate this function, including the Geweke, Hajvassilion, and Keane (GHK) algorithm (Nhemachena *et al.*, 2014). This study follows the GHK simulator approach that uses the STATA routine following Cappellari and Jenkins (2003) to estimate the model as shown in equation 3.5:

$$pr(y_{1,\dots,}y_n|x = \int_{-\infty}^{(2y_i-1)x'\beta_1} \int_{-\infty}^{(2y_i-1)x'\beta_2} \int_{-\infty}^{(2y_i-1)x'\beta_3} \dots . \times$$

$$\int_{-\infty}^{(2y_i-1)x'\beta_n} \phi(\varepsilon_{1,}\varepsilon_{2,}\varepsilon_3, \dots \dots, \varepsilon_n; Z'RZ) d\varepsilon_n \dots \dots d\varepsilon_1\, d\varepsilon_2\, d\varepsilon_3{}' \qquad (3.5)$$

Where $Z = diag\ [2\ y_{1-}1 , \dots \dots ,2\ y_{n-}1\ ]$.

Where x is a vector of explanatory variables, β_n are conformable parameter vectors, and random error terms $\varepsilon_1 , \varepsilon_2 , \varepsilon_3, \dots \dots \dots, \varepsilon_n$ are distributed as a multivariate normal distribution with zero means, unitary variance and a $n \times n$ contemporaneous correlation matrix $R = [\rho_{ij}$, with density $\phi(\varepsilon_{1,}\varepsilon_{2,}\varepsilon_3, \dots \dots, \varepsilon_n; R)$. The likelihood contribution for an observation is the *n*-variate standard average probability.

The marginal effects of explanatory variables on the propensity to adopt each of the different crop production systems are calculated as follows:

$$\partial P_i ./\partial x_i = \emptyset(x'\beta)\beta_i, = 1,2,3, \dots \dots . n \qquad (3.6)$$

Where P_i is the probability (or likelihood) of event i (increased use of each crop production system), $\phi(\cdot)$ is the standard univariate normal cumulative density distribution function, $and\ \beta$ are regressors and model parameters vectors, respectively.

3.3.4 Justification for Inclusion of Hypothesised Independent Variables

Table 3.1 presents the expected sign for each crop production system, measures, and rationale of the independent variable.

Table 3.1 : Summary of variable description and expected sign.

Variables	Measures	H_1	H_2	H_3	Rationale
Traditional (**H_1**)	1 was assigned for farmers who used this system, and 0 otherwise.				This variable indicates whether the household uses traditional crop production methods, such as locally available seeds, manual labour, traditional knowledge, and traditional farming practices.
Organic (**H_2**)	1 was assigned for farmers who used this system, and 0 otherwise.				This variable indicates whether the household uses organic methods for crop production, such as using natural fertilisers, avoiding pesticides and synthetic chemicals, and promoting biodiversity.
Conventional (**H_3**)	1 was assigned for farmers who used this system, and 0 otherwise.				This variable indicates whether the household uses conventional crop production methods, such as synthetic fertilisers, pesticides, and modern technologies.
Independent variables					
Age	The age of the respondent was measured in a number of years.	+	-	+	Age has a positive influence on both traditional and conventional systems. Older farmers are more likely to stick with traditional, conventional farming methods due to their years of experience and resistance to change (Alexopoulos *et al., 2010*). Age is also expected to have a negative impact on organic methods because younger farmers are more open to adopting modern and innovative crop production systems, as they might be more educated and willing to experiment with new technologies and methods (Sapbamrer and Thammachai, 2021).
Household size	Total number of people living in a household	+	+	+	Larger households have more labour resources available, which makes it easier to engage in labour-intensive traditional, organic, and conventional farming methods (Sharmin *et al*., 2012).
Farming Years	Farming experience is measured as the number of farming years (continuous variables)	-	+	+	Farmers with extensive experience are more open to adopting modern and efficient crop production systems, such as conventional and organic systems, as they gain exposure to new technologies and practices, and they are less likely to adopt traditional production systems (Sapbamrer and Thammachai, 2021)
Farm Size	Total land size measured in hectares.	-	+	+	Larger land holdings encourage farmers to adopt modern and mechanised crop production systems to optimise resource use and increase productivity (Sapbamrer and Thammachai, 2021). This indicates that as the total land size in hectares increases, farmers will likely choose organic or conventional crop production systems. Furthermore, farm size is expected to have a negative impact on traditional systems as smaller landholders prefer traditional crop production systems because they lack the resources and capital necessary to invest in modern technologies and large-scale farming (Sapbamrer and Thammachai, 2021)
Extension officer visits	Number of visits of the extension officer to the respondent	+	+	+	More frequent visits by extension officers lead to increased adoption of modern, old, and improved crop production systems as farmers receive more information, training, and support (Kassie *et al.,* 2013)

Farmers' group	0= non-members 1= member of the group	+	+	+	Farmers of groups or cooperatives can access shared knowledge, resources, and collective decision-making processes that promote adopting modern and sustainable crop production systems (Haldar and Damodaran, 2022). Therefore, the expected sign is positive, indicating that farmers' group membership increases the likelihood of choosing modern crop production systems.
Location	0= Umbumbulu 1= Swayimana	±	±	±	The expected sign for the impact of location on the choice of crop production system could be either positive or negative, and it largely depends on the unique socioeconomic, agroecological, and cultural factors specific to Umbumbulu and Swayimana. These factors could influence farmers' preferences, resource access, and adoption of different crop production systems.
Gender	1= male; 0 = female	–	–	–	Female farmers have unique knowledge and skills related to traditional and sustainable farming practices and are more open to community-based and environmentally friendly approaches. Therefore, gender is expected to have a negative impact on all three production systems, implying that female farmers are associated with a higher likelihood of choosing traditional or sustainable crop production systems (Unay-Gailhard and Bojnec, 2021.).
Education	Ordinal variable where 1= No schooling, 2= Primary, 3= Secondary, 4= Tertiary	–	+	+	Higher levels of education give individuals access to modern agricultural knowledge and technologies, making them more likely to adopt advanced and efficient crop production systems (Sapbamrer and Thammachai, 2021). On the other hand, individuals with lower levels of education may rely more on traditional and customary farming practices, which they have learned from their families and communities (Sapbamrer and Thammachai, 2021).
Use of credit	1= if the household head has used credit, and 0= otherwise.	-	+	+	Households with access to credit use it to invest in modern farming technologies, purchase improved seeds, and adopt more efficient crop production systems (Kapoor, 2023).
Access to storage	Do you have access to storage 0= No or 1= otherwise	+	+	+	Households with access to storage facilities are more likely to adopt modern crop production systems that produce larger yields since they can store and manage the harvested crops effectively (Kim *et al*., 2020).

H_1 presents expected signs for a traditional production system.

H_2 presents expected signs for an organic production system.

H_3 presents expected signs for a conventional system.

3.4 Results and Discussions

This section presents the results of various statistical data analyses from 300 participants. These analyses include the chi-square test, used to measure categorical variables; t-test, used to measure continuous variables; and multivariate probit analysis, computed to determine factors affecting the choice of production system.

3.4.1 Descriptive Results

Table 3.2 shows that the chi-square test was performed on household participation and non-participation in different production systems. The results revealed that group membership had a statistically significant difference ($p<0.05$) between TPS participants and non-participants. Approximately 95% of TPS non-participants needed group membership. About 76% of TPS participants did not have group members. Table 3.2 further shows that 10% of household heads who did not have group membership did participate in OPS. Approximately 55% of OPS participants had group membership. Lastly, the results show that 92% of household heads who did not have group membership did not participate in CPS. Approximately 53% of household heads who participated in CPS had group membership. According to Soofizada (2023), households that are part of a group have better access to resources, such as training, funds, or equipment, which make it easier for them to participate in production systems like TPS, OPS, or CPS.

The results revealed that location was statistically significantly different ($p<0.01$) between TPS, OPS, and CPS participants and non-participants. The results indicated that 53% and 47% of TPS participants were from Umbumbulu and Swayimana, respectively. In terms of OPS participants, about 90% were from Umbumbulu, and 10% were from Swayimana. Lastly, 65% of CPS participants were from Umbumbulu, and 35% were from Swayimana. The higher participation rate of Umbumbulu smallholder farmers in each production system could be attributed to Umbumbulu having more favourable geographical conditions, such as better soil quality, climate, or access to water resources, making it more suitable for these production systems (Manqana, 2022).

Results showed a statistically significant difference of 1% between access to storage and participation in the organic production system. Approximately 48 % of OPS non-participants needed access to storage. Results further show that about 69% of OPS participants did have access to storage. The higher participation rate in the organic production system (OPS) among households with access to storage could be influenced by the fact that access to storage facilities allows households to manage their resources, such as harvesting crops. This helps prevent spoilage and loss, making it more feasible to engage in OPS, which often involves organic and perishable products (Chen *et al*., 2022).

Table 3.2 shows that the use of credit plays a vital role in a farmer's decision to participate in OPS and CPS. Use of credit was statistically significant at 1% between OPS and CPS non-participants and participants. Household heads who did not use credit, about 68% were OPS non-participants, and 32% who did not use credit were also non-participants. About 36% of OPS participants subsampled did not use credit, and 64% did use credit. Furthermore, 65% of CPS non-participants did not use credit, and 34% did use credit. About 44% of CPS participants did not use credit, and 56% of participants did use credit. Ijioma and Osondu (2015) stated that using credit provides farmers with the financial resources to invest in their farming operations. This includes purchasing seeds, fertilisers, equipment, and other inputs for organic and conventional farming. Without credit, farmers lack the upfront capital to participate in these systems.

The t-test results in Table 3.3 show that age was statistically significantly different between TPS participants and non-participants ($p<0.10$). The results show that TPS non-participants had an average age of 58 years, and TPS participants had an average of 52 years.

There was a statistically significant difference ($p<0.01$) in farm size of non-participants and participants of OPS and CPS. OPS and CPS non-participants had an average farm size of 0.70 ha, whereas OPS participants had an average farm size of 1.40 ha, and CPS participants had 1.12 ha.

Farming years were statistically significant (p<0.1)) between CPS participants and non-participants. The t-test shows that the average farming years of CPS non-participants was 11 years, and CPS participants were 14 years.

Table 3.2 : Chi-square tests measuring categorical variables.

Variables	Categories	Traditional Production System			Organic Production System			Conventional Production System		
		Non-participants (*n=22*)	Participants (*n=278*)		Non-participants (*n=213*)	Participants (*n=87*)		Non-participants (*n=200*)	Participants (*n=100*)	
		Per cent		X^2	Per cent		X^2	Per cent		X^2
Group membership	0= No	95	76	**	90	45	***	92	47	***
	1= Yes	5	24		10	55		8	53	
Location	0= Umbumbulu	18	53	***	34	90	***	43	65	***
	1= Swayimana	82	47		66	10		57	35	
Gender	0= Female	59	73	n. s	70	77	n. s	72	74	n. s
	1= Male	41	27		30	23		28	26	
Education	1= No schooling	50	45	n. s	47	41	n. s	43	50	n. s
	2= Primary	36	19		19	24		21	19	
	3= Secondary	9	29		28	28		30	24	
	4= Tertiary	5	6		6	7		6	7	
Access to storage	0= No	41	43	n. s	48	31	***	43	43	n. s
	1= Yes	59	57		52	69		57	57	
Use of credit	0= No	59	58	n. s	68	36	***	65	44	***
	1= Yes	41	42		32	64		34	56	

Note: ***, **, * represent significant levels at 1%,5% and 10%, respectively. n.s represent not significant.

Table 3.3 : T-test measuring continuous variables.

Variable	Traditional Production System					Organic Production System					Conventional Production System				
	Non-participants (n=22)		Participants (n=278)			Non-participants (n=213)		participants (n=87)			Non-participants (n=200)		Participants (n=100)		
	Mean	**Std. dev.**	**Mean**	**Std. dev.**	***t-test***	**Mean**	**Std. dev.**	**Mean**	**Std. dev.**	***t-test***	**Mean**	**Std. dev.**	**Mean**	**Std. dev.**	***t-test***
Age	58	11.8	52.219	13.811	*	52.495	14.4	53.115	12.609	**n. s**	52	14.43	53	12.27	**n. s**
Hsize	6	4.6	8	4.167	**n. s**	8	4.48	7.253	3.40	**n. s**	7.6	4.31	7.46	3.978	**n. s**
Farming Years	11	10.29	12.251	10.188	**n. s**	12	9.85	12.322	11.001	**n. s**	11.3	10.30	14	9.79	*
Farm Size	1.3	1.57	0.865	1.439	**n. s**	0.7	1.15	1.400	1.919	***	0.70	1.12	1.285	1.89	***
EXToffVisit	0.81	1.56	0.644	1.266	**n. s**	0.67	1.29	0.632	1.286	**n. s**	0.66	1.24	0.65	1.36	**n. s**

Note: ***, **, * represent significant levels at 1%, 5% and 10%, respectively. n.s presents not significant.

3.4.2 Multivariate Probit Regression Results

The multivariate probit regression model was used to determine characteristics that determine farmers' choice of crop production system. The likelihood ratio test based on the log-likelihood values of the multivariate probit model indicates significant joint correlations wald x^2 (33) = 170.23; χ^2=0.001 justifying estimation of the multivariate probit that considers different crop production system options as opposed to separate univariate probit models and consequently the unsuitability of aggregating them into one or more than one crop production or no crop production. The study used marginal effects rather than coefficients to interpret the magnitude of impact-independent variables.

Group membership was expected to affect all the choices of crop production systems positively, and this hypothesis aligns with the observed positive and statistically significant effects, as shown in Table 3.4. The marginal effect results show that group membership had a positive and statistically significant effect on conventional (p<0.01), traditional (p<0.01), and organic (p<0.05) production systems. Furthermore, the marginal effects results show that a member-to-farmers group results in a 31.9% increase in farmers participating in the traditional production system, a 5.2% increase in the probability of participating in the organic production system and a 51.9% increase in participating in the conventional production system. The results imply that having group membership influences smallholder farmers to participate in each production system. These results can be attributed to the knowledge-sharing dynamics within farmers' groups. Members of farmers' groups often engage in discussions, workshops, and training sessions, where they learn about various production systems. This aligns with the hypothesis that group membership facilitates access to knowledge and information about different crop production methods. The results are aligned with the findings of Singh *et al.* (2017), who stated that farmers' groups frequently provide access to crucial resources such as improved seeds, fertilisers, and machinery.

Table 3.4 : Coefficient estimates and marginal effects results on determinants of farmers' adoption of specific production systems.

Variables	**Traditional**				**Organic**				**Conventional**			
	Coef.	**Std. Err.**	**P>|z|**	**dy/dx**	**Coef.**	**Std. Err.**	**P>|z|**	**dy/dx**	**Coef.**	**Std. Err.**	**P>|z|**	**dy/dx**
Farmers group	0.952	0.232	**0.001*** **	0.319***	0.946	0.556	**0.089***	0.052*	1.434	0.215	**0.000*** **	0.519***
Gender	-1.528	0.238	**0.001*** **	-0.441***	-0.785	0.303	**0.01** **	-0.067**	-0.223	0.185	0.229	-0.071
Location	-0.222	0.218	0.308	-0.058	-0.329	0.251	0.190	-0.034	-0.011	0.183	0.953	-0.022
Age	-0.018	0.010	**0.077***	-0.005*	-0.028	0.011	**0.008*** **	-0.002***	-0.007	0.008	0.388	-0.002
Education	0.010	0.119	0.935	0.001	0.053	0.144	0.715	0.003	-0.025	0.096	0.791	-0.004
Hsize	-0.041	0.025	0.107	-0.012	0.029	0.033	0.384	0.002	-0.018	0.020	0.387	-0.006
Farming years	0.001	0.011	0.943	0.001	0.012	0.013	0.366	0.001	0.015	0.009	**0.097***	0.004*
Farm size	0.168	0.077	**0.029** **	0.047**	-0.165	0.082	**0.044** **	-0.013**	0.080	0.063	0.204	0.034
Storage	0.015	0.210	0.942	0.003	-0.094	0.271	0.729	-0.007	-0.341	0.183	**0.062***	-0.122*
Use of credit	0.519	0.204	**0.011** **	0.149**	-0.290	0.276	0.293	-0.023	0.320	0.180	**0.077***	0.112*
EXToffVisit	0.003	0.078	0.968	-0.001	-0.085	0.089	0.335	-0.008	0.020	0.067	0.761	0.007
_cons	2.179	0.910	**0.017** **		4.244	1.052	**0.001** **		-0.147	0.686	0.830	

Number of obs= 300 Wald $x^2(33)$ = 170.23 Prob $>x^2$=0.000 **Note**: ***, **, * represent significance level at 1%,5% and 10%, respectively**.** dy/dx represent marginal effects.

The initial hypothesis posited a positive relationship between access to storage and conventional production systems. However, the marginal effects results indicate a significant and contrary negative impact at the 10% significance level. Access to storage leads to a statistically significant 11.2% reduction in the likelihood of participating in conventional production systems. The results align with Branca *et al.* (2022), who found that access storage decreases the probability of a farmer using a conventional production system because access to storage gives farmers greater flexibility in timing their crop sales. When storage facilities are available, farmers store their produce and wait for more favourable market conditions or higher prices (Branca *et al.*, 2022).

The results in Table 3.4 show that the relationship between traditional and organic production systems and gender was negative and statistically significant at 1% and 5%, respectively. The marginal effects results indicate that female farmers had a 44.1% increase in the likelihood of adopting TPS and 6.7% increase in using OPS. Per prior expectations, female farmers were more likely to participate in these two production systems than their counterparts. Female farmers face resource constraints, such as limited access to land and capital, which influence their choice of production systems. Traditional farming systems often require fewer external inputs and can be less capital-intensive than modern methods. This aligns with the study conducted by Jew *et al.* (2020), which stated that female farmers are more likely to participate in traditional systems due to resource constraints. Organic production systems are often associated with environmentally friendly and sustainable practices. Culliford and Bradbury (2020) have shown that women tend to have a higher level of environmental concern and are more inclined to adopt organic farming practices that prioritise environmental sustainability and the reduction of chemical inputs.

The hypothesis was that there would be a positive relationship between the age of the household head and participation in the traditional production system and a negative relationship with the organic production system. The results show that the age of the household head had a negative and statistically significant ($p<0.1$) and ($p< 0.01$) for both the traditional and organic production systems, respectively. The results imply that younger farmers were more likely to choose traditional production systems. Being an older farmer resulted in a 0.5% decrease in the probability of adopting TPS and a 0.2% decrease in the probability of adopting OPS. Traditional farming systems often involve diversified crop production, reducing the risk associated with crop failures (Akber *et al.*, 2020). Younger farmers perceive traditional methods as safer for food security and income stability (Akber *et al.,* 2020). Furthermore, younger farmers choose to use an organic production system because it is often perceived as a more sustainable and environmentally friendly approach (Akber *et al.,* 2020). Younger farmers are more likely to be environmentally conscious and to choose organic methods to minimise synthetic pesticides and fertilisers, reduce soil erosion, and promote long-term soil health.

This study found that a unit increase in farmer years of experience increases the probability of smallholder farmers adopting conventional production systems ($p< 0.097$). The marginal effects indicate that an increase in farming years results in a 0.4% increase in the probability of a household head using conventional production system. These findings are supported by Pimentel and Burgess (2014), who stated that farmers with more years of experience are more likely to have the knowledge, skills, financial resources, and networks to participate in conventional production systems effectively. They are more adaptable to new farming techniques and technologies, making conventional farming more appealing.

The initial hypothesis posited that farm size negatively influences traditional production systems while positively impacting organic production systems. Nevertheless, the empirical results show a statistically significant positive impact of farm size on TPS and a negative impact on OPS. An increase in farm size increases the likelihood of a smallholder farmer choosing the traditional production system by 4.7%, as indicated by marginal effects; this is due to more land available for traditional farming methods. The findings of this study contrast with those of Ladvenicová and Miklovičová (2015), who found a negative impact of farm size on output per hectare. Moreover, there is a 1.3% decrease in the likelihood of organic farming adoption among farmers with larger farms. The study's outcome is consistent with the research conducted by Ume *et al*. (2023), which also found that a farmer's farm size significantly influences the amount of land devoted to organic farming. This implies that farmers who possess their land and, therefore have authority over it may find it simpler to make the crucial decision to transition from one production system to another.

Credit use had a positive and statistically significant (p<0,05) impact on smallholder farmers choosing the traditional production system. Access to credit resulted in a 14.9% increase in the likelihood of TPS and CPS adoption. Credit allows farmers to invest in preserving traditional farming practices, such as seed saving and crop rotation, making them more likely to participate in a traditional production system. Credit allows farmers to access traditional inputs, such as non-hybrid seeds and natural fertilisers, making them more likely to participate in a traditional production system (Urago and Bozoğlu, 2021).

Credit use was positively and statistically significant at a 10% level with the conventional production system. Farmers with access to credit were likely to participate in a conventional production system by 11.2% because it allows them to invest in expensive agricultural inputs and technologies needed for conventional farming. Altieri *et al.* (2012) found that household finances positively influenced conventional farming practices. Farmers with access to credit can invest in technical assistance and training, making them more capable of using conventional inputs and technologies effectively and efficiently.

3.5 Conclusions and Recommendations

The study utilised a multivariate probit regression model to explore the factors influencing smallholder farmers' choice of crop production systems. The findings revealed significant relationships between variables and the likelihood of adopting specific systems. Farmers' group membership positively influenced their participation in all crop production systems. At the same time, gender played a role in traditional and organic farming choices, with female farmers being more likely to engage in these systems. The age of the household head negatively affected the adoption of traditional and organic farming, possibly due to physical limitations and risk aversion. Access to storage impacted participation in conventional production systems, highlighting the importance of storage facilities for farmers. Farmer experience positively influenced the likelihood of adopting conventional production systems, indicating that knowledge and resources gained through years of farming can influence crop choices. Farm size positively impacted organic and traditional production systems, while credit use was positively associated with traditional and conventional farming practices. These results offer valuable insights for policymakers and stakeholders seeking to support and promote sustainable and diverse crop production systems among smallholder farmers.

Based on the results and discussions, several recommendations can be made to support smallholder farmers' crop production choices. Firstly, promoting and facilitating farmers' group membership could enhance their access to resources, information, and market opportunities, ultimately increasing their likelihood of participating in various crop production systems. Secondly, special programs and initiatives targeted at female farmers could be designed to improve their access to resources and training in sustainable and organic farming, thereby encouraging their greater involvement in these production systems. Furthermore, providing smallholder farmers better access to storage facilities could mitigate post-harvest losses and financial risks, positively impacting their participation in conventional production systems. Lastly, offering credit facilities to farmers could enable them to invest in traditional inputs, technologies, and technical assistance, enhancing their capability to adapt and succeed in their preferred production.

References

Akber, M.A., Islam, M.A., Rahman, M.M., and Rahman, M.R., 2022. Crop diversification in southwest coastal Bangladesh: insights into farming adaptation. *Agroecology and Sustainable Food Systems*, 46(2), pp.316-324.

Alexopoulos, G., Koutsouris, A. and Tzouramani, I., 2010, July. Should I stay or should I go? Factors affecting farmers' decision to convert to organic farming as well as to abandon it. In *9th European IFSA Symposium, Vienna (Austria)* (pp. 1083-1093).

Altieri, M.A., Farrell, J.G., Hecht, S.B., Liebman, M., Magdoff, F., Murphy, B., Norgaard, R.B. and Sikor, T.O., 2018. Traditional Agriculture. *Agroecology*, pp. 107-144). CRC Press.

Altieri, M.A., Funes-Monzote, F.R. and Petersen, P., 2012. Agroecological efficient agricultural systems for smallholder farmers: contributions to food sovereignty. *Agronomy for sustainable development*, 32, pp.1-13.

Bello, N.I., Abubakar, A.S., Adamu, H. and Auwal, A.H., 2022. Systematic Review of Global Challenges of Sustainable Development. *International Journal of Environmental Pollution and Environmental Modelling*, *5*(1), pp.51-62.

Bisht, I.S., Mehta, P.S., Negi, K.S., Verma, S.K., Tyagi, R.K. and Garkoti, S.C., 2018. Farmers' rights, local food systems, and sustainable household dietary diversification: A case of Uttarakhand Himalaya in north-western India. *Agroecology and sustainable food systems*, 42(1), pp.77-113.

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

Chen, S., Brahma, S., Mackay, J., Cao, C. and Aliakbarian, B., 2020. The role of smart packaging systems in the food supply chain. *Journal of Food Science*, 85(3), pp.517-525.

Culliford, A. and Bradbury, J., 2020. A cross-sectional survey of the readiness of consumers to adopt an environmentally sustainable diet. *Nutrition Journal*, 19, pp.1-13.

Deb, D., Mandal, S., Deb, S., Choudhury, A. and Hembram, S., 2021. Crop Production Estimation Using Remote Sensing. *Geospatial Technologies for Crops and Soils*, pp.229-243.

Donkoh, S.A., Azumah, S.B. and Awuni, J.A., 2019. Adoption of improved agricultural technologies among rice farmers in Ghana: A multivariate probit approach. *Ghana Journal of Development Studies*, 16(1), pp.46-67.

El-Shafie, H.A.F., 2019. Insect pest management in organic farming system. Multifunctionality and impacts of organic and conventional agriculture, pp.1-20.

Fróna, D., Szenderák, J. and Harangi-Rákos, M., 2019. The challenge of feeding the world. *Sustainability*, 11(20), p.5816.

Gould, D., Compagnoni, A. and Lembo, G., 2019. Organic aquaculture: Principles, standards, and certification. Organic aquaculture: Impacts and future developments, pp.1-22.

Greene, W.H. and Hensher, D.A., 2010. Modelling ordered choices: A primer. Cambridge University Press.

Haldar, T. and Damodaran, A., 2022. Can cooperatives influence farmer’s decision to adopt organic farming? Agri-decision-making under price volatility. *Environment, Development and Sustainability*, *24*(4), pp.5718-5742.

Hawkins, P., Geza, W., Mabhaudhi, T., Sutherland, C., Queenan, K., Dangour, A. and Scheelbeek, P., 2022. Dietary and agricultural adaptations to drought among smallholder farmers in South Africa: a qualitative study. *Weather and Climate Extremes*, *35*, p.100413.

Ijioma, J.C. and Osondu, C.K., 2015. Agricultural credit sources and determinants of credit acquisition by farmers in Idemili Local Government Area of Anambra State. *Journal of Agricultural Science and Technology B*, 5(1), pp.34-43.

Jew, E.K., Whitfield, S., Dougill, A.J., Mkwambisi, D.D. and Steward, P., 2020. Farming systems and conservation agriculture: Technology, structures, and agency in Malawi. *Land Use Policy*, *95*, pp.104612.

Jouzi, Z., Azadi, H., Taheri, F., Zarafshani, K., Gebrehiwot, K., Van Passel, S. and Lebailly, P., 2017. Organic farming and small-scale farmers: Main opportunities and challenges. *Ecological Economics*, 132, pp.144-154

Kapoor, A., 2023. How just is the transition to organic farming from a gender lens?. *Just Transitions* (pp. 99-121). Routledge.

Kassie, M., Jaleta, M., Shiferaw, B., Mmbando, F. and Mekuria, M., 2013. Adoption of interrelated sustainable agricultural practices in smallholder systems: Evidence from rural Tanzania. *Technological forecasting and social change*, *80*(3), pp.525-540.

Kim, H.J., Kim, H.J., Jeon, J., Nam, K.C., Shim, K.S., Jung, J.H., Kim, K.S., Choi, Y., Kim, S.H. and Jang, A., 2020. Comparison of the quality characteristics of chicken breast meat from conventional and animal welfare farms under refrigerated storage. *Poultry Science*, *99*(3), pp.1788-1796.

Kopittke, P.M., Menzies, N.W., Wang, P., McKenna, B.A. and Lombi, E., 2019. Soil and the intensification of agriculture for global food security. *Environment International*, 132, pp.105078.

Ladvenicová, J. and Miklovičová, S., 2015. The relationship between farm size and productivity in Slovakia. *Visegrad Journal on Bioeconomy and Sustainable Development*, 4(2), pp.46-50.

Manqana, L., 2022. Farm typology and spatial variability of selected soil fertility parameters on selected small-holder farms in KwaZulu-Natal province, South Africa (Doctoral dissertation).

Mbatha, N.S.C., 2021. Trends and challenges of food security policy implementation: a case study of uMgungundlovu District Municipality (Doctoral dissertation).

Mendoza, T.C. and Villegas, P.M., 2018.PROMOTING THE ADOPTION OF GREEN. approaches to organic rice-based production, pp.1.

Mussida, C. and Zanin, L., 2020. Determinants of the choice of job search channels by the unemployed using a multivariate probit model. Social Indicators Research, 152(1), pp.369-420.

Ndlovu, P.N., Thamaga-Chitja, J.M. and Ojo, T.O., 2022. Impact of value chain participation on household food insecurity among smallholder vegetable farmers in Swayimana KwaZulu-Natal. *Scientific African*, 16, pp.e01168.

Ngcobo, G.N., 2019. Assessment of the constraints limiting the market participation of smallholder farmers in the Umbumbulu area of KwaZulu-Natal Province (Doctoral dissertation).

Nhemachena, C., Hassan, R. and Chakwizira, J., 2014. Analysis of determinants of farm-level adaptation measures to climate change in Southern Africa. *Journal of Development and Agricultural Economics*, 6(5), pp.232-241.

Oladele, O.I. and Tekena, S.S., 2010. Factors influencing agricultural extension officers' knowledge on practice and marketing of organic agriculture in North West Province, South Africa. *Life Science Journal*, 7(3), pp.91-98.

Oladimeji, S.A., Okomoda, V.T., Olufeagba, S.O., Solomon, S.G., Abol-Munafi, A.B., Alabi, K.I., Ikhwanuddin, M., Martins, C.O., Umaru, J. and Hassan, A., 2020. Aquaponics production of catfish and pumpkin: Comparison with conventional production systems. *Food Science and Nutrition*, 8(5), pp.2307-2315.

Pimentel, D. and Burgess, M., 2014. An environmental, energetic, and economic comparison of organic and conventional farming systems. Integrated Pest Management: Pesticide Problems, 3, pp.141-166.

Ramírez-Rivera, E.J., Rodríguez-Miranda, J., Huerta-Mora, I.R., Cárdenas-Cágal, A. and Juárez-Barrientos, J.M., 2019. Tropical milk production systems and milk quality: a review. Tropical animal health and production, 51(6), pp.1295-1305.

Sapbamrer, R. and Thammachai, A., 2021. A systematic review of factors influencing farmers' adoption of organic farming. *Sustainability*, *13*(7), pp.3842.

Sharmin, S., Islam, M.S. and Hasan, M.K., 2012. Socioeconomic analysis of alternative farming systems in improving livelihood security of small farmers in selected areas of Bangladesh. *The Agriculturists*, *10*(1), pp.51-63.

Singh, M., Maharjan, K.L., Singh, M., and Maharjan, K.L., 2017. Crop diversification under organic and conventional farming systems. Sustainability of organic farming in Nepal, pp.103-112.

Soofizada, Q., 2023. Evaluation of the effects of nutrient management on grain yield, quality, and rheological properties of common wheat varieties (Triticum aestivum L.

Ulian, T., Diazgranados, M., Pironon, S., Padulosi, S., Liu, U., Davies, L., Howes, M.J.R., Borrell, J.S., Ondo, I., Pérez-Escobar, O.A. and Sharrock, S., 2020. Unlocking plant resources to support food security and promote sustainable agriculture. *Plants, People, Planet*, 2(5), pp.421-445.

UME, C., Okpukpara, B., Chukwuma Ume, N., Ukwuaba, I., Omeje, E., Chiemela, C. and Ibe, C.J., 2023. Factors Influencing Smallholder Adoption of Organic Agriculture in Southeast Geopolitical Region of Nigeria. *Frontiers in Sustainable Food Systems*, 7, pp.1173043.

Unay-Gailhard, I. and Bojnec, Š., 2021. Gender and the environmental concerns of young farmers: Do young women farmers make a difference on family farms?. *Journal of Rural Studies*, *88*, pp.71-82.

Urago, G.G. and Bozoğlu, M., 2021. Literature Review on Farmers' Agricultural Credit Access in Ethiopia. *Anadolu Tarım Bilimleri Dergisi*, 37(2), pp.301-316.

Vågsholm, I., Arzoomand, N.S. and Boqvist, S., 2020. Food security, safety, and sustainability—getting the trade-offs right. *Frontiers in Sustainable Food Systems*, 4, pp.16.

Chapter 4: Factors Affecting the Decision of a Smallholder Farmer to Consume Underutilised Crops in South Africa: A Study of Swayimana and Umbumbulu Local Communities

Abstract

Underutilised crops, also known as neglected or orphan crops, have the potential to play a significant role in addressing food security, nutrition, and rural development challenges in developing countries such as South Africa. However, their consumption remains low. This research paper investigated the factors affecting the consumption of underutilised crops in South Africa. Data collected from 300 participants using a questionnaire was analysed using factor analysis and a binary logistic regression model. Factor analysis identified four patterns of farmers' attitudes and perceptions of underutilised crops, which were perception of production, taste, awareness, and availability. The binary logistic regression results show that perception of production and awareness of underutilised crops, membership in farmers group, willingness to buy underutilised crops, and gender of the household head and off-farm income had a negative impact on consumption of underutilised crops. On the other hand, government grants, perception of taste, household size, education level of a household head, and marital status had a positive impact on the decision to consume underutilised crops. The study recommended that efforts should be directed towards enhancing awareness, improving access to off-farm income opportunities, and fostering positive perceptions of underutilised crops to encourage their consumption in South Africa.

Keywords: Consumption, underutilised crops, binary logistic analysis, Factor Analysis

4.1 Introduction

The Green Revolution prioritised enhancing the yields of staple crops (such as maize, rice, and wheat) while neglecting the nutrient-rich. These underutilised crops could be produced in more environmentally friendly ways (Sobratee *et al*., 2022). Underutilised crops, also known as neglected and orphan species, such as sweet potatoes and taro roots, represent non-commodity wild or cultivated plant species that were once popular but have since been neglected by mainstream agriculture (Ismail *et al*., 2023; Mabhaudhi *et al*., 2016). Agronomic, genetic, economic, social, and cultural reasons have contributed to the neglect of these crops (Mabhaudhi *et al*., 2016). These crops are primarily cultivated on farms in resource-poor countries, where smallholder farmers play a pivotal role in their production. They utilise the seeds on small landholdings, often located in specific agroecological regions to supply their families with high-nutritional-value food (Sobratee *et al*., 2022). Underutilised crops have provided income for resource-poor farmers (Sobratee *et al*., 2022).

In response to the underutilisation of these crops, the African Orphan Crops Consortium is focusing on genetic enhancement of underutilised crops to improve their resilience and quality in the face of climate change, with the aim of diversifying agricultural output and consumption (Ismail *et al*., 2023). Various factors, such as the influence of multinational food corporations, government subsidy patterns, and low investments in underutilised crop breeding programs, have contributed to the shift towards consuming more staple crops (Revoredo-Giha *et al*., 2022).

Revoredo-Giha *et al*. (2022) stated that while interventions in production are essential, addressing the demand side through promoting the consumption of underutilised crops and goods derived from them is crucial. It not only ensures returns for producers but also serves as a strategy to combat poverty and promote healthier eating habits in the face of the growing consumption of processed foods.

Underutilised crops, often marginalised by mainstream agriculture, hold significant importance for smallholder farmers in resource-poor countries, serving as a source of high-nutritional-value food and income (Sobratee *et al*., 2022). Despite their potential benefits in improving human nutrition, income generation, and preserving cultural diversity, these crops have been largely neglected and overlooked in favour of more popular staples such as rice, wheat, and maize (Burchi *et al*., 2011).

This has led to a limited focus on the cultivation, research, and development of underutilised crops, highlighting the need for increased attention to their potential benefits for food security and rural development in regions like South Africa (Mabhaudhi *et al*., 2016). While some studies have looked at the health benefits of these crops, only some have explored the socio-cultural and economic factors influencing their consumption (Omotayo *et al*., 2018; Mbosso *et al*., 2020). Furthermore, the lack of research on the socio-cultural and economic factors influencing the consumption of underutilised crops, especially in specific regions like KwaZulu-Natal, underscores the necessity of understanding these factors for effective policy design (Omotayo *et al*., 2018). This study investigated the factors influencing smallholder farmers' decisions to consume underutilised crops, focusing on taro roots and sweet potatoes, in the communities of KwaZulu-Natal, South Africa.

4.2 Analytical Framework

The study used a random utility theory. At the household level, the decision to consume underutilised crops is based on the random utility framework (McFadden, 2012). The random utility theory assumes that a farmer, as a utility maximiser, would consume if the expected utility from consumption of underutilised crops ($U_i\ M$) is greater than when they do not consume ($Ui\ N$). That is, a farmer chooses to consume underutilised crops if the net utility, U_i*, i.e., ($U_i\ M- U_i\ N$) is greater than zero. The unobserved net utility can be expressed as a function of observable elements in the following latent variable model:

$$U_i^* = \alpha xi + \varepsilon_i,\ U_i = 1 \text{ if } U_i^* > 0 \qquad (4.1)$$

Where Ui is a dummy variable that equals 1 for smallholder farmers i in case of consumption and 0; otherwise, α is a vector of parameters to be estimated, x_i is a vector of household and farmer characteristics, and ε_i is an error term.

4.3 Research Methodology

4.3.1 Study Area, Sampling and Data Collection

The study site, sampling and data collection procedure are described in sections 3.3.1 and 3.3.2.

4.3.2 Statistical Analyses

Table 4.2 and Table 4.3 shows the descriptive statistics of continuous and categorical variables used in the study. Table 4.2 presents the results from continuous variables, while Table 4.3 presents the results from categorical variables. A T-test was done for the continuous variables, and a chi-square test was done for the categorical variables; these two tests were used to test whether the consumers and non-consumers of underutilised crops are statistically different from each other.

4.3.3 Factor Analysis

The first research question explores farmers' attitudes and perceptions towards underutilised crops. To address this question, Factor Analysis (FA) was utilised to reduce the 24 scaled attitudes and perceptions questions (see Appendix 4 Questions 40, 41,42, and 43). As a data reduction technique, FA groups together variables that are correlated into factors and simplifies analysis (Kline, 2014). To check for validity, the Kaiser-Meyer-Olkin (KMO) was computed, and for reliability, the study used Cronbach's Alpha. These 24 survey questions assessed farmer attitudes and perceptions towards underutilised crops and evaluated their preferences towards underutilised crops using a standard scaling approach.

Variables with eigenvalue loading less than 1 were dropped as factors with high eigenvalue loading (> 1) of items show convergent validity (Shrestha, 2021). Variables with KMO greater than or equal to 0.5 were considered high and acceptable (Napitupulu *et al*., 2017). This was followed by a reliability analysis based on Cronbach's alpha coefficients. According to Rauf *et al*. (2020) Cronbach's rule of thumb, any alpha coefficient that is larger than or equal to 0.6 is considered acceptable. The factor scores generated from the FA were then used in the binary logistic analysis as explanatory variables.

4.3.4 Empirical Model: Binary Logistic Regression Model

The study applied a binary logistic regression model to analyse the factors influencing the consumption of underutilised crops. The model was adapted from similar studies; for example (Omotayo and Aremu, 2020; Mutwedu *et al*., 2022). The binary model is motivated by the fact that when faced with a decision regarding consumption, a farmer either consumes or does not consume (Omotayo and Aremu, 2020). The logistic regression model was chosen because the literature shows that it can analyse farmer consumption decisions (Omotayo and Aremu, 2020; Mutwedu *et al*., 2022). The dependent variable for this study was the farmer being a consumer or non-consumer of underutilised crops with a value of 1 (if the farmer consumed underutilised crops) and 0 (otherwise). The likelihood of the farmer consuming underutilised crops is predicted odds $(Y = 1)$, that is, the ratio of the probability that $(Y = 1)$ to the probability that $Y \neq 1$:

$$\text{Odd Y} = \frac{P\,(Y=1)}{(1-P(Y=1))} \qquad (4.2)$$

The binary logistic regression model is specified as follows (Equation (4.3)): The logit (Y) is given by the natural log of Odds.

$$\text{In}\left(\frac{P\,(Y=1)}{(1-P(Y=1))}\right) = \log \text{Odds} = \text{Logit}(Y) \qquad (4.3)$$

This can be expanded as:

$$\text{Logit}(Y) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots. + \beta_n X_n + \varepsilon_i \qquad (4.4)$$

where Y = dependent variable (consumption) with 1 = consumer and 0 = otherwise; α = intercept, $,\ldots.,\beta_n =$ coefficients of the independent variables, $\ldots,X_n =$ the independent variables; $(p) =$ probability of farmer consuming underutilised crops; 1 - P =probability that a farmer does not consume underutilised crops; and ln = natural log.

With the independent variables of this model (X1 = Education, X2 = Household size, and so on, refer to Table 4.1), logistic regression for 'CONSUMPTION' in the study is expressed in the following form:

$$\log it(\text{consumption}) = \ln\left(\frac{P}{1-P}\right) = \alpha + \beta_1 + \cdots \beta_2 \ldots \qquad (4.5)$$

The criterion used to assess the overall significance of the binary logit model was the log-likelihood ratio following (Purhadi and Fathurahman, 2021).

4.4 Justification for Inclusion of Hypothesised Independent Variables

The independent variables used in the binary logistic model were obtained from literature, and the model indicated the significance of these variables in the consumption of underutilised crops, as presented in Table 4.1. Table 4.1 shows the independent (explanatory) variables, their measurements, and the expected outcome in relation to the dependent variable.

Education: The household head's educational level influences a farmer's knowledge and awareness of underutilised crops. Farmers with higher education levels are more likely to understand the nutritional benefits and potential market opportunities associated with these crops, thus impacting their decision to consume them (Brouwer, 2021).

Household size: The size of the household affects the demand for food and the need for diverse crop options. Larger households have greater dietary requirements and are more inclined to consume underutilised crops to achieve a balanced and varied diet (Gido *et al.*, 2017).

Marital status: Marital status is indicative of household dynamics, division of labour, and decision-making processes related to food consumption. It influences the availability and consumption patterns of underutilised crops within the household (Zulu *et al.*, 2022).

Access to credit: Access to credit facilitates investments in agricultural inputs, including the cultivation and consumption of underutilised crops. Farmers with better access to credit are more likely to invest in these crops, as they can afford the necessary resources for their production and are more likely to consume them (Mango *et al.*, 2018).

Government Grant: The availability of government grants targeted towards promoting underutilised crops incentivises farmers to engage in their production and consumption (Zulu *et al.*, 2022).

Gender: Gender plays a significant role in shaping farmers' behaviour, roles, and responsibilities within agricultural households. Female-headed households are more likely to consume underutilised crops (Zulu *et al.*, 2022).

Willingness to buy underutilised crops: This variable reflects the farmer's willingness to purchase and consume underutilised crops. Farmers with a positive inclination towards buying such crops are more likely to incorporate them into their consumption patterns (Sinyolo *et al.*, 2014).

Off-farm income: Off-farm income sources have an impact on a farmer's purchasing power and ability to afford a diverse range of food, including underutilised crops. Farmers with higher off-farm incomes are more open to purchasing and consuming these crops (Zulu *et al.*, 2022).
Extension office visit: Interaction with extension offices or agricultural extension services provides farmers with information and knowledge about underutilised crops. Such visits influence farmers' understanding and perception of the benefits associated with consuming these crops (William *et al.*, 2016).

Farmers group membership and training: Membership provides farmers with access to markets, knowledge sharing, and collective decision-making processes. Cooperative involvement introduces farmers to underutilised crops and encourages their consumption (Jenkins *et al*., 2018). Participating in agricultural training programs that focus on underutilised crops enhances farmers' knowledge, skills, and awareness, potentially influencing their decision to consume these crops.

Consumer perception variables: Farmers' decisions to consume underutilised crops are influenced by factors like production feasibility, taste preferences, awareness of nutritional benefits, and the availability of these crops in the market. The ease of cultivation, yield, and taste appeal contribute to shaping farmers' preferences in incorporating underutilised crops into their agricultural practices and diets (Gido *et al*., 2017).

Table 4.1: Independent variables

Variables	**Measurements**	**Expected Signs**
Education	1=No school, 2= Primary, 3= Secondary, 4= Tertiary	+
Household size	Continuous	+
Marital status	0= not married, 1= Married	-
Access to credit	0=No, 1= Yes	+
Government Grant	0=No, 1= Yes	+
Gender	0=No, 1= Yes	+
Willingness to buy underutilised crops.	0=No,1= Yes	+
Off-farm income	Continuous	-
Extension office visit	Continuous	±
Training	0=No, 1= Yes	+
Farmers group membership	0=No, 1= Yes	+
Perception on production	Factor score	+
Perception on taste	Factor score	+
Perception on awareness	Factor score	+
Perception on availability	Factor score	+

4.5 Results and Discussions

This section presents descriptive and empirical model results. Table 4.2 shows t-test results for continuous variables, Table 4.3 presents the Chi-square test of categorical variables, and Table 4.4 shows results from factor analysis. Lastly, Table 4.5 presents logistic regression analysis, marginal effects and VIF results.

4.5.1 Socio-Demographic Characteristics

The data collected from 300 smallholder farmers were analysed to portray the relevant demographic, social, economic, and asset endowment features of smallholder farmers. The data collected comprises of 89% underutilised crop consumers and 11% non-consumers, indicating that most smallholder farmers in rural areas consume underutilised crops such as taro roots and sweet potatoes. Descriptive analyses of both continuous (Table 4.2) and categorical variables (Table 4.3) indicated significant differences between the farmers who consume underutilised crops and those who do not.

The t-test found household size (Hsize) to be statistically different between the two sub-samples. Non-consumers had a mean of seven household members, and consumers had nine household members, supporting that households with slightly more people are more likely to consume underutilised crops, as indicated in Table 4.2.

Table 4.2: t-test results for continuous variables among non-consumers and consumers

Variables	**Non-Consumers (*n*=33) 11%**		**Consumers (*n*=267) 89%**		
	Mean	Std. Dev	Mean	Std. Dev	**t-test**
Household size	7.419	4.2	9.1	3.8	**
Off-farm Income (ZAR)	2095	1443.9	3056.1	7097.8	n. s

Note: *, **, ***, means the coefficient is statistically significant at 10%, 5% and 1% levels, n.s means not significant.

The chi-square test was computed for categorical variables, as shown in Table 4.3. Table 4.3 shows a statistical relationship at 1% between marital status and the consumption of underutilised crops among farmers. Among non-consumers, 4% were identified as unmarried, indicating that 96% of unmarried farmers consume underutilised crops. Within the same group, 22% of married farmers were categorised as non-consumers, implying that a significant proportion (78%) of married individuals did consume underutilised crops. According to Malkanthi and Silva (2014), married individuals have shared responsibilities within their households, leading to a greater emphasis on nutrition and the inclusion of diverse food sources in their diets.

Table 4.3: Chi-square test of categorical variables

Variables	Categories	Non-Consumers	Consumers	P-value
		%		
Marital status	0=not married (*n*=183)	4	96	***
	1= Married (*n*=117)	22	78	
Education	1=No school (*n*=137)	9	91	*
	2= Primary (*n*=62)	8	92	
	3= Secondary (*n*=83)	13	87	
	4= Tertiary (*n*=18)	28	72	
Access to credit	0=No (*n*=249)	11	89	n. s
	1= Yes (*n*=51)	12	88	
Government Grant	0=No (*n*=82)	7	93	n. s
	1= Yes (*n*=218)	12	88	
Gender	0=Female (*n*=115)	15	85	*
	1= Male (*n*= 185)	9	91	
Willingness To buy.	0=No (*n*=150)	20	80	***
	1= Yes (*n*=150)	2	98	
Extension office visit	0=No (*n*=119)	13	87	n. s
	1= Yes (*n*=181)	10	90	
Training	0=No (*n*=145)	10	90	n. s
	1= Yes (*n*=155)	12	88	
Farmers group membership	0=No (*n*=231)	13	87	**
	1= Yes (*n*=69)	4	96	

Note: *, **, ***, means the coefficient is statistically significant at 10%, 5% and 1% levels, n.s means not significant.

The results indicate that there is a 10% statistical difference in terms of educational attainment among both non-consumers and consumers of underutilised crops. Among non-consumers, 9% reported having no schooling, whereas the vast majority (91%) of consumers also fell into this category. Similarly, 8% of non-consumers had primary education, and a corresponding 92% of consumers shared this educational background. Furthermore, 13% of non-consumers had completed secondary education, and about 87% of consumers had attained a similar level of education. Finally, 28% of non-consumers reported having tertiary education, while 72% of consumers also had tertiary educational levels.

There is a significant association between gender and the decision to consume underutilised crops, with a p-value of 0.1. Among female farmers, approximately 15% were classified as non-consumers of underutilised crops, while the majority, 85%, were consumers of these crops. On the other hand, among male farmers, the percentage of non-consumers was lower, with 9% falling into this category. The majority of male farmers, 91%, were consumers of underutilised crops.

The results indicate an association between farmer' willingness to buy underutilised crops and their decision to consume these crops, as indicated by a p-value of 0.001. Among farmers who expressed a lack of willingness to buy underutilised crops (20%) did not consume them, and a significant majority (80%) still reported consuming these crops even though they were not willing to buy them. Farmers indicated they were not willing to buy underutilised crops because they were already growing these crops themselves, which made them readily available for consumption. It implies that self-production played a significant role in their consumption behaviour. Conversely, among farmers who expressed a willingness to buy underutilised crops, a small proportion (2%) reported not consuming these crops. This indicates that despite their willingness to purchase, some farmers needed to follow through with the actual consumption of underutilised crops. However, the majority (98%) of those who expressed a willingness to buy underutilised crops did consume them. This high level of actual consumption aligns with their intention to purchase, suggesting a strong relationship between willingness to buy and consumption behaviour.

The results indicate a significant association between farmers' group membership and the decision to consume underutilised crops, as indicated by the p-value of 0.05. Among non-farmers group members, approximately 13% did not consume underutilised crops, while a significant majority of 87% did consume these crops. Among farmers group members, only a small percentage of 4% did not consume underutilised crops, while the vast majority of 96% did consume them. Farmers indicated that farmers' groups provide valuable support, knowledge-sharing, and resources that encourage them to engage in the consumption of underutilised crops.

4.5.2 Factor Analysis of Attitude and Perception Variables

Before conducting the Factor Analysis (FA), the suitability of the model was tested by applying Kaiser-Meyer-Olkin (KMO) and Bartlett's test of Sphericity for the different sub-dimensions of empowerment. The Kaiser Meyer Olkin (KMO) test was about 76.6%, which indicated that the Factor Analysis was appropriate for the analysis. Bartlett's test of Sphericity was significant at 1% (p-value (0.000), X^2= 2672.72). Therefore, the FA was appropriate for measuring attitudes and perceptions. The application of the FA to the attitudes and perceptions dimension variables produced results that had eigenvalues greater than 1 using the Kaiser Criterion test.

FA variables that were retained and used in the binary logistic model are as follows:_factor1 was named consumer perception on production which is made up of 12 variables (eigenvalue is 5.4407 and proportion is 22.67%); factor2 was named consumer perception on taste (eigenvalue= 3.04751 proportion= 12.70%), which is made up of six variables; factor3 was named consumer perception on awareness which is made up of four variables eigenvalue = 1.80611 proportion =7.53%). Lastly, factor 4 was named consumer perception on availability, which is made up of three variables (eigenvalue =1.47324 proportion =6.14%) as presented in Table 4.4.

Table 4.4: Factor Analysis of attitudes and perception of underutilised crops.

Variables	**Perception on production**	**Perception on taste**	**Perception on awareness**	**Perception on availability**
Tartness (sourness)	-0.0664	0.0906	-0.2885	-0.0372
Flavour intensity	0.2641	**0.5666**	0.0875	-0.0781
Sweetness	0.3808	**0.7147**	0.1443	-0.0738
Texture	0.257	**0.6868**	0.1934	0.0883
Aroma	0.3202	**0.7946**	0.1862	0.0169
Nutritional value	0.2531	**0.5306**	0.0349	0.2849
Understanding of cultivation	0.2307	-0.0556	0.2657	0.0046
Familiarity with preparation	0.1985	**0.5998**	0.0058	0.0025
Quality of the product	**0.5828**	-0.2364	0.2419	-0.2886
Market demand	0.3342	0.1466	-0.1778	-0.0318
Reliability of the production process	**0.6483**	-0.2141	0.0603	0.0700
Responsiveness to customer needs	**0.6249**	-0.0950	-0.0902	0.0784
Transparency in production methods	**0.6815**	-0.1786	-0.1188	0.1818
Safety and hygiene standards during production	**0.5816**	-0.0924	**0.4343**	0.1629
Value for money in relation to the product's price	**0.6579**	-0.0926	**0.4149**	0.1772
Distribution channel	**0.6140**	0.0251	-0.3836	0.2262
Ethical practices in the production	**0.6538**	-0.1343	-0.2527	0.0868
Access to storage	**0.5314**	-0.0112	-0.1508	-0.1125
Access to transportation	**0.5991**	-0.1341	0.1329	**0.4754**
Environmental sustainability practices	**0.5984**	-0.1624	0.1868	**0..4868**
Availability in Season	0.2189	-0.2460	0.3678	**0.6591**
Availability of Information	0.359	-0.2637	**0.5682**	0.3134
Price stability	0.3028	-0.2587	**0.5438**	0.1634
Ease of accessibility	**0.5712**	-0.1364	0.1833	-0.3016
Eigenvalue	5.4407	3.04751	1.80611	1.47324
Proportion	22.67%	12.70%	7.53%	6.14%
Cumulative	22.67%	35.37%	42.89%	49.03%
KMO	0.766			
Alpha	0.8294			

Barlett's test of sphericity: Chi-square =2672.72, Degree of freedom=276, p-value=0.001

4.5.3 Binary Logistic Results

Table 4.5 provides a parameter estimate for the logistic regression model, and to check for multicollinearity, the VIF was computed. The VIF results show that there's no problem of multicollinearity amongst the exploratory variables, as they were all below 10. The logistic model was used to examine socio-economic factors that influence smallholder farmers to consume underutilised crops. Out of 15 identified independent variables, 11 independent variables had a statistically significant effect on the consumption of underutilised crops in the province of KwaZulu-Natal. These variables were consumer perception of production, consumer perception of taste, consumer perception of awareness, education, household size, marital status, government grant, gender, willingness to buy underutilised crops, off-farm income, and group membership.

Marginal effect results, as shown in Table 4.5, indicate that farmers' perception of the production of underutilised crops had a negative and statistically significant 1% impact on their decision to consume underutilised crops. The results imply that farmers who view underutilised crops as less valuable or desirable were less likely to consume them by 0.9%. This perception led to a lack of interest in cultivating or promoting underutilised crops, negatively impacting the farmer's income, food security, and community resilience. Suppose the farmer perceives that underutilised crops are difficult to grow and have low yields (Akinola *et al*., 2020). In that case, farmers may not invest the time or resources in producing them, limiting the availability of these crops in the market, and decreasing the farmer's profitability. This study's findings align with studies conducted by Akinola *et al*. (2020), who found a negative correlation between decision to consume and production perceptions.

A farmer's perception of underutilised crops' taste had a positive and statistically significant (p<0.1) impact on their decision to eat underutilised crops. The results of the marginal effects indicate that farmers' perceptions of an underutilised crop's taste increased the likelihood of farmers consuming underutilised crops by 0.5%. One possible reason for this result is that a positive perception of the taste of underutilised crops encourages farmers to value and prioritise their cultivation and consumption. Sinyolo *et al*. (2014) also found a positive impact of perceptions of taste on the decision of a farmer to consume underutilised crops.

Table 4.5: Binary logistic regression analysis

The decision to consume	Odds Ratio	Std. Err.	P>|z|	Marginal effects	VIF
Perception on production	0.516	0.086	**0.000******	-0.009	1.160
Perception on taste	1.373	0.232	**0.061***	0.005	1.410
Perception on awareness	0.690	0.142	**0.072***	-0.005	1.180
Perception on availability	1.144	0.356	0.666	0.002	1.140
Education	1.565	0.412	**0.088***	0.007	1.050
Household size	1.163	0.075	**0.019****	0.002	1.040
Marital status	6.864	4.049	**0.001******	0.039	1.120
Access to credit	0.549	0.403	0.415	-0.007	1.030
Government grant	5.225	3.765	**0.022****	0.024	1.040
Gender	0.316	0.184	**0.048****	-0.019	1.120
Willingness to buy	0.019	0.016	**0.000******	-0.057	1.380
Off-farm income	0.999	0.000	**0.034****	-0.000	1.060
Extension office visit	0.478	0.268	0.188	-0.012	1.080
Training	2.095	1.159	0.182	0.011	1.100
Group membership	0.184	0.136	**0.022****	-0.018	1.260
_Cons	0.209	0.369	0.375		
Mean VIF					1.14

Number of obs=300 LR chi2(15) =96.00 Prob > chi2=0.001 Pseudo R2=0.4618

Note: *, **, ***, means the coefficient is statistically significant at 10%, 5% and 1% levels,

The marginal effects results show that the absence of underutilised awareness yields a statistically negative and significant adverse impact ($p<0.1$) on the consumption of crops. This effect is rooted in the observation that farmers need more knowledge about the nutritional and health benefits associated with such crops and tend to undervalue their significance (Oyeyinka *et al*., 2017). Similarly, a need for more information regarding the potential economic gains linked to the cultivation and consumption of underutilised crops results in farmers viewing them as an unfeasible option. Moreover, inadequate familiarity with the appropriate agronomic practices for cultivating and preparing underutilised crops has impeded successful integration into farming practices and consumption patterns. Oyeyinka *et al*. (2017) highlighted that farmers who need more awareness of the cultural significance or traditional usage of underutilised crops tend to overlook their value and desirability. This insight emphasises the critical role of awareness in shaping the perceptions and attitudes of farmers towards underutilised crops, thereby influencing their adoption and consumption decisions.

Higher level education of the farmer increased the log odds of consuming underutilised crops by about 1.565 times, as shown in Table 4.5. A higher level of education equips farmers with the knowledge and skills to identify underutilised crops such as taro roots and sweet potatoes and understand their nutritional value and potential uses. A unit increase in the level of education resulted in a 0.7% increase in the probability of a farmer consuming underutilised crops. Education also makes farmers more aware of the health benefits of consuming underutilised crops, which can motivate them to consume these crops. The results differ from the findings of Zulu *et al*. (2022), who found that uneducated farmers were more likely to consume underutilised crops.

The results indicate that household size had a positive and significant impact on consumption of underutilised crops at a 5% significant level. The result suggests that larger household size farmers were more likely to consume underutilised crops. William *et al*. (2016) found that household size positively affects underutilised crop consumption. The study concluded that larger household sizes increased consumption of underutilised crops like taro roots and sweet potatoes. Household heads indicated that with more mouths to feed, farmers are more inclined to grow and consume these crops to ensure their family has enough to eat.

The results show that married farmers had nearly seven (odds ratio = 6.864) times the odds of consuming underutilised crops. The results imply that having a spouse or partner provides social and economic support, allowing the farmer to take risks and try new things, such as planting and consuming crops that may not have been grown or consumed previously. A spouse or partner also provides additional labour and resources to help plant and harvest underutilised crops, making it more feasible for the farmer to do so. These findings are aligned with the results of Zulu *et al*. (2022), who revealed that married farmers were more likely to consume underutilised crops.

Farmers who reported having higher off-farm income and receiving government grants had higher odds of consuming underutilised crops; an increase in off-farm income by an odds ratio of 1 and receiving government grants by the odd ratio of 5 increases the probability of a farmer consuming underutilised crops. The findings are consistent with the work of Jerop *et al*. (2018), who found that farmers with additional income sources have more financial stability and are more willing to take risks and try new things, such as planting and consuming underutilised crops. Off-farm and government grant income provide a farmer with additional resources, such as money to purchase seeds or equipment, which makes it more feasible for them to plant and consume underutilised crops. Moreover, off-farm income also increases farmers' awareness of the benefits of consuming underutilised crops, which may be less known or expected in their area and not widely produced (Jerop *et al*., 2018).

The results reveal a statistically significant relationship between gender and the decision to consume underutilised crops. The marginal effect for gender is negative (-0.019), indicating that being male is associated with a lower likelihood of consuming underutilised crops than being female. This finding suggests that female household heads are more inclined to decide to consume underutilised crops than their male counterparts. The observed gender difference in the decision to consume underutilised crops highlights the influence of gender norms, roles, and preferences in shaping dietary choices. Smith and Landry (2021) have indicated that women often have a closer connection to household food production and are more involved in food preparation and consumption decisions.

Willingness to buy underutilised crops had a negative and statistically significant ($p<0.000$) effect on a farmer's decision to consume underutilised crops. They were implying that farmers who were unwilling to buy underutilised crops were more likely to consume them. Farmers revealed they were unwilling to purchase underutilised crops because they produced them for subsistence (Mayes *et al*., 2012).

The analysis of marginal effects reveals a statistically significant and negative impact ($p<0.05$) on the consumption of underutilised crops, particularly among farmers affiliated with group memberships. The results imply that farmers without group membership were more likely to consume underutilised crops. One plausible explanation for the finding is that farmers without group memberships are more inclined to consume underutilised crops because of individual agency and decision-making autonomy. This autonomy allows them to make choices based on their assessments of crop diversity, nutritional benefits, and market opportunities. Research conducted by Carnegie *et al*. (2020) in rural agricultural communities demonstrated that farmers operating independently, without the influence of collective decision-making structures, exhibited a stronger sense of agency in their agricultural choices. This heightened agency empowered individual farmers to make independent decisions concerning crop selection and production practices. It allowed them to experiment with diverse crop varieties, including underutilised crops, without being influenced by group norms or conformity pressures.

4.6 Conclusions and Recommendations

This study investigated the socio-economic factors influencing farmers to consume underutilised crops in KwaZulu-Natal (KZN). The results of the binary logistic analysis provide valuable insights into the factors influencing the consumption of underutilised crops, specifically taro roots and sweet potatoes, among smallholder farmers in KZN. Among the 15 identified independent variables, 11 had a statistically significant effect on the decision to consume underutilised crops. Factors such as farmers' perception of production, consumption, and awareness of these crops, education level, household size, marital status, government grants, gender, willingness to buy, income, and farmers' group membership significantly influenced the consumption of underutilised crops. Notably, consumer perceptions played a critical role, with positive perceptions of taste, nutritional value, and market potential positively influencing farmers' decisions to consume these crops. On the other hand, a lack of awareness about underutilised crops and a negative perception of their production were associated with reduced consumption. Social factors, such as group membership and marital status, demonstrated significant impacts, indicating the influence of support networks and partner involvement on dietary choices.

Based on the findings, the study recommends promoting the consumption of underutilised crops in KZN and improving food security and nutrition among smallholder farmers. First, awareness-building campaigns and educational programs should be developed to inform farmers about the nutritional benefits and potential uses of underutilised crops, fostering positive perceptions and encouraging consumption. Efforts should be made to address negative perceptions of underutilised crop production, emphasising the advantages and sustainability of cultivating these crops. This can be achieved through training programs that equip farmers with the necessary skills and resources to grow and manage underutilised crops effectively.

Collaboration with local organizations and government agencies can facilitate access to government grants and financial support, enabling farmers to invest in underutilised crop production and consumption. Incentive programs that reward farmers for promoting these crops and adopting sustainable farming practices can also be effective in encouraging their consumption. Additionally, increased research and development efforts are needed to explore production incentives for underutilised crops, including the development of resilient varieties, innovative cultivation techniques, and value-added processing methods. By addressing these gaps and implementing these recommendations, policymakers and stakeholders can foster a positive environment that encourages the consumption of underutilised crops and contributes to more diverse and sustainable food systems in the region.

References

Akinola, R., Pereira, L.M., Mabhaudhi, T., De Bruin, F.M. and Rusch, L., 2020. A review of indigenous food crops in Africa and the implications for more sustainable and healthy food systems. *Sustainability*, 12(8), pp.3493.

Brouwer, R., 2021. Marketing Healthy Food in an African City: Consumer Motivations for Adopting Orange-Fleshed Sweet Potato in Maputo, Mozambique. *Food and Nutrition Bulletin*, 42(3), pp.361-377.

Burchi, F., Fanzo, J. and Frison, E., 2011. The role of food and nutrition system approaches in tackling hidden hunger. *International Journal of Environmental Research and Public Health*, *8*(2), pp.358-373.

Carnegie, M., Cornish, P.S., Htwe, K.K. and Htwe, N.N., 2020. Gender, decision-making and farm practice change: An action learning intervention in Myanmar. *Journal of Rural Studies*, *78*, pp.503-515.

Gido, E.O., Ayuya, O.I., Owuor, G. and Bokelmann, W., 2017. Consumption intensity of leafy African indigenous vegetables: towards enhancing nutritional security in rural and urban dwellers in Kenya. *Agricultural and Food Economics*, 5, pp.1-16

Ismail, T., Qamar, M., Khan, M., Rafique, S. and Arooj, A., 2023. Agricultural Biodiversity and Food Security: Opportunities and Challenges. *Neglected Plant Foods Of South Asia: Exploring and valorizing nature to feed hunger*, pp.1-27.

Jenkins, M., Shanks, C.B., Brouwer, R. and Houghtaling B., 2018. Factors affecting farmers' willingness and ability to adopt and retain vitamin A-rich varieties of orange-fleshed sweet potato in Mozambique. *Food Security*, 10, pp. 1501-1519.

Jerop, R., Dannenberg, P., George Owuor, G. and Mshenga, P., 2018. Factors affecting the adoption of agricultural innovations on underutilised cereals: The case of finger millet among smallholder farmers in Kenya. *African Journal of Agricultural Research*, 13(36), pp.1888-1900.

Kline, P., 2014. *An easy guide to factor analysis*. Routledge.

Mabhaudhi, T., O'Reilly, P., Walker, S. and Mwale, S., 2016. Opportunities for underutilised crops in southern Africa's post–2015 development agenda. *Sustainability*, *8*(4), pp.302.

Malkanthi, S.H. and Silva, P., 2014. Opportunities and challenges in cultivating underutilised field crops in Moneragala district of Sri Lanka. *Asian Journal of Agriculture and Rural Development*, 4(1), pp.96-105.

Mango, N., Makate, C., Mapemba, L. and Sopo, M., 2018. The role of crop diversification in improving household food security in central Malawi. *Agriculture and Food Security,* 7(1), pp.1-10.

Mayes, S., Massawe, F.J., Alderson, P.G., Roberts, J.A., Azam-Ali, S.N. and Hermann, M., 2012. The potential for underutilised crops to improve the security of food production. *Journal of Experimental Botany*, 63(3), pp.1075-1079.

Mbosso, C., Boulay, B., Padulosi, S., Meldrum, G., Mohamadou, Y., Berthe Niang, A., Coulibaly, H., Koreissi, Y. and Sidibé, A., 2020. Fonio and Bambara groundnut value chains in Mali: issues, needs, and opportunities for their sustainable promotion. *Sustainability*, *12*(11), pp.4766.

McFadden, D., 2012. Computing willingness–to–pay in random utility models. *Trade, Theory and Econometrics*, pp. 275-296. Routledge.

Mutwedu, V.B., Bacigale, S.B., Mugumaarhahama, Y., Muhimuzi, F.L., Munganga, B., Ayagirwe, R.B., Nguezet, P.M.D. and Manyawu, G., 2022. Smallholder farmers' perception and challenges toward the use of crop residues and agro-industrial byproducts in livestock feeding systems in Eastern DR Congo. *Scientific African*, *16*, pp.01239.

Napitupulu, D., Kadar, J.A. and Jati, R.K., 2017. Validity testing of technology acceptance model based on factor analysis approach. *Indonesian Journal of Electrical Engineering and Computer Science*, *5*(3), pp.697-704.

Omotayo, A.O. and Aremu, A.O., 2020. Underutilised African indigenous fruit trees and food–nutrition security: Opportunities, challenges, and prospects. *Food and Energy Security*, *9*(3), pp.220.

Omotayo, A.O. and Aremu, A.O., 2020. Underutilised African indigenous fruit trees and food–nutrition security: Opportunities, challenges, and prospects. *Food and Energy Security*, *9*(3), pp.220.

Oyeyinka, A.T., Pillay, K. and Siwela, M., 2017. Consumer awareness and acceptability of Bambara groundnut as a protein source for use in complementary foods in rural KwaZulu-Natal. *South African Journal of Clinical Nutrition,* 30(4), pp.87-92.

Rauf, U.A.A., Jabar, J. and Mansor, N., 2020. An Exploratory Factor Analysis for Measuring Knowledge Management Component Construct in Malaysian Public Higher Education. *PalArch's Journal of Archaeology of Egypt/Egyptology*, *17*(7), pp.4523-4534.

Revoredo-Giha, C., Zavala-Nacul, H. and Toma, L., 2022. Assessing the Nutritional Impact of an Increase in Orphan Crops in the Kenyan Diet: The Case of Millet. *Sustainability*, *14*(5), pp.2704.

Sinyolo, G.M., Wale, E. and Ortmann, G.F., 2014. Consumers' willingness-to-pay for underutilised vegetable crops: the case of African leafy vegetables in South Africa. Journal of Human Ecology, 47(3), pp.219-227.

Shrestha, N., 2021. Factor analysis as a tool for survey analysis. *American Journal of Applied Mathematics and Statistics*, *9*(1), pp.4-11.

Smith, T.A. and Landry, C.E., 2021. Household food waste and inefficiencies in food production.American Journal of Agricultural Economics, 103(1), pp.4-21.

Sobratee, N., Davids, R., Chinzila, C.B.,Mabhaudhi, T., Scheelbeek, P., Modi, A. T., Dangour, A.D. and Slotow, R., 2022. Visioning a food system for an equitable transition towards sustainable diets- a South African perspective.*Sustainability*, 14(6), pp.3280.

William, A., Donkoh, S.A. and George, N., 2016. Adoption of Bambara groundnut production and its effects on farmers' welfare in Northern Ghana. *African Journal of Agricultural Research*, 11(7), pp.583-594.

Zulu, S.S., Ngidi, M., Ojo, T. and Hlatshwayo, S.I., 2022. Determinants of consumers' acceptance of indigenous leafy vegetables in Limpopo and Mpumalanga provinces of South Africa. *Journal of Ethnic Foods*, 9(1), pp.1-9.

Chapter 5: Factors Influencing Intensity of Participation in Underutilised Crops Value Chain Among Smallholder Farmers: A Case Study of Taro Roots and Sweet Potatoes in Kwazulu-Natal, South Africa

Abstract

Despite the potential benefits of participating in underutilised crop value chains, most smallholder farmers fail to engage due to various challenges and barriers to entry. The study investigates the factors influencing smallholder farmers' decisions to participate in underutilised crop’ value chains in KwaZulu-Natal, South Africa. The data collected from a randomly selected sample of 300 farmers is analysed using descriptive and inferential statistics, including the chi-squared test and double-hurdle econometric model. The results show that market channels, produce wasted, access to credit, pest and disease management practices, and access to irrigation facilities are key factors determining farmers' decision to participate in the value chain and the intensity of their participation. Policymakers and stakeholders should develop diverse, efficient market channels, such as direct marketing, cooperative arrangements, and online platforms, to enhance smallholder farmers' access to buyers and improve their participation in underutilised crop value chains.

Keywords: Value chain, underutilised crops, market channels, double-hurdle model

5.1 Introduction

Underutilised crops significantly address food security, promote biodiversity, and diversify income sources in many regions (Mustafa *et al*., 2019). Mashamaite *et al*. (2021) stated that KwaZulu-Natal (KZN), South Africa, has diverse agroecological zones and favourable climatic conditions suitable for cultivating a wide range of crops such as sweet potato (*Ipomoea batatas*) and taro roots (*Colocasia esculenta*).

As such, these crops have been cultivated traditionally in KZN for subsistence purposes, providing food for local communities. However, their commercial production and marketing could be more extensive (Shange, 2004; Shackleton *et al*., 2010). According to Singh *et al*. (2011) and Bandula *et al.* (2023), enhancing value chain participation for underutilised crops leads to economic, social, and environmental benefits for farmers and the region. The potential of these two crops lies in their nutritional value, adaptability to local conditions, and versatility in processing (Chivenge *et al*., 2015; Sharma *et al*., 2016). The crops are rich in essential nutrients, dietary fibres, and vitamins, offering health benefits and contributing to balanced diets (Sharma *et al*., 2016). Moreover, they are resilient to climate variations and can thrive in diverse soil types, making them suitable for cultivation in different parts of KZN (Chivenge *et al*., 2015). Transitioning from the traditional cultivation of sweet potato and taro roots for subsistence purposes in KZN, there's a recognition that enhancing value chain participation, as highlighted by researchers such as Singh *et al*. (2011) and Bandula *et al.* (2023), can unlock economic benefits by integrating smallholder farmers into all stages of production, processing, and distribution (Ricketts *et al*., 2014).

Value chain participation encompasses all stages of crop production, processing, and distribution, focusing on improving the efficiency and effectiveness of each step. According to Ricketts *et al.* (2014), value chain participation refers to the extent to which smallholder farmers are integrated into the various stages from production to consumption. It encompasses their involvement in activities such as input supply, production, harvesting, post/harvest handling, processing, packaging, and labelling, marketing, and distribution (Ricketts *et al.* 2014; Ndlovu *et al*., 2021). In this study, value chain participation refers explicitly to the decision made by smallholder farmers to engage in the value chain activities of underutilised crops.

Chivenge *et al.* (2015) stated that the production of sweet potato and taro roots in KZN primarily serves local consumption, with limited quantities reaching the market. This underutilisation hampers the potential economic benefits to farmers and the broader agricultural sector. According to Ndlovu *et al.* (2021), addressing the barriers to value participation, such as inadequate marketing systems, transportation challenges, information asymmetry, and the role of intermediaries, is crucial for promoting value chain participation and unlocking the economic potential of these crops.

Previous studies such as Sinyolo *et al. (*2017), Maponya *et al*. (2016), and Mkuna and Wale (2022) have examined the market and value chain participation of various agricultural products such as maize. Still, limited research has focused specifically on sweet potato and taro roots in the context of KZN, South Africa. Therefore, this study aims to fill the research gap by applying the double-hurdle model, which allows for a comprehensive analysis of value chain participation decisions and level of participation. By investigating the determinants of value chain participation for underutilisation in KZN, this research seeks to inform strategies to enhance market linkages, improve farmers' income and livelihoods, and contribute to sustainable agricultural development in the region.

5.2 Analytical Framework

The data were collected from a sample of 300 respondents and were analysed using two statistical procedures. Initially, descriptive statistics such as means, standard deviations, and percentages were employed to describe and evaluate farmers' socioeconomic characteristics, institutional factors, and market characteristics in underutilised crops in the study area. Inferential statistics, including the chi-squared test, was then utilised to identify statistically significant differences between participants and non-participants in the value chain, specifically concerning categorical variables.

In the second part of the analysis, an econometric approach was employed to examine the factors influencing participation in the value chain and the level of involvement. The double-hurdle model, as proposed by Asfaw *et al.* (2022), is employed to assess the decision to participate and the intensity of value chain participation. An appropriateness test was conducted using the likelihood ratio (LR) best-fit test (equation 5.1) to check the suitability of the double-hurdle model.

$$\lambda = -2(LL_P - LL_{TR}) \qquad 5.1$$

In the statistical analysis, various log-likelihood values were computed: LL_P for the Probit model, and LL_{TR} for the truncated model. The λ symbol presents the LR statistical value, which follows a Chi-square distribution with degrees of freedom equal to the number of independent variables.

5.3 Methodology of the Study

5.3.1 Study Area, Sampling and Data Collection

The study site, sampling and data collection procedure are described in Sections 3.3.1 and 3.3.2.

5.3.2 Empirical Model: The Double-Hurdle Model

The double-hurdle Model is intended to analyse two decisions: first, whether to participate in the value chain and second, number of value chain activities (outcome).

Equation 5.2 shows how the current value chain participation decision is modelled using probit regression:

$$d_i^* = X_{1i}\beta_1 + \mu_i , \mu_i \text{ N}(0,1) \qquad 5.2$$

$$d_i = \begin{cases} 1 \; if \; d_i^* > 0 \\ 0 \; if \; d_i^* \leq 0 \end{cases} \qquad 5.3$$

Equation 5.4 models the intensity of participation measured as number of activities the farmer participated in within the value chain of underutilised crops as a truncated regression as follows:

$$Y_i^* = X_{2i}\beta_2 + v_i, v_i N(0, \sigma^2) \qquad 5.4$$

$$Y_i = \begin{cases} Y_i^* \; if \; Y_i^* > 0 \; and \; d_i = 0 \\ \quad 0 \; if \; Y_i^* \leq 0 \end{cases} \qquad 5.5$$

Where: X_{1i} and X_{2i} are vectors of explanatory variables that affect these two-stage decisions, respectively. μ_i and v_i are uncorrelated error terms for both decisions, respectively. β_1 and β_2 are the respective vectors of estimated parameters. d_i^* is latent or unobserved value of participation decision (if d_i^* =1; underutilised crops producers participated in the value chain and d_i^* =0; does not participate), d_i observed value participation decision, Y is the observed number of activities the farmer participated in, and Y_i^* is the latent or unobserved level of participation.

Assuming the error terms are independent, the stochastic specification it can be written as (equation 5.6):

$$\begin{pmatrix} \mu_i \\ v_i \end{pmatrix} N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & 0 \\ 0 & \sigma^2 \end{pmatrix}\right] \quad 5.6$$

The double-hurdle model with independent error terms can be estimated by the following log-likelihood function as follows (equation 5.7):

$$LL = \sum In \left[1 - \phi(X_{1i}\beta_1)\Phi\left(\frac{X_{2i}\beta_2}{\sigma}\right)\right] + \sum In \left[\phi(X_{1i}\beta_1)\frac{1}{\sigma}\Phi\left(\frac{Y_i - X_{2i}\beta_2}{\sigma}\right)\right] \quad 5.7$$

Where: Φ denotes the standard normal probability, ϕ is the density function; X_{1i} and X_{2i} represent independent variables for the probit model and the truncated model, respectively; β_1, σ, and β_2 are parameters to be estimated for each case.

5.3.3 Definition of Variables and Hypotheses

Table 5.1 provides the definitions and expected signs of independent variables used in the double-hurdle analysis to examine the factors influencing value chain participation and intensity among underutilised crop-producer households.

The participation decision is a binary dependent variable. It determines the likelihood of producers engaging in the underutilised crop value chain. This is done through a first hurdle regression model, specifically a probit regression model. In this model, a value of one presents producers who participate in the value chain, while a value of zero presents producers who do not participate in the value chain.

The level of participation is the number of activities the farmer is involved in within the value chain, which is defined as a count or discrete dependent variable. This variable presents the count of different value chain activities in which the farmer actively participates, such as harvesting, post-harvest handling, processing, packaging, labelling, marketing, distribution, and retailing.

Table 5.1: Definition and hypothesis signs for independent variables used in probit and truncated regression models.

Variables	Definition and Measurements	H_1	Rationale
Market Channel	The method through which underutilised are sold where 0=informal markets and 1= formal market	+	Formal marketing channels provide better market access and opportunities for farmers (Arinloy *et al*., 2015)
Produce wasted	Household experience produces waste where produce is discarded or becomes unusable. 0= No, 1= Yes	-	Frequent produce waste discourages farmers from engaging in value chain activities, as they may feel that their efforts are futile due to the high likelihood of losses (Ricket *et al.,* 2014).
Education	The level of education attained by the household head and is measured as an ordinal variable where 1=No school 2= Primary 3= Secondary 4= Tertiary.	-	Hlatshwayo *et al*. (2021) found that a household's educational level negatively impacts participation levels.
Access to credit	Availability and ease of obtaining credit or loans for agricultural purposes by a farmer from the government and 0= no and 1=yes	+	Access to credit positively influences farmers to participate in the value chain and intensity as it facilitates investment in production (Li *et al*., 2020)
Management practises	This variable indicates whether there are effective pest and disease management practices specifically developed for underutilised crops (0= ineffective practices, 1 = effective practices).	+	Effective pest and disease management practices can positively influence a farmer's value chain participation. By implementing successful pest and disease control measures, farmers can mitigate the risk of crop losses, improve crop quality, and enhance their marketability (Dong, 2021).

Irrigation system	The dummy variable measured if a farmer has access to the irrigation system and a value of 1 was assigned for yes and 0 otherwise.	-	Ndlovu *et at.* (2021) found that access to irrigation had a negative impact on value-chain participation; irrigation reduces production because of pest infestation.
Road type	A dummy variable measuring the type of road infrastructure available where 0= gravel and 1= tar	-	Otekunri *et al.* (2019) stated that road infrastructure negatively affects transportation efficiency and discourages farmers from participating in the value chain.
Distance to market	The physical distance between the farm and the market where 0 =less than 30km and 1 = more than 30km	-	Longer distances can increase transportation costs and discourage participation (Mossie *et al*., 2020).
Agricultural Training	Binary variable measuring if a farmer had received training in agriculture and value of 1=yes and 0=otherwise	+	Training can enhance farmers' knowledge and skills in production and marketing (Rubin and Manfre, 2014)
Livestock ownership	A binary variable measuring if a farmer owns livestock ownership where the value of 1=yes and 0=otherwise	+	Njuki and Sanginga (2013) stated that livestock ownership provides additional resources for crop production and marketing.
Ext. officers	Dummy variable measuring availability and utilisation of extension officers where the value of 1=yes and 0=otherwise	+	Access to extension officers can facilitate market linkages and provide valuable networks (Girma and Kuma, 2022)
Information	Binary variable measuring the access to market information. Where 1=yes and 0=otherwise	+	Access to market information helps farmers make informed decisions and navigate the value chain (Ndlovu *et al*., 2021)

$\mathbf{H_1}$ presents hypothesised signs for the decision to participate and the intensity of participation.

5.4 Results and Discussions

This section presents the results of various statistical analyses of the data from 300 participants. These analyses include the cross-tabulation for descriptive analysis and double-hurdle model model. The decision to participate in value chain was analysed using binary probit model (first hurdle) and the number of activities the farmer participated in was analysed using truncated model.

5.4.1 Descriptive Analysis

The comparison of categorical variables over dependent variables based on percentage counts was computed using the chi-squared test, as presented in Table 5.2. The results indicate that only 29% of the sample participated in the value chain. The difference in the percentage of value chain non-participants compared to participants is relatively large, which suggests a need for interventions to increase the participation of farmers in the value chain of underutilised crops.

Household heads who used informal market channels (friends and relatives) were approximately 79% who decided not to participate in the value chain. On the other hand, among household heads who used formal market channels (supermarket and wholesale), about 48% participated in the value chain. The p-value of 0.001 indicates that there is a statistically significant association between the type of market channel used (informal or formal) and participation in the value chain.

Approximately 22% of farmers who did not experience produce wasted engaged in the underutilised crop value chain. In contrast, among farmers who did experience produce wasted, around 35% participated in the value chain. The X^2 significant level of 0.01 confirms that there is a statistically significant relationship between the farmers' produce wasted experience and their decision to participate in the value chain.

Farm credit plays a crucial role in providing the necessary capital for initiating farm investments in both production and marketing activities. Credit enhances value chain participation and the number of activities the farmer is involved in. As a result, it fosters a greater likelihood of entering the value chain and intensifying participation, as supported by the findings of Dlamini and Huang (2019). The results reveal that there is an association between access to credit and the decision of a farmer to participate in the value chain at a 5% significant level. About 23% of farmers who had access to credit participated in the value chain. On the other hand, 35% of farmers who had access to credit participated in the value chain for underutilised products. According to the results of the chi-square test, there is a significant relationship between the presence of pest and disease management practices and farmers' decision to participate in the value chain. Among farmers who did have effective pest and disease management practices, 34% participated in the value chain. In contrast, among farmers who had ineffective practices, only 19% participated in the value chain.

The results presented in Table 5.2 demonstrate that farmers with a gravel road type had a participation rate of 22% in the value chain. On the other hand, among farmers with a tar road type, approximately 36% participated in the value chain. The statistical analysis indicates that there is a significant relationship between the type of road (gravel or tar) and the farmers' decision to participate in the value chain. Table 5.2 shows a significant level of 1% association between the distance travelled to the market and farmers' decision to participate in the value chain. Among farmers who travelled less than 30 km to the market, approximately 35% participated in the underutilised crop value chain. On the other hand, among farmers who travelled more than 30 km to the markets, 19% participated in the value chain.

The analysis demonstrates a statistically significant relationship (at a 5% significance level) between farmers' access to market information and their decision to participate in the value chain. Some 23% of farmers without access to market information participated in the value chain. Conversely, among farmers with access to market information, about 29% participated in the value chain.

Table 5.2: Cross-tabulation of value chain participation decision

Value chain participation decision				
Independent variables	**Categories**	**Non-participated n= (71%)** **Per cent**	**Participated (29%)**	**X^2 Sign. Level**
	0= Informal markets (*n*=219)	79	21	
Market Channel	1= Formal markets (*n*=81)	52	48	***
	0 = No (*n*=85)	78	22	
Produce wasted	1= Yes (*n*=215)	65	35	**
	1=No school (*n*=137)	75	24	
	2= Primary (*n*=62)	66	34	
	3= Secondary (*n*=83)	72	28	
Education	4= Tertiary (*n*=18)	56	44	n. s
	0= No (*n*=158)	77	23	
Access to credit	1= Yes (*n*=142)	65	35	**
	0= ineffective (*n*=197)	81	19	
Management practises	1=effective (*n*=103)	66	34	**
	0= No (*n*=153)	71	29	
Irrigation system	1= Yes (*n*=147)	71	29	n. s
	0= Gravel (*n*=162)	78	22	
Road type	1= Tar (*n*=138)	64	36	***
	0= less than 30km (*n*=175)	65	35	
Distance	1= More than 30km (*n*=125)	81	19	***
	0= No (*n*=254)	73	27	
Training	1= Yes (*n*=46)	63	37	n. s
	0= No (*n*=249)	73	27	
Livestock ownership	1= Yes (*n*=51)	65	35	n. s
	0= No (*n*=218)	69	3	
Ext. officer	1= Yes (*n*=82)	78	22	n. s
	0= No (*n*=133)	77	23	
Information	1= Yes (*n*=167)	71	29	**

NB: *, **,** indicate statistically significant at 1% and 5%, respectively, and **n.s** denotes not significant.

5.4.2 Econometric Results

The decision to participate in the value chain is believed to be influenced by socioeconomic factors. Before estimating the selection model, the possibility of multicollinearity issues was examined using the Variance Inflation Factor (VIF). The VIF value was below the critical threshold of 10 (Zainodin and Yap, 2013), indicating the absence of multicollinearity problems, as shown in Table 5.3.

Table 5.3: Variance Inflation factor test

Variable	**VIF**	**1/VIF**
Access to credit	2.52	0.398
Information	2.10	0.476
Market channel	1.58	0.634
Irrigation system	1.24	0.804
Produce wasted	1.21	0.824
Road type	1.15	0.870
Distance	1.12	0.893
Management practises	1.10	0.906
Training	1.05	0.950
Livestock ownership	1.05	0.955
Education	1.04	0.961
Ext. officer	1.04	0.963
Mean VIF	**1.35**	

5.4.2.1 Probit Estimates of Determinants of Value Chain Participation

Table 5.4 presents the results of the first hurdle of the double hurdle model, which measured the decision of a farmer to participate in the value chain. The marginal effects results reveal a statistically significant ($p<0.01$) and positive impact of the marketing channel on both the decision to participate in the value chain and the number of activities the farmer participated in. The marginal effects estimates indicate that when a household head has access to formal marketing channels, such as supermarkets, there is an increase in the probability of both their decision to participate in the value chain and the intensity of participation. These results demonstrate the importance of formal marketing channels in promoting value chain participation and facilitating the number of activities. The findings of this study support previous research, such as Mehdi *et al*. (2019) that has identified the importance of formalised marketing channels in promoting the profitability of citrus farmers. The results suggest that formalised marketing channels can help to reduce market inefficiencies, transaction costs, and market risks associated with the underutilised crop market. This can increase the competitiveness and sustainability of underutilised crops and contribute to rural development.

The marginal effect (0.184) indicates that there is a positive and significant relationship ($p<0.01$) between the produce wasted and the decision to participate in the value chain. In other words, a unit increase in produce wasted by households increases their likelihood of participating in the value chain. Contrary to earlier expectations based on the findings of Rickets *et al.* (2014), this study found that experiencing waste firsthand encourages households to seek ways to optimise their resource utilisation, such as value chain participation.

Table 5.4: Probit estimates of determinants of value chain participation.

	Probit estimates			**Marginal effects**		
Value Chain Participation	**Coef.**	**Std. Err.**	**P>|z|**	**dy/dx**	**Std. Err.**	**P>|z|**
Market channel	0.367	0.105	**0.000*****	0.116	0.033	0.000
Produce wasted	0.585	0.188	**0.002*****	0.184	0.058	0.002
Education	0.100	0.086	0.245	0.032	0.027	0.246
Access to credit	-0.222	0.128	**0.081***	-0.070	0.039	0.079
Management practice	0.589	0.195	**0.003*****	0.172	0.052	0.001
Irrigation system	0.346	0.190	**0.069***	0.109	0.059	0.066
Road type	0.204	0.176	0.244	0.064	0.055	0.245
Distance	-0.454	0.184	**0.013****	-0.139	0.053	0.009
Training	0.362	0.232	0.118	0.123	0.084	0.141
Livestock ownership	0.413	0.229	**0.071***	0.141	0.083	0.089
Ext. officers	0.508	0.204	**0.013****	0.146	0.053	0.005
Information	0.236	0.129	**0.067***	0.074	0.040	0.065
_cons	-2.154	0.518	**0.000*****			

Number of obs=300 LR $chi^2(12)$ =58.48 Prob > chi2=0.0000 Pseudo R2=0.1627

Log likelihood = -150.5027 **NB: ***, **** and * indicate statistically significant at 1%, 5% and 10%, respectively.

Table 5.4 shows that access to credit from government and formal financial institutions negatively impacts a farmer's decision to participate in the value chain. This negative effect is statistically significant ($p<0.1$), suggesting that when farmers have access to credit, they are less likely to engage in the value chain. The findings of this study contradict other studies, such as Li *et al.* (2020) and Ndlovu *et al*. (2021), who found a positive effect of credit on value chain participation. Possible explanations for the findings of this study are that when farmers have access to credit, they are more cautious about investing in underutilised crops due to the perceived uncertainties and risks associated with marketing them within the value chain. Smallholder farmers with access to credit in KZN stated that they focus their financial resources on more mainstream or high-demand crops perceived as having a higher likelihood of generating returns and ensuring loan repayment (Ndlovu *et al*., 2021).

The study results reveal that pest and disease management practices have a positive and statistically significant ($p<0.01$) impact on the decision of farmers to participate in the value chain, which implies that farmers who had effective management practices were more likely to participate in the value chain. The findings are aligned with those of Lagerkvist *et al*. (2012), who found that effective pest and disease management practices contribute to healthier crops with higher yields and better quality. Fischer *et al.* (2017) stated that when farmers can successfully control pests and diseases, their produce is more marketable and meets the quality standards required by the value chain actors. This increases the likelihood of their participation as their crops are in demand and fetch better prices within the value chain.

Results indicate that access to the irrigation system has a positive and statistically significant impact ($p<0.1$) on a farmer's decision to participate in the value chain. The results imply that household heads who access irrigation were more likely to participate in the value chain. The findings are like those of Ndlovu *et al.* (2021), who found that irrigation systems provide a reliable water source for crop growth and development, enabling farmers to cultivate underutilised crops often associated with high-value markets.

The study found that the distance from the farmer's location to the market has a negative and statistically significant impact ($p<0.01$) on smallholder farmers' decision to participate in underutilised crop value chains. The results suggest that farmers near the market were more likely to participate in the value chain. The results are consistent with Mossie *et al*. (2020), who found that distance negatively affected value chain participation. Longer distances to the market increase transportation costs and reduce the profitability of participating in the value chain. Farmers also face logistical challenges in transporting their crops to the market, which discourage them from participating in the value chain (Trooster *et al*., 2020)

Livestock ownership had a positive and statistically significant ($p<0.10$) impact on the decision to participate in the value chain and level of participation. This means that farmers who owned livestock ownership were more likely to participate and actively engage in more activities within the value chain. Chamboko *et al.* (2017) found that livestock ownership positively affects value chain participation. According to Barua *et al.* (2021), livestock ownership provides farmers with an additional source of income. Farmers who own livestock ownership can diversify their revenue streams by participating in the value chain and reducing their dependency on a single agricultural activity (Chamboko *et al.,*2017; Baru *et al.,*2021). This increased income stability and potential for higher earnings motivate farmers to participate in the value chain and engage in multiple activities within it.

The result shows that the extension officer positively impacted smallholder farmers' value chain participation ($p<0.01$). The implication of the result depicts that if farmers have access to an extension officer, the probability of participating in agricultural value chains is increased. This can be attributed to the fact that extension agents provide smallholder farmers with inputs, advisory services, agriculture information, and knowledge and skills that are essential for them to be active participants in agricultural value chains (Maliwichi *et al*., 2014). The result substantiates the findings of Abdu-Raheem and Worth (2011), who acknowledged that extension officers develop human capital and social capital through training for knowledge and skills and by helping farmers to form cooperatives or farmer associations that can link them to produce markets.

Marginal effects results show that market information had a positive and significant ($p<0.1$) effect on smallholder farmer’s value chain participation and intensity of participation. The implication of the result depicts that as smallholder farmers gain access to market information, the probability of participating in agricultural value chains is increased, and the level of value chain participation is also increased. This could be attributed to the fact that smallholder farmers need reliable and accessible market information to be able to market their products better, and they constantly need to receive information through both informal and formal channels (Ahmadu and Idisi, 2014). The result is consistent with the work of Kiptot and Franzel (2012), in which they acknowledged that with access to market information, smallholder farmers' decision-making is improved regarding farm production and marketing of produce, which will strengthen their participation in agricultural value chains.

5.4.2.2 Truncated Estimates of Determinants of the Intensity of Value Chain Participation

Table 5.5 presents the results of the second hurdle of the double-hurdle model analysis examining the determinants of the intensity of value chain participation. The results reveal that out of 12 factors, there are six that influence the intensity of participation, which are training, livestock ownership, ext. officer, information, access to credit, and market channel.

Marginal effects indicated that access to credit negatively and significantly influences the level of participation in the value chain at a 1% significant level. This depicts that having access to credit contributes negatively to the level of value chain participation among pooled-households. This could be attributed to the fact that smallholder farmers may acquire credit but use it for non-agricultural uses such as purchasing food, health, paying school fees, and for gatherings such as traditional ceremonies, marriage, and funerals. The result is contrary to the study of Sinyolo *et al*. (2016), who acknowledged that access to credit enhances agricultural productivity, which increases farm revenues and provides incentives for farmers to increase agricultural practices. However, the result of the study conforms to the study of Elahi *et al*. (2018), who found that farmers tend to use agricultural credit for non-farm purposes to make the livelihoods of the entire household sustainable.

The results indicate that agricultural training has a positive and statistically significant impact on the number of activities a farmer engages in ($p<0.10$). The findings suggest that farmers who have received training are more likely to participate in more activities within the value chain. The findings are like those of Rubin and Manfre (2014), who found a positive correlation between the two variables. Mossie *et al. (*2022) stated that agricultural training enhances farmers' understanding of quality standards, grading, and packaging requirements. This knowledge enables farmers to participate in more activities within the value chain.

The result shows that the extension officer negatively and significantly influences the level of participation. The implication of the results depicts that extension contacts with farmers negatively affect the level of value chain participation among farmers. This result is unexpected and contradicts the findings of (Usapfa, 2010; Ekepu *et al*., 2017), who found that there is a positive relationship between the intensity of value chain participation and extension contact with farmers. This implies that an increase in contacts with extension agents reduces the probability of smallholder farmers participating in the value chain market. This could be attributed to inadequate or unqualified staff members and poor organisation, which could limit the efficient dissemination of agricultural extension services (Feder *et al*., 2011). The result is consistent with the findings of Margono and Sugimoto (2011), who acknowledged that the linkages of extension-farmer interactions in distributing information to farmers have needed to be stronger and more effective.

Table 5.5: Truncated estimates of determinants of the intensity value chain participation

	Truncated estimates			Marginal effects		
Level of participation	**Coef.**	**Std. Err.**	**P>|z|**	**dy/dx**	**Std. Err.**	**P>|z|**
Market Channel	2.064	0.148	**0.000*** **	2.064	0.148	0.000
Produce wasted.	0.189	0.263	0.472	0.189	0.263	0.472
Education	0.061	0.124	0.622	0.061	0.124	0.622
Access to credit	-2.919	0.170	**0.000*** **	-2.919	0.170	0.000
Management practice	-0.301	0.264	0.255	-0.301	0.264	0.255
Irrigation system	0.038	0.266	0.887	0.038	0.266	0.887
Road type	-0.421	0.257	0.100	-0.423	0.257	0.100
Distance	-0.055	0.256	0.830	-0.055	0.256	0.830
Training	0.662	0.339	**0.052***	0.662	0.339	0.052
Livestock ownership	0.622	0.325	**0.056***	0.622	0.325	0.056
Ext. Officer	-0.583	0.273	**0.033****	-0.583	0.273	0.033
Information	3.036	0.178	**0.000*** **	3.036	0.178	0.000
_cons	2.266	0.719	**0.002*** **			
/Sigma	2.067	0.084	**0.000*** **			

Number of obs =300 Wald chi2(12) =3523.28 Prob > chi2=0.0000 Log-likelihood =643.56594 **NB:** ***, ** and * indicate statistically significant at 1%, 5% and 10%, respectively.

5.5 Conclusion and Recommendations

This study examined the factors influencing smallholder farmers' participation in value chains for underutilised crops in KwaZulu-Natal, South Africa. The double-hurdle results indicate that formal marketing channels play a significant role in promoting value chain participation and increasing the intensity of engagement. The double-hurdle model shows that access to credit, despite showing a negative effect on the decision to participate, positively influences the range of activities farmers engage in within the value chain. Effective pest and disease management practices, access to irrigation systems, proximity to markets, and livestock ownership emerge as key drivers of value chain participation. Moreover, access to extension officers and market information plays crucial roles in influencing farmers' decisions and their level of participation.

Efforts to promote value chain participation and enhance its intensity should focus on leveraging these identified factors. Encouraging the use of formal marketing channels could be advantageous in facilitating value chain integration. Addressing the challenges associated with produce wasted, such as through innovative post-harvest handling techniques and processing, could further enhance farmers' motivation to participate. While credit availability might seem counterproductive to value chain participation, tailored financial products and risk mitigation strategies can be explored to address farmers' concerns. Effective pest and disease management practices, along with adequate irrigation facilities, should be promoted to ensure healthy crops with higher market value. Efforts to reduce market-related challenges, such as distance to markets, could include improved transportation infrastructure and market linkages. Farmers' collaboration with extension officers and their access to market information should be strengthened to empower them with the necessary knowledge and insights for effective participation in the value chain.

References

Abdu-Raheem, K.A. and Worth, S.H., 2011. Household food security in South Africa: evaluating extension's paradigms relative to the current food security and development goals. *South African Journal of Agricultural Extension*, 39(2), pp.92-104

Ahmadu, J. and Idisi, P.O., 2014. Gendered participation in the cassava value chain in Nigeria. *Merit Research Journal*, 2(11), pp.147-153.

Asfaw, D.M., Shifaw, S.M. and Belete, A.A., 2022. Determinants of Market Participation Decision and Intensity among Date Producers in Afar Region, Ethiopia: A double-hurdle Approach. *International Journal of Fruit Science*, 22(1), pp.741-758

Bandula, A., Kibria, A.S. and Nath, T.K., 2023. Value Chain Map and Economic Performance of Potentially Important Underutilised Crops in Southeastern Sri Lanka. *Economic Botany*, pp.1-15.

Barua, P., Rahman, S.H. and Barua, M., 2021. Sustainable value chain approach for livestock-based livelihood strategies for communities of the southeastern coast of Bangladesh. *Modern Supply Chain Research and Applications*, 3(3), pp.191-225.

Chamboko, T., Mwakiwa, E. and Mugabe, P.H., 2017. Determinants of milk market participation and volume of sales to milk collection centres of the smallholder dairy value chain in Zimbabwe. *Journal of Agricultural Science*, 9(10), pp.156-167.

Chivenge, P., Mabhaudhi, T., Modi, A.T. and Mafongoya, P., 2015. The potential role of neglected and underutilised crop species as future crops under water-scarce conditions in Sub-Saharan Africa. *International Journal of Environmental Research and Public Health*, 12(6), pp.5685-5711.

D. Ricketts, K., G. Turvey, C. and I. Gómez, M., 2014. Value chain approaches to development: Smallholder farmer perceptions of risk and benefits across three cocoa chains in Ghana. *Journal of Agribusiness in Developing and Emerging Economies*, 4(1), pp.2-22.

Dong, L., 2021. Toward resilient agriculture value chains: challenges and opportunities. *Production and Operations Management*, 30(3), pp.666-675.

Ekepu, D., Tirivanhu, P. and Nampala, P., 2017. Assessing farmer involvement in collective action for enhancing the sorghum value chain in Soroti, Uganda. *South African Journal of Agricultural Extension*, 45(1), pp.118-130.

Feder, G., Birner, R. and Anderson, J.R., 2011. The private sector's role in agricultural extension systems: potential and limitations. *Journal of Agribusiness in Developing and Emerging Economies*, 1(1), pp.31-54.

Fischer, G., Gramzow, A. and Laizer, A., 2017. Gender, vegetable value chains, income distribution and access to resources: insights from surveys in Tanzania. *European Journal of Horticultural Science*, 82(6), pp.319-327.

Hlatshwayo, S.I., Ngidi, M., Ojo, T., Modi, A.T., Mabhaudhi, T. and Slotow, R., 2021. A typology of the level of market participation among smallholder farmers in South Africa: Limpopo and Mpumalanga Provinces. *Sustainability*, 13(14), pp.7699.

Kiptot, E. and Franzel, S., 2012. Gender and agroforestry in Africa: a review of women's participation. *Agroforestry Systems*, 84, pp.35-58.

Lagerkvist, C.J., Ngigi, M., Okello, J.J. and Karanja, N., 2012. Means-End Chain approach to understanding farmers' motivations for pesticide use in leafy vegetables: The case of kale in peri-urban Nairobi, Kenya. *Crop protection*, 39, pp.72-80.

Li, C., Ma, W., Mishra, A.K. and Gao, L., 2020. Access to credit and farmland rental market participation: Evidence from rural China. China Economic Review, 63, pp.101523

Maliwichi, L.L., Pfumayaramba, T.K. and Katlego, T., 2014. An analysis of constraints that affect smallholder farmers in the production of tomatoes in Ga-Mphahlele, LepelleNkumbi Municipality, Limpopo Province, South Africa. *Journal of Human Ecology*, 47(3), pp.269-274.

Maponya, P., Venter, S.L., Van Den Heever, E. and Mahlangu, S., 2016. Factors enhancing market participation: a case of smallholder farmers in Zululand district, KwaZulu-Natal in South Africa. *African Journal of Business and Economic Research*, 11(1), pp.117-142.

Margono, T. and Sugimoto, S., 2011. The barriers of the Indonesian extension workers in disseminate agricultural information to farmers. *International Journal of Basic And Applied Sciences*, 11(2), pp.7302-4747.

Mashamaite, C.V., Pieterse, P.J., Mothapo, P.N. and Phiri, E.E., 2021. Moringa oleifera in South Africa: A review on its production, growing conditions, and consumption as a food source. *South African Journal of Science*, 117(3-4), pp.1-7.

Mehdi, M., Ashfaq, M., Hassan, S. and Abid, M., 2019. Effect of marketing channel choice on the profitability of citrus farmers: evidence form Punjab-Pakistan. *Pakistan Journal of Agricultural Sciences*, 56(4).

Mkuna, E. and Wale, E., 2022. Explaining Farmers' Income via Market Orientation and Participation: Evidence from KwaZulu-Natal (South Africa). *Sustainability*, 14(21), pp.14197.

Mossie, M., Gerezgiher, A., Ayalew, Z. and Nigussie, Z., 2020. Determinants of small-scale farmers' participation in Ethiopian fruit sector's value chain. *Cogent Food and Agriculture*, 6(1), pp.1842132.

Mustafa, M.A., Mayes, S. and Massawe, F., 2019. Crop diversification through a wider use of underutilised crops: a strategy to ensure food and nutrition security in the face of climate change. Sustainable solutions for food security: combating climate change by adaptation, pp.125-149.

Ndlovu, P.N., Thamaga-Chitja, J.M. and Ojo, T.O., 2021. Factors influencing the level of vegetable value chain participation and implications on smallholder farmers in Swayimana KwaZulu-Natal. *Land Use Policy*, 109, pp.105611.

Njuki, J. and Sanginga, P.C., 2013. Gender and livestock ownership: key issues, challenges, and opportunities. Women, livestock ownership and markets: bridging the gender gap in Eastern and Southern Africa. New York: Routledge, pp.1-8.

Rubin, D. and Manfre, C., 2014. Promoting gender-equitable agricultural value chains: Issues, opportunities, and next steps. Gender in agriculture: Closing the knowledge gap, pp.287-313.

Shackleton, C., Paumgarten, F., Mthembu, T., Ernst, L., Pasquini, M. and Pichop, G., 2010. Production of and trade in African indigenous vegetables in the urban and peri-urban areas of Durban, South Africa. *Development Southern Africa*, 27(3), pp.291-308.

Shange, L.P., 2004. Taro [Colocasia esculenta (L.) Schott] production by small-scale farmers in KwaZulu-Natal: farmer practices and performance of propagule types under wetland and dryland conditions (Doctoral dissertation).

Sharma, H.K., Njintang, N.Y., Singhal, R.S. and Kaushal, P., 2016. Tropical roots and tubers: production, processing, and technology. John Wiley and Sons.

Sharma, V.P., 2015. Determinants of small milk producers' participation in organised dairy value chains: Evidence from India. *Agricultural Economics Research Review*, 28(2), pp.247-261.

Singh, H., Kumar, S. and Mittal, S., 2011. Value chains of agricultural commodities and their role in food security and poverty alleviation–a synthesis. *Agricultural Economics Research Review*, 24(1), pp.169-181

Sinyolo, S., Mudhara, M. and Wale, E., 2017. The impact of social grant dependency on smallholder maize producers' market participation in South Africa: Application of the double-hurdle model. *South African Journal of Economic and Management Sciences*, 20(1), pp.1-10.

Trooster, W., Auerbach, R. and Haysom, G., 2020. Strengthening participation in the organic value chain for small-scale farmers in Southern KwaZulu-Natal, South Africa. In Organic Food Systems: Meeting the needs of Southern Africa. CABI, Wallingford, England.

Tura, E.G., Goshub, D., Demise, T. and Kenead, T., 2016. Determinants of market participation and intensity of marketed surplus of teff producers in Bacho and Dawo districts of Oromia State, Ethiopia. *Journal of Agricultural Economics and Development*, 5(2), pp.20-32.

Usapfa, L., 2015. Value chain analysis and resource-use efficiency of small-holders broiler farmers in Capricorn District, Limpopo Province (Doctoral dissertation, University of Limpopo).

Zainodin, H.J. and Yap, S.J., 2013, September. Overcoming multicollinearity in multiple regression using correlation coefficient. AIP Conference Proceedings, 1557 (1), pp. 416-419. American Institute of Physics

Chapter 6: Exploration of the Relationship Between Crop Production Systems and Value Chains: Implication on Household Food Insecurity in KwaZulu-Natal, South Africa

Abstract

Household food insecurity persists in KwaZulu-Natal Province, South Africa, despite agriculture's significant contribution to the country's economy. The role that combinations of crop production systems and the value chain can play in improving household food security has yet to be addressed. This paper examines the combined effects of crop production systems and the value chains on household food insecurity. Principal Component Analysis transformed the correlated variables into three distinct domains: modern agro-production practices, sustainable market integration, and traditional knowledge. Ordered probit analysis was used to determine factors influencing household food insecurity measured using the Household Food Insecurity Access Scale using 300 randomly selected smallholder farmers. The results show that sustainable market integration, traditional knowledge focus, education, and livestock ownership significantly and negatively impact household food insecurity. Household size, household food expenditure, floods, and cash credit significantly and positively affect household food insecurity. Policymakers and stakeholders should prioritise sustainable market integration and traditional knowledge preservation while reducing food costs to combat household food insecurity.

Keywords: Relationship; PCA; ordered probit; HFIAS; food security

6.1 Introduction

Agriculture plays a significant role in many nations, driving both economic growth and employment opportunities, especially within Sub-Saharan Africa, where the issue of food insecurity continues to be a significant challenge (Meybeck *et al*., 2017). Kwa-Zulu-Natal Province in South Africa has a diverse agricultural sector, contributing significantly to the national food production (Mthembu and Zwane, 2017). However, household food insecurity remains a pressing issue, with a substantial part of the population experiencing inadequate access to safe and nutritious food (Tawodzera, 2017).

Kristjanson *et al*. (2012), Warren *et al*. (2015), Nkomoki *et al*. (2018), and Herrera *et al*. (2021) examined the relationship between agricultural practices and food security. However, according to author's knowledge no studies have been conducted that specifically focused on the interaction between crop production systems and value chains and their relationship with household food insecurity in South Africa. Akinnifesi *et al*. (2010), Wekesa *et al*. (2018), Mujeyi *et al*. (2021), and Noort *et al*. (2022) focused on crop production systems and their impact on household food security but overlooked the role of value chains. Similarly, Kissoly *et al*. (2017), Kumar *et al*. (2019), Mossie *et al*. (2021), and Ndlovu *et al*. (2022) explored the impact of value chains on household food security, neglecting the roles that specific crop production systems played. This research conducted to date demonstrates the need to understand the combined impact of crop production systems and value chains on household food security.

This study recognises that the impact of production systems cannot be viewed in isolation from the broader value chains within which they operate (Devaux *et al*., 2018). Value chains encompass various actors, processes, and relationships in agricultural production, processing, distribution, and consumption (Ndlovu *et al*., 2022). According to Tansey and Worsley (2014), both crop production systems and value chains can allow a comprehensive understanding of the factors influencing household food security.

6.2 Analytical Framework

This research used an ordered probit model to address the limitations associated with the binary choice models used in previous food security studies and using the statistical analysis software

STATA Version 15. In this case, the ordered probit regression model is preferred to multinomial logit or binary choice models in view of the discrete variable whose values are ordinal (Hlatshwayo *et al.*, 2022). This study effectively unveils crucial insights into the genuine condition of household food security using the ordered probit model.

The dependent variable used in this study is ordered with respect to categories of household food security. Nkegbe *et al.* (2017) stated that the selected model is helpful in determining the multiple determinants of household food security. Ordered probit regression models recognise the indexed nature of various response variables; in this study, food insecurity severities are the ordered response. Underlying the indexing in such models is a latent but continuous descriptor of the response, i.e.,

$$Y_i^* = \beta`X_i + \varepsilon_i, \quad (6.1)$$

Where Y_i^* is the latent and continuous measure, X_i is a vector of explanatory variables describing the independent descriptors, β is a vector of parameters to be estimated, and ε_i is a random error term.

The observed and coded discrete Y_i is determined from the model as follows:

$$\begin{aligned} Y_i &= 0 \quad \text{if } -\infty \leq Y_i^* \leq \mu_1 \\ &1 \text{ if } \mu_1 < Y^* \leq \mu_2 \\ &2 \text{ if } \mu_2 < Y^* \leq \mu_3 \\ &3 \text{ if } \mu_3 < Y^* \leq \infty \end{aligned} \quad (6.2)$$

The μ_1 presents thresholds to be estimated (along with the parameter vector β).

The probabilities associated with the coded responses of an ordered probit model are as follows:

$$\begin{aligned} Pn(0) &= \Pr(Y_n = 0) = \Pr(Y_n^* \leq \mu_1) = \Pr(\beta`Xi + \varepsilon i \leq \mu_1) \\ &= \Pr(\varepsilon i \leq \mu_1 - \beta`Xi = \emptyset(\mu_1 - \beta`Xi) \\ Pn(1) &= \Pr(Y_n = 1) = \Pr(\mu_1 \leq Y_n^* \leq \mu_2) \\ &= \Pr(\varepsilon i \leq \mu_2 - \beta`Xi) - \Pr(\varepsilon i \leq \mu_1 - \beta`Xi) \\ &= \emptyset(\mu_2 - \beta`Xi) - \emptyset(\mu_1 - \beta`Xi) \\ Pn(k) &= \Pr(Y_n = k) = \Pr(\mu_k < Y_n^* \leq \mu_k + 1) \\ &= \emptyset(\mu_{k+1} - \beta`Xi) - \emptyset(\mu_k - \beta`Xi) \\ Pn(K) &= \Pr(Y_n = K) = \Pr(\mu_k < Y_n^*) \\ &= 1 - \emptyset(\mu_k - \beta`Xi) \end{aligned}$$

Where *n* is an individual, *k* is a response alternative, $\mathrm{P}(Y_n = k)$ is the probability that individual *n* responds in a manner *k*, and $\emptyset(\ )$ is the standard normal cumulative distribution function. In the increasing nature of the ordered classes, the interpretation of this model's primary parameter set β.

6.3 Research Methodology

This study's data collection, population and sampling procedure are presented in Sections 3.4.2 and 3.4.3.

6.3.1 Data Analytical Methods

This study employs several data analytical methods, i.e., the Household Food Insecurity Access Scale (HFIAS) for food security measurement, Principal Component Analysis (PCA) for reducing the directionality in the permutations of combinations in the relationship between crop production systems and value chains, and an ordered probit regression model for determining factors influencing household food security. These methods collectively allow a comprehensive analysis of the intricate dynamics between crop production systems, value chains, and household food security.

6.3.1.1 Food Security Measurement

The study used the HFIAS to assess the food insecurity situation in smallholder farmers' households. The HFIAS has nine questions on the occurrence of food insecurity, each representing increasing severity, followed by frequency of occurrence questions. These frequency questions aim to determine how often the specific food security condition occurred within the past 30 days. The HFIAS Indicator Guide v3 (Coates *et al*., 2007) provides detailed instructions on using this questionnaire. It categorises household food security status into four categories as follows:

- A food-secure household rarely experiences any food insecurity (access) conditions or just experiences worry. HFIA category = 1 if [(Question (Q) 1 = 0 or Q1a = 1) and Q2 = 0 and Q3 = 0 and Q4 = 0 and Q5 = 0 and Q6 = 0 and Q7 = 0 and Q8 = 0 and Q9 = 0]. ("Household Food Insecurity Access Scale (HFIAS) for Measurement of Food Access: Indicator Guide VERSION 3")
- A mildly food insecure household sometimes or often worries about not having enough food and cannot eat preferred foods, eat a more monotonous diet than desired, or, however rarely, eat some foods considered undesirable. HFIA category

= 2 if [(Q1a = 2 or Q1a = 3 or Q2a = 1 or Q2a = 2 or Q2a = 3 or Q3a = 1 or Q4a = 1) and Q5 = 0 and Q6 = 0 and Q7 = 0 and Q8 = 0 and Q9 = 1].

- A moderate food insecure household sacrifices quality more frequently by eating a monotonous diet or, sometimes or often, undesirable foods. ("Household food insecurity, income loss, and symptoms of psychological"). They sometimes, however rarely, start cutting back on quantity by reducing the size or number of meals, although they do not experience any of the three main severe conditions. HFIA category = 3 if [(Q3a=2 or Q3a = 3 or Q4a = 2 or Q4a = 3 or Q5a = 1 or Q5a = 2 or Q6a = 1 or Q6a = 2) and Q7 = 0 and Q8 = 0 and Q9 = 1].
- A severely food insecure household goes further to cut down on meal size or the number of meals and or experiences any of the three most severe conditions (running out of food, going to bed hungry, or going the whole day and night without eating). HFIA category = 4 if [Q5a = 3 or Q6a = 3 or Q7a = 1 or Q7a = 2 or Q7a = 3 or Q8a = 1 or Q8a= 2 or Q8a = 3 or Q9a = 1 or Q9a = 2 or Q9a = 3] (Coates *et al.*, 2007).

6.3.1.2 Principal Component Analysis

The relationship between the crop production system and the value chain was explored using Principal Component Analysis (PCA). This study preferred Principal Component Analysis (PCA) over Factor Analysis (FA) as the former is primarily a dimensionality reduction technique, aiming to capture the maximum variance in the data without making strong assumptions about the underlying structure (Tripathi and Singal, 2019). In contrast, Factor Analysis assumes the existence of latent constructs driving the observed variable (Steenkamp and Maydeu-Olivares, 2023). PCA was chosen due to its ability to reduce dimensionality, capture maximum variance, provide uncorrelated components, and offer an objective criterion for component selection, all of which contribute to a more robust and interpretable analysis.

It's worth noting that before performing PCA, the variables were standardized to ensure comparability and consistency in their contributions to the principal components. PCA was then performed on the dataset, transforming the original variables into a set of uncorrelated principal components (PCs). Table 6.1 lists the variables used in PCA. The number of PCs to retain was decided using the Kaiser criterion. According to this criterion, any component with eigenvalues below 1 (after standardising the data) is discarded. Eigenvalues greater than 1 indicate that the corresponding component explains more variance than a single variable (Björklund, 2019).

Table 6.1: Variables used in Principal Component Analysis

Value Chain Variables	Measurements	Production System Variables	Measurements
Reliance on traditional knowledge and practices	Likert scale (1-5)	Crop yield per unit area	Kilograms per hectare (kg/ha)
Traceability and labeling practices	Yes/No	Use of synthetic fertilizers	Kilograms per hectare (kg/ha)
Direct marketing channels	Number of direct marketing channels	Use of chemical pesticides	Kilograms per hectare (kg/ha)
Organic certification	Yes/No	Use of traditional seed varieties	Percentage of seed usage
Post-harvest handling practices	Likert scale (1-5)	Reliance on traditional knowledge and practices	Likert scale (1-5)
Wholesale market	Yes/No	Use of natural pest control methods	Percentage of pest control usage
Local market integration (Local markets)	Percentage of sales	Use of organic fertilizers	Kilograms per hectare (kg/ha)
Traditional value-added products	Number of products	Agrobiodiversity	Number of crop species

6.3.1.3 Empirical Model: Ordered Probit Model

The household food security status depends on certain measurable factors (X_i) and unobservable factors (εi). The ordered probit model was estimated for the polychotomous dependent variable with four categories. Following Wooldridge (2010), the ordered probit model for Y (conditional on explanatory variables X_i) can be derived from a latent variable model as follows:

$$Y_i^* = \beta` X_i + \varepsilon_i, \qquad (6.4)$$

Where Y_i^* is the latent and continuous measure of food insecurity severity faced by smallholder farmers *i* in a rural area, X_i is a vector of explanatory variables describing the socio-economic characteristics of farmers (as in Table 6.1), β is a vector of parameters to be estimated, and ε_i is a random error term.

The observed and coded discrete food insecurity severity variable Y_i is determined from the model as follows:

$Y_i = 0$ if $-\infty \leq Y_i^* \leq \mu_1$ (Food secured)

1 if $\mu_1 < Y^* \leq \mu_2$ (Mildly to food secured)

2 if $\mu_2 < Y^* \leq \mu_3$ (Moderate to food insecure)

3 if $\mu_3 < Y^* \leq \infty$ (Severely food insecure) (6.5)

The μ_1 presents thresholds to be estimated (along with the parameter vector β).

The smallholder farmer food security determinants were identified through a literature review. Table 6.2 describes the explanatory variables used in the model and the expected signs of the potential explanatory variables.

Table 6.2: Variables used in the ordered probit analysis.

Dependent variable	Measurements	Expected sign	Rationale
HFIAS	1= Food secure, 2= Mildly food insecure, 3= Moderately food insecure and 4= Severely food insecure		Household food security status, measured using HFIAS.
Independent variables			
Hsize	Continuous variable measuring the number of people in the household	+	Larger households may have higher food requirements and face challenges in meeting those needs (Nkomoki *et al*., 2019)
Age	Number of years of the household head	-	Older household heads have more farming experience and are less likely to be food insecure (Zhou *et al*., 2019).
Education	0= No school , 1= Primary , 2= Secondary ,3= Tertiary	-	Higher education levels are often associated with better income potential and resource access, which can negatively affect food insecurity (Zhou *et al.,* 2019).
Livestock	Number of livestock owned by a household.	-	Households with more livestock may be better equipped to ensure their food security (Molina-Flores *et al*., 2020).
Household food expenditure	0= Low (≤60% total expenditure), 1 = High (>60% total expenditure)	-	Higher food expenditure may show better food security, suggesting that a larger amount of income is allocated to food (Akbar *et al.,* 2023).
Occupation	0 = non-farmer 1 = Farmer	-	Farmers may have more direct control over food production and better access to nutritious food than non-farmers (Lutomia *et al*., 2019).
Remittances	Receives remittances 0=No 1= Yes	-	Remittances, i.e., money sent by family members working in other locations, can contribute to household income and improve food security by increasing purchasing power (Zhou *et al*., 2019).
Floods	Affected by floods 0= No 1= Yes	+	Floods can significantly negatively impact agricultural production and food security (Week and Wizor, 2020).
Cash Credit	Access to cash credit 0= No 1= Yes	-	Households with access to cash credit may manage unexpected expenses and ensure food availability (Sani and Kemaw, 2019)
Modern agro-production practices (PC1)	Factor score	-/+	Modern agro-production practices, such as the use of synthetic fertilisers and chemical pesticides, are known to influence crop yields and agricultural productivity. Including PC1 allows us to investigate how modern farming techniques may affect food insecurity levels.
Sustainable market integration (PC2)	Factor score	-/+	Sustainable market integration can enhance market access, income diversification, and supply chain efficiency, potentially affecting food availability and accessibility. Including PC2 enables us to explore the role of market-oriented approaches in mitigating food insecurity.
Traditional knowledge (PC3)	Factor score	-/+	Traditional knowledge encompasses time-tested farming practices and local ability, potentially contributing to agricultural resilience and sustainable resource management. Including PC3 allows us to assess the influence of traditional knowledge on food security outcomes.

6.4 Results and Discussions

This section presents the results of various statistical analyses of the data from 300 participants. These analyses include the chi-square tests, one-way ANOVA, multicollinearity test, Principal Component Analysis (PCA), and an ordered probit model. The analytical tools facilitated a thorough investigation of the intricate relationships between food security levels, socio-economic parameters, crop production systems, value chains, and their interactions.

6.4.1 Descriptive Analysis Results

Table 6.3 shows that 36% of farmers were food secure, 33% were mildly food insecure, 22% were moderately, and 9% were severely food insecure. The chi-square test was employed to check the association between food security status measured as HFIAS and independent variables.

Table 6.3: Association between food security and socio-economic parameters

Variables	Measure	Food secure (*n*=107) 36%	Mildly food insecure (*n*=99) 33%	Moderately food insecure (*n*=66) 22%	Severely food insecure (*n*=28) 9%	X^2
Education	1= No School	53	42	47	29	**
	2= Primary	23	24	14	14	
	3=Secondary	19	30	32	50	
	4= Tertiary	5	4	7	7	
Household food expenditure	0= Low	57	62	58	64	n. s
	1 = High	43	38	42	36	
Occupation	0 = non-farmer	58	58	53	75	n. s
	1 = Farmer	42	42	47	25	
Remittances	0= No	52	41	52	68	*
	1= Yes	48	59	48	32	
Floods	0= No	53	61	62	64	n. s
	1= Yes	47	39	38	36	
Cash Credit	0= No	93	94	97	100	n. s
	1= Yes	7	6	3	0	

Note: *and ** means statistically significant at 10% and 5% levels, respectively, **n.s** means not significant.

Table 6.3 shows a statistically significant relationship between education and food security status ($p<0.05$). The results show that 53% of households that had no schooling were food secure, and in households that had primary education, about 23% were classified as food secure. About 19% had secondary education, and 5% had tertiary education and were classified as food secure. In the mildly food insecure category, about 42% had no schooling, 24% had primary education, 30% had secondary education, and 4% had tertiary education. The results further show that in the moderate food insecurity level, about 47% of households had no schooling, 14% had primary education, 32% had secondary education, and 7% had tertiary education. In the fourth category of food insecurity level, which is severe food insecurity, the results show that 29% of household heads had no schooling, 14% had primary education, 50% had secondary education, and 7% had tertiary education.

The results also show a statistically significant between receiving remittances and household food security ($p<0.1$). The result shows that for households with "No" remittances, approximately 52% of households are classified as food secure, 41% of households are mildly food insecure, 52% of households are moderately food insecure, and 68% of households are severely food insecure. For households with "Yes" remittances, about 48% of households are food secure, 59% are mildly food insecure, 48% are moderately food insecure, and 32% are severely food insecure.

Table 6.4 shows the relationship between household food security level and continuous variables, which was measured using one-way ANOVA. The statistical analysis in Table 6.4 revealed a significant difference in livestock-owned means across the different levels of food security ($p<0.01$). Livestock ownership varies significantly among households with different levels of food security. The mean value of livestock owned by food-secure households was 22. In comparison, households with mildly food insecurity had a mean livestock ownership of 18. moderately food insecure households had the mean livestock owned of 11. The lowest mean livestock owned value was among severely food-insecure households. These findings indicate that livestock ownership tends to decrease with an increase in food insecurity.

Table 6.4: One-way ANOVA results for household food security determinants

Variable	**Food secure**		**Mildly food insecurity**		**Moderately food insecurity**		**Severe food insecurity**		**F Significance**
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	
Household size (number of people)	8	4.29	7	4.42	8	4.11	8	3.22	n. s
Age (years)	53	13.28	51	13.26	54	14.85	49	14.43	n. s
Livestock owned (number of livestock)	22	0.88	18	1.85	11	1.98	3	2.56	***

Note: *** means statistically significant at 1% level, **n.s** means not significant

6.4.2 Multicollinearity Test of Variables

Inflation Factor (VIF)mong the independent variables was assessed using the Variance Inflation Factor (VIF), considered acceptable if the values were below 10. The findings in Table 6.5 indicate no multicollinearity issues since all the VIF values were below this threshold (Salmeron-Gomez *et al.,* 2020).

Table 6.5: Multicollinearity test of variables

Variable	VIF	1/VIF
Modern agro-productivity practices	3.66	0.27
Floods	3.02	0.33
Household food expenditure	1.44	0.69
Age	1.39	0.72
Education	1.26	0.79
Livestock owned	1.21	0.82
Occupation	1.15	0.87
Remittances'	1.12	0.89
Traditional knowledge focus	1.09	0.92
Sustainable market integration	1.09	0.92
Household size	1.03	0.97
Cash Credit	1.01	0.99
Mean VIF	1.54	

6.4.3 Principal Component Analysis Results

The Principal Component Analysis (PCA) was conducted to reduce the dimensionality of the interactive relationship between crop production systems and the value chain. When conducting PCA, a set of three principal components (PCs) were derived as shown in Table 6.6. Three PCs met the Kaiser criterion as they had eigenvalues exceeding one and collectively explained 36.31% of the total variance in the utilised variables. Specifically, the three components accounted for 15.06%, 11.79%, and 9.46% of the variance, respectively, as specified in Table 6.6. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy assesses the suitability of the data for PCA. The value of 0.615 indicates that the sample size and the intercorrelations among the variables are suitable for PCA.

PC1 presents a pattern related to modern agro-productivity practices. The positive loading values for "crop yield per unit area," "use of synthetic fertilisers," and "agrobiodiversity" " local market integration" suggests that these variables are positively correlated with each other and contribute to modern agro-productivity practices. This positive correlation implies that systems exhibiting higher crop yields, increased use of synthetic fertilisers, and greater agrobiodiversity tend to integrate better into local markets. This alignment of variables is consistent with the notion that modern agro-productivity practices often go hand in hand with increased market participation (Mishra *et al*., 2019).

PC2 presents a pattern related to sustainable market integration. The positive loading values for "reliance on traditional knowledge and practices, traceability and labelling practices, use of natural pest control methods, use of organic fertilisers, organic certification, post-harvest handling practices, market integration (wholesale market) indicate that these variables are positively correlated and contribute to sustainable market integration. High values in pc2 suggest an agricultural system that emphasises markets, traditional knowledge, and traceability in the supply chain.

PC3 presents a pattern related to a focus on traditional knowledge and practices. The positive loading values for direct marketing channels" and "reliance on traditional knowledge and practices" indicate that these variables are associated with a focus on traditional agricultural methods.

Table 6.6: Principal Component Analysis

Variable	PC1-Modern agro-productivity practices	PC2-Sustainable market integration	PC3-Traditional knowledge focus
Crop yield per unit area	**0.571**	0.036	0.336
Use of synthetic fertilisers	**0.738**	0.143	-0.017
Use of chemical pesticides	0.118	-0.090	0.110
Use of traditional seed varieties	0.134	0.284	0.228
Reliance on traditional knowledge and practices	-0.227	**0.462**	**0.526**
Traceability and labelling practices	-0.104	**0.474**	-0.379
Direct marketing channels	-0.089	0.023	**0.432**
Use of natural pest control methods	0.034	**0.562**	0.254
Use of organic fertilisers	-0.179	**0.416**	0.182
Organic certification	-0.004	**0.470**	-0.517
Post-harvest handling practices	-0.018	**0.455**	-0.142
Market integration (Wholesale market)	-0.246	**0.479**	-0.430
Agrobiodiversity	**0.826**	0.207	0.066
Local market integration (Local markets)	**0.712**	0.175	0.210
Traditional value-added products	-0.055	0.035	-0.135
Eigenvalue	2.258	1.769	1.419
Proportion	15.06%	11.79%	9.46%
Cumulative	15.06%	26.85%	36.31%
KMO	0.615		
Alpha	0.386		

LR test: independent vs. saturated: chi2(105) = 502.30 Prob>chi2 = 0.0000

6.4.4 Impact of the Interaction Between Crop Production System and Value Chain on Household Food Security

The ordered probit model was utilised to identify household characteristics that influence the food security status of smallholder farmers' households (as shown in Table 6.7). The results demonstrate that collectively, the estimated coefficients statistically significantly determine food security, as indicated by the LR statistic ($p<0.01$). The coefficients of the ordered probit model do not directly indicate the size of the effects of the explanatory variables. Instead, the marginal effects are presented and discussed. In this context, a positive value of the coefficient suggests an increase in the HFIAS score, indicating a higher likelihood of a household being food insecure. Conversely, a negative coefficient implies a higher probability of a household being food secure.

Table 6.7: Factors influencing household food security status.

Variables	**Coef.**	**Std. Err.**	**P-value**	Marginal effects			
				Food secure	**Mildly food insecure**	**Moderately food insecure**	**Severely food insecure**
Modern agro-productivity practices	0.051	0.055	0.349	0.018	-0.001	-0.008	-0.008
Sustainable market integration	-0.228	0.078	**0.003*****	-0.078*	0.005	0.037**	0.037***
Traditional knowledge focus	-0.113	0.067	**0.094***	-0.039**	0.002	0.018*	0.018*
Household size	0.026	0.009	**0.004*****	0.009***	-0.001	-0.004***	-0.004***
Age	0.004	0.005	0.438	0.001	-0.000	-0.001	-0.001
Education	-0.202	0.073	**0.006*****	-0.069*	0.004	0.033***	0.032***
Livestock owned.	-0.022	0.007	**0.001*****	-0.008***	0.000	0.004***	0.004***
Occupation	0.067	0.140	0.634	0.023	-0.001	-0.011	-0.011
Household food expenditure	0.454	0.170	**0.008*****	0.156***	-0.010	-0.073***	-0.073**
Remittances	0.165	0.133	0.214	0.057	-0.004	-0.027	-0.026
Floods	0.260	0.152	**0.088***	0.089*	0.006	0.042**	0.042*
Cash Credit	0.562	0.307	**0.067***	0.193*	-0.012	-0.091*	-0.090*

Number of obs=300 LR $Chi^2(12)$ =42.60 Prob>Chi^2=0.001Pseudo R^2=0.055 Log likelihood = -364.19357 **Note:** *and *** means coefficient and dy/dx are statistically significant at 10% and 1% levels, respectively.

The results show that sustainable market integration has a significant and negative association (*p*<0.01) with food insecurity levels (Table 6.7). The marginal effect shows that the effects are in two ways, i.e., further increases in food security when at the food secure level and increased food insecurity at high levels of food insecurity. The marginal effects results show that a unit increment in sustainable market integration at a food secure level yields a statistically significant 7.8% decrease in food insecurity. Omiti *et al*. (2009) and Shiferaw *et al*. (2011) have emphasised the positive role of market access and integration in enhancing food security for households that already meet their basic needs. Šūmane *et al*. (2018) and Elechi *et al.* (2022) suggest that market access improves food availability, diversity, and stability. Households with surplus production sell their products in markets, generating income to purchase a wider variety of foods, reducing the risk of food shortages (Cele and Mudhara, 2022). Conversely, the results also entail a 3.7% probability of transitioning from moderately to severely food insecure, i.e., becoming more food insecure. The results reflect the complex and context-dependent nature of food security outcomes. This finding is consistent with the concept of vulnerability to food insecurity. Households at higher food insecurity levels often need more resources and face various constraints that prevent them from fully benefiting from market integration. Smith and Frankenberger (2018) underscore the vulnerability of moderately food-insecure households to external shocks and stresses, which can exacerbate their food insecurity.

The result suggests that traditional knowledge focus has a statistically significant and negative impact ($p<0.1$) on household food security. The result indicates that an increase in traditional knowledge focus is associated with a statistically significant 3.9% decrease in food insecurity, and the results are consistent with the findings of Ndalilo *et al.* (2020) on the role of traditional knowledge systems in promoting food security. Traditional knowledge encompasses indigenous and local knowledge of agriculture, natural resource management, and food production (Adade-Williams *et al*., 2020). Food and Agriculture Organisation (FAO) (2017) highlighted the value of integrating traditional knowledge practices into modern agricultural systems. For instance, Bommarco *et al.* (2013) emphasise traditional ecological knowledge's contribution to sustainable resource management and food production. Traditional knowledge often includes valuable practices for crop cultivation, pest control, and water management that can enhance agricultural productivity and food security.

The results also show that the same increase in traditional knowledge focus results in a 1.8% probability of households transitioning from moderately food insecure to severely food insecure. The finding aligns with the recognition that traditional knowledge alone may not be a panacea for addressing food security, especially for households already facing moderate to severe food insecurity. The vulnerability of moderately food-insecure households to external shocks limits their capacity to fully leverage traditional knowledge systems to improve their food security status (Diaz-Bonilla *et al*., 2015).

Consistent with *a priori* expectations, larger households were more food insecure than households with smaller sizes, *ceteris paribus*. Overall, household size positively and statistically significantly impacted household food insecurity ($p<0.01$). The marginal effects results show that an increase in household size had a 0.9% increase in the likelihood of being food insecure and a 0.4% chance of sliding from severe food insecure to moderate food insecure, i.e., becoming more food secure. The finding that a larger family size leads to food insecurity at the food security level aligns with the notion that household size adversely impacts food security. Hawkins *et al.* (2022) have highlighted that larger family sizes strain resources, including food, in already food-secure households. In such cases, increased family size leads to a higher demand for food, potentially stretching available resources and increasing the risk of food insecurity (Hawkins *et al.*, 2022).

Conversely, the observation is that at higher levels of food insecurity, larger families benefit from extra labour and sharing of tasks, leading to improved food security outcomes. This finding is consistent with the Drammeh *et al*. (2019) emphasising the role of household labour in food production and security. In resource-constrained settings dependent on labour-intensive practices, additional family members can contribute to agricultural activities, such as farming and livestock management, enhancing food production and self-sufficiency (Drammeh *et al*., 2019). The concept of labour-sharing and cooperation within larger households has been explored in subsistence agriculture, where division among family members can improve food security outcomes (Naidoo *et al*., 2013).

The negative and statistically significant ($p<0.01$) relationship between level of education and food insecurity status suggests that higher educational levels of the household head are associated with a higher likelihood of households being food insecure. The marginal effects results suggest that at food secure levels, higher levels of education are likely to lead to improved food security outcomes. A higher level of education leads to a 6.9% increase in the chance of being more food secure. Mutisya *et al.* (2016) had similar findings and further stated that higher levels of education are often associated with increased knowledge and skills. Education equips individuals with a broader understanding of nutrition, agriculture, and economic concepts, which can positively influence food-related decision-making within the household (Parker *et al.*, 2012). Parker *et al.* (2012) noted that household heads with higher educational levels possess better agricultural and financial management skills, enabling them to make informed choices regarding crop production, income generation, and resource allocation, all of which can contribute to improved food security outcomes. However, the marginal effect results further show that an educated household head has a 3.3% increase in the chance of sliding from moderately food insecure to severely food insecure. These findings are aligned with the findings of Mutisya *et al.* (2016), which stated that highly educated individuals allocate a significant portion of their income to investments in their education and career development, leaving less disposable income for immediate needs like food.

The negative coefficient for livestock owned suggests that an increase in the number of livestock owned is associated with a higher likelihood of households being food secure ($p<0.01$). A unit increase in livestock ownership results in a 0.8% increase in likelihood of a household food being food secure and a 0.4% increase in the likelihood of transitioning from severely food insecure to moderately food insecure, i.e., more food secure. Kariuki *et al*. (2013) noted that livestock ownership provides households with an indirect and direct source of food in the form of income, milk, meat, and eggs. According to Kariuki *et al*. (2013), having more livestock means greater availability of animal-sourced protein and nutrients within the household's diet, contributing to improved food security and nutritional outcomes. Livestock ownership presents an asset diversification strategy for households as sole reliance on crop production for food and income is risky due to chances of crop failure, pests, or market fluctuations (Mulwa and Visser, 2020).

The results show that food expenditure has a positive and statistically significant impact ($p<0.01$) on household food security status. The positive relationship implies that households with higher food expenditures are more likely to experience higher levels of food insecurity. Higher food expenditure leads to a statistically significant 15.6% increase in the chance of sliding from food secure to mildly food insecure and a 7.3% chance of transitioning from moderately to severely food insecure. Akbar *et al*. (2023) found that households with a higher proportion of their expenditure allocated to food tend to be food insecure. The results suggest that these households have lower purchasing power or limited access to adequate food supplies.

Flooding was another major factor that determined food security in farm households. A positive and statistically significant relationship ($p<0.1$) exists between food insecurity and flood experiences. Table 6.7 indicates that experiencing floods leads to a statistically significant 8.9% increase in the chance of sliding from food secure to mildly food insecure and a 4.2% chance of sliding from moderately to severely food insecure. The impact of floods on agricultural systems results in various consequences, including crop damage and prolonged reduced productivity. These effects significantly contribute to food shortages within farming households, ultimately leading to severe food scarcity (Samim *et al.*, 2021). This finding agrees with recent research conducted in Afghanistan (Samim *et al.*, 2021) and Niger (Week and Wizor, 2020).

The relationship between access to credit and the level of household food security is positive and statistically significant ($p<0.1$). The marginal effects findings suggest that having access to cash credit leads to a 19.3% probability of transitioning from a food secure to a mildly food insecure status, which suggests that cash credit worsens household food security. The study's findings align with Bahiru *et al.* (2023), who suggest that poor households turn to cash credit when facing financial difficulties, including unexpected expenses or income shortages. While credit provides immediate relief and helps secure food, it often comes with interest and repayment obligations. Informal credit is accompanied by high interest rates, which makes poor households struggle to repay the loans (Bahiru *et al.*, 2023). In that case, it can lead to a cycle of debt and financial strain, ultimately resulting in a shift from food security to mild food insecurity. The marginal effects result further shows for household facing severe food insecurity access to cash credit increases the probability of transitioning from severely food insecure to moderately food insecure by 9%. Household facing severe food insecurity, access to credit provide a lifeline by allowing them to purchase essential food items or cover emergency expenses.

6.5 Conclusion and Recommendations

The study investigated the impact of the interaction between the crop production system and the value chain on household food security. The results from the ordered probit model revealed several significant factors influencing food insecurity status. Sustainable market integration (PC2) and traditional knowledge focus (PC3) showed a negative association with food insecurity. Furthermore, larger household sizes were associated with higher levels of food insecurity, mainly due to increased demand for food with limited resources. The household head's education level and livestock owned negatively affected food insecurity status. However, higher food expenditures were associated with increased food insecurity, indicating limited purchasing power or access to adequate food supplies. Lastly, flooding significantly contributed to food insecurity. Flooding results in degraded infrastructure and production bases.

Policymakers and stakeholders should prioritise sustainable market integration initiatives that facilitate smallholder farmers' access to markets, improve income opportunities, and promote environmentally friendly agricultural practices. Efforts should also be directed towards preserving and incorporating traditional knowledge in farming practices to enhance productivity and resilience in the face of challenges. Strategies to address the negative impact of larger household sizes on food security are crucial, such as promoting family planning and providing support to mitigate food shortages. Investing in education and training for farmers can lead to better agricultural and financial management practices, contributing to improved food security outcomes. Encouraging livestock ownership and promoting asset diversification can serve as a risk-reducing strategy for households and strengthen food security.

Interventions to support households with limited purchasing power should be explored to improve access to an adequate and diverse food source. Finally, proactive measures should be taken to minimise flooding and to address the consequences of flooding on agricultural systems, such as implementing flood prevention programmes through improved rural infrastructure. By implementing these recommendations, policymakers and stakeholders can work towards enhancing household food security and promoting sustainable agriculture.

References

Akinnifesi, F.K., Ajayi, O.C., Sileshi, G., Chirwa, P.W. and Chianu, J., 2010. Fertiliser trees for sustainable food security in the maize-based production systems of East and Southern Africa. A review. *Agronomy for sustainable development, 30*, pp.615-629.

Bahiru, A., Senapathy, M. and Bojago, E., 2023. Status of household food security, its determinants, and coping strategies in the Humbo district, Southern Ethiopia. *Journal of Agriculture and Food Research*, 11, pp.100461.

Björklund, M., 2019. Be careful with your principal components. *Evolution*, *73*(10), pp.2151-2158.

Bommarco, R., Kleijn, D. and Potts, S.G., 2013. Ecological intensification: harnessing ecosystem services for food security. *Trends in ecology and evolution*, *28*(4), pp.230-238.

Coates, J., Swindale, A. and Bilinsky, P., 2007. Household Food Insecurity Access Scale (HFIAS) for measurement of food access: indicator guide: version 3

Devaux, A., Torero, M., Donovan, J. and Horton, D., 2018. Agricultural innovation and inclusive value-chain development: a review. *Journal of Agribusiness in Developing and Emerging Economies*, *8*(1), pp.99-123.

Diaz-Bonilla, E., Piñeiro, V. and Elverdin, P., 2016. *External shocks, food security, and development: Exploring scenarios for Central America* (Vol. 1592). Intl Food Policy Res Inst.

Drammeh, W., Hamid, N.A. and Rohana, A.J., 2019. Determinants of household food insecurity and its association with child malnutrition in Sub-Saharan Africa: A review of the literature. *Current Research in Nutrition and Food Science Journal*, *7*(3), pp.610-623.

Hawkins, P., Geza, W., Mabhaudhi, T., Sutherland, C., Queenan, K., Dangour, A. and Scheelbeek, P., 2022. Dietary and agricultural adaptations to drought among smallholder farmers in South Africa: a qualitative study. *Weather and Climate Extremes*, *35*, pp.100413.

Herrera, J.P., Rabezara, J.Y., Ravelomanantsoa, N.A.F., Metz, M., France, C., Owens, A., Pender, M., Nunn, C.L. and Kramer, R.A., 2021. Food insecurity related to agricultural practices and household characteristics in rural communities of northeast Madagascar. *Food security*, *13*(6), pp.1393-1405.

Hlatshwayo, S.I., Ojo, T.O., Modi, A.T., Mabhaudhi, T., Slotow, R. and Ngidi, M.S.C., 2022. The determinants of market participation and its effect on food security of the rural smallholder farmers in Limpopo and Mpumalanga provinces, South Africa. *Agriculture*, 12(7), pp.1072.

Kariuki, J., Njuki, J., Mburu, S. and Waithanji, E., 2013. Women, livestock ownership and food security. *Women, Livestock Ownership and Markets*. Routledge.

Kissoly, L., Faße, A. and Grote, U., 2017. The integration of smallholders in agricultural value chain activities and food security: Evidence from rural Tanzania. *Food security*, *9*, pp.1219-1235

Kristjanson, P., Neufeldt, H., Gassner, A., Mango, J., Kyazze, F.B., Desta, S., Sayula, G., Thiede, B., Förch, W., Thornton, P.K. and Coe, R., 2012. Are food-insecure smallholder households making changes in their farming practices? Evidence from East Africa. *Food Security*, *4*, pp.381-397.

Kumar, A., Mishra, A.K., Saroj, S. and Joshi, P.K., 2019. Impact of traditional versus modern dairy value chains on food security: Evidence from India's dairy sector. *Food Policy*, *83*, pp.260-270.

Lutomia, C.K., Obare, G.A., Kariuki, I.M. and Muricho, G.S., 2019. Determinants of gender differences in household food security perceptions in the Western and Eastern regions of Kenya. *Cogent food and agriculture*, 5(1), pp.1694755.

Meybeck, A., Laval, E., Lévesque, R. and Parent, G., 2017, September. Food security and nutrition in the age of climate change. In Proceedings of the International Symposium organised by the Government of Québec in collaboration with FAO. Québec City (p. 132).

Molina-Flores, B., Manzano-Baena, P. and Coulibaly, M.D., 2020. The role of livestock in food security, poverty reduction and wealth creation in West Africa. FAO.

Mossie, M., Gerezgiher, A., Ayalew, Z. and Elias, A., 2021. Food security effects of smallholders' participation in apple and mango value chains in north-western Ethiopia. *Agriculture and Food Security, 10*, pp.1-15.

Mthembu, N.N. and Zwane, E.M., 2017. The adaptive capacity of smallholder mixed-farming systems to the impact of climate change: The case of KwaZulu-Natal in South Africa. Jàmbá: *Journal of Disaster Risk Studies*, 9(1), pp.1-9

Mujeyi, A., Mudhara, M. and Mutenje, M., 2021. The impact of climate-smart agriculture on household welfare in smallholder integrated crop–livestock farming systems: evidence from Zimbabwe. *Agriculture and Food Security*, *10*(1), pp.1-15

Mulwa, C.K. and Visser, M., 2020. Farm diversification as an adaptation strategy to climatic shocks and implications for food security in northern Namibia. *World Development*, *129*, pp.104906.

Mutisya, M., Ngware, M.W., Kabiru, C.W. and Kandala, N., 2016. The Effect of Education on Household Food Security in Two Informal Urban Settlements in Kenya: a Longitudinal Analysis. *Food Security* 8(4), pp.743–756. doi: https://doi.org/10.1007/s12571-016-0589-3.

Mutisya, M., Ngware, M.W., Kabiru, C.W. and Kandala, N.B., 2016. The effect of education on household food security in two informal urban settlements in Kenya: a longitudinal analysis. *Food Security*, *8*, pp.743-756.

Naidoo, K.D., Thamaga-Chitja, J.M. and Shimelis, H.A., 2013. Towards sustainable livelihoods through indigenous knowledge and water use security: Insights from small scale irrigation schemes in Limpopo Province. *Indilinga African Journal of Indigenous Knowledge Systems*, *12*(2), pp.301-324.

Ndalilo, L., Wekesa, C. and Mbuvi, M. T., 2020. Indigenous and local knowledge practices and innovations for enhancing food security under climate change: examples from Mijikenda communities in coastal Kenya. Sustainability Challenges in Sub-Saharan Africa II: Insights from Eastern and Southern Africa, pp.63-82.

Ndlovu, P.N., Thamaga-Chitja, J.M. and Ojo, T.O., 2022. Impact of value chain participation on household food insecurity among smallholder vegetable farmers in Swayimana KwaZulu-Natal. *Scientific African*, 16, pp.e01168.

Nkegbe, P.K., Abu, B.M. and Issahaku, H., 2017. Food security in the Savannah Accelerated Development Authority Zone of Ghana: an ordered probit with household hunger scale approach. *Agriculture and Food Security*, *6*(1), pp.1-11.

Nkomoki, W., Bavorová, M. and Banout, J., 2018. Adoption of sustainable agricultural practices and food security threats: Effects of land tenure in Zambia. *Land use policy*, *78*, pp.532-538

Nkomoki, W., Bavorová, M. and Banout, J., 2019. Factors associated with household food security in Zambia. *Sustainability*, 11(9), pp.2715.

Noort, M.W., Renzetti, S., Linderhof, V., du Rand, G.E., Marx-Pienaar, N.J., de Kock, H.L., Magano, N. and Taylor, J.R., 2022. Towards sustainable shifts to healthy diets and food security in sub-Saharan Africa with climate-resilient crops in bread-type products: A food system analysis. *Foods*, *11*(2), pp.135.

Omiti, J.M., Otieno, D.J., Nyanamba, T.O. and McCullough, E.B., 2009. Factors influencing the intensity of market participation by smallholder farmers: A case study of rural and peri-urban areas of Kenya. *African Journal of Agricultural and Resource Economics*, *3*(311-2016-5509), pp.57-82.

Parker, J.S., Wilson, R.S., LeJeune, J.T. and Doohan, D., 2012. Including growers in the "food safety" conversation: Enhancing the design and implementation of food safety programming based on farm and marketing needs of fresh fruit and vegetable producers. *Agriculture and Human Values*, *29*, pp.303-319.

Salmeron Gomez, R., Rodriguez Sanchez, A., García, C.G. and Garcia Perez, J., 2020. The VIF and MSE in raise regression. *Mathematics*, *8*(4), p.605.

Samim, S.A., Hu, Z., Stepien, S., Amini, S.Y., Rayee, R., Niu, K. and Mgendi, G., 2021. Food insecurity and related factors among farming families in Takhar region, Afghanistan. *Sustainability*, *13*(18), pp.10211

Sani, S. and Kemaw, B., 2019. Analysis of household's food insecurity and its coping mechanisms in Western Ethiopia. *Agricultural and food economics*, 7(1), pp.1-20.

Shiferaw, B., Hellin, J. and Muricho, G., 2011. Improving market access and agricultural productivity growth in Africa: what role for producer organisations and collective action institutions? *Food security*, *3*, pp.475-489.

Smith, L.C. and Frankenberger, T.R., 2018. Does resilience capacity reduce the negative impact of shocks on household food security? Evidence from the 2014 floods in Northern Bangladesh. *World Development*, *102*, pp.358-376.

Steenkamp, J.B.E. and Maydeu-Olivares, A., 2023. Unrestricted factor analysis: a powerful alternative to confirmatory factor analysis. *Journal of the Academy of Marketing Science*, 51(1), pp.86-113.

Šūmane, S., Kunda, I., Knickel, K., Strauss, A., Tisenkopfs, T., des Ios Rios, I., Rivera, M., Chebach, T. and Ashkenazy, A., 2018. Local and farmers' knowledge matters! How integrating informal and formal knowledge enhances sustainable and resilient agriculture. *Journal of Rural Studies*, *59*, pp.232-241.

Tansey, G. and Worsley, A., 2014. *The food system*. Routledge.

Tawodzera, G., 2016. Local Food Geographies the Nature and Extent of Food Insecurity in South Africa.

Tripathi, M. and Singal, S.K., 2019. Use of principal component analysis for parameter selection for development of a novel water quality index: a case study of river Ganga India. *Ecological Indicators*, *96,* pp.430-43

Warren, E., Hawkesworth, S. and Knai, C., 2015. Investigating the association between urban agriculture and food security, dietary diversity, and nutritional status: A systematic literature review. *Food Policy*, *53*, pp.54-66.

Week, D.A. and Wizor, C.H., 2020. Effects of flood on food security, livelihood and socio-economic characteristics in the flood-prone areas of the core Niger Delta, Nigeria. *Asian Journal of Geographical Research*, *3*(1), pp.1-17

Wekesa, B.M., Ayuya, O.I. and Lagat, J.K., 2018. Effect of climate-smart agricultural practices on household food security in smallholder production systems: micro-level evidence from Kenya. *Agriculture and Food Security*, *7*(1), pp.1-14.

Wooldridge, J.M., 2010. Econometric analysis of cross-section and panel data. MIT Press.

Zhou, D., Shah, T., Ali, S., Ahmad, W., Din, I.U. and Ilyas, A., 2019. Factors affecting household food security in the rural northern hinterland of Pakistan. *Journal of the Saudi Society of Agricultural Sciences*, 18(2), pp.201-210

Chapter 7: Conclusions and Recommendations

7.1 Summary

Enhancing underutilised crop production systems and integrating them into value chains can bolster household income, leading to improved household food security and nutrition outcomes. Smallholder farmers, by participating in both the production and consumption of underutilised crops, hold the potential to increase their household income and secure better food and nutrition outcomes. Despite their inherent promise, smallholder farmers confront a multitude of challenges that hinder their ability to access a reliable supply of quality food, whether through production or purchasing. The purpose of this study is to investigate and analyse the interconnections between underutilised crop production systems, value chains, and their implications for food security among smallholder farmers in selected rural areas in KwaZulu-Natal Province, South Africa. The specific objectives were to analyse the smallholder farmers' socio-economic determinants of underutilised crop production systems, to investigate factors influencing smallholder farmers' consumption of underutilised crops, to evaluate the determinants of smallholder farmers' participation intensity in underutilised crop value chains, and to explore the impact of the relationship between crop production systems and value chains on household food security.

Descriptive statistics, multivariate probit, double-hurdle model, Household Food Insecurity Access Scale (HFIAS), ordered probit regression model, Principal Component Analysis (PCA), Factor Analysis (FA), binary logistic regression model, and marginal effects were employed to achieve the specific objectives. The results from the study and literature showed that smallholder farmers are still faced with challenges that make their underutilised crop production and value chain remain marginalised and unimproved. The results showed that institutional, technical, and socio-demographic factors influence smallholder farmers' crop production systems and value chain participation. This implies a need to improve these factors, which will spontaneously enhance the conditions in which smallholder farmers operate and live.

The study hypothesised that the nexus of crop production systems and value chain systems impacts rural households' food security. The hypothesis was accepted as analyses done in this study showed that the relationships between crop production systems and value chain such as sustainable market integration and traditional knowledge focus have an impact on household food security. This showed that intervention is needed to improve, control, and monitor the environment that smallholder farmers are exposed to.

7.2 Conclusions

According to the results of the multivariate probit analysis, it is evident that various factors influence the selection of different crop production systems among smallholder farmers. Farmers' group membership, gender, age, farm size, and credit utilisation were identified as key drivers affecting the choice of the traditional production system. On the other hand, when it comes to the adoption of the organic production system, farmers' group membership, gender, farm size, and age were the significant influencing factors. The selection of the conventional production system was shaped by farmers' group membership, years of experience in farming, accessibility to storage facilities, and the utilisation of credit. These findings underscore the multifaceted nature of decision-making in agricultural practices, where a combination of socio-economic and contextual variables play a pivotal role in guiding farmers' choices regarding production methods.

Factor analysis showed four patterns in the perception and attitudes of underutilised crops, which were consumer perception of production, taste, awareness, and availability. The binary logistic regression model identified key drivers impacting consumption patterns, including consumer perceptions of production, taste, awareness, and availability. Moreover, the research demonstrated that various socio-economic variables, such as membership to farmers groups, gender of the household head, and off-farm income, significantly influence the consumption of underutilised crops. Furthermore, the study also revealed positive influencers, such as government grants, perception of taste, household size, education level of the household head, and marital status, suggesting avenues for promoting the consumption of underutilised crops.

The double-hurdle regression model showed that market channels, produce waste, access to credit, pest and disease management practices, and access to irrigation facilities are key factors determining farmers' decision to participate in the value chain and the intensity of their participation.

Principal Component Analysis (PCA) revealed three distinct relationships: modern agricultural practices represented (PC1), sustainable market integration (PC2), and traditional knowledge focus (PC3). The ordered probit analysis results suggest that a combination of factors related to agricultural practices (such as sustainable market integration and traditional knowledge), socio-economic indicators (including education level and livestock ownership), and household dynamics (such as household size, food expenditure, and vulnerability to natural events like floods) collectively influence household food security which was measured using HFIAS.

Based on the findings of this study, it can be concluded that the study's hypothesis on the interconnection between crop production systems and value chain systems impacting rural households' food security was accepted. The study has identified a vital relationship within farming practices and also shed light on the importance of connections between crop production systems and value chains. The newfound knowledge emphasises that understanding and optimising these relationships (specifically in sustainable market integration and traditional knowledge) are key factors in influencing household food security, amongst other factors. This information provides a fresh perspective/view on the complex dynamics between how crops are produced and integrated into value chains, offering valuable guidance for developing effective strategies to improve food security. The results of various analyses highlighted both positive and negative impacts of these relationships and other factors on food and nutrition security, emphasising the need for interventions to improve the conditions in which smallholder farmers operate and live.

7.3 Recommendations and Policy Implications

Based on the findings of the study, several recommendations and policy implications emerge:

Enhancing Supportive Institutions: Given the influence of institutional factors on smallholder farmers' crop production systems and value chain participation, there is a pressing need to strengthen support institutions. This could involve the establishment of robust extension services, providing technical assistance, and facilitating access to credit and storage facilities.

Promoting Education and Awareness: Recognising the significance of consumer perception, taste, and awareness in influencing the consumption of underutilised crops, educational campaigns and awareness programs should be implemented. These initiatives can promote the nutritional benefits and taste of underutilised crops, thereby fostering increased consumption.

Facilitating Market Integration: Improving market channels, reducing produce waste, and enhancing access to credit, irrigation facilities, and pest management practices would encourage more smallholder farmers to participate in the value chain. Policymakers should focus on creating a **supportive** environment that fosters robust and sustainable market integration for underutilised crops.

Strengthening Agricultural Practices: Emphasising a holistic approach to agricultural practices, combining modern techniques with traditional knowledge, could lead to sustainable production systems. Implementing training programs and knowledge-sharing platforms could aid in enhancing agricultural practices among smallholder farmers.

Household Resilience Building: Given the influence of socio-economic indicators and household dynamics on food security, interventions aimed at improving household resilience should be prioritised. These may include providing financial support, improving education levels, and implementing measures to mitigate vulnerability to natural events.

Policy Coherence and Coordination: It is essential to ensure coherence and coordination among various policies related to agriculture, nutrition, and rural development. Aligning policies to create a conducive environment for smallholder farmers while also promoting the consumption and production of underutilised crops would significantly contribute to enhancing food security and nutrition outcomes.

Continuous Monitoring and Evaluation: Establishing a robust monitoring and evaluation framework is crucial for assessing the effectiveness of implemented interventions. Regular assessments can provide insights into the progress made and help identify areas for further improvement and refinement of policies and programs.

By implementing these recommendations and policy implications, stakeholders and policymakers can contribute to creating an enabling environment that supports the sustainable production, consumption, and integration of underutilised crops in the value chain, thereby bolstering food security and nutrition outcomes for rural households in KwaZulu-Natal, South Africa.

7.4 Limitations of the Study and Suggestions for Further Research

While the study contributes crucial insights into the interconnection between underutilised crop production systems, value chains, and household food security in rural areas of KwaZulu-Natal, South Africa, it is essential to acknowledge the limitations of this research. The findings are drawn from data collected in specific rural areas of KwaZulu-Natal, potentially constraining the generalisability of the study's results beyond these specific contexts. Considering the complex socio-economic and agricultural diversity in South Africa, future research endeavours should encompass a broader geographical scope to ensure a comprehensive understanding of the complexities and variations in underutilised crop production systems and their implications for food security. Moreover, a critical examination of potential biases in the data collection process and a robust sensitivity analysis could further strengthen the study's validity and reliability.

Furthermore, this study underscores the need for caution when applying the recommendations to broader policy frameworks. It highlights the importance of tailoring interventions to specific regional contexts to ensure their effectiveness and sustainability. Emphasising the need for adaptive and context-specific policies, future research endeavours should aim to explore the transferability of the identified interventions to other regions in South Africa and similar agricultural landscapes globally. By addressing these limitations and charting a path for future research, scholars can contribute to a more nuanced understanding of the dynamics underpinning the nexus of crop production systems, value chains, and household food security, fostering more effective and inclusive policy interventions.

Appendices

Appendix 1: Ethical Approval

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

02 June 2022

Thobani Cele (215042163)
School Of Agri Earth & Env Sc
Pietermaritzburg Campus

Dear T Cele,

Protocol reference number: HSSREC/00004201/2022
Project title: The nexus of crops production system and value chain system in addressing household food security in KwaZulu-Natal.
Degree: PhD

Approval Notification – Expedited Application

This letter serves to notify you that your application received on 16 May 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 02 June 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

Appendix 2: Gate Keeper Letter

agriculture, land reform & rural development

Department: Agriculture, Land Reform and Rural Development
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF AGRICULTURE, LAND REFORM & RURAL DEVELOPMENT KWAZULU – NATAL
PRIVATE BAG X9000, PIETERMARITZBURG, 3200, 188 HOOSEN HAFFEJEE STREET, TEL: (033) 355 4300 FAX: (033) 355 4300

Date: 25th May 2022

Miss Thobani Cele
School of Environment and Agricultural Sciences
University of KwaZulu-Natal
Private Bag X01
Scottsville
3209

To all whom it may concern

Permission letter to conduct research on The Nexus of Crop Production System and Value-Chain System in Addressing Household Food Security in Swayimane, KwaZulu-Natal.

With reference to your email dated 25th of May 2022.

Permission is hereby granted to Miss Thobani Cele a student of Doctor of Philosophy in Food Security at the University of KwaZulu-Natal, to conduct research **The Nexus of Crop Production System and Value-Chain System in Addressing Household Food Security in Swayimane,KwaZulu-Natal.**
By conducting and administering:
1) questionnaire to 300 randomly selected smallholder farmers
This permission is valid for a period of three years from 26th of May 2022 to 26th of May 2025.

The original signed copy of this letter serves as the permission letter and should therefore be available for inspection if required. This Unit is to be supplied with a report by the end of the research period detailing the work carried out and progress/results achieved.

Gatekeeper consent form

I.....N. MNDAWENI.....in my capacity as.....CHIEF DIRECTOR.....hereby give permission to Miss Thobani Cele (student number: 215042163) to conduct research at Swayimane..

Signature...... [redacted] ....

Date....31/05/2022..........

AGRICULTURE, LAND REFORM & RURAL DEVELOPMENT
PSSC OFFICE - KZN, PRIVATE BAG X9000
PIETERMARITZBURG 3200
2022 -05- 31
TEL: 033 355 4300
UMQONDISI WESIFUNDA - KWAZULU NATAL
UMNYANGO WEZOLIMO, UKWABIWA KOMHLABA, NOKUTHUTHUKISWA KWEZINDAWO ZASEMAKHAYA

Appendix 3: Individual Participant Consent Form.

INFORMED CONSENT FORM

Dear Participant,

My name is Thobani Cele. I am currently doing Doctor of Philosophy specialising in Food Security at the University of KwaZulu-Natal, Pietermaritzburg Campus, South Africa. The title of my research is **The Nexus of Crop Production Systems and Value Chains in Addressing Food Security in KwaZulu-Natal, South Africa.** The aim(s) of the study is to address household food insecurity in South Africa by linking smallholder farmers' crop production system with their value chains. I am interested in interviewing you to share your experiences and observations on the subject matter.

Please note that:

- The information that you provide will be used for scholarly research only.
- Your participation is entirely voluntary. You have a choice to participate, not participate or stop participating in the research. You will not be penalized for taking such an action.
- Your views in this interview will be presented anonymously. Neither your name nor identity will be disclosed in any form in the study.
- The interview will take about 30 to 45 minutes.
- The record as well as other items associated with the interview will be held in a password-protected file accessible only to myself and my supervisors. After a period of 5 years, in line with the rules of the university, it will be disposed by shredding and burning.
- If you agree to participate, please sign the declaration attached to this statement (a separate sheet will be provided for signatures)

I can be contacted at: School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal, Pietermaritzburg Campus, Scottsville,
Email: Thobanivpa@gmail.com

Thank you for your contribution to this research.

DECLARATION

I...(full names of participant) hereby confirm that I understand the contents of this document and the nature of the research project, and I consent to participating in the research project. I understand that I am at liberty to withdraw from the project at any time, should I so desire. I understand the intention of the research. I hereby agree to participate.

I consent / do not consent to have this interview recorded (if applicable)

SIGNATURE OF PARTICIPANT Date

....

Appendix 4: Data Collection Tool

Survey-questionnaire

1. Please indicate your location. (0 = Umbumbulu, 1 = Swayimana)
2. What is the gender of a household head? (1 = Male, 0 = Female)
3. What is the age of a household head in years?
4. What is your marital status? (0 = Unmarried, 1 = Married)
5. What is the highest level of education of the household head? (1 = No schooling, 2 = Primary, 3 = Secondary, 4 = Tertiary)
6. How many people currently live in your household?
7. What is the occupation of the household, with 0 representing non-farmers and 1 representing farmers?
8. How many years of farming experience do you have?
9. What is the total size of your farm used for the cultivation of underutilised crops in hectares?
10. Would you categorise your production system as Traditional? (1 = Yes, 0 = No)
11. Would you categorise your production system as Organic? (1 =Yes, 0 =No)
12. Would you categorise your production system as Conventional? (1 =Yes, 0 =No)
13. Do you have access to extension services? (1 = Yes, 0 = No)
14. How many visits have you received from an extension officer in the past year?
15. Do you have access to market information? (1 = Yes, 0 = No)
16. Does the household have access to cash credit? (0 for No, 1 for Yes)
17. Have you used credit for farming purposes? (1 = Yes, 0 = No)
18. Do you have access to credit from the government or formal financial institutions? (0 = No, 1 = Yes)
19. Do you have any income from sources other than farming? (1= Yes, 0=No)

    15a. If yes, how much do you receive from off-farm income? Rands
20. Have you received any government grants, such as old age or unemployment grants? (0 = No, 1 = Yes)
21. Do you have access to storage facilities for your agricultural produce? (1 = Yes, 0 = No)
22. Are you willing to purchase underutilised crops? (0 = No, 1 = Yes)
23. How many visits have you had from the extension office in the past year?
24. Are you a member of any farmers' group? (0 = No, 1 = Yes)
25. Do you sell underutilized crops? (0= No, 1=Yes)

26. What is the primary channel through which underutilised crops are sold? (0 = Informal markets, 1 = Formal market)
27. Do you implement any the pest and disease management practices? (0= No, 1=Yes)
28. Are the pest and disease management practices that you used effective or ineffective? (0 = Effective practices, 1 = Ineffective practices)
29. Do you have access to an irrigation system? (1 = Yes, 0 = No)
30. What type of road infrastructure is available near your farm? (0 = Gravel, 1 = Tar)
31. What is the physical distance between your farm and the market? (0 = Less than 30km, 1 = More than 30km)
32. Have you received any training in agriculture? (1 = Yes, 0 = No):
33. Do you own any livestock? (1 = Yes, 0 = No)
34. What is the number of livestock owned by a household?
35. Is the food expenditure of the household low (≤60% of total expenditure) or high (>60% of total expenditure)?
36. Does the household receive remittances? (0 for No, 1 for Yes)
37. Has the household been affected by floods? (0 for No, 1 for Yes)
38. Are you currently participating in the value chain of underutilised crops? (0 = No, 1 = Yes)
39. On a scale of 1 to 5, where 1 indicates low reliance and 5 indicates high reliance, how much do you rely on traditional knowledge and practices in your farming activities?
40. Do you implement traceability and labeling practices for your agricultural products? (Yes/No)
41. How many direct marketing channels do you utilise to sell your agricultural products?
42. Have you obtained organic certification for your farming practices? (Yes/No)
43. On a scale of 1 to 5, where 1 indicates poor practices and 5 indicates excellent practices, how would you rate your post-harvest handling practices?
44. Do you sell your agricultural products in the wholesale market? (Yes/No)
45. What percentage of your agricultural products do you sell in local markets?
46. How many traditional value-added products do you produce from your agricultural products?
47. What is the average crop yield per hectare on your farm? (Kilograms per hectare)
48. What is the amount of synthetic fertilisers used per hectare on your farm? (Kilograms per hectare)

49. What is the amount of organic fertilizers used per hectare on your farm? (Kilograms per hectare)
50. What is the amount of chemical pesticides used per hectare on your farm? (Kilograms per hectare)
51. What percentage of traditional seed varieties do you use for your crops?
52. On a scale of 1 to 5, where 1 indicates low reliance and 5 indicates high reliance, how much do you rely on traditional knowledge and practices in your farming activities?
53. What percentage of natural pest control methods do you use in your farming practices?
54. How many different crop species do you cultivate on your farm?
55. In the table below, please, for each activity, indicate with a "Yes" or "No" to specify whether the farmer is currently participating in that particular value chain activity.

Value Chain Activity	**1= Yes or 0= No**
Seed production	
Crop cultivation	
Harvesting	
Post-harvest handling and processing	
Packaging and labelling	
Transportation and logistics	
Storage and warehousing	
Quality control and assurance	
Certification and standards compliance	
Marketing and promotion	
Value-addition and product development	
Sales and distribution	
Exporting	
Importing	
Contract farming	
Agro-processing	
Retailing	
Fertiliser application	
Sorting	
Grading	

Market research and analysis	
Networking and collaboration with stakeholders	
Policy advocacy and engagement	
Value chain analysis and planning	
Sustainability and social responsibility	
Total Number of activities	

56. Please rate your perception and attitudes of underutilised crops on the following aspects using a Likert scale where 1 presents "Very dissatisfied" and 5 presents "Very satisfied".

Perception and attitudes of underutilised crop	**Ratings(**1= Very dissatisfied, 2= dissatisfied, 3=Neutral, 4= satisfied, 5= Very satisfied)
Quality of the product	
Reliability of the production process	
Consistency in product availability	
Responsiveness to customer needs and preferences	
Transparency in production methods	
Safety and hygiene standards during production	
Value for money in relation to the product's price	
Ethical practices in the production process	
Access to storage	
Access to transportation	
Environmental sustainability practices in production	
Flavor intensity	
Sweetness	
Texture	
Aroma	
Nutritional value	

Versatility (adaptability of taste in different culinary dishes)	
Complexity	
Tartness (sourness)	
Aftertaste	
Availability of information	
Perceived benefits	
Familiarity with preparation	
Perception of importance	
Understanding of cultivation	
Knowledge	
Local sourcing	
Price stability	
Geographic accessibility	
Availability in season	
Ease of accessibility	
Market demand	
Distribution channel	

57. Household Food Insecurity Access Scale (HFIAS)

No	Question	Response Options 0= No 1= Yes	If Yes, how often did this happen? (1= Rarely 2= Sometimes 3= Often)
1.	In the past 4 weeks, did you worry that your household would not have enough food?		
2.	In the past 4 weeks, were you or any household member not able to eat the kinds of foods you preferred because of lack of resources?		
3.	In the past 4 weeks, did you or any household member have to eat a limited variety of foods due to a lack of resources?		
4.	In the past 4 weeks, 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?		
5.	In the past 4 weeks, did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?		
6.	In the past 4 weeks, did you or any household member have to eat fewer meals in a day because of a lack of resources to get food?		
7.	In the past four weeks, was there ever no food to eat of any kind in your household because of a lack of resources to get food?		
8.	In the past 4 weeks, did you or any household member go to sleep at night hungry because there was not enough food?		
9.	In the past 4 weeks, did you or any household member go a whole day and night without eating anything because there was not enough food?		