UNLOCKING THE POTENTIAL ROLE OF NEGLECTED AND UNDERUTILISED CROPS IN ENHANCING FOOD SECURITY AND BUILDING A CLIMATE-RESILIENT FOOD SYSTEM FOR RURAL HOUSEHOLDS IN KWAZULU-NATAL, SOUTH AFRICA

By

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ABSTRACT

Climate change and food system homogenisation threaten agricultural biodiversity and nutritional security, with smallholder farmers in developing regions facing heightened vulnerability. This study contributes new empirical evidence on the status, determinants, and impacts of cultivating neglected and underutilised crops (NUCs) among smallholder farmers in KwaZulu-Natal, South Africa, where declining agrobiodiversity undermines dietary resilience and climate adaptation.

Using data from 319 smallholder farmers across uMkhanyakude and King Cetshwayo District Municipalities, and employing Tobit regression, investment appraisal, and an Ordered Probit Endogenous Switching Regression model, the study reveals a moderate adoption rate (40%). Adopters are predominantly older, female, married farmers with stronger traditional knowledge and notably less engagement with formal agricultural institutions, a counter-intuitive finding that challenges conventional extension assumptions. Adopters achieved significantly higher net profits (ZAR 8,500/ha) and superior investment returns (IRR 38.2%), with strong resilience to market and yield shocks. The OP-ESR model confirms causal welfare impacts: adoption increased dietary diversity and alleviated food insecurity, with counterfactual analysis revealing larger potential gains for non-adopters.

The study makes three explicit contributions to knowledge**.** First, it provides empirical evidence in the South African smallholder context that formal institutional factors, such as education, access to extension services, and agricultural training, negatively correlate with NUC adoption, whereas indigenous knowledge and cultural affiliation are the primary drivers. Second, using counterfactual analysis, it demonstrates that non-adopters stand to benefit more from adoption than current adopters, with direct implications for intervention targeting. Third, it uniquely shows that incorporating NUCs (pumpkin leaves, beans, cream-fleshed sweet potato) into culturally central staple foods improves protein quality, fibre, mineral content, and amino acid profiles without compromising consumer acceptability, thereby bridging agrobiodiversity conservation with tangible nutritional outcomes.

The study concludes that NUCs offer a viable pathway for enhancing economic resilience, food security, and dietary quality. Scaling their impact requires policies that formally recognise indigenous knowledge, reorient extension services, and implement gender-sensitive interventions targeting female custodians of these crops.

Keywords: Smallholder Farmers, Indigenous Knowledge, Food Security, Cost-Benefit Analysis, Endogenous Switching Regression, Agricultural Biodiversity, Consumer Acceptability**.**

PREFACE

The research work described in this thesis was conducted in the School of Agriculture and Science, College of Agriculture, Engineering and Science at the University of KwaZulu-Natal between March 2023 and July 2025. This thesis comprises independent, manuscript-style chapters, and some minor repetition may occur across sections. This PhD research was supervised by Dr Lelethu Mdoda and co-supervised by Dr Laurencia Govender.

Signed: [redacted] **Date:** 02/04/2026

Mr Sesethu Samuel Ntlanga (Candidate)

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

Signed: [redacted] **Date:** 02/04/2026

Dr Lelethu Mdoda (Supervisor)

Signed: [redacted] **Date:** 02/04/2026

Dr Laurencia Govender (Co-supervisor)

DECLARATION 1: PLAGIARISM

I, **Sesethu Samuel Ntlanga,** declare that:

I. The research reported in this thesis, except where otherwise indicated, is my original research.

II. This thesis has not been submitted for any degree or examination at any other university.

III. This thesis does not contain other persons' data, pictures, graphs or other information unless specifically acknowledged as being sourced from other persons.

IV. This thesis does not contain other authors' writing unless specifically acknowledged as being sourced from other researchers. Where other written sources have been quoted, then:

a. Their words have been rewritten, but the general information attributed to them has been referenced.

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Signed: **Date:** 02/04/2026

Mr Sesethu Samuel Ntlanga (Candidate)

DECLARATION 2: PUBLICATIONS

All the chapters in the following publications (under review) are from the research presented in this thesis and have not yet been **published.**

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DEDICATION

To Nosakhele Ntlanga, Sicelo Ntlanga, Somila Ntlanga, Bugcisa Mantu, and Sibusiso Ntlanga.

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LIST OF ACRONYMS

AOCC:	African Orphan Crop Consortium
ATE:	Average Treatment Effect
ATT:	Average Treatment Effect on the Treated
ATU:	Average Treatment Effect on the Untreated
CAADP:	Comprehensive Africa Agricultural Development Programme
CBA:	Cost-Benefit Analysis
CFSP:	Cream Fleshed Sweet Potato
COGTA:	Department of Cooperative Governance and Traditional Affairs
CSI:	Coping Strategy Index
DPME:	Department of Planning, Monitoring and Evaluation
FAO:	Food and Agriculture Organisation
GDP:	Gross Domestic Product
HDDS:	Household Dietary Diversity Score
HFIAS:	Household Food Insecurity Access Score
IK:	Indigenous Knowledge
KCDM:	King Cetshwayo District Municipality
KPAs:	Key Performance Areas
KZN:	KwaZulu-Natal
NUCs:	Neglected and Underutilised Crops
OP-ESR:	Ordered Probit Endogenous Switching Regression Model
RUT:	Random Utility Theory
SA:	South Africa
SDGs:	Sustainable Development Goals
SEA:	Sensory Evaluation Attributes
SSA:	sub-Saharan Africa
STATA:	Statistical Software for Data Science
Stats-SA:	Statistics South Africa
TPB:	Theory of Planned Behaviour
TRM:	Tobit Regression Model
UDM:	uMkhanyakude District Municipality
UDM IDP:	uMkhanyakude District Municipality Integrated Development Plan
UN:	United Nations

CHAPTER 1: INTRODUCTION

1.1 Background of the study

The twenty-first century faces a convergence of challenges such as population growth, urbanisation, and climate change that threaten the stability of global food systems. With the global population projected to reach 9.7 billion by 2050 (United Nations, 2022), demand for food, water, and agricultural land intensifies, placing unprecedented pressure on ecosystems (Javed et al., 2024). Simultaneously, climate change increases the frequency and severity of droughts, floods, and shifting rainfall patterns, reducing agricultural productivity and heightening uncertainty in food production (Lesk et al., 2022; Clarke et al., 2022; Wu et al., 2021). These intertwined pressures have renewed global attention on Sustainable Development Goal 2 (Zero Hunger), yet progress remains uneven, particularly in regions where food systems are most vulnerable (Hendriks et al., 2023; Ogwu et al., 2024).

Sub-Saharan Africa (SSA) exemplifies this vulnerability. Despite agriculture employing the majority of the population and contributing substantially to national economies (Sakho-Jimbira & Hathie, 2020; Jayne et al., 2021), the region continues to experience pervasive food insecurity and malnutrition (Alaimo et al., 2020; Mugambi & Rusinamhodzi, 2022). Approximately 25% of the world's malnourished population resides in SSA, where rural communities bear a disproportionate share of this burden (FAO et al., 2022; Hedden et al., 2021). Critically, the region now faces a double burden of malnutrition, including undernutrition and overnutrition co-existing within populations, communities, and even households (Fanzo et al., 2021; Agostoni et al., 2023). This paradox reflects a chronic lack of dietary diversity, as rural households increasingly rely on calorie-dense but nutrient-poor staple foods (Fongar et al., 2019; Sibhatu & Qaim, 2017), while simultaneously experiencing rising rates of overweight and obesity linked to dietary transitions and urbanisation (Ruel et al., 2020; van Berkum, 2023). Addressing this crisis requires diversifying food sources toward nutrient-dense, climate-resilient crops (Mustafa et al., 2019; Horton et al., 2021).

Climate change further exacerbates these vulnerabilities across SSA. Erratic rainfall, prolonged droughts, and soil degradation have reduced crop yields, disproportionately affecting smallholder farmers who rely on rainfed agriculture (Ahmed et al., 2023; Ogenga et al., 2018; Borrelli et al., 2020). Land degradation and declining soil health have intensified food production challenges, particularly in nutrient-poor smallholder farming systems (Gomiero, 2016; Lal, 2015; Ekka et al., 2023). Urbanisation has also reshaped agricultural dynamics, with rural-urban migration altering labour availability and food demand patterns (Djurfeldt, 2015; Kuusaana & Eledi, 2015; Beckers et al., 2020). These compounded pressures have led to persistent food insecurity and malnutrition across the continent (Kumar et al., 2018; Owino et al., 2022; Khatri et al., 2024).

South Africa reflects these broader continental challenges. Despite being a middle-income country with a relatively developed agricultural sector, food insecurity persists, affecting an estimated 23% of the population (StatsSA, 2023). Rural areas, particularly the former homelands, exhibit the highest rates of food insecurity and malnutrition, where smallholder farmers operate under rainfed, low-input systems with limited access to extension services and modern technologies (Hlatshwayo et al., 2021; Obi & Seleka, 2011). Climate change has intensified these challenges, with KwaZulu-Natal (KZN) experiencing increased drought frequency and extreme weather events that undermine agricultural productivity (Ngcamu, 2022; Calzadilla et al., 2014; Turpie & Visser, 2013). The province encapsulates a critical paradox that forms the central tension for this study. KZN is recognised as a centre of agrobiodiversity, home to the highest concentration of neglected and underutilised crop species (NUCs) in South Africa, many of which are historically valued for their drought tolerance, nutritional density, and cultural significance (Mabhaudhi et al., 2018; Mudau et al., 2022; Modi & Mabhaudhi, 2016). Yet, simultaneously, KZN records some of the highest rates of child stunting and malnutrition in the country, with over 27% of children under five affected (StatsSA, 2023). This coexistence of high agrobiodiversity with high malnutrition signals a critical disconnect between the availability of nutrient-rich indigenous crops and their utilisation within local food systems (Hunter et al., 2019; Akinola et al., 2020).

Neglected and underutilised crops, also referred to as indigenous, orphan, or minor crops, offer a potential pathway to address these interconnected challenges (Hossain et al., 2021; Imathiu, 2021; Katoch & Katoch, 2020). These species are typically nutrient-dense, drought-tolerant, and adapted to marginal soils, requiring fewer external inputs than conventional staples such as maize and wheat (Chivenge et al., 2015; Chiurugwi et al., 2019; Ulian et al., 2020). Indigenous crops have sustained rural communities for generations and remain integral to traditional food systems and cultural practices (Swiderska et al., 2022; Pacheco-Trejo et al., 2023; Singh et al., 2023). Research has documented their superior nutritional profiles, including higher protein, mineral, and fibre content compared to conventional staples (Desire et al., 2021; Rawat et al., 2023; Omotayo & Aremu, 2020). Furthermore, their cultivation supports agrobiodiversity conservation and provides livelihood opportunities for smallholder farmers (Bandula & Nath, 2020; Joshi & Gauchan, 2022; Chandra et al., 2020). Despite these demonstrated benefits, NUCs remain peripheral in mainstream agricultural policies, research agendas, and market systems across SSA (Mabhaudhi et al., 2019; Ndlovu et al., 2024; Mudombi-Rusinamhodzi & Rusinamhodzi, 2022).

The persistent neglect of NUCs is particularly evident in South Africa. While policy documents acknowledge their potential, implementation remains weak, with extension services continuing to prioritise conventional crops (Senyolo et al., 2018; Senyolo et al., 2019; Hlatshwayo et al., 2021). Traditional knowledge associated with NUC cultivation and preparation is declining, particularly among younger generations, due to dietary transitions and the marginalisation of indigenous foods in formal education and media (Kesa et al., 2023; Lekgoa et al., 2016; Trolio et al., 2016). Market access for NUCs remains constrained by underdeveloped value chains, limited processing infrastructure, and consumer perceptions that associate indigenous foods with poverty or backwardness (Arumugam et al., 2022; Aworh, 2015; Senyolo et al., 2018). These barriers have resulted in low cultivation rates, with NUC production increasingly confined to isolated, socioeconomically marginal areas (Mabhaudhi et al., 2017; Mugiyo et al., 2021; Ndlovu et al., 2024).

Despite growing recognition of NUCs' potential, research in the South African context reveals significant gaps. First, the socioeconomic determinants of NUC adoption remain poorly understood. While studies have documented declining traditional knowledge (Ndhlovu, 2020; Hornby, 2020) and weak extension services (Senyolo et al., 2018; Tey et al., 2017), no study in KZN has quantitatively assessed the relative influence of institutional factors, such as extension access and agricultural training, against cultural factors such as indigenous knowledge and traditional affiliation on adoption decisions. Second, the economic viability and causal welfare impacts of NUC cultivation have not been rigorously evaluated. Existing work has primarily focused on nutritional and agronomic aspects (Mabhaudhi et al., 2017; Mudau et al., 2022; Akinola et al., 2020), with no application of counterfactual analysis to estimate causal welfare gains for smallholders. Third, the nutritional potential of NUCs has been studied in isolation from consumer acceptability, and no research in KZN has examined whether incorporating these crops into culturally central staple foods improves nutritional outcomes without compromising acceptability (Guiné et al., 2021; Raneri et al., 2019; Haq et al., 2022).

This study addresses these gaps by investigating the status, determinants, and impacts of NUC cultivation among smallholder farmers in KZN. Specifically, it provides new empirical evidence on: (i) the socioeconomic and institutional drivers of adoption; (ii) the economic viability and causal welfare impacts of NUC cultivation; and (iii) the nutritional and consumer acceptability outcomes of integrating NUCs into staple foods. By doing so, the study contributes to evidence-based policy and intervention design for integrating NUCs into sustainable, resilient, and inclusive food systems in South Africa (Woodhill et al., 2022; Pretty & Bharucha, 2014; Gillespie & van den Bold, 2017).

1.2 Problem Statement

For over a decade, neglected and underutilised crops have been championed in SSA as a panacea for the intertwined crises of climate change, malnutrition, and agrarian distress (Mabhaudhi et al., 2018; Chivenge et al., 2015; Mustafa et al., 2019). Yet, despite sustained advocacy, agricultural policy, extension services, and staple food systems in South Africa remain stubbornly focused on a handful of climate-vulnerable crops, such as maize and wheat (Hlatshwayo et al., 2021; Senyolo et al., 2018; Obi & Seleka, 2011). This presents a critical paradox where NUCs remain neglected after decades of being promoted as the solution.

This study posits that the persistent neglect stems from a fundamental disconnect in the existing evidence base. Prior research has created isolated silos documenting nutritional value in one study (Desire et al., 2021; Hunter et al., 2019; Rawat et al., 2023), agronomic resilience in another (Chivenge et al., 2015; Chiurugwi et al., 2019; Mabhaudhi et al., 2019), and cultural significance in a third (Swiderska et al., 2022; Kesa et al., 2023; Singh et al., 2023). However, this fragmented approach has failed to generate the integrated, actionable evidence required to shift policy and practice (Ndlovu et al., 2024; Mudau et al., 2022; Mugiyo et al., 2021). Consequently, smallholder farmers in KZN remain trapped in a system that encourages them to grow climate-risky staple crops, perpetuating income losses and dietary vulnerability (Calzadilla et al., 2014; Ngcamu, 2022; Turpie & Visser, 2013).

To resolve this paradox, this study addresses the core weaknesses in the evidence base through three integrated objectives, moving from isolated gaps to a cohesive solution.

First, the existing literature identifies barriers to NUC adoption, such as weak extension services and declining traditional knowledge (Senyolo et al., 2018; Ndhlovu, 2020; Hlatshwayo et al., 2021). However, the relative influence of modern institutional factors versus deep-seated cultural factors on adoption decisions remains unquantified (Tey et al., 2017; Bandula & Nath, 2020). Without this, policy remains ambiguous, promoting NUCs through institutional channels that may inadvertently conflict with the cultural drivers of adoption. Policies fail, leaving farmers with conflicting signals that perpetuate the status quo of maize and wheat dependence (Mabhaudhi et al., 2018; Ndlovu et al., 2024).

Second, the economic case for NUCs remains based on potential rather than empirical evidence. While their agronomic hardiness is established (Mabhaudhi et al., 2017; Chivenge et al., 2015; Omotayo & Aremu, 2020), there is no rigorous, counterfactual analysis comparing the profitability and welfare outcomes of NUC adopters with non-adopters while controlling for selection bias (Aworh, 2015; Arumugam et al., 2022; Senyolo et al., 2019). Consequently, without this causal evidence, policymakers cannot confidently attribute improved food security or income to NUC adoption, making it impossible to justify a systemic shift away from subsidised maize (Hedden et al., 2021; FAO et al., 2022).

Third, nutritional analyses have shown that NUCs are nutritionally superior (Desire et al., 2021; Rawat et al., 2023; Hunter et al., 2019), yet these findings are irrelevant if the resulting food is not consumed. No study in South Africa has tested whether incorporating NUCs into culturally sacred staple foods, like stiff pap, can enhance nutrition without triggering consumer rejection on sensory or cultural grounds (Guiné et al., 2021; Kesa et al., 2023; Raneri et al., 2019). The risk of developing nutritious but unacceptable products remains high, ensuring that even successful cultivation efforts fail to translate into improved dietary diversity (Haq et al., 2022; Trolio et al., 2016; Weerasekara et al., 2020).

This study resolves the NUC adoption paradox by moving beyond fragmented, siloed research. It provides the first integrated assessment for KZN that combines: (1) a quantitative analysis of the institutional versus cultural drivers of adoption; (2) a counterfactual, causal analysis of the economic and welfare impacts of adoption; and (3) a sensory and nutritional evaluation of NUC-enriched staple foods. By generating this cohesive evidence, the study provides the actionable evidence base required to finally break the policy deadlock and transition smallholder food systems from climate-vulnerable monocultures to resilient, culturally appropriate, and economically viable NUC-inclusive systems (Woodhill et al., 2022; Pretty & Bharucha, 2014; Gillespie & van den Bold, 2017; Hendriks et al., 2023).

1.3 Objectives

The main objective of the study is to investigate the potential of underutilised crops to enhance food security and build a climate-resilient food system in the KZN province.

Specific objectives are as follows:

i. To assess knowledge, attitudes and practices toward underutilised crops.
ii. To quantify the potential contribution of underutilised crops to diversified and resilient food security strategies and determine factors influencing the adoption.
iii. To conduct a cost-benefit analysis of underutilised crop production.
iv. To evaluate the nutritional composition, sensory acceptability, and community perceptions of stiff pap composite dishes prepared from the indigenous crop.

1.4 Hypotheses

The following hypotheses were formulated:

i. There will be a significant positive correlation between knowledge of the nutritional benefits of underutilised crops and a positive attitude towards their cultivation and consumption.
ii. Smallholder farmers who integrate underutilised crops into their farming system have a significantly higher household dietary diversity score, and knowledge and market access are positive determinants for smallholders' participation in NUC cultivation.
iii. The profitability of underutilised crop production is significantly influenced by farm size due to lower labour costs.
iv. The composite stiff pap demonstrates a nutritionally enhanced profile, meets minimum thresholds for sensory acceptability, and is perceived as favourable by the community as a culturally appropriate and beneficial food.

1.5 Research questions

i. What is the level of knowledge, attitudes, and practices of farmers and communities toward underutilised crops?

ii. What is the potential contribution of underutilised crops to diversified and resilient food security strategies, and what socio-economic, cultural, and environmental factors influence their adoption?

iii. What are the costs and benefits associated with the production of underutilised crops, and how economically viable is their cultivation for smallholder farmers?

iv. Does the composite stiff pap prepared from the indigenous crop achieve acceptable levels of nutritional quality, sensory liking, and positive community perception for potential adoption as a dietary staple?

1.6 Justification of the study

This study makes four interconnected contributions to food systems, agricultural economics, and nutrition science, directly confronting the central constraint that has historically limited the integration of neglected and underutilised crops (NUCs). Also, the persistent stigma frames these crops as "poverty foods", crops of last resort associated with rural backwardness rather than viable agricultural commodities.

First, this is the first study in KZN to quantitatively disaggregate the relative influence of institutional versus cultural determinants of NUC adoption, with explicit attention to how stigma shapes farmer decision-making. While existing research has identified barriers such as weak extension services and declining traditional knowledge (Senyolo et al., 2018; Ndhlovu, 2020), these factors have been examined in isolation. Using multivariate analysis that simultaneously tests institutional access, such as extension, training, and credit, alongside cultural variables, such as traditional authority and indigenous knowledge. This study provides novel evidence that cultural factors, particularly internalised stigma and the perceived status of maize, exert a stronger influence on adoption than institutional factors. This challenges the policy assumption that improving extension alone will drive NUC uptake.

Second, this study provides the first counterfactual, causal analysis of the economic and welfare impacts of NUC adoption among smallholder farmers, directly rebutting the assumption that NUCs are economically inferior to conventional staples. The existing literature has documented the nutritional and climate resilience traits of indigenous crops (Mabhaudhi et al., 2017; Chivenge et al., 2015), but has not rigorously addressed selection bias in welfare assessments. Using an endogenous switching regression (ESR) framework, this study compares adopters and non-adopters with comparable characteristics, isolating the causal effect of NUC cultivation on household income, food security, and dietary diversity. The results demonstrate that NUC adoption yields significant welfare gains beyond those achieved by comparable farmers growing maize and wheat, providing the robust evidence base previously absent from policy discourse.

Third, this study bridges the gap between nutritional science and consumer behaviour by evaluating both the nutrient composition and sensory acceptability of NUC-enriched traditional staples, addressing the stigma that even nutritionally superior crops will be rejected if perceived as markers of poverty. This is the first South African study to systematically quantify the nutritional profile of stiff pap composite meals incorporating indigenous crops alongside a sensory evaluation that explicitly probes status perceptions. The findings identify formulations that optimise nutritional gains without compromising taste, texture, and cultural familiarity, while revealing that acceptability is shaped not only by sensory attributes but by the symbolic meanings consumers attach to NUC-based foods. This provides a pathway for normalising indigenous crops as everyday foods rather than famine reserves.

Fourth, this study contributes a strategic framework for strengthening NUC value chains that is grounded in empirical evidence, directly addresses the stigma constraint, and aligns with South Africa's agricultural policy priorities. By integrating findings from farmer surveys revealing how stigma shapes adoption, nutritional analysis countering perceptions of inferiority, and consumer sensory trials by demonstrating pathways to destigmatised consumption, the framework generates actionable insights across the value chain from production to consumption. Critically, it includes strategies for repositioning NUCs from "poverty foods" to "smart foods”, climate-resilient, nutritionally dense, and economically viable, structured around South Africa's key performance areas (KPAs) for agriculture and rural development.

Together, these contributions address the central paradox motivating this research: why NUCs have remained neglected despite decades of advocacy. By providing causal evidence on adoption drivers that accounts for stigma, welfare impacts that rebut assumptions of economic inferiority, consumer acceptability that identifies pathways to destigmatised consumption, and a value chain framework that explicitly addresses psychological and cultural barriers, this study generates the integrated knowledge base required to shift agricultural policy and practice toward diversified, resilient, and culturally appropriate food systems.

1.7 Scope and delineation of the study

This study is delineated across three dimensions, such as geographic, demographic, and crop-specific, analytical, each selected to optimise the validity and relevance of the findings for understanding the integration of neglected and underutilised crops (NUCs) into smallholder food systems.

The study was conducted in the uMkhanyakude and King Cetshwayo District Municipalities in KZN. These districts were purposively selected based on three criteria. First, both districts report among the highest stunting rates in the province, with child malnutrition exceeding 25% in several sub-districts (KZN Department of Health, 2022), making them priority areas for nutrition-sensitive agricultural interventions. Second, these districts represent contrasting agro-ecological zones: uMkhanyakude is characterised by semi-arid conditions and high climate variability, while uThukela encompasses both irrigable lowlands and rain-fed highlands, enabling a comparative analysis of NUC adoption across different climatic contexts. Third, both districts have documented historical cultivation of indigenous crops, with established local knowledge of species such as amadumbe (*Colocasia esculenta*), cowpeas (*Vigna unguiculata),* and Sweet potato, cassava, groundnut, pumpkin, and pumpkin leaves yet these crops have declined significantly in recent decades, making them ideal sites for investigating the drivers of and barriers to NUC adoption. The study does not extend to urban or peri-urban areas, nor to other districts in KZN or other provinces, as the findings are intended to inform context-specific interventions in these high-need, NUC-relevant rural settings.

For the purposes of this study, "smallholder farmers" are defined as households cultivating less than two hectares of land, primarily for subsistence consumption, with surplus sold informally when market access exists. This definition aligns with Statistics South Africa's classification of smallholder agriculture and captures the predominant farming population in the study districts. Given the central role of women in NUC production, processing, and household food provisioning in KZN, the study deliberately oversampled female-headed households (targeting 60% of the sample) to ensure that gender-specific barriers and opportunities were adequately captured. Additionally, to examine the retention and transmission of traditional knowledge, the study included both youth (aged 18–35) and elders (aged 60 and above) in qualitative components, enabling analysis of generational differences in NUC knowledge and attitudes. The study excludes large-scale commercial farmers and households with no agricultural activity, as the research questions focus specifically on smallholder systems where NUC integration holds greatest potential for food security impact.

The study focused on seven indigenous neglected and underutilised crop (NUC) species cultivated and consumed in the study districts: amadumbe (*Colocasia esculenta*), cowpeas (*Vigna unguiculata*), sweet potato (*Ipomoea batatas*), cassava (*Manihot esculenta*), groundnut (*Arachis hypogaea*), pumpkin (*Cucurbita maxima*), and pumpkin leaves. These crops were selected based on a combination of nutritional, agronomic, and cultural criteria: amadumbe for its high energy density, iron and zinc content, and cultural centrality as a traditional staple; cowpeas for their dual-purpose utility (leaves and grain), protein contribution, and established informal market presence; sweet potato for its vitamin A content (particularly orange-fleshed varieties) and drought tolerance; cassava for its exceptional drought tolerance and role as a food security reserve crop during lean seasons; groundnut for its protein and fat content, nitrogen-fixing properties, and cash crop potential; and pumpkin and pumpkin leaves for their complementary contributions, the fruit providing vitamin A and fibre, the leaves providing readily available iron and protein critical for maternal and child nutrition along with minimal input requirements and cultural familiarity. Collectively, these seven crops represent diversity across plant parts utilised (tubers, pulses, roots, legumes, fruits, leafy vegetables), use patterns (subsistence staple, reserve food, cash crop), and agronomic traits (drought tolerance, soil improvement, low input requirements), enabling comparative analysis across different NUC typologies. The study excludes other indigenous crops (e.g., sorghum, millet, moringa, Bambara groundnut) and all exotic crops such as maize, wheat, commercial potato varieties, as these fall outside the scope of the research questions concerning the specific neglected and underutilised indigenous species with documented historical cultivation and contemporary relevance in the study districts.

The study examines the NUC value chain from production through to consumption, with analytical focus on three stages: (1) production and post-harvest handling, (2) processing and value addition, and (3) marketing and consumption. The cost-benefit analysis is limited to on-farm production costs and household-level returns, excluding large-scale commercial processing or export market dynamics, as these are not relevant to the smallholder context under study. The nutritional analysis is limited to macronutrient composition (protein, carbohydrate, fibre) and key micronutrients (iron, zinc, vitamin A) of the three selected crops in both raw and prepared forms (stiff pap composite meals), excluding detailed phytochemical or anti-nutrient profiling, which is beyond the scope of this study.

1.8 Definition of terms

Adoption (of Neglected and Underutilised Crops)

Refers to the decision by a smallholder farmer to cultivate and/or utilise at least one neglected and underutilised crop species within their farming or household food system during the reference period.

Agrobiodiversity

The variety and variability of plant species, crops, and genetic resources used directly or indirectly for food and agriculture, including cultivated, semi-domesticated, and wild species.

Climate-Resilient Food System

A food system that can withstand, adapt to, and recover from climate-related shocks and stresses while ensuring sustainable food availability, access, utilisation, and stability.

Composite Stiff Pap

A traditional maize-based staple food modified in this study through the incorporation of indigenous crops (such as pumpkin leaves, beans, or cream-fleshed sweet potato) to enhance nutritional value while maintaining cultural acceptability.

Coping Strategies Index (CSI)

A food security indicator that measures the frequency and severity of household behaviours adopted in response to food shortages, with higher scores indicating greater food insecurity.

Cost-Benefit Analysis (CBA)

An economic evaluation method used to compare the costs and benefits associated with underutilised crop production to assess profitability, efficiency, and economic viability.

Endogenous Switching Regression (ESR)

An econometric model that accounts for selection bias by jointly modelling the decision to adopt underutilised crops and the resulting welfare outcomes.

Food Security

A condition in which all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life.

Household Dietary Diversity Score (HDDS)

A quantitative indicator measuring the number of food groups consumed by a household within the previous 24 hours, used to assess access to diverse and nutritious foods.

Household Food Insecurity Access Scale (HFIAS)

A standardised tool used to assess household food insecurity based on experiences of anxiety, insufficient food quality, and insufficient food intake over a recall period.

Indigenous Knowledge (IK)

Knowledge, practices, and beliefs developed by local and indigenous communities over generations, particularly relating to crop cultivation, food preparation, preservation, and utilisation.

Neglected and Underutilised Crops (NUCs)

Crop species that are locally important for food, nutrition, and livelihoods but are marginalised in agricultural research, policy frameworks, extension services, and commercial markets.

Non-Adopters

Smallholder farmers who do not cultivate or utilise neglected and underutilised crops during the study period.

Ordered Probit Endogenous Switching Regression (OP-ESR)

A hybrid econometric model combining ordered probit and endogenous switching regression techniques to estimate the causal impact of NUC adoption on ordered food security outcomes.

Smallholder Farmers

Rural agricultural producers characterised by small landholdings, limited access to capital and inputs, reliance on family labour, and partial or full dependence on agriculture for household food security and income.

Sensory Acceptability

The degree to which consumers perceive food products as acceptable based on attributes such as taste, texture, aroma, colour, and overall liking.

Underutilised (or Orphan) Crops

Plant species with limited commercial importance at national or global levels but which possess significant nutritional, ecological, cultural, and livelihood value at local or regional levels.

Value Addition

The process of improving the economic and nutritional value of agricultural products through processing, preparation, packaging, or product development.

Welfare Outcomes

Changes in household well-being resulting from NUC adoption, measured in this study through food security indicators such as HDDS, CSI, and HFIAS.

1.9 Organisation of the study

The study consists of seven chapters. The first chapter provides an introduction and background to the study. Also, it presents the problem statement, objectives, research questions, and the study's significance. Chapter two presents the systematic literature review that guides the research study. Chapters 3 to 6 present the core research findings, each formatted as a standalone paper, directly addressing the study's objectives.

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CHAPTER 2: INTEGRATING ORPHAN CROPS INTO SUSTAINABLE FOOD SYSTEMS IN SUB-SAHARAN AFRICA: A SYSTEMATIC REVIEW OF PRODUCTION CHALLENGES AND VALUE-ADDING OPPORTUNITIES

Abstract

Orphan crops, also known as neglected and underutilised species (NUCs), are nutrient-dense, climate-resilient, and integral to traditional African farming systems. Predominantly cultivated by smallholder farmers in marginal environments, these crops are well-adapted to drought, poor soils, and erratic rainfall, positioning them as crucial for sustainable food production in sub-Saharan Africa (SSA). Amid rising food insecurity, climate-induced agricultural risks, and socio-economic disparities, orphan crops hold significant potential to diversify food systems, improve dietary quality, and enhance climate resilience. Yet they remain undervalued due to limited research, weak policy integration, and inadequate commercialisation frameworks. This systematic review critically examines the role of orphan crops in promoting sustainable food systems and food security in SSA, identifying key production constraints and value addition opportunities for effective commercialisation. Following a PRISMA-guided approach, peer-reviewed literature, grey sources, and policy documents from the past two decades were analysed thematically. The findings show that crops such as Bambara groundnut, marama bean, and finger millet are rich in proteins, essential minerals (iron, zinc, calcium), and bioactive compounds. Their inherent drought tolerance and adaptability to marginal soils make them strategic assets for climate-smart agriculture. However, low yields, lack of improved varieties, fragmented value chains, cultural stigmatisation, and inadequate policies constrain their utilisation. To unlock the potential of NUCs, this study recommends integrating them into national agricultural and nutrition strategies, establishing climate-resilient seed systems, incentivising private sector participation, and promoting public awareness campaigns. Transformative, cross-sectoral policies are essential to enhance production, market access, and consumer acceptance, leveraging NUCs for nutrition, economic empowerment, and sustainable rural development**.**

Keywords: Orphan crops, Food security, Climate resilience, Value chain development, Sub-Saharan Africa, Indigenous crops

2.1 Introduction

The prevailing global food system is characterised by a fundamental failure: its inability to deliver both food security and nutritional adequacy in a sustainable and equitable manner. Despite producing enough calories to feed the global population, this system is underpinned by a dangerous over-reliance on a mere handful of staple crops such as maize, wheat, rice, and soy. This narrow agrobiodiversity has created a fragile food supply, vulnerable to climatic shocks, pest outbreaks, and market volatility. Consequently, it has given rise to a phenomenon known as "hidden hunger," a form of micronutrient malnutrition that affects over two billion people globally, resulting from diets that are calorie-sufficient but critically deficient in essential vitamins and minerals (FAO, 2022; von Grebmer et al., 2021). This failure is starkly evident in Sub-Saharan Africa (SSA), a region where the agricultural sector is the cornerstone of socio-economic life but is simultaneously confronting the converging pressures of climate change, environmental degradation, and rapid population growth (Bedeke, 2023; Omotoso et al., 2023).

This review is guided by Food Systems Theory, which provides a crucial lens for moving beyond a linear, production-focused analysis to a holistic understanding of how interconnected activities, starting from production and processing to distribution and consumption, interact with broader environmental, socio-economic, and political drivers to shape food security outcomes (Ericksen, 2008; HLPE, 2020). Within this theoretical framework, the over-reliance on a few major crops in SSA is not merely a production issue but a systemic vulnerability. The cultivation of these staples, often promoted by post-colonial agricultural policies and global market forces is increasingly threatened by soil degradation, biodiversity loss, and their poor suitability to the region's diverse agroecological zones (Smith et al., 2020; Nguyen et al., 2023). Consequently, despite the region’s deep agricultural roots, where approximately 75% of the population engages in farming (Moyo, 2016), over 282 million people experience food insecurity. The focus on caloric staples has failed to address the region’s nutritional needs, perpetuating high rates of hunger and malnutrition (Onyeaka et al., 2022).

In this context of systemic failure, neglected and underutilised crop species (NUCs) are also known as orphan, indigenous, or traditional crops that have emerged not as a simple alternative but as a strategic entry point for food system transformation. Species such as sorghum, millet, amaranth, Bambara groundnut, and teff are deeply embedded in African food cultures and are well-adapted to marginal environments where major staples falter (Tadele, 2019; Mabhaudhi et al., 2019). From a Food Systems Theory perspective, NUCs offer the potential to restructure the system at multiple leverage points and they can enhance agroecological resilience through their tolerance to drought and poor soils (Cullis & Kunert, 2017). They contribute to dietary diversity and combat hidden hunger through their superior nutritional profiles (Yaqoob et al., 2023) and create new economic opportunities for smallholder farmers by diversifying production and developing local value chains (Florence Suma et al., 2014).

Despite this potential, NUCs remain marginalised within the dominant food system. Their underutilisation is a consequence of systemic path dependency, where historical neglect by research, policy, and commercial actors has created a self-reinforcing cycle of low investment, poor market infrastructure, and limited institutional support (Dawson et al., 2019; Hendre et al., 2019). This has resulted in persistent production challenges, such as low yields and a lack of improved seeds, as well as post-harvest and market constraints that prevent their integration into formal value chains. Furthermore, the existing body of knowledge on NUCs is fragmented and dispersed, hindering a comprehensive understanding of their potential and the systemic interventions needed to support them. This lack of a consolidated evidence base limits policymakers, donors, and agribusinesses' ability to make informed decisions that could disrupt the current unsustainable trajectory.

To address these gaps, this study conducts a systematic review to examine the integration of NUCs into sustainable food systems as a strategy to counter the global food system failure in SSA. Grounded in Food Systems Theory, the review critically analyses the interconnected production, processing, and market constraints that impede the cultivation and commercialisation of these crops. It evaluates their nutritional and agroecological contributions as a direct countermeasure to hidden hunger and climate vulnerability, and it identifies the structural and institutional barriers that perpetuate their marginalisation. By synthesising and structuring the fragmented literature, this study aims to reposition NUCs as foundational assets for building climate-resilient, nutritionally adequate, and economically viable food systems. Ultimately, this research contributes to the discourse on food system transformation in SSA by advancing a conceptual argument for how leveraging NUCs can address the complex, interconnected challenges of food insecurity, climate change, and rural poverty, thereby aligning with the African Union’s Agenda 2063 and the United Nations Sustainable Development Goals.

2.2 Materials and Methods

2.2.1 Search strategy, inclusion and exclusion criteria

This systematic literature review has followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses checklist, which is formally known as PRISMA. This review study has used three academic databases, namely ScienceDirect, Web of Science, and EBSCOhost, to search for articles regarding the role of Orphan crops in food security, their challenges, and opportunities for value chain or value-addition development. These databases were chosen because they have a great depth and broad coverage of high-level academic and interdisciplinary scientific publications and journals. The various combinations of key words such as ‘‘orphan crops’’ OR ‘‘neglected and underutilised crops’’ AND ‘‘rural smallholder farmers’’ AND ‘‘food security’’ AND ‘‘marginal environment’’ AND ‘‘Production challenges’’ AND ‘‘value chain development opportunities’’ were used to search for relevant articles relevant to the subject matter, which yielded the results of 703 ScienceDirect articles, 582 Web of Science articles and 663 Ebsco-HOST articles. This resulted in a total of 1948 articles retrieved from these three databases. This review study used the existing literature conducted between 2000 and 2024. After redefining and filtering the search in terms of location (Sub Saharan Africa), language (English), document type (full-text articles, peer reviews) and Access type (Open Access), removing the duplicates, the results were reduced to 63 Science Direct articles, 40 Web of Sciences articles and 107 Ebsco- Host articles. This made a total of 210 articles retrieved. Thirdly, after a thorough review of the remaining articles' titles and abstracts and the removal of less relevant and unrelated articles, a total of 157 articles remained. Lastly, the exclusion process was implemented, resulting in the exclusion of 86 articles. The main reason for the exclusion is that these articles did not correlate to the themes focusing on (a) “contribution of Orphan crops on food security, (b)their challenges and (c) opportunities for value chain or value addition of orphan food crops” conducted in the SSA region. Finally, 57 full-text articles were included and advanced for full and thorough screening, data extraction and qualitative synthesis. The flow diagram for the article’s screening and selection is shown in Figure 1.

2.2.2 Data recording, management and analysis

The full texts and peer-reviewed articles were carefully screened by the researchers to evaluate their eligibility, validity, and reliability for this systematic literature review, following the exclusion and inclusion criteria. The retrieved articles were then exported to EndNote software, version 8, and duplicates were removed. Further, all the studies that did not address the objectives of the review study were excluded. The data was then analysed based on the objectives of the review. Also, the retrieved data was analysed based on the Authorship, year of publication, location, method used and their findings. This review is solely focusing on perspectives of contribution of orphan crops to food security, challenges of orphan crops and Opportunities of value chain development. Then their findings were synthesised and identified the literature gaps.

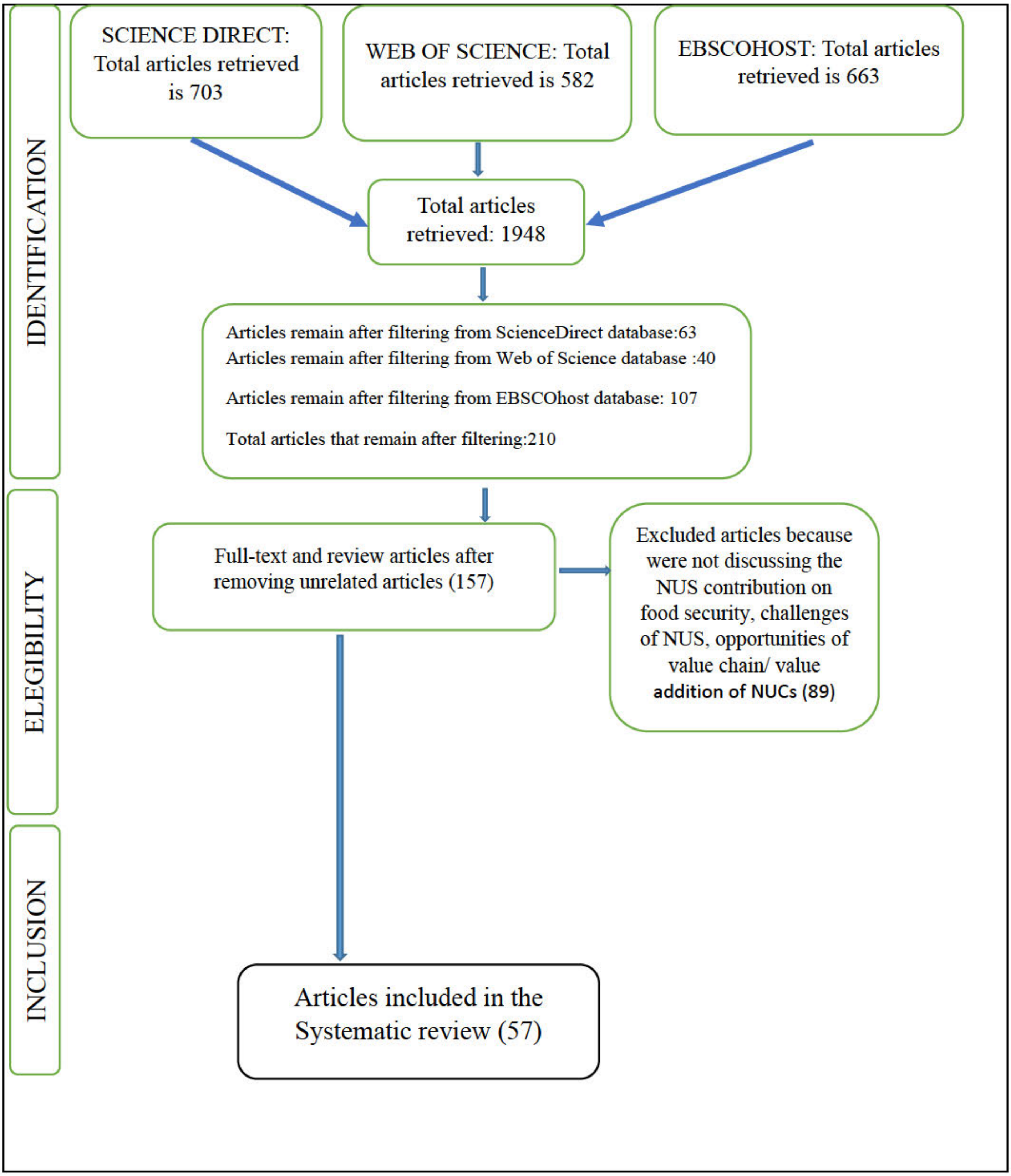

Figure 2.1: PRISMA (Source: Author's compilation)

2.3 Results

2.3.1 Nutritional profiles of orphan crops in sub-Saharan Africa

Orphan crops are often rich sources of essential micronutrients, dietary fibre, vitamins, and unique phytochemicals that are frequently lacking in dominant staple diets. The nutritional profile of key orphan crops cultivated in Sub-Saharan Africa is summarised in Table 2.1. This data illustrates their complementary role in addressing specific nutrient deficiencies prevalent in the region, such as iron, zinc, vitamin A, and protein.

Table 2.1: Nutritional profiles of orphan crops in sub-Saharan Africa

Crop Name	Key Nutritional Highlights	Health & Dietary Benefits	Source
Bambara Groundnut	High protein (18-25%), balanced carbs/fat, rich in Iron (4.9-48mg), Zinc, Calcium, Magnesium	"Complete food"; drought-tolerant; complements cereal-based diets	(Majola et al., 2021)
Finger Millet	Exceptionally high Calcium (300-350mg), good protein (5-12%), high fibre	Gluten-free; anti-diabetic properties; non-acid-forming	(Wright & Devos, 2024) (Onipe & Ramashia, 2022)
Marama Bean	Very high protein (30-39%) and oil (36-48%) content	Drought-tolerant; tuber is also edible; "complete food" potential	(Cullis et al., 2019) (Cullis et al., 2023)
Vegetable Cowpea	Leaves: High protein (29-34%), Iron (10.5-16.3mg), Zinc, Calcium. Pods: Good protein (21-26%) and minerals	Dual-purpose (leaf and pod); nutrient density varies by environment	(Gerrano et al., 2022)
African Nightshade	Leaves: Rich in Calcium (480mg), Iron (10mg), Vitamin A, Vitamin C	High in antioxidants (beta-carotene, anthocyanins)	(Baldermann et al., 2016)
Teff	Rich in Iron and Calcium; balanced amino acid profile	Gluten-free; resilient to drought and waterlogging	(Cheng et al., 2017); (Chanyalew et al., 2019)
Fonio	Good protein (7.5-11%), very high Iron (82.6mg), Zinc	Fast-maturing (6-8 weeks); drought-tolerant; gluten-free	(Addai et al., 2022) (Ibrahim & Achigan-Dako, 2021)
White Lupin	Very high protein (28-45%), high fibre (30-40%), beneficial lipids	Improves soil fertility (N-fixation); "sweet" varieties have low alkaloids	(Atnaf et al., 2020)

Tylosema fassoglense	Favourable amino acid profile, essential minerals (calcium, magnesium, phosphorus, zinc)	Medicinal properties: antimicrobial and antidiarrheal effects	(Munialo et al., 2024)

The comprehensive analysis of nutritional profiling across multiple studies in Table 2.1 reveals that orphan crops have significant nutritional potential to address food and nutrition security in SSA. Majola et al. (2021) demonstrated that Bambara groundnut serves as a "complete food" with high protein content (18-25%) and rich mineral composition, including iron (4.9- 48 mg), zinc, calcium, and magnesium, providing balanced nutrition for vulnerable populations. Similarly, Cullis et al. (2019) reported that the marama bean has exceptionally high protein (30-39%) and oil (36-48%) content, rivalling major legumes such as soybeans and peanuts in nutritional value. The nutritional diversity of orphan crops is further evidenced by Gerrano et al. (2022), who found that vegetable cowpea offers dual-purpose nutrition through both leaves and pods, with leaves containing high protein (29-34%), iron (10.5-16.3 mg), zinc, and calcium, while pods provide good protein (21-26%) and essential minerals. Wright and Devos (2024) highlighted finger millet's exceptional calcium content (300-350 mg), combined with good protein levels (5-12%) and high fibre, while also being gluten-free with anti-diabetic properties. Addai et al. (2022) emphasised fonio's nutritional advantages, including good protein content (7.5-11%), very high iron levels (82.6 mg), and zinc, complemented by its fast maturation and drought tolerance. The medicinal dimension of orphan crops is illustrated by Munialo et al. (2024), who documented Tylosema fassoglense's favourable amino acid profile, essential minerals, and bioactive compounds with antimicrobial properties.

Despite this compelling evidence, significant research gaps persist in the nutritional profiling of orphan crops. A critical gap concerns the standardisation of analytical methodologies across studies, as nutritional values for the same crop often show substantial variation between different studies. For instance, iron in Bambara groundnut ranges from 4.9 to 48 mg, making direct comparisons and conclusive dietary recommendations challenging. Furthermore, there is a notable lack of comprehensive data on the bioavailability of nutrients and the impact of traditional processing methods on nutrient retention and the reduction of anti-nutritional factors. Research has also largely neglected the compositional changes across different growth environments and developmental stages, with few studies investigating how agronomic practices and environmental stresses affect nutritional quality. Additionally, there remains insufficient exploration of the synergistic health effects of consuming multiple orphan crops within diverse dietary patterns, and limited understanding of how their integration into food systems translates into measurable improvements in human nutritional status. Addressing these gaps through coordinated research efforts is crucial to fully harness the nutritional potential of orphan crops in combating malnutrition and achieving food security in Sub-Saharan Africa.

2.3.2 Health benefits associated with orphan crops

Orphan crops possess significant nutritional and therapeutic potential that remains underutilised. The health benefits attributed to these crops, as identified in existing research, are synthesised in Table 2.2. This summary illustrates their potential role in addressing specific nutrient deficiencies and health conditions.

Table 2.2: Documented health benefits of orphan crops

Crop Name	Key Health Benefits	Bioactive Compounds	Medicinal Applications	Sources
Finger Millet	Anti-diabetic properties, antioxidant activity, anti-inflammatory effects, cholesterol reduction, improved digestive health	Polyphenols, tannins, flavonoids, dietary fibre, phytates	Management of type 2 diabetes, cardiovascular disease prevention, and gastrointestinal health	(Wright & Devos, 2024); (Onipe & Ramashia, 2022); (Mane et al., 2024)
Tylosema fassoglense	Antimicrobial activity, antidiarrheal properties, therapeutic applications	Phenolics, alkaloids, flavonoids, terpenoids, tannins	Treatment of diarrhoea, microbial infections, and traditional medicine practices	(Munialo et al., 2024)
African Nightshade	Antioxidant protection, anti-inflammatory effects, vision health, and immune support	Beta-carotene, anthocyanins, vitamin C, and vitamin A	Eye health maintenance, immune system enhancement, oxidative stress reduction	(Baldermann et al., 2016)
Bambara Groundnut	Antioxidant activity, cholesterol management, and blood sugar regulation	Polyphenols, catechins, dietary fibre, resistant starch	Cardiovascular health, diabetes management, and weight control	(Majola et al., 2021); (Popoola et al., 2022)
Underutilised Legumes	Anti-inflammatory effects, antioxidant protection, cardiovascular health, and anti-carcinogenic potential	Phenolic compounds, flavonoids, phytosterols, saponins	Chronic disease prevention, metabolic syndrome management	(Ayilara et al., 2022) (Chongtham et al., 2022)

Neglected Medicinal Plants.	Various therapeutic applications, antimicrobial activity, and chronic disease management	Diverse phytochemicals, including phenolics, alkaloids, and flavonoids	Traditional medicine, pharmaceutical precursors, and nutraceutical development	(Mudau et al., 2022)

Table 2.2 shows that orphan crops provide significant health benefits beyond basic nutrition, primarily due to their high levels of bioactive compounds. Wright and Devos (2024); and Onipe and Ramashia (2022) established that finger millet possesses well-documented anti-diabetic properties, with its high polyphenol and fibre content contributing to improved blood glucose regulation and insulin sensitivity. The seed coat, particularly rich in tannins and flavonoids, exhibits strong antioxidant and anti-inflammatory properties that support cardiovascular health and reduce the risk of chronic diseases. Similarly, Munialo et al. (2024) systematically reviewed Tylosema fassoglense and identified significant antimicrobial and antidiarrheal properties, with specific phytochemicals, including phenolics and alkaloids, contributing to its therapeutic applications in traditional medicine.

Baldermann et al. (2016) highlighted that African nightshade provides substantial antioxidant protection through its high concentrations of beta-carotene and anthocyanins, supporting vision health and immune function. The combination of vitamin C and various phytochemicals enhances its ability to reduce oxidative stress and inflammation. Majola et al. (2021) and Popoola et al. (2022) documented the cardiovascular benefits of Bambara groundnut, with its polyphenol content and dietary fibre contributing to cholesterol management and blood sugar regulation, making it valuable for the prevention of metabolic syndrome. The multiple varieties of underutilised legumes, as examined by Ayilara et al. (2022) and Chongtham et al. (2022), exhibit diverse health benefits, including anti-carcinogenic potential and the management of chronic diseases through various phenolic compounds, flavonoids, and phytosterols. Mudau et al. (2022) further emphasised that neglected medicinal plants contain diverse phytochemicals with multiple therapeutic applications, serving as important resources for traditional medicine and potential pharmaceutical development.

Despite these documented benefits, significant research gaps persist**.** There is limited clinical evidence validating traditional uses, with most studies relying on in vitro or animal models rather than human trials. The mechanisms of action for many bioactive compounds remain poorly understood, and optimal consumption levels for therapeutic effects are undetermined. Furthermore, the synergistic effects of multiple bioactive compounds within whole food matrices and the impact of processing on the retention of bioactivity require comprehensive investigation. Addressing these gaps through targeted clinical research and mechanistic studies is crucial for fully leveraging the health-promoting potential of orphan crops in preventive healthcare and therapeutic applications.

2.3.4 Environmental sustainability of orphan crops

Orphan crops contribute significantly to environmental sustainability and climate resilience within agricultural systems, particularly in marginal environments. These crops, which are typically more resilient to localised stresses such as drought, salinity, and extreme heat, provide a critical strategy for adapting to climate change. Their cultivation supports the diversification of food systems, which enhances ecosystem stability and reduces the risk of total crop failure. The contributions of orphan crops to environmental sustainability—including climate resilience, resource efficiency, and ecosystem stability are conceptualised in Figure 2.1.

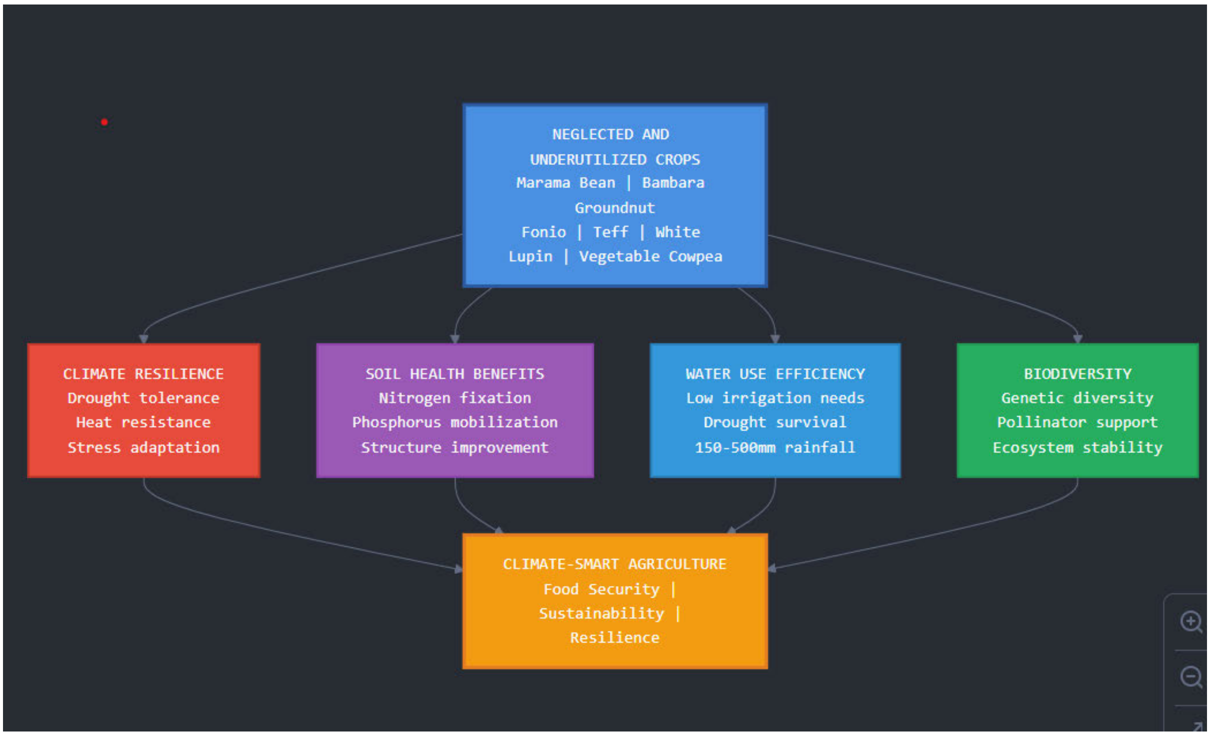

Figure 2.2: Environmental sustainability of orphan crops (Source: Author's compilation)

The evidence from Figure 2.2 demonstrates that orphan crops possess significant environmental sustainability advantages, particularly through their adaptation to challenging growing conditions and contribution to ecosystem health. Cullis et al. (2019, 2023) established that marama bean shows exceptional climate resilience, thriving in extreme drought conditions with temperatures exceeding 37°C while maintaining productivity on minimal rainfall (150-500 mm annually). Its deep taproot system and water storage capabilities enable survival in arid environments where conventional crops fail, while simultaneously supporting soil structure and requiring minimal nutrient inputs. Similarly, Majola et al. (2021) and Popoola et al. (2022) documented the remarkable drought avoidance mechanisms and nitrogen-fixing capabilities of bambara groundnut, which improve soil fertility while reducing the need for synthetic fertilisers in marginal agricultural systems.

Addai et al. (2022) and Ibrahim and Achigan-Dako (2021) highlighted fonio's unique environmental adaptations, particularly its rapid 6-8-week maturation cycle, which enables it to complete its lifecycle before seasonal droughts intensify, representing a crucial "drought escape" strategy. This characteristic, combined with its ability to grow on poor, degraded soils, positions fonio as a valuable crop for land rehabilitation and climate adaptation. Cheng et al. (2017) and Chanyalew et al. (2019) emphasised teff's dual tolerance to both drought and waterlogging conditions, providing farmers with a resilient option across variable climate scenarios while contributing to soil conservation through its extensive root system.

The soil improvement capabilities of orphan legumes are particularly noteworthy. Atnaf et al. (2020) demonstrated that white lupin not only fixes atmospheric nitrogen but also mobilises insoluble phosphorus in soils, effectively improving nutrient availability for subsequent crops and reducing fertiliser requirements. Gerrano et al. (2022) noted that vegetable cowpea contributes to sustainable intensification through its nitrogen-fixing abilities and efficient resource use, supporting soil health while providing food security.

Despite these documented sustainability benefits, significant research gaps remain. There is limited quantitative data on the carbon sequestration potential of orphan crops and their contribution to mitigating climate change. The mechanisms underlying their stress tolerance are not fully understood at the molecular and physiological levels, which hinders breeding efforts aimed at enhancing resilience. Furthermore, their integration into sustainable farming systems and contribution to agroecological intensification require more systematic investigation. The potential for orphan crops to restore degraded lands and support ecosystem services beyond food production represents another critical area for future research. Addressing these gaps through interdisciplinary studies could unlock their full potential as components of climate-resilient, sustainable agricultural systems.

2.3.5 Production challenges for orphan crops

The cultivation and scaling of orphan crops are hindered by a distinct set of agronomic and systemic constraints. These challenges, which span the entire production chain, often arise from decades of research and policy neglect in favour of major commodity crops. This section outlines the key bottlenecks, from limited genetic improvement to poor seed systems, that currently restrict their yield potential and widespread adoption by farmers. These interconnected production challenges are outlined in Figure 2.3.

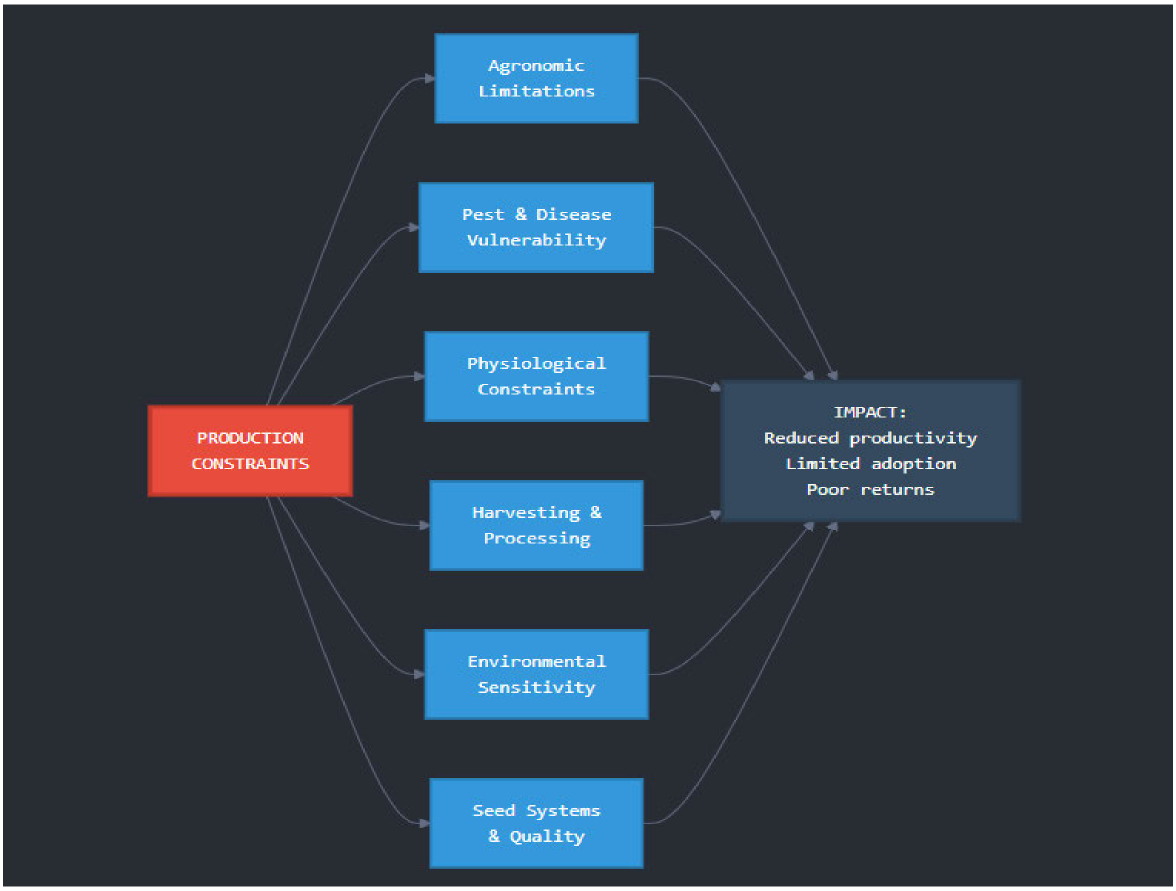

Figure 2.3: Production challenges for NUCS (Author's compilation)

Figure 2.3 reveals significant production challenges that fundamentally constrain the cultivation and scaling of neglected and underutilised species. Majola et al. (2021) and Chanyalew et al. (2019) documented critical agronomic limitations, including inherently low yield potential and a lack of improved varieties, resulting in lower productivity than in major staple crops. Cullis et al. (2019) emphasised that extended maturation periods in crops like marama bean, which can take 2-4 years to flower and set seed, create substantial barriers to farmer adoption and commercial production.

Seed systems and quality issues present fundamental constraints to NUCS production. Adejumobi et al. (2022) demonstrated that yam cultivation relies heavily on informal seed networks and backyard sources, resulting in inconsistent seed quality and limited availability of improved planting materials. McMullin et al. (2021) identified the absence of formal seed systems as a critical bottleneck, while Tadele (2019) highlighted that poor seed quality and limited storage protocols contribute to genetic erosion and unreliable production outcomes.

Pest and disease vulnerabilities present major production risks. Adejumobi et al. (2022) identified significant susceptibility to field pests and diseases in yam cultivation, while Majola et al. (2021) noted similar vulnerabilities in Bambara groundnut, where limited pest management knowledge exacerbates yield losses. Cullis et al. (2023) highlighted that the absence of developed control measures for diseases like anthracnose in marama bean threatens production stability and crop expansion.

Physiological constraints further complicate cultivation efforts. Cullis and Kunert (2017) demonstrated that complex flowering biology and poor fruit set in orphan legumes lead to unreliable and unpredictable production outcomes. Adejumobi et al. (2022) documented seed dormancy issues and poor germination rates in yams, which hinder successful crop establishment and uniform field performance. Alternatively, harvesting and processing challenges add substantial costs to production. Adejumobi et al. (2022) described labour-intensive harvesting methods for yams due to their geocarpic nature, while Majola et al. (2021) noted the absence of appropriate processing technologies for Bambara groundnut, resulting in high post-harvest losses and quality deterioration.

Environmental sensitivity represents another critical production constraint. Gerrano et al. (2022) revealed high genotype-by-environment interactions in vegetable cowpea, where nutritional and yield traits vary significantly across different growing locations, complicating breeding and cultivation recommendations. Chemura et al. (2022) projected that climate change will substantially reduce suitable growing areas for crops like cocoyam, threatening future production potential.

However, critical research gaps persist in addressing these production challenges. There is limited development of improved varieties specifically bred for yield stability and stress tolerance in NUCS. The optimisation of agronomic practices, including planting densities, nutrient management, and irrigation requirements, remains underexplored for most species. Furthermore, integrated pest management strategies tailored to NUCS are largely unavailable, and mechanisation options for harvesting and processing require significant investment in research and development. The establishment of formal seed systems and quality control mechanisms represents another crucial area that requires immediate attention to ensure the sustainable production of these valuable species.

2.3.6 Socio perceptions and attitudes on orphan crops

Cultural perceptions and social status associations emerge as particularly formidable barriers to NUCS adoption. Multiple studies document the profound stigmatisation of NUCS as "poor people's food" or "famine foods," creating social resistance that frequently outweighs nutritional advantages (Matthews & Ghanem, 2021). This perception is reinforced by strong associations with poverty and rural life, leading to status-driven rejection, especially among urban and younger consumers seeking modern food identities. The characterisation of NUCS as "backward" or outdated traditions further compounds these negative perceptions, creating significant social barriers to consumption and preference for modern staples that symbolise economic progress and urban sophistication.

2.3.7 Chemical composition of NUCS

The chemical composition of Neglected and Underutilised Crops (NUCS) forms the foundation of their nutritional value and potential health benefits, yet also presents challenges for consumer acceptance. Extensive research has documented the diverse phytochemical profiles of various NUCS. Majola et al. (2021) reported that Bambara groundnut contains significant levels of polyphenols, catechins, and dietary fibre, which contribute to its antioxidant activity and cholesterol-lowering properties. Similarly, Munialo et al. (2024) systematically identified a diverse range of phytochemicals in *Tylosema fassoglense*, including phenolics, alkaloids, flavonoids, terpenoids, and tannins, which are responsible for its antimicrobial and antidiarrheal properties. These bioactive compounds, while beneficial for health, often contribute to sensory characteristics that may affect consumer acceptance.

2.3.8 Sensory evaluation for NUCS

Sensory evaluation studies reveal particularly significant challenges in consumer acceptance of NUCS-based products, primarily driven by inherent physicochemical properties and evolving consumer expectations. Majola et al. (2021) demonstrated that Bambara groundnut's extended cooking time often requires several hours of preparation, and its characteristically dense, firm texture substantially reduces its appeal to modern urban consumers who prioritise convenience and time efficiency in food preparation. This challenge is compounded by Mabhaudhi et al. (2019), who identified that unfamiliar taste profiles, including earthy, bitter, or astringent notes common in many NUCS, and deeply ingrained texture preferences for refined staples, create substantial psychological and practical barriers to the adoption of NUCS. Furthermore, appearance standards heavily favouring conventional foods systematically disadvantage NUCS, which frequently exhibit unusual colours, irregular shapes, or heterogeneous textures compared to the uniform, processed appearance of mainstream alternatives. These sensory factors collectively create a significant "novelty barrier" that profoundly influences both initial trial and crucial repeat purchases of NUCS products, effectively limiting their market penetration and commercial viability**.**

2.3.9 Consumer acceptance of NUCS

Consumer acceptance studies highlight the complex, often contradictory interplay between chemical composition, sensory properties, and cultural preferences, creating a fundamental tension between health potential and marketability. Mudau et al. (2022) noted that while many NUCS possess valuable nutraceutical properties derived from their unique phytochemical profiles, their strong, distinctive flavours and potent aromas, resulting from these beneficial compounds, often render them unpalatable to unaccustomed consumers without substantial processing intervention. This paradox is further exemplified by Onipe and Ramashia (2022), who emphasised that finger millet's characteristically robust, slightly bitter taste and distinctive dark colouration, though directly indicative of its high polyphenol content and associated health benefits, frequently necessitate sensory masking or modification strategies to achieve broader market appeal. These findings collectively suggest that the very chemical compounds responsible for NUCs' significant health benefits simultaneously create substantial sensory challenges that inherently limit consumer acceptance, presenting a fundamental dilemma for product development and commercialisation efforts.

2.3.10 Value addition development opportunities

Despite the challenges associated with orphan food crops, the value addition presents opportunities to unlock the full potential of the orphan food crops (Low et al., 2017; Munialo et al., 2024). Evidently, Ethiopia’s teff value chain has made some progress into international markets, which has grown and generated a revenue of $50 million per year (Bachewe et al., 2019) due to high demand for gluten-free flours and nutraceuticals (Cheng et al., 2017; Low et al., 2017; McMullin, 2021; Cullis et al., 2023). This is attributed to the policy support, such as export liberation lift ban, value chain transformation through yield boosting varieties and mechanisation (Bachewe et al., 2019), yet the smallholder equitable inclusion and post-harvest innovations remain highly questionable. Moreover, the nutrition boosting programs intervention, such as biofortification of sweet potatoes have had positive impacts, reducing vitamin A deficiency by 23 percent (Low et al., 2017; Mane et al., 2024). On the other hand, the genomic attempts, such as speed breeding, have shown some potential to reduce variety development timelines by 60 percent (Ribaut & Ragot 2019). Further, participatory selection for disease-resistant *enset* and CRISPR-edited low-phytate finger millet are used to enhance the plant productivity performance and nutritional quality (Ribaut & Ragot, 2019; Muzemil, 2021; Mekonenn et al., 2022). Equally important, the new processing technologies, such as the modular mills, lowered the post-harvest losses of fonio from 30% to 8%, while fermentation techniques have reduced the anti-nutrients in cowpea by at least 40 percent and this has improved the food safety and shelf life of these food crops (Orr et al., 2020; Adejumobi, 2022). These successes show that the transformation of the orphan crop value chain enabled farmers and stakeholders to harness the economic benefits. However, significant research gaps remain regarding the equity implications of commercialisation, particularly whether emerging value chains will genuinely benefit smallholder producers.

Regardless of these advances, there are still major hindrances that inhibit the development of the value chain process. These include the infrastructure developments, such as the storage facility to limit their post-harvest losses and technological innovations, particularly genomic technologies, which further hampered the equitable economic benefits (Low et al., 2017). Munialo et al. (2024) confirm that value addition reduces post-harvest losses to crops like taro that have approximately 40 - 60 percent post-harvest losses due to poor storage and handling. Moreover, the limited integration of orphan food crops across the value chain beyond production signifies the insufficient economic and market modelling frameworks (Ali & Bhattacharjee, 2023). Over and above, the literature shows that there is a lack of comprehensive economic viability, cost-benefit analyses, and market, consumer acceptance, penetration, and market development studies to quantify the commercialisation of orphan food crops.

2.3.11 Marketing approaches for neglected and underutilised species

The commercialisation of Neglected and Underutilised Crops (NUCs) necessitates the development of sophisticated marketing strategies that address complex market failures and consumer behaviour patterns. McMullin et al. (2021) posit that effective market creation for

NUCS requires a segmented approach, distinguishing between subsistence-oriented rural markets and quality-differentiated urban markets. This necessitates the development of distinct value propositions: for rural smallholders, marketing must emphasise production reliability and risk reduction, while urban consumers respond better to narratives surrounding health benefits and culinary novelty. Bachewe et al. (2019) demonstrate through a Teff value chain analysis that strategic market positioning in urban centres can catalyse widespread commercial adoption, particularly when products are linked to cultural heritage and premium quality perceptions. Orr et al. (2020) further establish that market development must be institutionally supported through robust supply chain infrastructure, including standardised quality metrics, efficient aggregation mechanisms, and reliable distribution networks. Contemporary digital marketing platforms and e-commerce channels present particularly viable mechanisms for reaching younger demographic cohorts while simultaneously improving market information symmetry and reducing transaction costs across fragmented value chains.

2.3.12 Strategic branding frameworks for NUCS commercialisation

The development of strategic branding frameworks represents a critical intervention for overcoming deeply embedded socio-cultural perceptions that hinder NUCS commercialisation. Matthews and Ghanem (2021) argue that systematic rebranding initiatives must consciously dissociate these crops from their historical associations with poverty while emphasising their distinctive nutritional and environmental attributes. Leakey et al. (2021) propose positioning NUCS within the climate-smart agriculture paradigm, thereby appealing to environmentally conscious consumers through demonstrated sustainability credentials and the provision of ecosystem services (Atnaf et al., 2020; Leakey et al., 2021; van Zonneveld et al., 2021; Popoola et al., 2022). The implementation of formal quality certification mechanisms, including geographic indication labelling and organic certification, provides tangible branding assets that facilitate product differentiation and premium pricing strategies. Furthermore, narrative branding incorporating cultural heritage elements and traditional knowledge systems can establish authentic emotional connections with consumers while preserving indigenous food sovereignty. However, Leakey et al. (2021) caution that branding strategies must maintain cultural sensitivity to avoid alienating traditional consumer bases who value these crops for their authenticity and socio-cultural significance. The strategic deployment of culinary influencers and subject matter experts can further enhance brand credibility and accelerate consumer adoption by disseminating knowledge and exerting normative influence.

2.3.13 Policy framework

The development of an effective policy framework is a fundamental prerequisite for mainstreaming Neglected and Underutilised Crops (NUCs) into formal agricultural systems. Current policy environments remain largely fragmented and often inadvertently disadvantage NUCS through preferential treatment of major staple crops (Ndlovu et al., 2024). McMullin et al. (2021) emphasise that successful NUCS integration requires moving beyond isolated interventions toward comprehensive policy approaches that simultaneously address production, consumption, and market development constraints (Talabi et al., 2022). Tadele argues that agricultural policies must explicitly recognise the strategic value of orphan crops in building climate-resilient food systems and allocate commensurate institutional support, especially as a countermeasure to land degradation and climate change (Talabi et al., 2022). Emerging frameworks suggest that effective NUCS policy should integrate these species into national agricultural development plans while establishing clear regulatory pathways for improved varieties, particularly those developed through modern breeding techniques (Zambrano et al., 2022). This is particularly crucial for creating an enabling environment that recognises the multifunctional role of NUCS in achieving food security, nutrition, and environmental sustainability (Tadele, 2019).

2.3.14 Investment landscape

The mobilisation of strategic investment is critical for overcoming the significant financial barriers that constrain NUCS development and commercialisation. Current investment patterns reveal substantial funding gaps, particularly for early-stage research and value chain infrastructure, with orphan crops suffering from neglect and abandonment by the scientific community due to very low or no investments in research and genetic improvement (Talabi et al. 2022). Orr et al. (2020) demonstrate through their business case analysis that while returns on NUCS research and development can be substantial, the perceived risks and long-time horizons often deter private sector engagement (Zambrano et al., 2022). This necessitates innovative financing mechanisms, including blended finance models that combine public and private capital, targeted grant funding for foundational research, and value chain financing that addresses specific bottlenecks from production to market access Mudau et al., 2022). Furthermore, strategic investment should prioritise the development of formal seed systems, processing technologies, and market infrastructure that can enhance the commercial viability of NUCS (Orr et al., 2020). International donors and development agencies play a crucial role in catalysing initial investments; however, long-term sustainability requires the gradual engagement of domestic financial institutions and private sector actors, who can drive scale and market integration (Ndlovu et al. 2024).

2.3.15 Research priorities

Strategic research investment is essential for addressing the significant knowledge gaps that hinder the effective utilisation and improvement of NUCS. Current research efforts remain disproportionately focused on major crops, resulting in a substantial innovation deficit for orphan species (Talabi et al., 2022). Hendre et al. (2019) emphasise the urgent need to develop genomic resources and modern breeding tools that can accelerate genetic improvement in NUCS, leveraging advances in genomics and molecular biology (Talabi et al., 2022). Beyond genetic enhancement, research must also address critical gaps in agronomic management, post-harvest processing, and nutritional profiling to optimise production systems and enhance their utilisation (Orr et al., 2020).

Recent advances in omics technologies have opened new pathways for the comprehensive characterisation of bioactive compounds in underutilised plants, revealing their potential for sustainable functional applications in food and pharmaceuticals (Hendre et al., 2019). Additionally, transdisciplinary research that engages farmers, consumers, and other value chain actors is crucial for ensuring that technological innovations align with user preferences and market demands (Ndlovu et al., 2024). Capacity building through specialised training programs and research partnerships can further strengthen the scientific foundation for NUCS improvement, creating a sustainable pipeline of innovations to support their integration into climate-resilient agricultural systems.

2.4 Discussion

This systematic review has synthesised evidence from diverse studies investigating the potential of Neglected and Underutilised Species (NUCS) to enhance food security, nutrition, and environmental sustainability in Sub-Saharan Africa (SSA). The findings present a compelling yet complex narrative: while NUCS possess undeniable agronomic, nutritional, and economic potential, their systematic marginalisation across research, policy, and market domains has perpetuated a cycle of underutilisation. This discussion interprets these findings within the broader context of agricultural development, examines the intricate interdependencies between identified challenges and opportunities, and proposes a comprehensive framework for mainstreaming them.

The most striking finding of this review is the stark contrast between the documented benefits of NUCS and their persistent neglect. On one hand, the nutritional profiling reveals that crops such as Bambara groundnut, marama bean, and finger millet are nutritional powerhouses, rich in proteins, essential minerals, and bioactive compounds capable of addressing pervasive micronutrient deficiencies (Cullis et al., 2019; Majola et al., 2021; Wright & Devos, 2024). Their inherent climate resilience, exemplified by drought tolerance in marama bean and fast maturation in fonio (Addai et al., 2022), positions them as strategic assets for climate adaptation. Yet, this potential remains largely untapped due to several factors. The "orphan" status of these crops is not a natural state but a consequence of deliberate and inadvertent consumer choices. Decades of agricultural research and policy have channelled resources into a few staple crops, creating a cycle of comparative advantage. This has systematically disadvantaged NUCS, which remains uncompetitive without parallel investments in crop development and value chain, thereby further marginalising it (Tadele, 2019).

The barriers to adoption are not merely agronomic but are deeply rooted in socio-cultural and economic perceptions. The stigmatisation of NUCS as "poor people's food" (Matthews & Ghanem, 2021) is a powerful social barrier that transcends nutritional logic. As Cele and Mkhize (2025) astutely observe, economic advancement can paradoxically reduce reliance on these crops, as they become associated with a past of poverty rather than a future of health and sustainability. This highlights that strategies focused solely on improving production will fail unless they simultaneously address these deeply embedded cultural narratives and status dynamics.

The evidence clearly indicates that a parallel approach is insufficient to break the cycle of neglect. The mainstreaming of NUCS requires an integrated, multi-disciplinary strategy that simultaneously targets the key leverage points of research, policy, markets, and consumer perception. From a breeding perspective, the severe lack of improved varieties is a fundamental bottleneck. The application of modern genomic tools, such as the reference genomes being developed by the African Orphan Crops Consortium (Hendre et al., 2019), is no longer a luxury but a necessity. Genomics-assisted breeding can significantly accelerate the improvement of complex traits, such as yield, drought tolerance, and nutritional content (Ibrahim & Achigan-Dako, 2021). Furthermore, research must extend beyond the farm gate to include the development of appropriate-scale processing technologies that mitigate undesirable traits, such as long cooking times, thereby enhancing convenience and consumer appeal (Majola et al., 2021).

From a strategic market creation and value addition perspective, moving NUCS from subsistence to commerce requires deliberate market creation. This involves two parallel tracks. First, there is a need to develop value-added products that align with urban consumer lifestyles, such as gluten-free teff flour, instant fonio cereals, and functional ingredients from finger millet bran (Bachewe et al., 2019; Onipe & Ramashia, 2022). Second, strategic branding and marketing are crucial to reshape perceptions. As Leakey et al. (2021) suggest, repositioning NUCS as climate-smart and cultural foods can create premium market niches, distancing them from associations with poverty and appealing to health-conscious and environmentally aware consumers.

From the policies and targeted investment perspectives, the current policy environment in SSA often inadvertently disadvantages NUCS. Reform is needed to integrate these crops explicitly into National Agricultural Investment Plans under frameworks such as the Comprehensive Africa Agricultural Development Programme (CAADP). Policies must create clear regulatory pathways for improved seeds and incentivise private sector investment through de-risking mechanisms (Orr et al., 2020; McMullin et al., 2021). Public investment is crucial for funding the foundational R&D that the private sector often lacks the resources to finance, while blended finance models can be utilised to build the necessary market infrastructure.

The strength of the proposed framework lies in the synergies between its components. For instance, genomic research provides the improved varieties that are a prerequisite for successful commercialisation. Conversely, effective branding and market demand create the economic pull that justifies sustained investment in research. Supportive policies are the glue that binds these efforts together, ensuring coordination and providing the enabling environment for both research and market initiatives to flourish. A failure in one component can undermine the entire system, for example, releasing a high-yielding variety without parallel efforts to develop its market will lead to farmer disillusionment and abandonment.

2.5 Limitations and future research directions

This review has several limitations. The quality of the synthesis depends on the original studies, which often lack standardised methodologies, particularly for nutritional and sensory analyses.

There is also a geographic bias in the literature, with certain regions and crops being over-represented. Furthermore, many studies are diagnostic, identifying challenges, but there is a scarcity of robust, empirical evidence on the effectiveness of different intervention strategies.

Future research should therefore prioritise Implementation Science, conducting rigorous impact evaluations of different NUCS mainstreaming models to identify what works and under what conditions. Furthermore, targeted research in Sensory and Consumer Science is critical to deconstructing the drivers of acceptance and aversion. By applying standardised evaluation protocols, researchers can pinpoint the specific flavours, textures, and aromas that limit adoption, thereby providing an evidence-based roadmap for product development that enhances palatability. Additionally, further research should be conducted on policy frameworks, examining the power dynamics and institutional interests that influence agricultural research priorities and policy decisions, to better understand how to advocate for NUCS. Furthermore, future research should focus on climate resilience modelling, quantifying the potential of specific NUCS to mitigate production risks under various climate change scenarios.

2.6 Conclusion

This systematic review establishes that neglected and underutilised species (NUCs) are not merely nutritionally adequate substitutes for conventional staples but possess distinct agronomic, nutritional, and climate-adaptive advantages that position them as strategic assets for food system transformation in Sub-Saharan Africa (SSA). The evidence synthesised across 20 years of literature demonstrates that crops such as Bambara groundnut, marama bean, and finger millet offer superior drought tolerance, protein density, and micronutrient profiles relative to maize and wheat, yet remain systematically marginalised within research, policy, and market systems.

Three interconnected constraints explain this persistent marginalisation. First, production-level barriers, including low yields from unimproved landraces, limited access to quality seed, and weak extension support, undermine productivity and farmer confidence. Second, value chain fragmentation, characterised by inadequate processing infrastructure, poor market linkages, and the absence of quality standards, prevents scale-up beyond subsistence production. Third, and most critically, the cultural stigmatisation of NUCs as "poverty foods" operates across all levels, shaping farmer adoption decisions, consumer preferences, and policy prioritisation.

These constraints are not independent but mutually reinforcing, creating a cycle of neglect that this review has systematically documented.

Addressing this cycle requires a coordinated, systems-level strategy that integrates three interdependent pillars. First, scientific and agronomic advancement must move beyond descriptive nutritional analyses to include participatory breeding programmes that improve yield, uniformity, and stress tolerance while retaining the sensory and cultural attributes valued by local communities. Second, market-oriented commercialisation demands investment in processing technologies, quality grading systems, and market infrastructure that enable smallholder farmers to access higher-value market segments rather than remaining confined to informal, low-return channels. Third, policy and institutional reform must embed NUCs within national agricultural investment plans, nutrition strategies, and climate adaptation frameworks, shifting them from the periphery to the core of SSA's agricultural development agenda.

This review contributes to the literature by providing the first systematic synthesis that explicitly links production constraints, value chain barriers, and commercialisation pathways within a unified analytical framework. For policymakers, the findings underscore those piecemeal interventions such as seed distribution without market development, or nutritional advocacy without addressing stigma, are unlikely to succeed. Instead, transformative impact requires simultaneous action across the three pillars identified. For researchers, the review highlights critical evidence gaps, particularly the scarcity of rigorous impact evaluations of NUC interventions and the absence of longitudinal studies tracking adoption and welfare outcomes over time.

Ultimately, this review demonstrates that realising the potential of SSA's agrobiodiversity is not a matter of simply "improving" NUCs as standalone commodities. It fundamentally requires reconfiguring the systems of research, policy, markets, and culture within which these crops are produced, processed, and consumed. By doing so, SSA can leverage its indigenous crop heritage to build food systems that are not only more resilient and nutritious but also more equitable, grounded in the crops and knowledge systems of its rural communitie This systematic review establishes that neglected and underutilised species (NUCs) are not merely nutritionally adequate substitutes for conventional staples but possess distinct agronomic, nutritional, and climate-adaptive advantages that position them as strategic assets for food system transformation in Sub-Saharan Africa (SSA). The evidence synthesised across 20 years of literature demonstrates that crops such as Bambara groundnut, marama bean, and finger millet offer superior drought tolerance, protein density, and micronutrient profiles relative to maize and wheat, yet remain systematically marginalised within research, policy, and market systems.

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CHAPTER 3: SMALLHOLDER FARMERS' PERCEPTIONS AND ATTITUDES TOWARD UNDERUTILISED CROPS IN KWAZULU-NATAL PROVINCE, SOUTH AFRICA

Abstract

Traditional agricultural systems face unprecedented challenges from climate change, market pressures, and institutional biases, threatening the preservation of underutilised crops (NUCs). In South Africa, NUCs offer significant potential for enhancing food security and climate resilience, yet their adoption remains limited among smallholder farmers. This study examined smallholder farmers' perceptions and attitudes toward NUCs in KwaZulu-Natal (KZN) Province using the Theory of Planned Behaviour framework. Data from 319 farmers were collected through a structured questionnaire and analysed using Tobit regression. Findings revealed statistically significant differences between adopters (39.8%) and non-adopters (60.2%), with adopters showing more positive perceptions (mean index = 0.76) and attitudes (mean index = 0.79) across all variables. Empirical results found that gender had a negative relationship with both perception and attitude indices ($p=0.001$ and $p=0.012$, respectively), indicating females have more positive orientations toward NUCs. Age demonstrated a positive impact ($p<0.001$ and $p=0.001$, respectively), while education showed negative effects ($p=0.011$ and $p=0.027$, respectively). Institutional factors, including access to extension services ($p=0.002$ and $p=0.006$) and agricultural training ($p=0.004$ and $p=0.010$), negatively influenced farmers' perceptions and attitudes, suggesting these systems prioritise commercial crops over traditional varieties. Awareness emerged as the strongest positive predictor ($p<0.001$). Traditional knowledge sources dominated information channels, with 78.4% of farmers citing family elders as primary sources. Findings suggest policymakers should reform extension services to integrate NUC promotion using culturally sensitive approaches, strengthen intergenerational knowledge transfer programs, and develop women-focused agricultural support, recognising their role as traditional crop custodians. Addressing these factors will enhance smallholder farmers' adoption of NUCs and promote sustainable agriculture and food security in KZN.

Keywords: Underutilised crops, Smallholder farmers, Perceptions and Attitudes, Traditional knowledge, Theory of Planned Behaviour

3.1 Introduction

Globally, agriculture faces unprecedented pressures from climate change, population growth, and the dominance of commercial production systems that have marginalised traditional farming practices (Narula, 2024; Dutto, 2025). These trends have profound implications for food security, biodiversity conservation, and the preservation of indigenous knowledge (Mabhaudhi et al., 2019; Adefila et al., 2024). In sub-Saharan Africa (SSA), where agriculture employs approximately 54% of the working population and contributes 15% to regional GDP (FAO, 2022; Gallouo, 2023), the vulnerability of rainfall-dependent farming systems is particularly acute (Kom et al., 2022; Onyeaka et al., 2024). South Africa mirrors these continental patterns: although agriculture contributes only 2-3% to national GDP (FAO, 2022), it remains vital for rural livelihoods, particularly for smallholder farmers who constitute the majority of agricultural producers (Nhlozi, 2023; Shelembe et al., 2024). KwaZulu-Natal (KZN) Province exemplifies these challenges while presenting unique opportunities. Its diverse agro-ecological conditions support millions of smallholder households, and its rich agricultural heritage includes traditional crops that have sustained Zulu communities for generations (Buthelezi et al., 2013; Mzimela & Moyo, 2025).

Underutilised crops, also referred to as neglected and underutilised species (NUCs), orphan crops, or indigenous crops, offer a promising response to these challenges. Historically important for food security, these species have been marginalised in modern agricultural systems (Chivenge et al., 2015; Imathiu, 2021). They include indigenous vegetables, traditional grains, and drought-tolerant legumes that possess significant nutritional and agronomic advantages (Hossain et al., 2021; Nkwonta et al., 2023). Well-adapted to local environments, NUCs typically require minimal external inputs and exhibit inherent tolerance to drought, pests, and diseases (Shai et al., 2025). Their superior nutritional profiles and contributions to biodiversity and cultural preservation are well documented (Anju & Kumar, 2022; Zondi et al., 2022).

Despite these recognised benefits, the cultivation of NUCs has declined significantly across SSA, with many traditional varieties facing extinction due to changing agricultural practices and institutional neglect (Leakey et al., 2022; Mmbando, 2025). Extension services, training programmes, and research institutions have historically prioritised commercial crop production, contributing to the erosion of indigenous knowledge and reduced awareness among farming communities (Mabhaudhi et al., 2019; Kumar et al., 2025). Consequently, smallholder farmers who could benefit most from these crops often lack the knowledge and support necessary for their cultivation.

The cultivation of underutilised crops depends critically on farmers' perceptions and attitudes. Perception refers to how farmers understand the potential benefits, costs, and risks associated with NUCs, while attitude reflects their evaluative judgments toward cultivating these crops (Fronda, 2023; Pattiasina et al., 2023). Research demonstrates that these psychological factors often outweigh technical or economic considerations in determining farmer behaviour. Pattiasina et al. (2023) found that farmers' perceptions of traditional practices strongly predict cultivation decisions, while Juah & Nhamo (2023) established that positive attitudes toward indigenous crops increase the likelihood of cultivation, even under resource constraints.

In South Africa, limited research has systematically examined smallholder farmers' perceptions and attitudes toward underutilised crops. While studies have documented the nutritional benefits and climate resilience of NUCs (Mabhaudhi et al., 2019; Zondi et al., 2022), few have investigated the combined influence of demographic, social, and institutional factors on perceptions and attitudes within a theoretical framework. This gap is particularly concerning given the documented decline in traditional crop cultivation and the associated loss of agricultural biodiversity and cultural knowledge.

This study addresses this gap by examining smallholder farmers' perceptions and attitudes toward underutilised crops in KZN Province, South Africa, using the Theory of Planned Behaviour as its theoretical framework. Specifically, the research seeks to: (i) assess farmers' awareness and knowledge of underutilised crops; (ii) examine their perceptions regarding the benefits, costs, and risks associated with NUC cultivation; (iii) evaluate their attitudes toward cultivating these crops; and (iv) identify the socioeconomic and institutional factors that influence these perceptions and attitudes. The findings will provide insights for policymakers, extension services, and development organisations working to preserve agricultural biodiversity and enhance food security through traditional crop systems, thereby contributing to sustainable agriculture and rural development in South Africa

3.2 Theory for examining perceptions and attitudes towards underutilised crops

This study is anchored in the Theory of Planned Behaviour (TPB), as developed by Ajzen (1991), to explore the factors influencing smallholder farmers' perceptions and attitudes toward underutilised crops in KZN Province. The TPB posits that behavioural intention and the immediate antecedent of action is shaped by three conceptually distinct constructs including attitudes (favourable or unfavourable evaluations of the behaviour), subjective norms (perceived social pressure to perform or not perform the behaviour), and perceived behavioural control (perceived ease or difficulty of performing the behaviour, reflecting past experience and anticipated obstacles) (Ajzen, 1991). This framework has been widely applied in agricultural research examining innovation adoption, crop diversification, and traditional farming systems (Borges et al., 2014; Hyland et al., 2016; Bonke & Musshoff, 2020).

Figure 3.1 presents the conceptual model guiding this study. The figure illustrates the standard TPB relationships, with attitudes, subjective norms, and perceived behavioural control each exerting direct effects on behavioural intention, which in turn predicts actual behaviour. However, the figure also depicts the key adaptation made in this study: the inclusion of socioeconomic characteristics such as income, education, farm size, and resource access as exogenous determinants positioned to influence perceived behavioural control specifically. This adaptation is visually represented by arrows flowing from these socioeconomic factors into the perceived behavioural control construct, distinguishing the model from Ajzen's original specification.

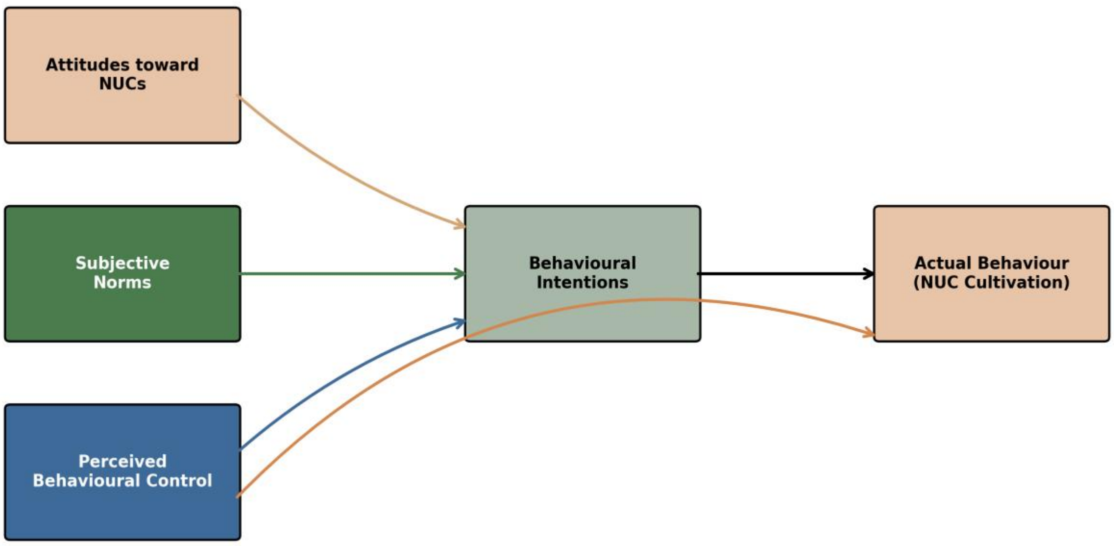

Figure 3.1: The theory of planned behaviour in the context of NUC cultivation (Source: Adapted from Ajzen (1991))

This adaptation is both theoretically justified and empirically necessary. In Ajzen's (1991) original formulation, perceived behavioural control is treated as a relatively stable psychological perception shaped by beliefs about facilitating factors and obstacles. However, in smallholder farming contexts, particularly within marginalised agricultural systems such as those in KZN, perceived behavioural control is not merely a matter of individual psychology. It is fundamentally constrained or enabled by tangible, structural realities. A farmer's perception of whether they can cultivate underutilised crops is substantively determined by their access to productive resources, including land, labour, capital, seed availability, and technical knowledge. For example, a farmer with limited land may perceive cultivating an unfamiliar crop as impractical, while a farmer with higher income may view the same activity as entirely feasible, regardless of their underlying attitudes. Wauters et al. (2020) and Abegunde et al. (2020) demonstrate that socioeconomic factors such as these operate through perceived control perceptions to shape adoption decisions, a finding consistent with the resource-based view of agricultural decision-making.

This study, therefore, extends Ajzen's (1991) original TPB model in two specific ways. First, it explicitly positions socioeconomic characteristics as antecedents of perceived behavioural control, thereby recognising that in resource-constrained settings, control perceptions are partially determined by objective resource endowments rather than arising solely from internal beliefs. Second, the model incorporates the institutional context of KZN's communal farming systems into the subjective norms construct. While Ajzen conceptualised subjective norms broadly as generalised social pressure, this study operationalises them to capture the specific influence of family elders, traditional authorities, and community network actors who function as the primary custodians of indigenous agricultural knowledge in this context (Chivenge et al., 2015; Meijer et al., 2019).

This adapted framework offers analytical advantages over the standard TPB model. By distinguishing between the psychological and structural determinants of behaviour, it avoids conflating farmers' willingness to cultivate NUCs (attitudes) with their ability to do so (control perceptions shaped by socioeconomic constraints). This distinction is critical for policy formulation: findings that reveal negative attitudes may require awareness campaigns, whereas findings that reveal positive attitudes but low perceived control point to structural interventions such as seed distribution, extension support, or market development. The framework thus provides a more nuanced understanding of how psychological and material factors jointly shape smallholder farmers' orientations toward underutilised crops, enabling more targeted and effective intervention strategies.

3.3 Materials and methods

3.3.1 Description and study area selection

This study was conducted in KZN Province of South Africa. The province was purposively selected due to its dominance in rural smallholder farming and its rural setting. The study area also provided an ideal opportunity to research these crops, given their widespread cultivation by smallholder farmers and the region's suitable climate (Qwabe et al., 2021). The uMkhanyakude District Municipality and the King Cetshwayo District Municipality were purposively selected as the study area due to their topographical nature and landscape that are suitable for the production of neglected and underutilised food crops (Mulopo & Chimbari, 2021; Pactrick, 2021). Figure 3.2. represents the map of the selected study locations.

The uMkhanyakude District Municipality is situated in the northernmost part, whereas the King Cetshwayo District Municipality is located in the north-eastern region of KZN (Mthembu & Hlophe, 2020; Abegunde et al., 2020; Cooperative Governance and Traditional Affairs, 2023/11). UDM covers a land mass of 12,818 km^2 with a population of approximately 686,090 (Mthembu and Hlophe, 2020), and KCD with a land mass of 94,341 km2 971 135 population (COGTA, 2023/11). Both KCDM and UDM have warm, good climates with mild winters and hot, humid summers, while UDM is characterised by a steady rise in temperature, declining rainfall, and increased drought frequency and severity, particularly in the northern regions, which affects agricultural production (COGTA, 2023/11; uMkhanyakude IDP, 2023). Furthermore, these districts are characterised by predominantly rural populations that rely heavily on subsistence agriculture, thereby increasing their vulnerability to climate change (Hosea, 2021; Pactrick, 2021; Mulopo and Chimbari, 2021; Mzimela and Moyo, 2025). This reliance makes them an ideal context for this study, which seeks to understand attitudes and perceptions regarding the production and use of underutilised food crops as a potential resilience strategy.

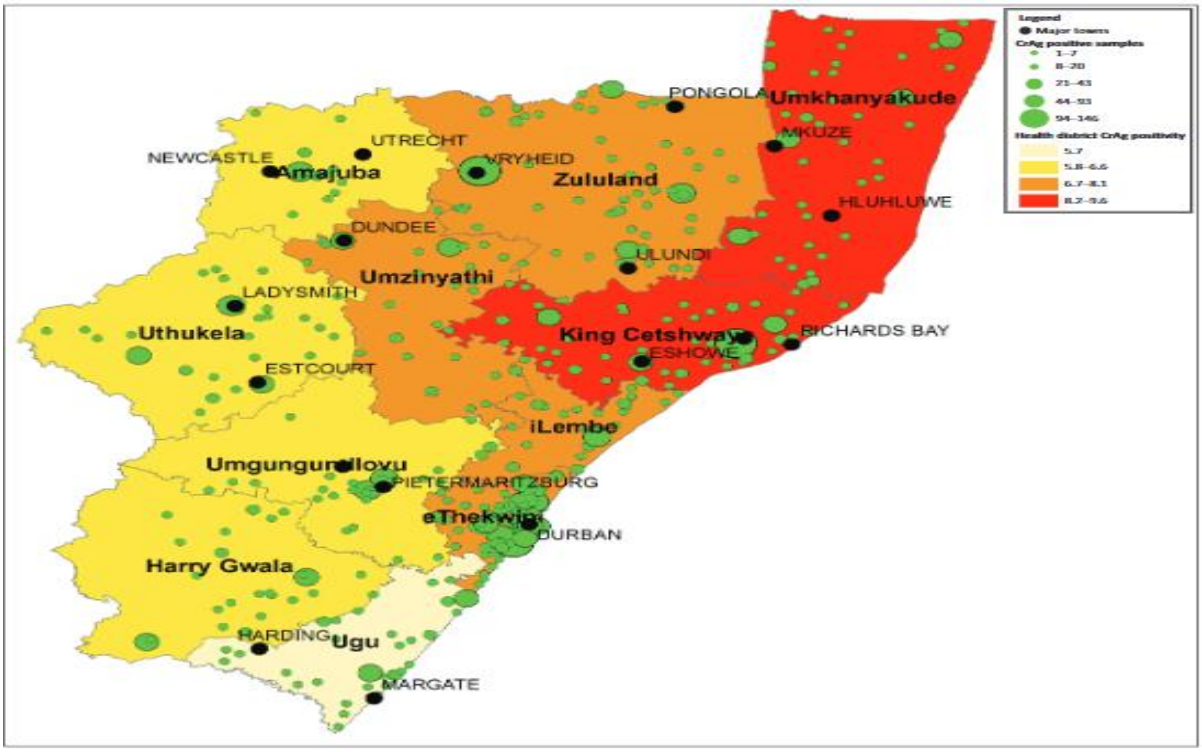

Figure 3.2: uMkhanyakude and King Cetshwayo District Municipalities Map (Source: Author's compilation)

This section presents the materials and methods employed to examine smallholder farmers' perceptions and attitudes toward underutilised crops in KZN Province. The methodology encompasses the study area description, sampling procedures, data collection instruments, and analytical techniques. A cross-sectional research design with a mixed-methods approach was employed, gathering both quantitative and qualitative data. This approach was chosen to ensure triangulation and greater validity (Schoonenboom & Johnson, 2022; Guetterman et al., 2023), and to address study objectives that were both qualitative and quantitative in nature (Creamer, 2020). Cross-sectional research designs effectively utilise data from diverse disciplinary backgrounds while being comparatively less expensive and time-consuming (Akhtar, 2016; Creswell & Creswell, 2017).

3.3.2 Sampling

A multi-stage sampling procedure was employed to ensure representativeness and enhance the generalisability of findings to the broader population of smallholder farmers cultivating underutilised crops in KZN. The sampling procedure involved four distinct stages, combining purposive and probability sampling techniques in a systematic manner appropriate to each stage's objective.

Two district municipalities, namely uMkhanyakude District Municipality and King Cetshwayo District Municipality, were purposively selected. This purposive selection was based on three criteria: (i) documented vulnerability to climate change, which ensures relevance to the study's focus on climate adaptation; (ii) prevalence of traditional crop cultivation, which ensures sufficient presence of the target behaviour; and (iii) predominantly rural populations relying on subsistence agriculture, which aligns with the study's focus on smallholder farmers. These criteria were applied to select districts where underutilised crop cultivation is most relevant and observable (Pactrick, 2021; Mulopo & Chimbari, 2021). Purposive selection at this stage was appropriate because the objective was to identify districts with the specific characteristics necessary to address the research questions, rather than to generalise across all districts in KZN.

From each selected district municipality, two local municipalities were purposively selected based on the prevalence of underutilised crop cultivation and the presence of documented climate-related agricultural challenges. This purposive approach ensured that the local municipalities included in the study exhibited the phenomena of interest, namely, the coexistence of climate vulnerability and traditional crop cultivation. The selection was informed by agricultural extension records, municipal development plans, and consultation with district-level agricultural officers.

From each selected local municipality, rural communities were randomly selected. A sampling frame of communities was developed through consultation with local agricultural extension officers and traditional authorities, who provided lists of farming communities within each local municipality. From these lists, communities were randomly selected to ensure that the study captured a representative range of farming conditions within each local municipality. This random selection at the community level introduced probabilistic sampling into the design, reducing selection bias and enhancing the generalisability of findings to the broader set of communities within the selected local municipalities.

Within each selected community, a stratified random sampling approach was applied to ensure representation of different farmer groups. The sample from each community was stratified into two strata: (i) smallholder farmers currently cultivating underutilised crops (adopters), and (ii) smallholder farmers not cultivating underutilised crops (non-adopters). Adopters were defined as farmers who had cultivated at least one underutilised crop species (indigenous vegetables, traditional grains, drought-tolerant legumes, or indigenous fruits) during the 2023/2024 farming season. Non-adopters were farmers who had not cultivated any underutilised crops during the same period but were engaged in other agricultural activities. Within each stratum, participants were randomly selected from farmer lists provided by extension officers and community leaders. This stratified random sampling ensured that the study captured both perspectives while maintaining random selection within each group.

The sample size of the study was determined by using Cochran's (1977) formula because the population of areas selected was unknown. A Cochran’s (1977) is presented below:

$$n_0 = \frac{(t^2)*(p)(q)}{(d)^2} = \frac{(1.96)^2(.5).5)}{(.5)^2} = 384$$

Where:

t = value for selected alpha level of .025 in each tail = 1.96 when

(p)(q) = estimate of variance = 0.25 (maximum possible proportion (0.5) * (1-0.5) maximum possible proportion (0.5) produces maximum possible sample size).

d = acceptable margin of error for proportion being estimated = 0.05 (error researcher is willing to accept).

To achieve a 95% confidence level that the actual margin error falls within 5%, which gives a good precision of the research, where the findings can be generalised to the population. However, due to resource and time constraints encountered during the field data collection phase, the final sample comprised 319 smallholder farmers. This reduction in sample size (16.9% from the calculated 384) did not significantly compromise the statistical power or representativeness of the study. The achieved sample size maintains a confidence level of 95% with a marginally increased margin of error of 5.5% (calculated using the same statistical parameters: t=1.96, p=0.5, q=0.5), which remains within acceptable limits for agricultural adoption and perception studies in developing country contexts (Yamane, 1967; Israel, 2013). The sample size of 319 respondents is considered adequate for multivariate statistical analyses such as Tobit regression models employed in this study, as it exceeds the minimum threshold of 15-20 observations per predictor variable recommended for regression analyses (Hair et al., 2014). With 16 predictor variables in the model, the achieved sample provides approximately 20 observations per variable, ensuring robust statistical inference.

3.3.3 Data collection

Primary data was collected using a structured questionnaire administered to 319 smallholder farmers across KZN Province. The questionnaire gathered information on farmers' perceptions and attitudes toward underutilised crops and socioeconomic characteristics. Pre-testing was conducted with 32 respondents (10% of the sample size) one month before actual data collection in Msunduzi Local Municipality, a site not included in the main study. The pre-testing results were excluded from the final analysis to enhance research integrity, in accordance with methodological recommendations (Bond et al., 2023).

Six enumerators were recruited and received training in research ethics, interview methodologies, and data synthesis. All questionnaires were directly administered by interviewers to minimise interpretation errors and response bias. Practical challenges encountered in the field included difficulty locating respondents, unforeseen weather disruptions, and occasional reluctance from some farmers due to survey fatigue. The research team addressed these issues through advanced scheduling, adaptable timetables, and clear communication of research significance. Ethics clearance was granted by the University of KwaZulu-Natal (protocol number: HSSREC/00007019/2024). Before data collection, written informed consent was obtained from all participating smallholder farmers, ensuring proper documentation and compliance with institutional ethics requirements.

The data collected focused on smallholder farmers' engagement with underutilised crops, including indigenous vegetables (such as amaranth, spider plant, and African nightshade), traditional grains (such as sorghum and millet), drought-tolerant legumes (such as cowpeas and bambara groundnuts), and indigenous fruits. The questionnaire captured farmers' awareness, cultivation practices, perceptions of benefits and constraints, and attitudes toward these traditional crop species.

3.3.4 Data analysis

The collected data were coded and entered into Excel spreadsheets for cleaning and preliminary analysis. Perception and attitude indices were constructed from Likert scale items and quantified using Stata version 18, allowing for systematic measurement of farmers' views. Descriptive statistics were employed to characterise smallholder farmers' demographic and socioeconomic profiles, encompassing frequency distributions (percentages) and measures of central tendency (means, ranges, and standard deviations). Tobit regression models were employed to analyse determinants of perception and attitude indices, allowing understanding of both the nature of farmers' perceptions and the factors that shaped them.

3.3.4.1 Descriptive statistics

Descriptive statistics were employed to characterise smallholder farmers' demographic and socioeconomic profiles. The descriptive analysis encompassed frequency distributions (percentages) and measures of central tendency (means, ranges, and standard deviations). The data were presented through tables and figures to provide a clear visual representation of the findings. This approach was particularly important as studies by Chivenge et al. (2015) indicated that many smallholder farmers unconsciously cultivate underutilised crops as part of their traditional farming systems, with much knowledge remaining hidden in indigenous knowledge systems. Therefore, it was critical to identify and assess the frequency of farmers using specific underutilised crops such as indigenous vegetables, traditional grains, drought-tolerant legumes, and indigenous fruits. The descriptive analysis also facilitated examination of farmers' perceptions and attitudes toward these crops, providing a foundation for the subsequent Tobit regression analysis of perception/attitude determinants.

3.3.4.2 Perception and attitude indices analysis

The study employed perception and attitude indices constructed from Likert scale items. Likert scales are widely used to measure attitudes, opinions, and perceptions on a psychometric scale (Robinson, 2024). In this study, respondents indicated their level of agreement with statements about underutilised crops on a 5-point scale ranging from "Strongly Disagree" (1) to "Strongly Agree" (5). The Likert scale provided highly reliable estimates to examine perceptions and attitudes towards underutilised crops among the surveyed smallholder farmers. Table 3.1 presents the statements used to measure smallholder farmers' perceptions and attitudes toward underutilised crops.

Table 3.1: Measurement of smallholder farmers' perceptions and attitudes towards underutilised crops

Attribuites	Statement
Perceptions	• NUCs will improve my household's food security. • NUC production is entirely a female activity, and men should forget about growing it. • NUC production is not profitable. If a neighbour seeks my opinion on increasing production, I will not advise him/her to cultivate them. • NUCs require less rainfall and are resistant to pests and diseases. • NUC production conserves biodiversity. • NUC production lacks institutional support (Research, extension, credit and Market). • NUCs are alternative foods that improve household nutritional status. • NUCs' production can increase rural household income. • If NUCs improve, seeds are made available on the market, and we can adopt • Most farmers in this area should join their colleagues in revitalising mass NUCs production to ensure food security. • CSAPs preserve land quality for maize cultivation. • CSAPs are environmentally friendly. • NUCs' production require less inputs.
Attitudes	• I am willing to adopt NUCs with or without financial support. • NUC's farming is a woman's activity. • NUCs' consumption may cause health problems. • NUCs are not grown and handled in a cleaner way. • NUCs are unfashionable. • NUCs are time-consuming to prepare compared to fast foods. • NUCs' taste, appearance, and quality are not good. • NUCs are pleasant and palatable. • NUCs have health benefits. • NUCs are cultural foods. • NUCs are relatively cheap and easy to prepare • NUCs provide alternative food options for communities.

Source: Author's own conceptualisation informed by the literature (Chivenge et al., 2015; Pattiasina et al., 2023).

The perception index was constructed by calculating the mean score across all 14 perception items for each respondent. Similarly, the attitude index was calculated as the mean score across all 13 attitude items. For negatively worded items (e.g., "NUC production is entirely a female activity," "NUCs are poor people's food"), responses were reverse-coded before index calculation to ensure consistency in interpretation. These indices were then normalised to a 0-1 scale using the formula:

Normalised Index = (Raw Score - Minimum Possible Score) / (Maximum Possible Score - Minimum Possible Score)

A normalised index value closer to 1 indicates more positive perceptions or attitudes toward underutilised crops, while values closer to 0 indicate more negative perceptions or attitudes. The normalised indices served as dependent variables in the Tobit regression models.

3.3.5 Tobit regression model

The Tobit regression model, originally developed by Tobin (1958), was employed to analyse the determinants of perception and attitude indices in this study. The Tobit model was selected for several methodological reasons. First, the dependent variables (perception and attitude indices) are continuous but constrained within the 0-1 range, making Ordinary Least Squares (OLS) regression inappropriate as it may produce biased and inconsistent parameter estimates (Wooldridge, 2010). Second, the Tobit model accounts for the censored nature of the data, where observations may cluster at the lower (0) or upper (1) bounds of the index scale (Greene, 2018). Third, this approach has been successfully applied in similar agricultural perception and adoption studies examining farmers' attitudes toward climate-smart practices (Abdulai, 2016), conservation agriculture (Lalani et al., 2021), and sustainable farming technologies (Wauters et al., 2020).

The Tobit model can be specified as follows:

$$Y^* = \beta_o + \beta_{1Xi} + \beta_{2X2} + \beta_{kXki} + \varepsilon_i$$

$$Y_i = Y_i \, if \; 0 < Y_i < 1$$

$$Y_i = 0 \; if Y_i \leq 0$$

$$Y_i = 1 \; if Y_i \geq 1$$

Where:

$Y^{*}i$ is the latent (unobserved) dependent variable

Y_i is the observed dependent variable (perception index)

$X_{1i}X_{2i} \dots, X_{ki}$ are independent variables (factors affecting perception)

$\beta_{0,}\beta_1, \beta_2 \dots, \beta_k$ are coefficients to be estimated

ε_i is the error term, assumed to be normally distributed

The Tobit model estimates parameters using Maximum Likelihood Estimation (MLE), which provides consistent and asymptotically efficient estimates under the assumption of normally distributed errors. The model offers several advantages for this study: (1) it provides unbiased parameter estimates when dependent variables are censored, unlike OLS which would underestimate the true effects (Tobin, 1958); (2) it allows interpretation of marginal effects on the latent variable, providing insights into how factors influence underlying perceptions beyond observable bounds; and (3) it has established precedent in agricultural research examining farmer perceptions and attitudes (Bontsa et al., 2024; Moutouama et al., 2022). However, the Tobit model assumes homoscedasticity and normality of error terms. To address potential heteroscedasticity, robust standard errors were computed. Two separate Tobit regression models were estimated: one with the perception index as the dependent variable and another with the attitude index as the dependent variable.

3.3.6. Description of the explanatory variables

Table 3.2 summarises the explanatory variables included in the Tobit regression model to analyse the determinants of perceptions and attitudes toward underutilised crops among smallholder farmers in KZN. These variables include gender, age, education, family size, household income, farm size, farming years, average distance to farm, access to climate information, access to agricultural credit, membership in an agricultural group, access to extension services, agricultural training, awareness of underutilised crops, and adoption status. The explanatory variables are hypothesised to influence smallholder farmers' perceptions and attitudes toward underutilised crops.

Table 3.2: Explanatory variables used in the Tobit regression model for analysing perceptions and attitudes toward underutilised crops and their expected outcomes

Variable	Description and Measurement (Type)	Expected Outcome (+/-)
Gender	Smallholder farmer's gender (female = 0; male = 1) (dummy)	+
Marital status	Marital status of the smallholder farmer (single = 0; wedded (married, divorced, widowed) = 1) (dummy)	+/-
Age	Age of the smallholder farmer in years (continuous)	+/-
Education	Number of years of formal schooling by the smallholder farmer (continuous)	+
Family Size	Number of members in the smallholder farmer's household (continuous)	+
Household Income	Total household income of the smallholder farmer (continuous)	+
Farm Size	Size of the smallholder farmer's land in hectares (continuous)	+
Farming Years	Number of years of farming experience by the smallholder farmer (continuous)	+
Average Distance to Farm	The distance from home to the farm site in kilometres (continuous)	-
Access to Climate Information	Whether the smallholder farmer has access to climate information (no = 0; yes = 1) (dummy)	+
Access to Agricultural Credit	Whether the smallholder farmer has access to agricultural credit (no = 0; yes = 1) (dummy)	+
Membership in Agricultural Group	Whether the smallholder farmer belonged to an agricultural-related group or association (no = 0; yes = 1) (dummy)	+
Access to Extension Services	Whether the smallholder farmer has access to extension services (no = 0; yes = 1) (dummy)	+
Agricultural Training	Whether the smallholder farmer received specialized agricultural training (no = 0; yes = 1) (dummy)	+
Awareness of Underutilised Crops	Whether the smallholder farmer is aware of underutilised crops (no = 0; yes = 1) (dummy)	+
Adoption Status	Whether the smallholder farmer has adopted any underutilised crops (no = 0; yes = 1) (dummy)	+

Note: +/− Depicts the direction of influence (**positive/negative**) (Source: Author (2025))

3.3.7 Limitations of the methodology

Several methodological limitations should be acknowledged when interpreting the findings of this study. First, the cross-sectional research design captures perceptions and attitudes at a single point in time, limiting the ability to establish causal relationships or examine how perceptions evolve. Longitudinal studies would provide deeper insights into the dynamic nature of farmer perceptions toward underutilised crops. Second, the study relies on self-reported data, which may be subject to social desirability bias, where respondents provide answers they believe are more socially acceptable rather than their true perceptions. To mitigate this limitation, the questionnaire was carefully designed with both positively and negatively worded items, and enumerators were trained to establish rapport and ensure confidentiality.

Third, the perception and attitude indices are constructed from Likert scale responses, which assume equal intervals between response categories. While Likert scales are widely accepted in social science research, they may not perfectly capture the nuances of farmer perceptions. Fourth, the sample was drawn from two district municipalities in KZN Province, which may limit the generalisability of findings to other regions of South Africa with different agro-ecological and socioeconomic conditions. However, the purposive selection of districts with diverse climatic conditions enhances the external validity within the KZN context. Finally, the study focused on a defined set of underutilised crops, and perceptions may vary for specific crop types not explicitly examined. Despite these limitations, the methodology employed provides robust insights into the factors shaping smallholder farmers' perceptions and attitudes toward underutilised crops in KZN Province.

3.4 Results and discussion

3.4.1 Socio-demographic profile

The findings are discussed within the framework of the Theory of Planned Behaviour (TPB), which posits that behavioural intentions and ultimately adoption decisions are shaped by three interrelated constructs: attitudes (evaluations of the behaviour), subjective norms (perceived social pressure), and perceived behavioural control (perceived ease or difficulty of performing the behaviour) (Ajzen, 1991). In the context of NUC cultivation, adoption is examined through these three theoretical lenses, with demographic and socioeconomic characteristics understood as factors that shape these underlying psychological constructs.

Attitudes refer to farmers' positive or negative evaluations of cultivating NUCs, shaped by beliefs about expected outcomes such as nutritional value, climate resilience, and cultural significance (Ajzen, 1991; Pattiasina et al., 2023). The age profile of adopters (mean 54.3 years compared to 42.8 years for non-adopters, $p < 0.001$) strongly suggests that positive attitudes toward NUCs are concentrated among older farmers. This 11.5-year age gap indicates that elderly farmers hold more favourable evaluations of these crops, likely because they possess direct experience with their benefits and view them as integral to cultural heritage and food security. In TPB terms, older farmers have developed strong behavioural beliefs that NUCs are reliable, nutritious, and culturally appropriate which translate into positive attitudes toward cultivation.

The education finding further supports this attitudinal interpretation. Adopters completed fewer years of formal schooling (8.0 vs. 9.3 years, $p = 0.034$), suggesting that positive attitudes toward NUCs are rooted in traditional knowledge systems rather than formal agricultural education. Farmers with less formal education may hold more favourable attitudes toward indigenous crops because their agricultural knowledge has been shaped by intergenerational transmission rather than by extension curricula that prioritise commercial varieties. This aligns with the TPB premise that attitudes are formed through accessible beliefs (Ajzen, 1991), which for these farmers derive from lived experience and cultural heritage rather than institutional training.

The gender pattern, with females constituting 72.9% of adopters compared to 34.4% of non-adopters ($p < 0.001$), also reflects attitudinal differences. Women in smallholder farming systems often bear primary responsibility for household food security and may hold more favourable attitudes toward crops that ensure dietary diversity and family nutrition. Their positive evaluations of NUCs are shaped by outcome beliefs related to household welfare, a finding consistent with studies showing women's greater engagement with traditional food crops (Chivenge et al., 2015).

Subjective norms capture the perceived social pressure farmers experience regarding NUC cultivation, reflecting the influence of family elders, community members, traditional authorities, and social networks (Ajzen, 1991; Zeweld et al., 2017). The marital status finding provides strong evidence for the role of subjective norms. Married farmers exhibit dramatically higher adoption rates (93.8% of adopters vs. 57.4% of non-adopters, $\chi^2 = 57.24$, $p < 0.001$). Within the TPB framework, this suggests that married farmers experience greater social pressure from spouses, extended family, and household decision-making structures—to maintain traditional cropping practices. Marriage may embed farmers more deeply in community and family networks that value cultural continuity and food self-sufficiency, thereby reinforcing normative expectations around NUC cultivation.

The household size finding (7.2 members for adopters vs. 5.8 for non-adopters, $p < 0.001$) also reflects normative influences. Larger households may generate stronger social expectations around food provisioning and may include elders who exert normative pressure to maintain traditional crops. In TPB terms, the subjective norm component is strengthened when farmers perceive that important referents (family elders, household heads) approve of NUC cultivation. The distance to market finding (23.5 km for adopters vs. 18.7 km for non-adopters, $p < 0.001$) can also be interpreted through the lens of subjective norms. Farmers living farther from markets may rely more heavily on local social networks and community exchange systems, where NUCs retain cultural value and normative significance. In such contexts, the perceived social approval for cultivating traditional crops may be higher than in communities more integrated into commercial market systems.

Perceived behavioural control relates to farmers' perceptions of the ease or difficulty of cultivating NUCs, influenced by access to resources such as land, labour, seeds, knowledge, and institutional support (Ajzen, 1991; Lalani et al., 2021). The land holding finding is central to this construct: adopters operate on significantly larger land holdings (0.72 vs. 0.49 hectares, $p < 0.001$). Within the TPB framework, larger land holdings enhance perceived behavioural control because farmers have greater flexibility to allocate land to diverse crops without jeopardising income from commercial staples. This finding aligns with the theoretical premise that control perceptions are shaped by resource availability.

Employment status further illuminates perceived behavioural control. Unemployed farmers are more likely to adopt NUCs (66.3% vs. 50.8% for employed farmers, $p = 0.024$). This suggests that farmers with fewer alternative income sources perceive NUC cultivation as a feasible strategy for household provisioning and livelihood security. In TPB terms, necessity shapes control perceptions: when formal employment is unavailable, the perceived ease of engaging in subsistence-oriented agriculture increases.

The income finding, non-adopters have significantly higher earnings (ZAR 4,469 vs. ZAR 3,195, $p = 0.002$) reinforces this interpretation. Farmers with lower incomes may perceive NUC cultivation as one of the few viable livelihood options, thereby reporting higher perceived behavioural control relative to their resource constraints. This finding also suggests that NUC adoption is driven more by necessity than by financial capacity, consistent with TPB's emphasis on control perceptions as distinct from objective resource endowments.

The findings on extension service access ($p = 0.011$), agricultural training ($p < 0.001$), and group membership ($p < 0.001$) reveal a complex relationship with perceived behavioural control. All three show inverse associations with adoption: adopters have less access to extension services (29.1% vs. 13.1%), less formal agricultural training (25.2% vs. 49.2%), and lower participation in agricultural groups (29.1% vs. 54.1%). Within the TPB framework, these findings indicate that perceived behavioural control for NUC cultivation is derived not from formal institutional support but from traditional knowledge systems, saved seeds, and informal community networks. Farmers who lack access to formal agricultural institutions which typically promote commercial crops may nonetheless maintain high perceived behavioural control for NUCs because they possess alternative knowledge and resource systems. This interpretation is consistent with the TPB premise that control perceptions are shaped by access to the specific resources and skills relevant to the behaviour in question, regardless of whether those resources are formal or informal.

Credit access showed no significant difference between groups ($p = 0.356$), with high overall access rates (88.4%). In TPB terms, this suggests that credit availability does not function as a control belief relevant to NUC adoption, likely because these crops require minimal external inputs and rely on saved seeds and traditional practices. The absence of a significant difference indicates that financial services are not perceived by farmers as either facilitating or constraining NUC cultivation.

Collectively, these findings demonstrate that NUC adoption in KZN is shaped by all three TPB components, though through distinct mechanisms. Positive attitudes toward NUCs are concentrated among older, less formally educated farmers whose behavioural beliefs are rooted in lived experience and cultural heritage. Subjective norms favouring adoption operate most strongly through household structures, with married farmers and those in larger households experiencing social pressure to maintain traditional crops. Perceived behavioural control is enhanced by larger land holdings and necessitated by unemployment and lower incomes, yet is sustained through informal knowledge systems rather than formal institutional support.

Critically, the findings reveal that perceived behavioural control for NUC cultivation operates differently than for commercial crops. While extension services, formal training, and group membership enhance control perceptions for commercial agriculture, NUC adopters draw upon alternative resources, intergenerational knowledge, saved seeds, and community networks to maintain high control perceptions. This distinction has important implications for intervention design, as efforts to promote NUCs must recognise and support these informal resource systems rather than simply replicating the institutional structures developed for commercial crops.

Table 3.3: Summary of demographic characteristics of respondents

Variable	Adopters (n=127)	Non-adopters (n=192)	Statistical Test	P-value
Gender (% Female)	72.9%	34.4%	χ^2	$p < 0.001$***
Marital Status (% Married)	93.8%	57.4%	$\chi^2 = 57.24$	$p < 0.001$***
Employment Status (% Unemployed)	66.3%	50.8%	χ^2	$p = 0.024$**
Age (Mean years)	54.3	42.8	t-test	$p < 0.001$***
Education (Mean years)	8.0	9.3	t-test	$p = 0.034$**
Household Size (Mean members)	7.2	5.8	t-test	$p < 0.001$***
Monthly Income (Mean ZAR)	3,195	4,469	t-test	$p = 0.002$***
Land Holdings (Mean hectares)	0.72	0.49	t-test	$p < 0.001$***
Distance to Market (Mean km)	23.5	18.7	t-test	$p < 0.001$***
Extension Service Access (%)	29.1%	13.1%	χ^2	$p = 0.011$**
Agricultural Training (%)	25.2%	49.2%	χ^2	$p < 0.001$***
Agricultural Group Membership (%)	29.1%	54.1%	χ^2	$p < 0.001$***
Credit Access (%)	88.4%	88.4%	χ^2	$p = 0.356$

Note: *, **, & *** show statistical significance at the 10%, 5% and 1% levels, respectively. (Source: Survey data (2025))

3.4.2 Comparison of perception indices between adopters and non-adopters

The perception index analysis revealed significant differences between adopters and non-adopters of underutilised crops (Table 3.4). Adopters demonstrated a mean perception index of 0.76 (SD = 0.11), significantly higher than non-adopters' mean of 0.52 (SD = 0.14) (t = 16.23, p < 0.001). This substantial difference of 0.24 units indicates that farmers who cultivate NUCs perceive these crops more favourably across dimensions, including nutritional benefits, climate resilience, cultural significance, and food security contributions.

The perception index scores ranged from 0.49 to 0.94 among adopters, compared to 0.21 to 0.78 among non-adopters. These findings align with the Theory of Planned Behaviour framework, where positive perceptions toward a behaviour contribute to favourable attitudes and subsequent behavioural intentions. Research by Pattiasina et al. (2023) similarly found that farmers with positive perceptions of traditional crops were significantly more likely to maintain their cultivation. The perception gap between groups suggests that targeted interventions to enhance awareness and understanding of NUC benefits could facilitate adoption among non-adopters.

Table 3.4: Comparison of the perception index between adopters and non-adopters

Variable	Adopters (n=127)	Non-adopters (n=192)	t-value	p-value
Perception Index			16.23	<0.001***
Mean	0.76	0.52		
Std. Deviation	0.11	0.14		
Minimum	0.49	0.21		
Maximum	0.94	0.78		

Note: *** indicates statistical significance at p < 0.001, (Source: Survey data (2025))

3.4.3 Comparison of attitude indices between adopters and non-adopters

The attitude index comparison revealed statistically significant differences between adopters and non-adopters (Table 3.5). Adopters exhibited a mean attitude index of 0.79 (SD = 0.10), significantly higher than non-adopters' mean of 0.54 (SD = 0.13) (t = 17.89, p < 0.001). This difference of 0.25 units demonstrates that farmers currently cultivating NUCs maintain substantially more positive attitudes toward these crops, reflecting stronger evaluative judgments about the value and importance of traditional crop cultivation.

The attitude index encompasses farmers' willingness to cultivate NUCs, their enthusiasm for learning about traditional crops, and their perceptions of personal and community benefits derived from NUC cultivation. The significant gap between adopters and non-adopters supports the TPB framework's proposition that attitudes toward a behaviour significantly influence behavioural intentions. Similar findings were reported by Juah and Nhamo (2023), who demonstrated that positive attitudes toward indigenous crops strongly predicted cultivation intentions among smallholder farmers in Ghana. Zeweld et al. (2017) also found that attitudes were the strongest predictor of sustainable agricultural practice adoption in Ethiopia.

Table 3.5: Comparison of the attitude index between adopters and non-adopters

Variable	Adopters (n=127)	Non-adopters (n=192)	t-value	p-value
Attitude Index			17.89	<0.001***
Mean	0.79	0.54		
Std. Deviation	0.10	0.13		
Minimum	0.52	0.24		
Maximum	0.96	0.81		

Note: *** indicates statistical significance at p < 0.001, (Source: Survey data (2025))

3.4.4 Comparison of awareness between adopters and non-adopters

A significant disparity emerged when comparing awareness levels between adopters and non-adopters of NUCs (Table3.6). Among the 127 adopters, 98.4% (n=125) demonstrated high awareness levels of underutilised crops, while only 1.6% (n=2) showed limited awareness. In contrast, among the 192 non-adopters, 75.0% (n=144) exhibited awareness of NUCs, while 25.0% (n=48) demonstrated limited or no awareness. This substantial difference (χ^2 = 24.67, p < 0.001) indicates that awareness serves as a fundamental prerequisite for adoption, supporting the theoretical framework of planned behaviour where knowledge and awareness influence attitudes and subsequent behavioural intentions.

Table 3.6: Comparison of NUC awareness levels between adopters and non-adopters among smallholder farmers in KwaZulu-Natal Province

Awareness Category	Adopters (n=127)		Non-adopters (n=192)		Chi-square	p-value
	n	%	N	%		
Overall NUC Awareness						
High awareness	125	98.4	144	75.0	24.67	<0.001***
Limited/No awareness	2	1.6	48	25.0		
Crop Category Awareness						
Indigenous vegetables	114	89.8	126	65.6	19.23	<0.001***
Traditional grains	107	84.3	100	52.1	28.45	<0.001***
Drought-tolerant legumes	100	78.7	80	41.7	34.12	<0.001***
Indigenous fruits	91	71.7	74	38.5	26.89	<0.001***

Note: *** indicates statistical significance at p < 0.001, (Source: Survey data (2025))

The depth of awareness also differed significantly between groups. Adopters demonstrated comprehensive knowledge spanning multiple crop categories, with 89.8% aware of indigenous vegetables, 84.3% familiar with traditional grains, 78.7% knowledgeable about drought-tolerant legumes, and 71.7% aware of indigenous fruits. Non-adopters showed more limited awareness patterns, with 65.6% aware of indigenous vegetables, 52.1% familiar with traditional grains, 41.7% knowledgeable about drought-tolerant legumes, and 38.5% aware of indigenous fruits. These findings suggest that adopters possess more comprehensive traditional knowledge systems, potentially inherited through intergenerational knowledge transfer within families that maintained traditional farming practices (Kom et al., 2022; Diko, 2023). The awareness gap between adopters and non-adopters reflects broader patterns documented in recent literature, where traditional knowledge preservation varies significantly across farming communities. Research has shown that awareness of underutilised crops is closely linked to cultural practices, family agricultural history, and exposure to traditional farming systems (Kapari et al., 2023). The higher awareness levels among adopters may be attributed to their continued engagement with traditional knowledge holders, participation in indigenous seed networks, and maintained connections to cultural practices that emphasise the value of traditional crops (Buthelezi et al., 2013).

Furthermore, the awareness differences highlight the importance of targeted extension and educational programs. The fact that 25% of non-adopters demonstrate limited awareness suggests significant opportunities for knowledge transfer interventions. Recent studies have emphasised that effective awareness-raising requires a combination of formal extension services and informal knowledge sharing networks that respect indigenous knowledge systems while introducing scientific validation of traditional practices (Mnukwa et al., 2025). The challenge lies in developing culturally appropriate educational approaches that bridge the gap between traditional knowledge and contemporary agricultural practices, particularly for younger farmers who may have limited exposure to indigenous agricultural systems.

3.4.5 Information sources of neglected and underutilised crops by smallholder farmers

Understanding the information sources through which smallholder farmers acquire knowledge about NUCs is crucial for developing effective extension strategies and communication pathways. The diversity of information channels reflects the complex interplay between traditional knowledge systems and contemporary agricultural information networks, highlighting the need for integrated approaches that respect indigenous knowledge while leveraging modern communication technologies.

3.4.5.1 Primary sources of information about underutilised crops

The study revealed a diverse array of information sources through which smallholder farmers in KZN acquire knowledge about NUCs, with significant variations between adopters and non-adopters (Table 3.7). Traditional knowledge sources dominated the information landscape, with 78.4% of farmers citing family elders and traditional knowledge holders as their primary source of information about underutilised crops. This finding aligns with recent research emphasising that traditional knowledge systems remain the backbone of agricultural information in rural South African communities (Diko, 2023; Kom et al., 2022).

Informal farmer-to-farmer networks emerged as the second most important information source, cited by 71.2% of respondents. These peer-to-peer communication networks facilitate knowledge sharing within farming communities and have been documented as highly effective channels for the diffusion of agricultural innovation across SSA (Izuchukwu et al., 2023). Community meetings and traditional leaders ranked third at 65.8%, reflecting the continued importance of traditional authority structures in the dissemination of agricultural knowledge within rural KZN communities.

Table 3.7: Information sources for NUCs among smallholder farmers by adoption status

Information Source	Overall (n=319)		Adopters (n=127)		Non-adopters (n=192)		Chi-square	p-value
	n	**%**	**n**	**%**	**n**	**%**		
Family elders/Traditional knowledge holders	250	78.4	118	92.9	132	68.8	21.45	<0.001***
Farmer-to-farmer networks	227	71.2	105	82.7	122	63.5	11.23	0.001***
Community meetings/Traditional leaders	210	65.8	98	77.2	112	58.3	9.67	0.002**
Radio programs	186	58.3	78	61.4	108	56.3	0.68	0.410
Agricultural extension officers	134	42.0	38	29.9	96	50.0	10.89	0.001***
Television programs	112	35.1	44	34.6	68	35.4	0.02	0.888
Mobile phones/SMS	89	27.9	31	24.4	58	30.2	1.06	0.304
Demonstration farms	67	21.0	34	26.8	33	17.2	3.45	0.063
NGOs/Development organisations	54	16.9	28	22.0	26	13.5	3.21	0.073
Internet/Social media	34	10.7	12	9.4	22	11.5	0.26	0.610

Note: ** $p < 0.01$, *** $p < 0.001$; Multiple responses allowed, (Source: Survey data (2025))

3.4.5.2 Differences in information sources between adopters and non-adopters

The study findings reveal a clear dichotomy between traditional and formal information channels in NUC knowledge dissemination. Traditional channels, including family elders, farmer networks, and community leaders, demonstrate stronger associations with NUC adoption, while formal channels, particularly extension services, show inverse relationships with adoption behaviour. This pattern reflects broader challenges in agricultural knowledge systems where formal institutions may inadvertently undermine traditional agricultural practices (Mabhaudhi et al., 2019; Kapari et al., 2023).

Mass media channels, including radio (58.3%) and television (35.1%), showed relatively high utilisation across both groups without significant differences between adopters and non-adopters. However, their effectiveness in promoting NUC adoption appears limited, suggesting that while these channels provide broad agricultural information, they may lack the specific cultural and technical knowledge required for traditional crop cultivation (Saravanan et al., 2022). Recent studies have emphasised the potential for radio and television programs to support NUC promotion through targeted content that respects indigenous knowledge while providing scientific validation of traditional practices (Efthymiou, 2025).

Digital information sources, including mobile phones/SMS (27.9%) and internet/social media (10.7%), showed relatively low utilisation rates, reflecting broader challenges in digital access within rural KZN. This finding aligns with research indicating that while digital technologies offer significant potential for agricultural knowledge dissemination, their effectiveness is constrained by infrastructure limitations, literacy challenges, and the need for culturally appropriate content (Priya et al., 2025). The findings highlight the critical need for integrated communication strategies that bridge traditional and modern information systems. Effective NUC promotion requires approaches that respect and strengthen indigenous knowledge networks while leveraging appropriate technologies to enhance information accessibility and quality. This includes developing culturally sensitive extension programs, creating platforms for intergenerational knowledge transfer, and utilising mass media and digital technologies to support rather than replace traditional knowledge systems.

3.4.6 Adoption status by district municipality

Figure 3.3 presents the distribution of NUC adoption across the two study district municipalities in KZN Province. The analysis reveals notable geographical variations in adoption patterns, with distinct differences between uMkhanyakude and King Cetshwayo district municipalities.

The results indicate relatively similar adoption patterns across both district municipalities, with uMkhanyakude showing a marginally higher adoption rate (40.0%) compared to King Cetshwayo (39.6%). Both districts demonstrate the broader provincial pattern where non-adopters constitute the majority of smallholder farmers, representing 60.0% and 60.4% respectively. This distribution reflects the broader challenges facing traditional crop systems across Sub-Saharan Africa, where, despite the recognised benefits of underutilised crops, adoption rates remain relatively low among smallholder farmers due to market pressures, institutional support systems, and changing agricultural policies that prioritise commercial crops (Branca et al., 2022; Mnukwa et al., 2025). The comparable adoption rates between these two coastal district municipalities suggest that geographical proximity and similar agro-ecological conditions may influence adoption patterns. Both uMkhanyakude and King Cetshwayo districts share characteristics that may contribute to similar NUC adoption behaviours, particularly regarding traditional knowledge systems and cultural practices. Both districts have strong Zulu cultural heritage and traditional farming practices, which may explain the presence of adopters who maintain indigenous agricultural knowledge (Buthelezi et al., 2021; Diko, 2023). The preservation of traditional knowledge in KZN has been documented to include practices such as indigenous weather prediction, crop management techniques, and the cultivation of traditional crops that have been passed down through generations (Kom et al., 2022; Shai et al., 2025).

The predominance of non-adopters (approximately 60%) in both districts reflects common rural development challenges, including limited market access, inadequate extension services, and economic pressures favouring commercial crops. Research indicates that only 34% of farmers have adequate access to extension services, which significantly impacts their likelihood of adopting alternative agricultural practices (Mnukwa et al., 2025; Kapari et al., 2023). Recent studies have highlighted that socio-economic and perceptual factors significantly influence smallholder farmers' decisions regarding traditional crop cultivation. Cele and Mkhize (2025) demonstrated that despite the nutritional, economic, and environmental benefits of underutilised crops, their consumption remains low due to various multifaceted determinants. Similarly, Zondi et al. (2022) found that market participation of indigenous crops significantly impacts household food security among smallholder farmers. The consistency in adoption patterns across these districts, combined with their similar subtropical coastal climates and agro-ecological contexts (Wale & Mkuna, 2025), suggests that intervention strategies could be effectively implemented at a regional level. This spatial analysis provides valuable insights for targeting policy interventions that address the complex interplay between traditional knowledge systems, cultural values, and practical constraints characterising smallholder farmers' decisions in coastal KZN (Kom et al., 2022; Kapari et al., 2023).

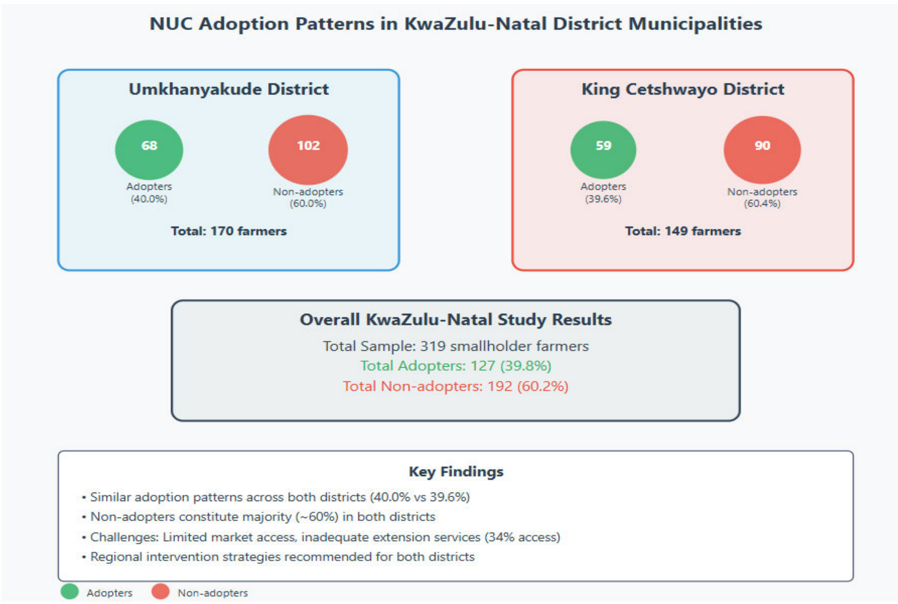

Figure 3.3: Distribution of neglected and underutilised crops (NUC) adoption patterns among smallholder farmers in uMkhanyakude and King Cetshwayo District Municipalities, KZN Province, South Africa (n=319), (Source: Survey data (2025)).

3.4.7 Tobit regression results: Determinants of smallholder farmers' perceptions and attitudes toward underutilised crops in KwaZulu-Natal province

3.4.7.1 Factors affecting perceptions toward underutilised crops by smallholder farmers

Table 3.8 summarises factors affecting perceptions toward underutilised crops by smallholder farmers. The Tobit model demonstrates strong statistical significance with a likelihood ratio chi-squared value of 402.73 ($p < 0.0001$), indicating the selected variables collectively have significant explanatory power. The log-likelihood value of 189.45, together with the significant likelihood ratio test, confirms substantial improvement over the intercept-only model. The pseudo-R^2 of 0.681 indicates approximately 68.1% of the variation in the dependent variable is explained by the predictor variables. The model includes 319 observations, with 315 uncensored and 4 right-censored observations, suggesting the Tobit specification was appropriate for handling the censored nature of the data.

Table 3.8: Factors affecting perceptions toward underutilised crops by smallholder farmers

Variable	Coefficient	Std. Error	t-value	p-value
Gender	-0.0523	0.0162	-3.23	0.001***
Marital Status	0.0689	0.0198	3.48	0.001***
Age	0.0032	0.0009	3.56	0.000***
Education	-0.0087	0.0034	-2.56	0.011**
Family Size	0.0156	0.0041	3.80	0.000***
Household Income	-0.0000184	0.0000098	-1.88	0.061*
Farm Size	0.0423	0.0187	2.26	0.024**
Farming Years	0.0045	0.0018	2.50	0.013**
Distance to Farm (km)	0.0023	0.0011	2.09	0.197
Access to Agricultural Credit	0.0189	0.0156	1.21	0.227
Member of Agricultural Group	-0.0196	0.0159	-1.23	0.219
Access to Extension Services	-0.0512	0.0168	-3.05	0.002***
Agricultural Training	-0.0467	0.0162	-2.88	0.004**
Employment Status	-0.0356	0.0147	-2.42	0.016**
Awareness of NUCs	0.1234	0.0189	6.53	0.000***
Adoption Status	0.0876	0.0171	5.12	0.000***
Constant	0.2567	0.0523	4.91	0.000***
Std error of estimate (Sigma)	0.0821	0.0041	-	0.000***
Model statistics				
Number of observations	319			
Uncensored observations	315			
Right-censored observations	4			
Log likelihood	189.45			

Note: *, **, & *** show statistical significance at the 10%, 5% and 1% levels, respectively. Source: Survey data generated through Stata version 18 (2025).

The Tobit regression model results show that gender, marital status, age, education, family size, household income, farm size, farming years, extension services, agricultural training, employment status, awareness of NUCs, and adoption status significantly influenced farmers' perceptions toward underutilised crops.

Gender was negative and statistically significant at the 1% level (p=0.001) with a coefficient of -0.0523. This suggests that male farmers have perception scores 0.0523 units lower than female farmers, indicating that females demonstrate substantially more positive perceptions toward underutilised crops. This finding aligns with the demographic analysis showing that 72.9% of adopters are female, confirming women's role as primary custodians of traditional food systems and their greater receptivity to culturally significant crops. This result is consistent with recent findings by von Maltitz and Bahta (2024), who found that women are typically the custodians of indigenous knowledge and practice in South African agricultural systems. Additionally, Mzimela and Moyo (2025) found that female-headed households in South Africa are the primary conservators of traditional agricultural knowledge and drought-resistant crops.

Marital status was positive and statistically significant at the 1% level (p=0.001) with a coefficient of 0.0689. This indicates that married farmers have perception scores 0.0689 units higher than single farmers. This finding aligns with the demographic evidence showing that 93.8% of adopters are married, suggesting that household decision-making dynamics and cultural practices within married households favour the maintenance of traditional cropping systems. However, this result contrasts with findings by Singh et al. (2022), who found that marital status had no significant effect on indigenous crop adoption among smallholder farmers in Fiji, suggesting that the relationship between marital status and traditional crop adoption may be context-specific.

Age was positive and statistically significant at the 1% level (p=0.000) with a coefficient of 0.0032. This indicates that for each additional year in a farmer's age, their perception score toward underutilised crops increases by 0.0032 units. The findings confirm that older farmers have more favourable perceptions of underutilised crops, supporting the demographic evidence that adopters are significantly older (mean 54.3 years vs. 42.8 years for non-adopters). This relationship reflects the fact that elderly farmers possess indigenous knowledge and cultural wisdom regarding traditional crops that younger generations may lack. This finding is strongly supported by Shai et al. (2025), who found that older farmers demonstrated better indigenous farming practices and traditional knowledge retention.

Education was negative and statistically significant at the 5% level (p=0.011) with a coefficient of -0.0087. This means each additional year of formal education decreases a farmer's perception score toward underutilised crops by 0.0087 units. This finding supports the demographic pattern where adopters have less formal education (8.0 vs. 9.3 years), indicating that traditional knowledge and cultural practices are more influential than formal education in shaping positive perceptions toward underutilised crops. Similarly, Masekoameng and Molotja (2019) demonstrated that the significance and value of indigenous knowledge systems practices in subsistence farming are limited at the national level in South Africa, with formal education systems favouring Western and scientific modes of crop production over traditional knowledge.

Family size was positive and statistically significant at the 1% level (p=0.000) with a coefficient of 0.0156. This indicates that for each additional household member, perception scores increase by 0.0156 units. This aligns with the demographic finding that adopters have larger households (7.2 vs. 5.8 members), suggesting that larger families have greater motivation for food security and more available labour for traditional crop production. This finding is consistent with Hlatshwayo et al. (2022), who found that larger households in Limpopo and Mpumalanga provinces show higher engagement with indigenous crops due to food security needs.

Household income was negative and statistically significant at the 10% level (p=0.061) with a coefficient of -0.0000184. This indicates that higher income farmers have slightly lower perception scores toward underutilised crops, supporting the demographic evidence that adopters earn less (ZAR 3,195 vs. ZAR 4,469), suggesting that underutilised crops are viewed more favourably by necessity-driven farmers rather than those with higher financial capacity.

This finding is consistent with Cele and Mudhara (2024), who found that lower-income households in KZN show greater reliance on traditional crops for food security, and aligns with recent research by Thaba-Nkadimene et al. (2019), who demonstrated that underutilised crops serve as important coping strategies for resource-poor rural women in South Africa.

Farm size was positive and statistically significant at the 5% level (p=0.024) with a coefficient of 0.0423. This means farmers with larger land holdings have perception scores 0.0423 units higher per hectare. This aligns with the demographic finding that adopters operate larger farms

(0.72 vs. 0.49 hectares), indicating that larger farms facilitate diversification and enable farmers to dedicate portions of their land to traditional crops alongside commercial varieties. This result supports recent findings by Wale and Mkuna (2025), who demonstrated that farm size significantly affects crop productivity and diversification strategies. Similarly, Hlatshwayo et al. (2022) found that larger farms enable greater agricultural diversification.

Farming years were positive and statistically significant at the 5% level (p=0.013) with a coefficient of 0.0045. This suggests that each additional year of farming experience increases perception scores by 0.0045 units, indicating that experienced farmers value traditional knowledge and practices accumulated over years of agricultural engagement. This finding aligns with Kom et al. (2022), who demonstrated that experienced farmers possess more comprehensive indigenous knowledge for climate adaptation. Additionally, von Maltitz and Bahta (2024) found that farming experience enhances traditional knowledge systems among livestock farmers.

Employment status was negative and statistically significant at the 5% level (p=0.016) with a coefficient of -0.0356. This suggests that employed farmers have perception scores 0.0356 units lower than unemployed farmers, supporting the demographic finding that 66.3% of adopters are unemployed. This indicates that underutilised crops provide income stability and serve as coping livelihood strategies for unemployed farmers. This finding is consistent with recent research by Mzimela and Moyo (2025), who demonstrated that unemployed farmers show greater adoption of indigenous crops as alternative livelihood strategies. However, this finding contrasts with research by Barrett et al. (2022), who found that off-farm employment sometimes provides resources that enable farmers to invest in diverse cropping systems, including traditional varieties in Kenya and Tanzania.

Access to Extension services was negative and statistically significant at the 1% level (p=0.002) with a coefficient of -0.0512. This indicates that farmers with access to extension services have perception scores 0.0512 units lower than those without such access. This finding supports the demographic evidence that adopters have less access to extension services (29.1% vs. 13.1%), suggesting that formal extension services focus on commercial crop promotion rather than traditional varieties, creating barriers to positive perceptions toward underutilised crops. This result is consistent with findings by Mabhaudhi et al. (2019), who found that extension systems in South Africa are not designed to promote traditional farming practices.

Agricultural training was negative and statistically significant at the 5% level (p=0.004) with a coefficient of -0.0467. This means that farmers with formal agricultural training have perception scores 0.0467 units lower than those without formal training. This aligns with the demographic pattern showing that adopters have less formal training (25.2% vs. 49.2%), indicating that formal training programs emphasise modern commercial crops over traditional knowledge systems. This finding is strongly supported by recent research by Diko (2023), who demonstrated that agricultural training institutions often marginalise indigenous knowledge in favour of commercial crop production techniques.

Awareness of NUCs was positive and statistically significant at the 1% level (p=0.000) with a coefficient of 0.1234. This suggests that farmers aware of underutilised crops have perception scores 0.1234 units higher than those who are unaware, highlighting the fundamental role of knowledge and awareness in shaping positive perceptions toward traditional crops. This finding is strongly supported by Cele and Mkhize (2025), who identified awareness as a critical determinant of underutilised crop consumption among smallholder farmers. Similarly, Shai et al. (2025) found that farmers with higher awareness of indigenous farming methods demonstrated better traditional crop management practices. This result also aligns with findings by Chepkoech et al. (2020), who found that awareness significantly influenced the adoption of indigenous vegetables among farmers in Kenya.

Adoption status exhibited a strong positive influence at the 1% level (p = 0.000) with a coefficient of 0.0876, indicating that adopters have perception scores 0.0876 units higher than non-adopters. This substantial effect demonstrates that farmers with experience in underutilised crops develop significantly more positive perceptions, highlighting the importance of practical experience in shaping favourable attitudes toward traditional crops. This finding supports the Theory of Planned Behaviour framework and is consistent with recent research by Hlatshwayo et al. (2022), who found that farmers with direct experience cultivating indigenous crops developed significantly more positive attitudes toward traditional farming systems. Additionally, Kom et al. (2022) demonstrated that practical experience with indigenous agricultural practices strengthens farmers' commitment to traditional knowledge systems.

3.4.8 Factors affecting attitudes toward underutilised crops by smallholder farmers

Table 3.9 summarises factors affecting attitudes toward underutilised crops by smallholder farmers. The pseudo-R^2 of 0.587 indicates that approximately 58.7% of the variation in attitudes is explained by the model variables, suggesting strong explanatory power while appropriately reflecting that attitudes are influenced by somewhat different factors than perceptions. The likelihood ratio chi-squared value of 356.89 ($p < 0.0001$) confirms the model's statistical significance.

Table 3.9: Factors affecting attitudes toward underutilised crops by smallholder farmers

Variable	Coefficient	Std. Error	t-value	p-value
Gender	-0.0387	0.0154	-2.51	0.012**
Marital Status	0.0534	0.0189	2.83	0.005***
Age	0.0028	0.0008	3.50	0.001***
Education	-0.0071	0.0032	-2.22	0.027**
Family Size	0.0134	0.0039	3.44	0.001***
Household Income	-0.0000156	0.0000091	-1.71	0.087*
Farm Size	0.0381	0.0178	2.14	0.033**
Farming Years	0.0039	0.0017	2.29	0.022**
Distance to Farm (km)	0.0019	0.0010	1.90	0.058*
Access to Agricultural Credit	0.0231	0.0148	1.56	0.119
Member of Agricultural Group	-0.0334	0.0151	-2.21	0.027**
Access to Extension Services	-0.0445	0.0160	-2.78	0.006***
Agricultural Training	-0.0398	0.0154	-2.58	0.010**
Employment Status	-0.0298	0.0140	-2.13	0.034**
Awareness of NUCs	0.1067	0.0180	5.93	0.000***
Adoption Status	0.0743	0.0163	4.56	0.000***
Constant	0.2134	0.0498	4.28	0.000***
Sigma	0.0782	0.0039	-	0.000***

Model Statistics

Number of observations	319
Uncensored observations	317
Right-censored observations	2
Log likelihood	201.67
LR chi^2 (16)	356.89
Prob > chi^2	0.000
Pseudo R^2	0.587

Note: *, **, & *** show statistical significance at the 10%, 5% and 1% levels, respectively. Source: Survey data generated through Stata version 18 (2025).

The attitude determinants largely mirror the perception model, but with some notable differences in magnitude and significance levels. Age remains positive and highly significant (p=0.000, coefficient=0.0028), confirming that older farmers maintain more positive attitudes toward underutilised crops due to their cultural connection and traditional knowledge. However, this contrasts with findings by Jerop et al. (2020), who found that younger farmers in Kenya showed more positive attitudes toward improved traditional varieties when supported by appropriate extension services, suggesting that age effects on attitudes may be moderated by institutional support. Gender continues to show that females have significantly more positive attitudes (p=0.012, coefficient=-0.0387), reinforcing their role as custodians of traditional food systems. Marital status shows a positive relationship (p=0.005, coefficient=0.0534), indicating that married farmers have more positive attitudes toward underutilised crops, aligning with the demographic finding that 93.8% of adopters are married and supporting the role of household decision-making dynamics in traditional crop maintenance. This result aligns with von Maltitz and Bahta (2024), who found that women are typically the custodians of indigenous knowledge in agricultural systems. Additionally, Mzimela and Moyo (2025) demonstrated that female farmers show stronger positive attitudes toward traditional drought-resistant crops. However, this finding contrasts with research by Alemayehu et al. (2021), who found no significant gender differences in attitudes toward traditional crops in Ethiopia when controlling for education and access to resources.

Education maintains its negative relationship (p=0.027, coefficient=-0.0071), supporting the finding that formal education reduces appreciation for traditional crops while indigenous knowledge enhances positive attitudes. This result is consistent with Diko (2023), who demonstrated that formal education systems often marginalise indigenous knowledge in favour of Western scientific approaches to agriculture. Similarly, Masekoameng and Molotja (2024) found that formal education systems in South Africa favour Western modes of crop production over traditional knowledge systems, negatively affecting attitudes toward indigenous farming. Employment status remains negatively significant (p=0.034, coefficient=-0.0298), confirming that unemployed farmers view underutilised crops more favourably as alternative livelihood strategies. Thaba-Nkadimene et al. (2023) found that unemployment drives more favourable attitudes toward indigenous crops among rural women in South Africa. However, this result contrasts with findings by Barrett et al. (2022) who found that employed farmers in some East African contexts showed more positive attitudes toward traditional crops because off-farm income provided resources for agricultural experimentation and reduced production risks

Family size shows a strong positive relationship (p=0.001, coefficient=0.0134), indicating that larger households have more positive attitudes toward underutilised crops, likely due to greater food security needs and available labour for traditional crop production. This aligns with the demographic finding that adopters have significantly larger households (7.2 vs. 5.8 members).

However, this finding contrasts with research by Kassie et al. (2021) who found that very large households in Ethiopia sometimes showed negative attitudes toward labour-intensive traditional crops due to competing demands on family labour. Farm size remains positive and significant (p=0.033, coefficient=0.0381), supporting that larger farms enable diversification and dedication of land portions to traditional crops alongside commercial varieties. This result is supported by Wale and Mkuna (2025), who demonstrated positive relationships between farm size and diversification attitudes. Farming years continue to show positive effects (p=0.022, coefficient=0.0039), indicating that experienced farmers value traditional practices accumulated over years of agricultural engagement. This finding is supported by Kom et al. (2022), who demonstrated that farming experience enhances attitudes toward indigenous practices. Additionally, von Maltitz and Bahta (2024) found that experienced farmers show stronger positive attitudes toward traditional knowledge systems.

Household income maintains its negative relationship (p=0.087, coefficient=-0.0000156), suggesting that lower-income farmers view underutilised crops more favourably as necessity-driven alternatives rather than choice-based adoptions. This finding is consistent with Mzimela and Moyo (2025), who found that economic necessity drives positive attitudes toward traditional crops among resource-poor farmers. A member of an agricultural group shows a negative relationship (p=0.027, coefficient=-0.0334), indicating that formal agricultural group membership reduces positive attitudes toward underutilised crops, likely because these groups focus on commercial crop production and modern farming techniques rather than traditional varieties. This finding is supported by Diko (2023), who demonstrated that formal agricultural institutions often create barriers to traditional farming attitudes. However, this result contrasts with Nyantakyi-Frimpong's (2017) findings, which showed that some agricultural cooperatives in Ghana successfully promoted positive attitudes toward traditional crops when they incorporated indigenous knowledge into their programs.

Extension services and Agricultural training maintain their negative relationships (p=0.006 and p=0.010, respectively), reinforcing that formal agricultural institutions create barriers to positive attitudes toward underutilised crops by promoting commercial varieties over traditional options. This finding aligns with recent research by Masekoameng and Molotja (2019), who found that formal extension services often undermine positive attitudes toward indigenous knowledge systems.

Awareness of NUCs remains strongly positive (p=0.000, coefficient=0.1067), confirming the fundamental role of knowledge and awareness in shaping positive attitudes. Adoption Status continues to show strong positive effects (p=0.000, coefficient=0.0743), demonstrating that practical experience with underutilised crops significantly enhances positive attitudes. This finding is strongly supported by Cele and Mkhize (2025), who identified awareness as a critical determinant of positive attitudes toward underutilised crops. Similarly, Shai et al. (2025) found that awareness significantly influences farmer attitudes toward indigenous practice.

These empirical results provide strong validation for the Theory of Planned Behaviour framework outlined in the study. The significant effects of demographic factors on both perception and attitude indices confirm that individual characteristics fundamentally shape the attitudinal component of the TPB model. The negative relationships with formal institutions (extension services, agricultural training) and the positive relationships with traditional factors (age, cultural knowledge) demonstrate how subjective norms from different knowledge systems compete in farmers' decision-making processes. The perceived behavioural control component is clearly demonstrated through the effects of resource-related variables (income, farm size, credit access), showing how practical constraints interact with psychological factors to influence adoption intentions. The strong positive effects of adoption status in both models illustrate the TPB's emphasis on how direct experience reinforces attitudes and strengthens behavioural intentions. These findings reveal that successful promotion of underutilised crops requires addressing the complex interplay between traditional knowledge systems, cultural values, and practical constraints, making the TPB framework invaluable for developing culturally appropriate and effective intervention strategies.

3.5 Conclusion and recommendations

This study examined the perceptions and attitudes of smallholder farmers toward underutilised crops in KZN Province. The findings reveal significant disparities between adopters (40%) and non-adopters (60%), with adopters consistently demonstrating more positive perceptions and attitudes across all measured variables. These psychological factors play a crucial role in adoption decisions, as evidenced by the statistically significant differences in perception and attitude indices between the two groups. The study found that socioeconomic factors significantly influence farmers' perceptions and attitudes. Gender showed a negative relationship with both indices, indicating females have more positive orientations, while age and family size demonstrated positive impacts. Adoption status emerged as the strongest predictor, with adopters scoring significantly higher on both indices compared to non-adopters. Institutional factors, including access to extension services and agricultural training, negatively influenced farmers' views toward NUCs, suggesting these systems prioritise commercial crops over traditional varieties.

A critical finding was the dominant role of awareness in shaping positive perceptions and attitudes, with 98.4% of adopters demonstrating high awareness levels compared to 75.0% of non-adopters. Traditional knowledge sources dominated information channels, with family elders and farmer-to-farmer networks serving as primary sources rather than formal extension services. The application of the Theory of Planned Behaviour provided insights into how attitudes, subjective norms, and perceived behavioural control collectively shape farmers' adoption intentions, while revealing that traditional knowledge systems and cultural practices significantly influence these psychological constructs. These findings demonstrate that effective promotion of underutilised crops requires addressing both the preservation of indigenous knowledge systems and the integration of traditional practices with contemporary agricultural development approaches. Based on the research findings, the following recommendations are proposed:

- Culturally Sensitive Extension Programs: Restructure extension services to integrate traditional knowledge with scientific approaches, training extension officers to respect and build upon indigenous agricultural practices rather than promoting only commercial crops.
- Women-Focused Agricultural Support: Develop targeted programs recognising women's role as custodians of traditional crops, improving their access to land, credit, and agricultural resources to enhance capacity for maintaining indigenous farming systems.
- Intergenerational Knowledge Transfer: Establish formal platforms facilitating knowledge exchange between elderly knowledge holders and younger farmers to prevent erosion of traditional agricultural wisdom.
- Awareness and Education Campaigns: Implement comprehensive campaigns educating farmers about nutritional, economic, and environmental benefits of underutilised crops, utilizing multiple channels including traditional networks, mass media, and digital platforms.

- Traditional Knowledge Documentation: Support systematic documentation and validation of indigenous agricultural practices to preserve valuable knowledge while providing scientific backing for traditional methods.
- Market Development Initiatives: Develop market infrastructure and value chains for underutilised crops, establishing processing facilities and linking farmers to urban and international markets to provide economic incentives for adoption.
- Policy and Institutional Reforms: Reform agricultural policies to recognise and support indigenous knowledge systems alongside modern practices, ensuring educational curricula integrate traditional knowledge with scientific approaches.
- Community-Based Seed Networks: Strengthen traditional seed systems and community-based networks to maintain genetic diversity and ensure seed availability for underutilised crops.
- Demonstration Sites: Establish demonstration farms showcasing successful integration of traditional and modern agricultural practices, providing tangible evidence of benefits and practical learning opportunities.

By addressing these factors, stakeholders can enhance the adoption of underutilised crops among smallholder farmers in KZN, ultimately strengthening food security, preserving cultural heritage, and promoting agricultural biodiversity in the face of climate change and market pressures.

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CHAPTER 4: THE CONTRIBUTION OF NEGLECTED AND UNDERUTILISED CROPS AND THEIR IMPACT ON RURAL FOOD SECURITY IN KWAZULU-NATAL PROVINCE, SOUTH AFRICA

Abstract

Rural food insecurity persists despite a national food surplus, driven by poverty and reliance on a narrow range of staple crops in South Africa. This study assessed the contribution of Neglected and Underutilised Crops (NUCs) to food security among smallholder farmers. Using an Endogenous Switching Regression model with data from 319 households, the research found that 40% of the households cultivated NUCs, primarily valued for their drought tolerance. Participation was positively driven by traditional knowledge but negatively associated with formal agricultural extension, revealing a critical institutional bias. The results demonstrated that NUC cultivation significantly improves food security outcomes. Adopters achieved higher dietary diversity, with 67% scoring high on the Household Dietary Diversity Score (HDDS), and a reduced use of negative coping strategies, with 52% in the Coping Strategy Index (CSI), compared to non-adopters. The analysis revealed distinct welfare pathways; income and education influenced non-adopter outcomes, while traditional knowledge and crop diversity drove adopter welfare. The counterfactual analysis from the ESR model showed that non-adopters would gain the most from adopting NUCs with an Average Treatment Effect on the Untreated (ATU) of a 2.145-point increase in HDDS and a 3.789-point decrease in CSI, indicating significant untapped potential for improving household welfare. The study concludes that NUCs are a viable strategy for enhancing food security and resilience. It recommends policies to mainstream these crops, integrate indigenous knowledge into extension services to counter existing biases, and create robust market linkages to unlock their full benefits for smallholder farmers.

Keywords: neglected and underutilised crops, , Nutrition security, household dietary diversity, endogenous switching regression, smallholder farmers, South Africa.

4.1 Introduction

Food insecurity remains a persistent development challenge across sub-Saharan Africa (SSA), where poverty, unemployment, and climate variability heighten vulnerability to hunger and malnutrition (Ofori et al., 2021; Bjornlund et al., 2022). Approximately 278 million people in SSA experience food insecurity, with rural households bearing the heaviest burden (FAO, 2022). Despite increases in aggregate food production, global food systems remain heavily dependent on a narrow set of staples such as maize, rice, and wheat, which supply over two-thirds of global caloric intake (Gatto et al., 2021). This overdependence reduces agricultural biodiversity and exposes vulnerable populations to food insecurity when climate or market shocks disrupt staple crop yields (FAO et al., 2020).

South Africa reflects these patterns. While national food availability is stable, 23.6% of South Africans experience moderate or severe food insecurity (Stats SA, 2023). KwaZulu-Natal (KZN) is among the most affected provinces, with 18.6% of households food-insecure and an additional 14.3% at risk (Thamaga-Chitja et al., 2025). Rural communities in KZN remain heavily dependent on maize, a crop increasingly threatened by droughts, floods, and temperature extremes (Giller et al., 2021). This reliance creates a paradox, despite the availability of diverse, locally adapted neglected and underutilised crops (NUCs) such as sorghum, millet, bambara groundnut, and indigenous leafy vegetables, adoption remains low. These crops are climate-resilient, nutritionally superior, and culturally significant, yet farmers continue to prioritise maize (Mabhaudhi et al., 2018; Ndlovu et al., 2024).

This tension between indigenous agricultural knowledge and modern market pressures lies at the heart of the NUC marginalisation problem. Several factors explain why farmers persist with maize despite NUCs' apparent advantages. First, institutional bias in agricultural policy, extension services, and research funding has historically prioritised commercial staples over traditional crops (Newton, 2025; Marimo & Otieno, 2025). Second, seed systems for NUCs remain underdeveloped, limiting access to quality planting material. Third, cultural perceptions that stigmatise NUCs as "poor people's food" suppress both demand and farmer motivation (Minde et al., 2021; Mudau et al., 2022). Fourth, fragmented value chains and poor market integration mean that even when farmers cultivate NUCs, they face difficulties converting harvests into reliable income (Adelabu & Franke, 2023; Glatzel et al., 2025). These constraints collectively undermine the economic case for NUC adoption, reinforcing farmers' preference for maize, which is a crop supported by established input supply chains, extension advice, and market structures, despite its vulnerability to climate shocks.

While a growing body of literature documents the agronomic and nutritional attributes of NUCs, few studies in South Africa and none specifically in KZN have applied rigorous econometric methods to quantify the causal impact of NUC adoption on multidimensional household food security indicators. Existing research largely focuses on descriptive assessments of NUC potential, nutritional composition, and constraints to adoption, without establishing measurable effects on outcomes such as household dietary diversity, food consumption scores, crop income, or household resilience to climate shocks. This methodological gap is significant: without causal estimates, policymakers cannot determine whether investments in NUC promotion translate into meaningful improvements in food security, nor can they compare the cost-effectiveness of NUC interventions against alternative agricultural development strategies.

This study addresses this gap by assessing the contribution of NUC adoption to rural food security among smallholder farmers in KZN, South Africa. Using an endogenous switching regression (ESR) model, the study estimates the causal effect of NUC participation on household food security outcomes, controlling for selection bias arising from observable and unobservable factors. The analysis quantifies the impact of adoption on three dimensions of food security: dietary diversity (measured by the Household Dietary Diversity Score), food consumption (measured by the Food Consumption Score), and household income from crop production. By providing empirical, impact-oriented evidence, the study aims to inform policy frameworks and investment decisions regarding NUC value chain development, agricultural extension priorities, and climate adaptation strategies in South Africa and the broader SSA region.

4.2 Theoretical framework

This study is underpinned by the Random Utility Theory (RUT), which offers a robust economic lens for understanding household decision-making in agricultural contexts characterised by competing livelihood options. RUT asserts that households behave as rational agents who choose the alternative that yields the greatest perceived utility, given their resource limitations, access to information, and prevailing risks (McFadden, 1972; Manski, 1977). The participation of neglected and underutilised crops (NUCs) represents one such decision, where farmers must weigh perceived benefits such as drought tolerance, nutritional gains, cultural relevance, and market potential against constraints that include labour requirements, lack of extension support, or limited commercialisation pathways.

At its core, RUT formalises utility as a latent construct composed of both measurable and unobservable elements (Ben-Akiva & Lerman, 1985):

$$U_{ij} = V_{ij} + \varepsilon_{ij}$$

The condition for a household to participate in NUC production rather than not participate is:

$$U_{i}^{participate} > U_{i}^{non-participate}$$

Which implies:

$$V_{i}^{participate} + \varepsilon_{i}^{participate} > V_{i}^{non-participate} + \varepsilon_{i}^{non\text{-}participate}$$

This utility-driven decision-making process can be statistically analysed using discrete choice models such as probit or logit frameworks to estimate the probability of NUC participation as a function of measurable household attributes (Greene, 2018). Yet, participation decisions are inherently endogenous: the same unobservable factors influencing participation may also influence food security outcomes.

A rural household endowed with strong indigenous knowledge, for example, may adopt NUCs, prepare them in nutritionally advantageous ways, and consequently experience improved dietary diversity. Similarly, a household with entrepreneurial motivation may commercialise NUCs to expand income streams and enhance economic access to food. These unobserved characteristics contained in εij\varepsilon_{ij}εij create self-selection bias, meaning adopters and non-adopters differ in ways that standard regression models cannot capture (Maddala, 1983). Because the same unobservable factors that influence the utility of participating in NUC production (such as indigenous knowledge, farming experience, food culture, or motivation) may also influence household food security outcomes, the participation decision becomes endogenous. Random Utility Theory, therefore, directly motivates the use of an Ordered Profit Endogenous Switching Regression (OP-ESR) model, which allows the participation equation and the food security outcome equations (HFIAS, HDDS, and CSI) to share correlated error terms. By linking the discrete participation choice to the ordered food security outcomes through an OP-ESR framework, the model corrects for selection bias and produces unbiased causal estimates of how participation in NUC production affects household dietary diversity, household food access, and coping capacity.

Addressing this requires a methodological approach that explicitly accounts for selection into treatment. The Ordered Probit Endogenous Switching Regression (OP-ESR) model provides a suitable framework to estimate the causal impact of NUC participation on food security while correcting for biases arising from unobservable heterogeneity (Heckman, 1979). Through this approach, the study isolates the true welfare contributions of NUCs, distinguishing them from underlying household traits that influence both choices and outcomes.

The RUT framework, therefore, performs a dual role in this study. It gives theoretical justification for viewing NUC participation as a rational response to risk, resource scarcity, and nutritional needs. It also guides the empirical strategy toward scientifically rigorous evaluation of how NUCs contribute to food security dimensions such as availability, accessibility, and dietary quality among rural households in KwaZulu-Natal. This alignment ensures that conclusions generated are both conceptually meaningful and methodologically sound, thereby supporting evidence-based policies to strengthen agricultural diversification and resilience within South Africa’s food systems

4.3 Methodology

4.3.1 Description and study area selection

This study was conducted in KwaZulu-Natal Province of South Africa. The province was purposively selected because of its dominance of rural smallholder farming and its rural setting. The study area also offered an ideal opportunity to research underutilised crops due to their prevalent cultivation by smallholder farmers and the region's suitable climate for diverse traditional crop production (Qwabe et al., 2021). The uMkhanyakude District Municipality and the King Cetshwayo District Municipality were purposively selected as the study area due to their topographical nature and landscape that are suitable for the production of neglected and underutilised food crops, as well as their documented food security challenges that make them ideal for assessing the contribution of these crops to rural food security (Pactrick, 2021; Mulopo and Chimbari, 2021).

The uMkhanyakude District Municipality is situated in the northernmost part, whereas the King Cetshwayo District Municipality is located in the north-eastern region of KwaZulu-Natal (Mthembu and Hlophe, 2020; Abegunde et al., 2020; Cooperative Governance and Traditional

Affairs, 2023/11). UDM covers a land mass of 12,818 km² with a population of approximately 686,090 (Mthembu and Hlophe, 2020), and KCD with a land mass of 94,341 km² and 971,135 population (COGTA, 2023/11). Both KCDM have warm, good climate with mild winters and hot, humid summers, while UDM is characterised by a steady rise in temperature and declining rainfall and increased drought frequency and severity, particularly in the northern regions, affecting agricultural production (COGTA, 2023/11; uMkhanyakude IDP, 2023).

Furthermore, these districts are characterised by a predominantly rural population that relies heavily on subsistence agriculture, with significant levels of food insecurity and malnutrition, increasing their vulnerability to climate change (Hosea, 2021; Pactrick, 2021; Mulopo & Chimbari, 2021; Mzimela & Moyo, 2025). This reliance and vulnerability make them an ideal context for this study, which seeks to assess how underutilised crops contribute to food security and serve as resilience strategies for rural poor households. The districts' agro-ecological diversity supports various traditional crops, including indigenous vegetables (*imifino*), traditional grains (sorghum, finger millet), drought-tolerant legumes (cowpeas, Bambara groundnuts), and indigenous fruits, providing an excellent research environment for evaluating the food security impacts of these underutilised crop systems.

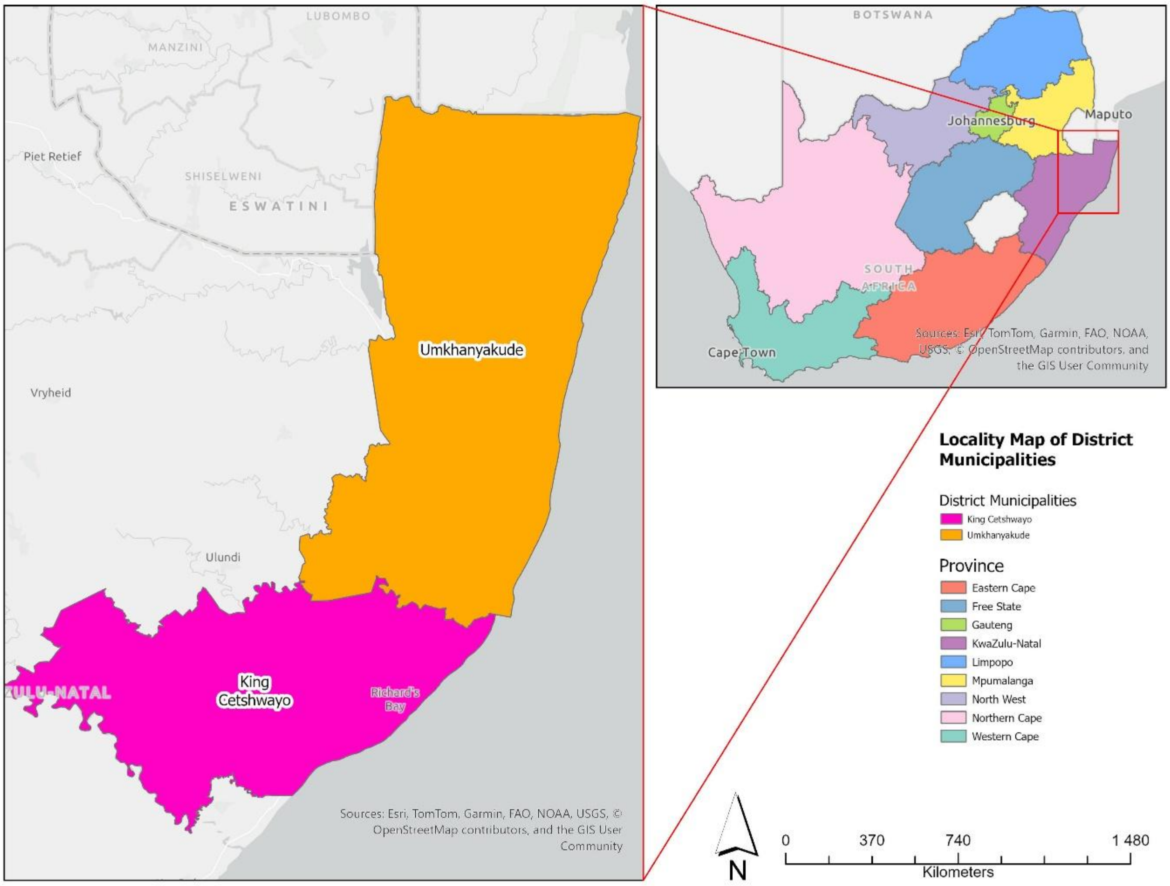

Figure 4.1: Study area Map (Source: (Author's compilation))

4.3.2 Sampling

A cross-sectional research design was employed in this study to assess the contribution of underutilised crops to rural food security among smallholder farmers. A cross-sectional research design was chosen because it is relatively less expensive and time-consuming, while allowing for the simultaneous assessment of food security indicators across different farming systems (Creswell, 2017). Furthermore, the study employed a mixed-methods approach, incorporating both qualitative and quantitative data, to gain an in-depth understanding of how underutilised crops contribute to household food security outcomes. This approach has been selected because it strengthens the validity and credibility of the research and provides a comprehensive understanding of the complex relationships between crop choices and food security (Cypress, 2017).

This research employed a multi-stratified random sampling procedure to ensure diverse representation of smallholder farmers with varying levels of underutilised crop cultivation and food security outcomes (Maziya et al., 2024). In the first stage, the uMkhanyakude and the King Cetshwayo District Municipalities were purposively selected due to their diverse agro-ecological characteristics, frequent susceptibility to climate change issues, heavy reliance on subsistence agriculture, and documented presence of underutilised crop cultivation. Then, proceeded to select two local municipalities in each district due to their significant contribution to underutilised crop production and their representation of different food security contexts. In stage two, stratified sampling was used. A stratified sampling approach was applied, whereby participants were grouped into strata based on their underutilised crop cultivation patterns and food security status (Ahmed et al., 2017; Ogundeji, 2022). Therefore, participants were grouped into those who actively cultivated underutilised crops as a significant component of their farming system and those who focused primarily on conventional crops. This stratification enables a comprehensive comparison of food security outcomes across different levels of underutilised crop engagement, allowing for robust analysis of their contribution to rural food security through dietary diversity and coping strategies assessment. The third stage was implemented, whereby farmers practising NUCs were randomly selected from each rural community within the local municipalities to ensure geographical representation across different agro-ecological zones.

The sample size of the study was determined by using Cochran's (1977) formula because the population of areas selected was unknown. A Cochran’s (1977) is presented below:

$$n_0 = \frac{(t^2)*(p)(q)}{(d)^2} = \frac{(1.96)^2(.5).5)}{(.5)^2} = 384$$

Where:

t = value for selected alpha level of .025 in each tail = 1.96 when

(p)(q) = estimate of variance = 0.25 (maximum possible proportion (0.5) * (1-0.5) maximum possible proportion (0.5) produces maximum possible sample size).

d = acceptable margin of error for proportion being estimated = 0.05 (error researcher is willing to accept).

To achieve a 95% confidence level with a 5% margin of error, parameters that provide good precision for generalising findings to the population, the initial target sample size was 384 households. However, due to resource and time constraints during the data collection phase, the final achieved sample comprised 319 smallholder farmers, yielding an 83.1% response rate.

A design effect of 1.0 was applied, consistent with the simple random sampling assumption used during sample size calculation. A non-response bias check comparing key demographic characteristics of respondents and non-respondents (age and sex of household head, household size, and farming experience), based on information obtained from local extension officers, showed no meaningful differences, indicating minimal non-response bias. This reduction in sample size (16.9% below the calculated 384) did not significantly compromise the statistical power or representativeness of the study. The achieved sample size maintains a 95% confidence level with a slightly increased margin of error of 5.5%, which remains acceptable for agricultural and food security research in developing-country contexts (Yamane, 1967; Israel, 2013). Therefore, the final sample of 319 households is adequate for the descriptive statistics, food security indices, and econometric analyses, including the Ordered Probit Endogenous Switching Regression (OP-ESR) model, used in this study

4.3.3 Data collection

Primary data were collected using self-administered structured questionnaires. The questionnaire captured information on smallholder farmers' demographic and socio-economic characteristics, agricultural production activities, food security status, traditional knowledge, participation in the cultivation and utilisation of NUCs, and the challenges faced in NUC production. The questionnaire was pre-tested prior to the main data collection to assess clarity, relevance, and reliability, and to refine the instrument where necessary. The pre-test also served as a training platform for enumerators, who were fluent in the local language (IsiZulu), to ensure accurate communication and interpretation during interviews. Participation in the study was entirely voluntary, and informed consent was obtained from all respondents. The researcher worked closely with local extension officers to identify and reach households engaged in NUC production across the King Cetshwayo and uMkhanyakude District Municipalities. Data collection took place between 02 March and 30 April 2025. Ethical clearance for the study was granted by the University of KwaZulu-Natal's Humanities and Social Sciences Research Ethics Committee (HSSREC/00007019/2024). All ethical protocols were observed, including the use of written informed consent forms emphasising voluntary participation, anonymity, and confidentiality. Given that data were collected across multiple communities and districts, the analysis accounted for potential intra-cluster correlation. Accordingly, standard errors were clustered at the village or municipality level rather than relying solely on conventional robust standard errors, thereby improving the statistical reliability and validity of the estimates.

4.3.4 Data analysis

This paper assessed the contribution of neglected and underutilised crops and their impact on rural food security among smallholder farmers. The collected survey data were organised and initially processed using Microsoft Excel spreadsheets for data entry and preliminary cleaning. For a comprehensive statistical analysis, Stata version 18 was employed. The study employed a cross-sectional research design with a mixed-methods approach to gather comprehensive data on NUCs participation patterns and their food security effects among smallholder farmers. This design facilitated the assessment of how NUCs cultivation affects farmer food security through the Household Dietary Diversity Score (HDDS), Household food Insecurity Access Scale (HFIAS) and Coping Strategies Index (CSI) as food security indicators and the ESR model to evaluate the causal impact of NUCs participation on food security outcomes, providing crucial insights into the food security effects of traditional crop participation in rural production systems

4.3.5 Descriptive statistics

Descriptive statistics were used to summarise the demographic and socioeconomic characteristics of smallholder farmers participating in and not participating in NUC production. The analysis included frequency distributions, percentages, means, and standard deviations to provide an overview of key household and farm attributes. Tables and figures were employed to present the results clearly and facilitate comparison between participant groups. The descriptive statistics also quantified the extent of NUC cultivation across major categories such as cereals, legumes, vegetables, and root crops. Farmers were classified according to their level of participation in NUC production, enabling a clearer understanding of engagement patterns. These descriptive findings provided foundational insights that informed the subsequent econometric analysis of the relationship between NUC participation and household food security outcomes.

4.3.6 The Household Dietary Diversity Score (HDDS)

The Household Dietary Diversity Score (HDDS) was selected as the primary tool to assess the utilisation dimension of food security among smallholder farmers (Swindale & Bilinsky, 2006). It functions as a robust proxy for diet quality and micronutrient adequacy by measuring the variety of food groups consumed (Ruel, 2003). This makes it particularly valuable for evaluating how cultivating Neglected and Underutilised Crops (NUCs) influences dietary patterns, as demonstrated in similar agricultural contexts (Sibhatu & Qaim, 2018). The metric's validity is well-established, having been extensively applied in agricultural research to link on-farm diversity to nutritional outcomes (Dillon et al., 2015; Koppmair et al., 2017). For this study, dietary diversity was measured using a 24-hour recall period across 12 standard food groups (FAO, 2011). Households were then classified as having low (1-4), medium (5-8), or high (>9) dietary diversity based on their scores (Kennedy et al., 2011).

This methodological approach allowed for a direct comparison of dietary outcomes between farmers cultivating NUCs and those using conventional methods. The core objective was to quantify the association between traditional crop cultivation and the quality of household diets. The HDDS is especially apt for this purpose as it can capture improvements driven by increased consumption of diverse, indigenous, nutritious varieties. By focusing on food groups, it provides crucial insights into how NUCs can enhance the quality and resilience of household food consumption. The application of this standardised tool ensures the findings are comparable with broader literature on agriculture-nutrition linkages (Sibhatu & Qaim, 2018). Ultimately, it provides a clear measure of the nutritional contribution of NUCs within local food systems.

Table 4.1: Food groups used for calculating the HDDS

Food groups	Number
1. Any bread, rice, or any other foods made from millet, sorghum, maize, wheat, or any other locally available grain	A
2. Any potatoes, yams, cassava, or any other foods made from roots or tubers	B
3. Any vegetables	C
4. Any fruits	D
5. Any beef, pork, lamb, rabbit, chicken, duck, other birds, and organ meats	E
6. Any eggs	F
7. Any fresh or dried fish, or shellfish	G
8. Any foods made from beans, peas, and lentils	H
9. Any yoghurt, milk, or milk products	I
10. Any food made with oil, fat or butter	J
11. Any sugar	K
12. Any food, such as coffee or tea	L

Note: If the answer was yes, awarded 1 point, and if the answer was no, awarded 0 points

Source: Adapted from Swindale and Bilinsky (2006)

4.3.7 The Coping Strategies Index (CSI)

The CSI was selected as a complementary measurement tool to assess household coping mechanisms in response to food insecurity, providing crucial insights into the behavioural responses and adaptive strategies employed by farming households when experiencing food access constraints. The CSI measures the frequency and severity of coping behaviours that households employ when they cannot access adequate food, serving as an indicator of food insecurity severity and household vulnerability (Maxwell & Caldwell, 2008). Unlike static measures of food availability, the CSI captures the dynamic nature of household food security by examining behavioural adaptations, making it particularly valuable for evaluating how neglected and underutilised crop cultivation affects household resilience and food security coping capacity.

The CSI has been extensively validated and applied in agricultural research contexts to assess food security outcomes. Knueppel et al. (2010) employed the CSI to evaluate food security interventions among smallholder farming communities in East Africa. Jones et al. (2014) utilised the CSI to examine the relationship between agricultural diversification and household food security resilience. More recently, Chegere (2020) applied the CSI to assess the impact of conservation agriculture on household food security coping strategies in Tanzania. The CSI is particularly suitable for this study as it captures how traditional crop cultivation may enhance household capacity to cope with food insecurity through improved food production diversity, reduced dependence on external inputs, enhanced climate resilience, and strengthened local food systems.

The CSI instrument comprises a standardised list of coping strategies that households commonly employ when facing difficulties with food access. These strategies are weighted according to their severity, with more severe coping strategies receiving higher weights to reflect their greater indication of food insecurity. The coping strategies examined include dietary changes (such as consuming less preferred foods, limiting portion sizes, and reducing meal frequency), asset depletion strategies (including selling productive assets and borrowing food or money), and social strategies (such as relying on help from relatives or community members). Each strategy is assigned a severity weight based on its reversibility and impact on future livelihood security.

Respondents were asked to recall the frequency of each coping strategy employed during the previous 30 days, following the standard CSI methodology. The frequency responses were coded as: 0 = Never, 1 = Rarely (1-2 times per month), 2 = Sometimes (3-10 times per month), and 3 = Often (more than 10 times per month). The CSI score for each household was calculated by multiplying the frequency of each strategy by its severity weight and summing across all strategies. Higher CSI scores indicate greater food insecurity and more frequent use of severe coping strategies, while lower scores indicate better food security status and less reliance on detrimental coping mechanisms.

Table 4.2: Coping strategies and severity weights used in the CSI calculation

Coping Strategy	**Severity Weight**
Rely on less preferred/less expensive foods	1
Borrow food or rely on help from friends/relatives	2
Limit portion size at mealtimes	1
Restrict consumption by adults for children to eat	3
Reduce number of meals eaten per day	2
Skip entire days without eating	4
Sell productive assets (tools, livestock, land)	4
Engage in casual labour for food	2
Send household members elsewhere to eat	3
Harvest immature crops	3

Note: Severity weights range from 1 (least severe) to 4 (most severe) based on reversibility and long-term impact on livelihood security.

Source: Adapted from Maxwell and Caldwell (2008) and contextualised for rural farming communities

The CSI provides several advantages for this study's assessment of NUCs cultivation impacts on food security. Firstly, it captures the experiential dimension of food insecurity by focusing on actual household behaviours rather than theoretical food access calculations. Secondly, the CSI is sensitive to seasonal variations in food security, which is particularly relevant for agricultural households whose food security status fluctuates in line with their production cycles. Thirdly, the index enables comparison of food security coping capacity between NUC adopters and conventional farming households, providing insights into how traditional crop cultivation affects household resilience. Finally, the CSI complements the HDDS by capturing the behavioural dimension of food security, creating a comprehensive assessment framework that examines both dietary quality (HDDS) and coping mechanisms (CSI) in response to traditional crop participation.

4.3.8 Household food insecurity access scale

The Household Food Insecurity Access Scale was used in this study to assess the food insecurity experiences of the rural smallholder farmers in KCDM and uMkhanyakude District Municipality in participation of NUCs. HFIAS has been identified as a reliable and valid measure of food security in the study area. HFIAS consists of nine items assessing household food insecurity experiences within the previous 4 weeks. Further, three indicators of household food insecurity include the HFIAS score, the severity of food insecurity and the overall prevalence of food insecurity calculated using responses to these nine conditions. The affirmative responses are then scored from 0 to 3 based on the frequency of occurrences, which is categorised into rarely, sometimes or often. Therefore, the total scores of 0 – 1, 2 – 7, 8 – 14, and 15 - 27 indicated food security, mild food insecurity, moderate food insecurity and severe food insecurity, respectively. The HFIAS indicator was also employed by Honarvar et al. (2023) to evaluate households' food insecurity and factors related to it in Golestan province, North of Iran. Similarly, Gewu et al. (2021) used HFIAS to examine the effects of traditional foods on household food security in Seme sub-County of Kenya.

Table 4.3: HFIAS questions for rural household food security

Question	**Summary of the questions**
1	Worry about food
2	Unable to eat preferred foods
3	Eat just a few kinds of foods.
4	Eat food that they really do not want to eat.
5	Eat a smaller meal
6	Eat fewer meal in a day.
7	No food of any kind in the household
8	Go to sleep hungry
9	Go a whole day and night without eating.

Source: Coates et al., 2007

4.3.9 The Ordered Profit Endogenous Switching Regression (OP-ESR) Model

The Ordered Probit Endogenous Switching Regression (OP-ESR) model was employed to address potential endogeneity and selection bias while accounting for the ordinal nature of food security indicators, thereby establishing robust causal relationships between NUCs participation and household food security outcomes. This model is particularly suitable for this study because it simultaneously handles two critical issues: the ordered categorical nature of food security measures (such as HFIAS categories of mild, moderate, and severe food insecurity) and the self-selection bias arising from farmers' voluntary participation decisions where unobserved factors may influence both participation choices and food security outcomes.

The OP-ESR framework has been increasingly applied in agricultural and development economics to evaluate program impacts with ordinal outcomes. Lokshin and Sajaia (2004) developed the maximum likelihood estimator for this model, providing a comprehensive solution for endogenous switching with ordinal outcomes. Assefa et al. (2020) applied OP-ESR to assess the impact of sustainable agricultural practices on food security levels in Ethiopia, while Manda et al. (2018) utilised the approach to evaluate how technology participation affects poverty status categories among smallholder households. More recently, Koppa et al. (2022) employed OP-ESR to examine the impact of conservation agriculture on dietary diversity scores in Zambia, and Gebreggziabher et al. (2023) applied the model to analyse how irrigation participation influences food consumption score categories in drought-prone regions.

The OP-ESR model is especially appropriate for analysing NUCs participation effects because traditional crop cultivation decisions are often influenced by complex cultural factors, indigenous knowledge transmission, and household-specific preferences that may not be fully observable but significantly affect both participation decisions and the probability of households falling into specific food security categories. The model addresses this endogeneity by explicitly modelling both the participation decision and the ordered food security outcomes while accounting for potential correlation between their error structures.

The OP-ESR framework consists of two main components: a selection equation that models the NUCs' participation decision, and outcome equations for the ordered food security categories for both adopters and non-adopters. The selection equation is specified as:

$$A_i^* = Z_i\gamma + \mu_i$$

$$A_i = \begin{cases} 1 & \text{if } A_i^* > 0 \\ 0 & \text{otherwise} \end{cases}$$

Where A_i^* is a latent variable representing the propensity to adopt NUCs, A_i is the observed participation decision, Z_i Is a vector of exogenous variables affecting participation, γ is a parameter vector, and μ_i is the error term.

The outcome equations for the ordered food security categories are specified as:

$$Y_i^* = X_i\beta_j + \varepsilon_{ji} \text{for } j = 0,1$$

$$Y_i = k \text{if } \tau_{k-1} < Y_i^* \leq \tau_k \text{for } k = 1,2, \dots, K$$

Where Y_i^* Is the latent food security propensity, Y_i is the observed food security category, X_i is a vector of exogenous covariates, β_j are regime-specific parameters, ε_{ji} are error terms, and τ_k are threshold parameters defining the ordered categories.

The error terms are assumed to follow a bivariate normal distribution:

$$(\mu_i, \varepsilon_{0i}, \varepsilon_{1i}) \sim N(0, \begin{bmatrix} 1 & \rho_0 & \rho_1 \\ \rho_0 & 1 & 0 \\ \rho_1 & 0 & 1 \end{bmatrix})$$

Where ρ_0 and ρ_1 represent the correlation coefficients between the selection equation error and the outcome equation errors for non-adopters and adopters, respectively.

The OP-ESR model enables calculation of treatment effects on the ordered outcomes, including the Average Treatment Effect on the Treated (ATT) for specific food security categories:

$$ATT_k = E[P(Y_{1i} = k \mid A_i = 1) - P(Y_{0i} = k \mid A_i = 1)]$$

This represents the change in probability of being in the food security category k for NUC adopters due to participation.

The OP-ESR model provides several methodological advantages for analysing NUCs' impact on food security. First, it corrects for selection bias while properly handling the ordinal nature of food security measurement scales. Second, it allows for the estimation of counterfactual probabilities for each food security category, enabling a comprehensive comparison of what would have happened to adopters across all insecurity levels if they had not adopted NUCs. Third, the model provides direct tests for endogeneity through the significance of the correlation coefficients ρ_0 and ρ_1, indicating whether unobserved factors jointly influence participation decisions and food security outcomes. This comprehensive approach ensures that the estimated impacts of NUCs participation on food security probabilities represent genuine causal effects rather than spurious correlations, which is particularly crucial for traditional crop systems where complex cultural and knowledge factors influence both participation decisions and vulnerability to food insecurity.

4.3.10 Description of variables used in The OP -ESR model

Table 4.4 summarises the variables included in the OP-ESR model for analysing the causal impact of NUCs participation on household food security outcomes. The selection equation includes variables hypothesised to influence the participation decision, while the outcome equations include factors affecting food security status. Some variables appear in both equations to control for their effects on both participation and outcomes, following the approach established by Chivenge et al. (2015) and Mabhaudhi et al. (2019) for underutilised crop research.

Table 4.4: Variables used in the Endogenous Switching Regression Model for NUCs Analysis

Variable	Description and Measurement	Expected Effect
Selection Equation (NUCs Participation Decision)		
Age of household head	Age in years (continuous)	+
Gender of household head	1 = male, 0 = female (dummy)	-
Education level	Years of formal schooling (continuous)	-
Household size	Number of household members (continuous)	+
Household income	(Total household income (continuous)	+
Farm size	Total land area in hectares (continuous)	+
Access to extension	1 = yes, 0 = no (dummy)	-
Traditional knowledge	1 = has traditional knowledge, 0 = no (dummy)	+
Distance to market	Distance in kilometres (continuous)	+
Awareness of NUCs	1 = aware, 0 = not aware (dummy)	+
Cultural affiliation	1 = strong cultural ties, 0 = weak (dummy)	+
Outcome Equations (Food Security)		
Age of household head	Age in years (continuous)	+
Gender of household head	1 = male, 0 = female (dummy)	-
Education level	Years of formal schooling (continuous)	+
Household size	Number of household members (continuous)	-
Farm size	Total land area in hectares (continuous)	+

Off-farm income	1 = has off-farm income, 0 = no (dummy)	+
Livestock ownership	Number of livestock units (continuous)	+
Asset ownership	Value of productive assets (continuous)	+
Crop diversity	Number of different crops grown (continuous)	+
Storage facilities	1 = has storage, 0 = no storage (dummy)	+

Note: + indicates a positive expected effect, - indicates a negative expected effect. Expected effects are based on the literature review of NUCs participation studies (Chivenge et al., 2015; Mabhaudhi et al., 2019; Zondi et al., 2022). Source: Author's compilation based on underutilised crops literature

The OP-ESR model provides several advantages for analysing NUCs' impact on food security. First, it corrects for selection bias by explicitly modelling the participation decision and accounting for the correlation between unobserved factors affecting participation and food security outcomes. Second, it allows estimation of counterfactual outcomes, enabling comparison of what would have happened to adopters if they had not adopted NUCs, and what would happen to non-adopters if they adopted traditional crops. Third, the model provides robust standard errors and enables testing of whether selection bias is present through correlation coefficients between error terms. This comprehensive approach ensures that the estimated impacts of NUCs participation on food security represent genuine causal effects rather than spurious correlations, which is particularly important for traditional crop systems where complex cultural and knowledge factors influence participation decisions.

4.4 Results and discussion

4.4.1 Socio-demographic profile of smallholder farmers in the study area

The demographic and farm characteristics (Table 4.5) of smallholder farmers in KZN Province reveal significant differences between adopters and non-adopters of Neglected and Underutilised Crops (NUCs). The results from the statistical tests, as detailed in Table 3, reveal several significant demographic and socio-economic differences between adopters and non-adopters of NUCs. A highly significant association ($\chi^2 = 20.17$, $p < 0.001$) exists between gender and participation, with 68.5% of adopters being female compared to 43.2% of non-adopters. This strongly reinforces the suggestion that women dominate the NUC value chain. These results corroborate the findings of Ngidi et al. (2023), who argued that the majority of females participate in the production and utilisation of NUCs compared to males because they are the primary custodians of knowledge regarding their preparation, cooking, and storage.

Marital status also shows a significant relationship with participation ($\chi^2 = 12.73$, $p < 0.001$), as 88.2% of adopters were married, compared to 71.4% of non-adopters. This supports the implication that married households are more likely to engage in NUC production. Similarly, Zondi et al. (2022) found that married households made informed joint decisions about the production and utilisation of NUCs, leveraging collaboration to diversify their cropping systems. Conversely, access to institutional support shows an inverse relationship with participation. A significantly lower proportion of adopters had access to extension services (31.5% vs. 47.9% of non-adopters; $\chi^2 = 8.81$, $p < 0.001$) and were members of a farm organisation (37.0% vs. 52.1%; $\chi^2 = 7.20$, $p < 0.001$). This corroborates the conclusion that NUC cultivation relies more on traditional knowledge than on formal agricultural support. The results are somewhat similar to the findings of Omotayo and Aremu (2024), who reported that extension services and agricultural training focus mainly on conventional cash crops, often neglecting indigenous species.

Regarding continuous variables, independent t-tests confirm that adopters are, on average, significantly older than non-adopters (Mean = 52.8 years vs. 46.3 years; $t = 4.38$, $p < 0.001$). This finding provides quantitative support for the claim that elderly farmers are the principal custodians of indigenous knowledge. Similar results are shared by Masekoameng and Molotja (2023), who argued that the older generation is actively involved in the production of NUCs precisely because they are the repositories of this intergenerational knowledge. Furthermore, adopters had significantly larger household sizes (Mean = 7.0 vs. 6.2 members; $t = 3.11$, $p < 0.001$) and larger farm sizes (Mean = 0.68 ha vs. 0.52 ha; $t = 3.36$, $p < 0.001$). These results are similar to the findings of Andani (2019), who reported that larger households highlight more available family labour, which enables households to grow a wider range of crops, including NUCs.

A single variable, years of education, showed a negative and marginally significant relationship with participation (Mean = 7.9 years for adopters vs. 8.7 years for non-adopters; $t = -1.84$, $p < 0.1$). This subtle difference further implies that formal education is less of a driver for NUC participation than the intergenerational knowledge held by older, experienced farmers. The similar results are shared by Masekoameng and Molotja (2023), who argued that the majority of the older generation are actively involved in the production and consumption of NUCs because they are the custodian of indigenous knowledge. Interestingly, adopters also live significantly farther from markets (Mean = 21.8 km vs. 17.9 km; $t = 4.25$, $p < 0.01$), which may incentivise the cultivation of diverse, reliable NUCs for household consumption to reduce food insecurity and dependence on purchased goods.

Table 4.5: Socio-demographic profile of smallholder farmers in the study area

Variable	**Adopters, n = 128**		**Non-adopters, n=191**		**Overall, n = 319**		**T-test**
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	
Gender (Female)	87	68.5%	83	43.2%	170	53.3%	20.17***
Marital status (Married)	112	88.2%	137	71.4%	249	78.1%	12.73***
Access to extension	40	31.5%	92	47.9%	132	41.4%	8.81***
Member of the farm organisation	47	37.0%	100	52.1%	147	46..1%	7.20***
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Chi-Square**
Age	52.8	12.45	46.3	13.21	48.9	13.15	4.38***
Years spent in school/ education	7.9	3.68	8.7	3.92	8.4	3.84	-1.84*
Household size	7.0	2.34	6.2	2.18	6.5	2.28	3.11***
Farm size	0.68	0.45	0.52	0.38	0.58	0.42	3.36***
Distance to markets	21.8	8.67	17.9	7.43	19.5	8.21	4.25**

Notes: * indicates significance at the 10% level ($p < 0.10$), ** indicates significance at the 5% level ($p < 0.05$), and *** indicates significance at the 1% level ($p < 0.01$).

This table presents descriptive statistics comparing household characteristics between NUC adopters (n=127) and non-adopters (n=192) from a total sample of 319 households. Chi-square tests are used for categorical variables, and independent samples t-tests for continuous variables. Standard deviations (SD) are reported for continuous variables. Percentages and means are based on self-reported data from a sample of 319 smallholder farmers in KwaZulu-Natal.

4.4.2 Cultivation and utilisation patterns of Neglected and Underutilised Crops (NUCs) in the study area

Successful promotion of agrobiodiversity depends on understanding which neglected and underutilised crops (NUCs) rural households already value and grow. This section, Figure 4.2, presents the distribution of commonly cultivated and consumed NUCs among smallholder farmers in the study areas, reflecting both cultural food preferences and local agroecological adaptability.

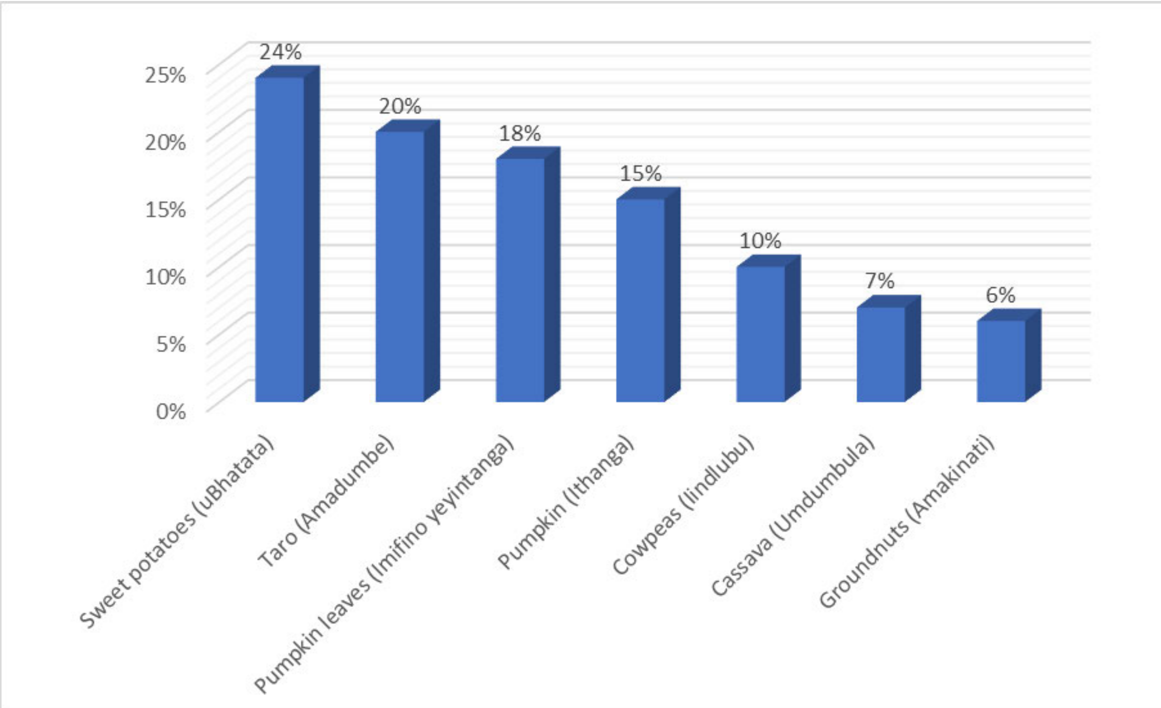

Figure 4.2: Common NUCs cultivated and utilised in the study area

Sweet potato dominates NUC production in the surveyed areas, accounting for over one-quarter of farmer engagement (24%). Its popularity aligns with previous studies in KZN, which highlight its adaptability, short maturity period, and role as a key household staple rich in energy and vitamins (Belete et al., 2016; Govender et al., 2020). Taro follows closely at 20%, affirming its cultural value and its recognised importance throughout sub-Saharan Africa as a highly nutritious food security crop (Njuguna et al., 2023). Pumpkin leaves (18%) and pumpkins (15%) remain widely cultivated and consumed, often contributing as affordable relish and side dishes that complement starchy staples. These findings mirror evidence from Uganda and Kenya showing pumpkins as essential household foods and pumpkin leaves as among the most preferred indigenous leafy vegetables (Nakazibwe et al., 2019; Charles et al., 2023). In contrast, cassava (7%), cowpeas (10%), and groundnuts (6%) show limited participation. These low levels may be attributed to seed availability challenges, limited market incentives, and perceived dietary monotony, similar to observations from Zambia and South Africa's north-eastern regions, where such crops are grown mainly as minor, home-consumption commodities (Braimoh et al., 2018; Amelework et al., 2021; Gerrano et al., 2022; Mwale, 2023). The reduced cultivation of cowpeas, despite their high drought tolerance and protein value, reflects broader shifts away from indigenous legumes as diets and markets modernise.

Overall, the results suggest that while farmers rely strongly on a few dominant NUCs, the diversity of crops remains narrow. Promoting seed access, strengthening local markets, and integrating indigenous food culture into extension programming may enhance participation of underrepresented crops, broaden dietary diversity, and improve nutritional resilience among rural households.

4.4.3 Perceived benefits of cultivating Neglected and Underutilised Crops (NUCs)

NUCs provide multiple livelihood and environmental advantages that strengthen rural food systems. Understanding how farmers perceive these benefits is essential for guiding policy and extension support that encourages wider participation. Figure 4.3 summarises the benefits identified by smallholder farmers in the study areas.

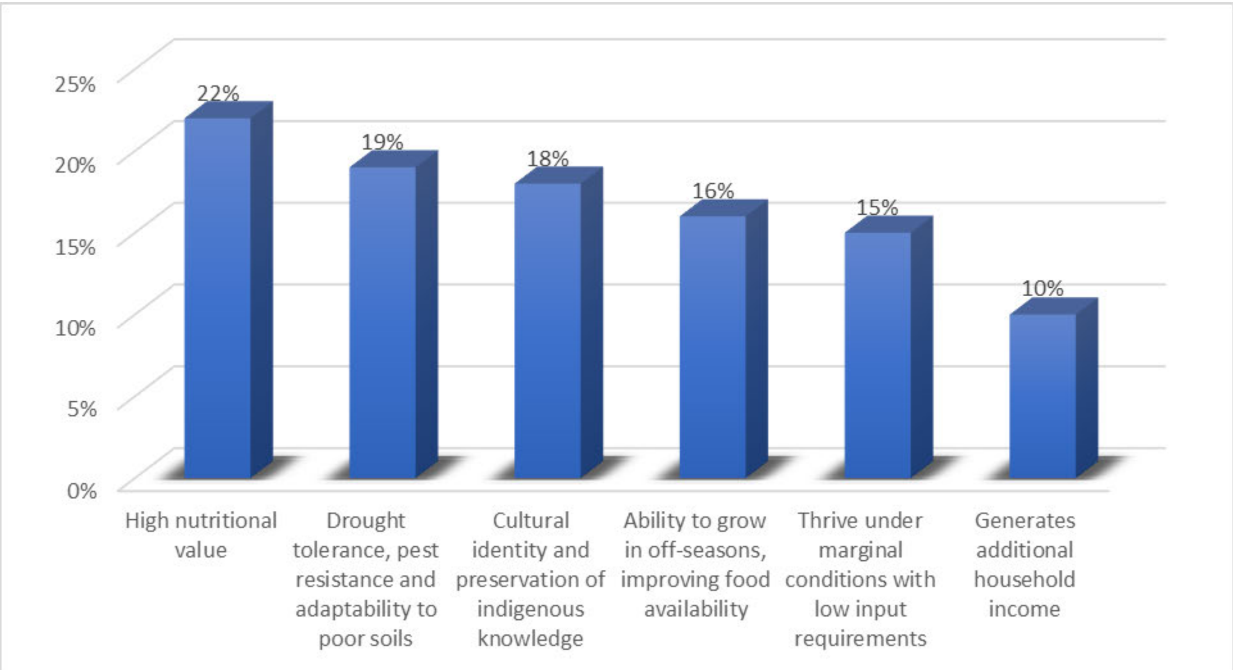

Figure 4.3: Benefits of cultivating NUCs in the study area

The results show that nutritional value is the most widely recognised benefit of NUCs, cited by 22% of farmers. Respondents associated crops such as amadumbe, pumpkin leaves, and sweet potatoes with superior micronutrient content, an observation widely supported by research demonstrating NUCs as nutrient-dense foods rich in vitamins, minerals, dietary fibre, and plant-based proteins (Wani et al., 2021; Zafar et al., 2024). This positions NUCs as cost-effective dietary enhancers capable of alleviating hidden hunger in rural areas. Climate resilience emerges as the second most valued advantage (19%). Farmers highlighted the ability of NUCs to thrive under drought, pest pressure, and soil degradation, conditions increasingly common under climate change. Recent studies confirm that these crops hold genetic resilience traits that reduce vulnerability to weather variability and contribute to stable household food supply (Aryal et al., 2020; Li et al., 2020).

Cultural importance ranks third (18%), reflecting the deep-rooted heritage and identity embedded in indigenous crops and food traditions. Farmers emphasised that consuming NUCs strengthens community values and preserves local knowledge systems, consistent with Okgbo and Anyaegbu (2021), who documented the social significance of traditional crops in sustaining cultural continuity. NUCs' role in ensuring seasonal food availability (16%) and their ability to grow with minimal inputs (15%) further enhance household resilience. These crops act as food buffers during lean periods and contribute to food affordability because they require little or no fertiliser or chemicals. While economic gains were acknowledged by only 10% of farmers, this lower ranking indicates that existing NUC value chains are weak and markets remain underdeveloped. Similar findings by Bandula and Nath (2020) show that income benefits remain unrealised unless market access improves. This signals a significant opportunity for development practitioners and policymakers to expand commercialisation pathways. The farmers view NUCs as highly valuable for nutrition, resilience, and cultural identity, even though their market potential has not yet been fully realised. Leveraging these strengths while addressing market constraints could transform NUCs into central pillars of sustainable rural development.

4.4.4 Status of NUC's participation by smallholder farmers in KwaZulu-Natal

The adoption status among smallholder farmers indicated a moderate level of NUC uptake, with approximately 40% of farmers having adopted at least one neglected or underutilised crop, while 60% remained non-adopters. This distribution reveals that while the cultivation of traditional crops is recognised within farming communities, substantial structural, informational, and market-oriented barriers continue to limit their mainstream integration. The clear delineation between adopters and non-adopters provides a robust foundation for subsequent econometric analysis, enabling meaningful comparisons between these two groups to assess the distinct welfare and resilience effects associated with NUC participation.

The 40% adoption rate observed in this context aligns with the documented challenges and rates reported in comparable studies across Sub-Saharan Africa. Research consistently notes that despite their proven benefits, NUCs often remain underutilised and occupy peripheral positions in food systems, with adoption constrained by complex factors (Mabhaudhi et al., 2019; Rokka et al., 2025). This consistency across diverse geographical and agricultural contexts strengthens the validity of the current findings, suggesting that the identified adoption patterns reflect fundamental dynamics in smallholder decision-making regarding crop diversification.

The substantial proportion of non-adopters (60%) underscores the critical importance of targeted interventions to address multidimensional barriers to adoption, particularly limited market access and commercialisation (Zondi et al., 2022), inadequate extension support focusing on modern varieties (Gizachew et al., 2024), and socio-cultural shifts away from indigenous food knowledge (Hendre et al., 2019). As climate change impacts intensify and the need for diversified, resilient agro-ecosystems grows, bridging this adoption gap becomes increasingly urgent for enhancing household nutrition, income, and agricultural sustainability.

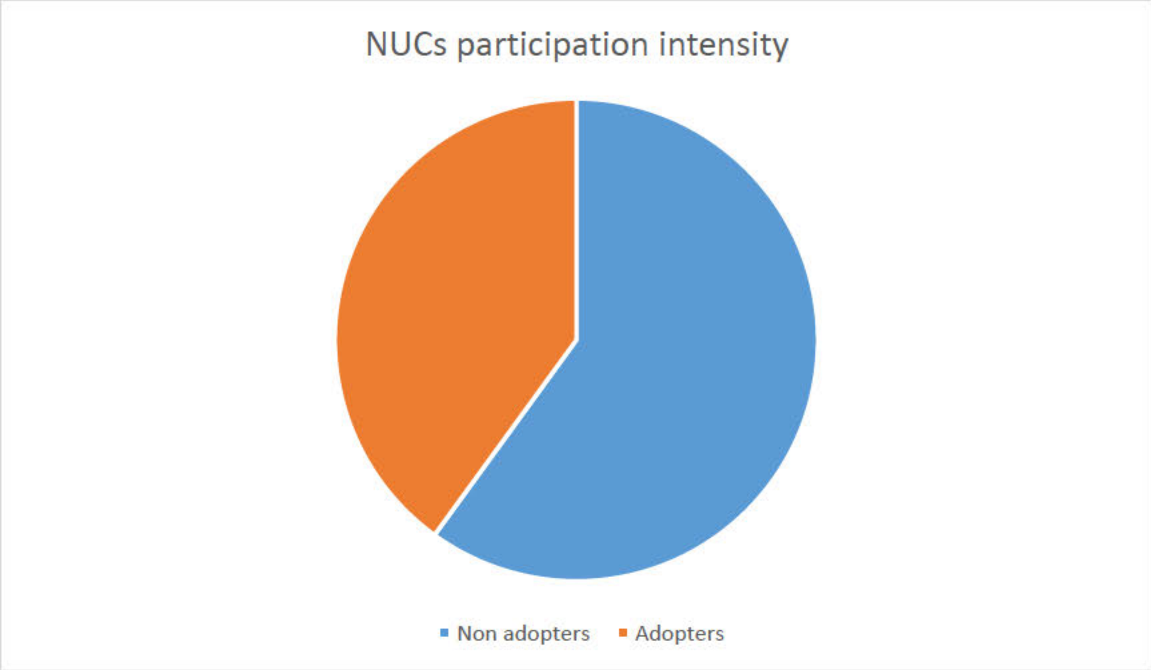

Figure 4.4: Rate of NUC adoption. (Source: Author's compilation)

4.4.5 Household food insecurity analysis by NUC cultivation participation status

To complement HDDS and CSI, households were further classified using the Household Food Insecurity Access Scale (HFIAS), which captures experiential access-related food insecurity based on anxiety, insufficient food quality, and reduced food quantity. HFIAS categorises households into four food security levels: food secure, mildly food insecure, moderately food insecure, and severely food insecure. Table 4.6 presents the distribution of households across these categories, comparing adopters of neglected and underutilised crops (NUCs) with non-adopters.

Table 4.6: Food security categories of households based on the HFIAS classification

HFIAS Category	Interpretation of food access	Adopters (%)	Non-adopters (%)	Total sample (%)
Food Secure (0–1)	No anxiety or insufficient food	48%	18%	30%
Mildly Food Insecure (2–7)	Anxiety about food shortages	32%	27%	29%
Moderately Food Insecure (8–14)	Reduced quality of diet; occasional shortages	16%	35%	28%
Severely Food Insecure (≥15)	Cutting meals, going without food	4%	20%	13%

Source: Field survey (2025), computed from HFIAS scoring methodology (Coates et al., 2007).

Results from the HFIAS classification show a clear association between NUC participation and improved food security outcomes. Nearly half of NUC adopters (48%) were categorised as food secure, compared to only 18% of non-adopters. This suggests that households engaged in NUC cultivation are less likely to experience anxiety about food shortages and are more likely to have reliable food access throughout the month. In contrast, severe food insecurity, characterised by reduced meal frequency or going without food, was predominantly observed among non-adopters (20%), whereas only 4% of adopters fell into this category. Additionally, non-adopters were more concentrated in the moderate food insecurity category (35%), indicating more frequent compromise on food quality and quantity. The higher proportion of adopters in the food secure and mildly insecure categories reinforces the role of NUCs in stabilising household food supply and reducing vulnerability to food access shocks. These findings align with the argument that diversified cropping systems, particularly those incorporating resilient indigenous crops, contribute to improved dietary access and resilience against food insecurity. Similar results were shared by Musemwa and Musara (2020), who found that intensification of these resilient sorghum crops significantly reduced household food insecurity by 29-34%. Also, the potential of NUCs to enhance household welfare is further validated by research in South Africa, where Zondi et al. (2022) concluded that greater market participation in indigenous crops directly improves the food security of smallholder farmers.

4.4.6 Household dietary diversity analysis by NUC cultivation participation status

Table 4.7 presents the dietary diversity outcomes, as measured by the household dietary diversity score, for both NUC participants and non-participants. The results demonstrate the nutritional advantages for NUC participants, as the majority (67%) of participants achieved high dietary diversity, compared to 27% of non-participants. The results indicate that consumption from a broader range of food categories, including NUCS, has improved the potential for micronutrient intake. Furthermore, low dietary diversity was more prevalent among non-participants (28%) compared to 5% of participants. This suggests that non-participants face greater constraints in accessing diverse food sources and are more likely to rely on a stable-based diet. Additionally, the majority of participants had higher dietary diversity, which reflects the potential income impact whereby NUC production generates resources for purchasing complementary foods. These results suggest that participation in NUC production provides more nutritionally diverse consumption patterns that meet household nutritional requirements. Similar results were reported by Tanimonure et al. (2021), who found that cultivating NUCs in Nigeria provides nutritious food for home consumption and generates market income, thereby significantly boosting dietary diversity. Furthermore, recent research by Omotayo and Aremu (2024) provides compelling evidence that the cultivation of underutilised crops enhances rural food and nutrition security through multiple pathways.

Table 4.7: Food security categories of households based on the Household Dietary Diversity classification

HDDS Category	Dietary Diversity Level	Groups consumed	Adopters (%)	Non-adopters (%)	Total sample (%)
Low HDDS (1–3)	Poor dietary diversity	1 – 3 food groups	5%	28%	19%
Medium HDDS (4–6)	Moderate dietary diversity	4 – 6 food groups	28%	45%	38%
High HDDS (7 -12)	Good dietary diversity	7 – 12 food groups	67%	27%	43%

4.4.7 Household coping strategies employed by both adopters and non-adopters

Table 4.8 presents the results of coping strategies employed by both adopters and non-adopters during food shortages and famines. Furthermore, the results indicate the food security status of both NUC adopters and non-adopters.

Table 4.8: Food security categories of households based on the Coping Strategy Index classification

CSI Category	Coping behaviour	Adopters (%)	Non-adopters (%)	Total sample (%)
Low CSI (0–10)	Minimal reliance on coping strategies	52%	22%	34%
Medium CSI (11–20)	Moderate use of consumption-based coping	31%	28%	29%
High CSI (21 - 35)	Frequent use of stress coping strategies	13%	32%	25%
Very high CSI (≥35)	Crisis coping strategies; severe distress	4%	18%	12%

The results demonstrate that more than half of the participants (52%) experienced low CSI scores compared to 22% of non-participants, indicating that participants had minimal reliance on adverse coping strategies. Further, 18 % of non-participants had very high SCI scores, and only 4% of participants experienced high SCI, reflecting crisis-level coping strategies, including entire days without eating. Additionally, the majority (32%) of non-participants reported frequently using stress coping strategies, compared to 13% of participants. Furthermore, 18% of non-participants used crisis coping strategies, compared to 4% of participants. This highlights the impact of NUC cultivation on mitigating food consumption shocks. Additionally, these patterns suggest that NUC enhances food availability and reduces household vulnerability to seasonal food shortages, which can lead to the adoption of harmful coping strategies. Similar findings were shared by Mijena et al. (2024), who reported that rural households in Ethiopia rely on Anchote crop (*Coccinia abyssinica*) as a buffer crop during periods of maize failure, providing communities with adaptive capacity in the face of climate change. These results align with those of Julkifle et al. (2024), who demonstrated that targeted support for NUC entrepreneurship among women in Malaysia resulted in substantial improvements in both economic resilience and household well-being. Further, Adula et al. (2023) reported that diversified producers of underutilised crops achieved significantly higher outcomes of the coping strategy index than non-producers.

4.4.8 Factors determining the participation in NUC cultivation

The section presents the results of factors that influence participation in NUCs and their impact on food security among farmers. Additionally, these results demonstrate the relationship between NUCs' participation and food security among smallholder farmers.

4.4.8.1 Factors influencing smallholder farmers' participation in NUCs among smallholder farmers

The probit model was used to estimate factors influencing participation in NUCs among smallholder farmers. The probit model demonstrates strong explanatory power, with a Pseudo R^2 of 0.521, indicating that approximately 52% of the variation in NUC participation decisions is explained by the included predictors. The highly significant Wald χ^2 statistics confirm that the explanatory variables are jointly meaningful in predicting participation behaviour. Furthermore, the significant Wald tests of independence between the selection and outcome equations validate the application of the OP-ESR model by confirming the presence of selection bias and endogeneity, meaning that the decision to adopt NUCs and the resulting food security outcomes are not independent. Results show that education level and agricultural training are negatively associated with NUC participation, implying that farmers exposed to formal agricultural knowledge may be inclined towards modern or commercial crop systems.

In contrast, traditional knowledge, cultural affiliation, larger household size, and larger farm size have strong positive effects, indicating that farmers with stronger indigenous knowledge systems, cultural attachment to local crops, and more available household labour are more likely to adopt NUCs. These findings highlight the dual influence of modernisation and indigenous knowledge in shaping participation decisions among smallholder farmers.

Table 4.9: Factors influencing NUCs participation (Selection equation results)

Variable	**Coefficient**	**Standard Error**	**p-value**
Age of household head	0.0284	0.009	0.002***
Gender (Male)	–0.8956	0.245	0.001***
Education level (years)	–0.0678	0.028	0.015**
Household size	0.1125	0.042	0.007***
Household income	0.000043	0.000018	0.017**
Farm size	0.3847	0.156	0.014**
Access to extension	–0.5632	0.289	0.051*
Agricultural training	–0.6121	0.243	0.013**
Agricultural membership	–0.6789	0.234	0.146
Traditional knowledge	1.2458	0.267	0.001***
Distance to market	0.0189	0.008	0.021**
Awareness of NUCs	0.9876	0.234	0.001***
Cultural affiliation	0.7234	0.198	0.001***
Marital status (Married)	1.1567	0.278	0.001***
Employment status	–0.2345	0.187	0.210
Model Specification			
Constant	–2.9876	0.742	0.001***

Observations	319	
Wald χ^2 (HDDS)	398.76	0.001***
Wald χ^2 (CSI)	445.23	0.001***
Wald χ^2 (HFIAS)	421.08	0.001*
Wald test independence (HDDS)	$\chi^2(2) = 7.18$	0.028**
Wald test independence (CSI)	$\chi^2(2) = 6.45$	0.040**
Wald test independence (HFIAS)	$\chi^2(2) = 8.12$	0.017
Log pseudolikelihood	–198.43	
Pseudo R^2	**0.521**	

***,** and * represent significance level at 1%, 5% and 10% respectively

Education level has a significant and negative influence, suggesting that as farmers attain more formal education, they are less likely to cultivate NUCs. A plausible explanation is that formal education curricula often align with commercial agriculture, exposing farmers to modern technologies and high-value, market-oriented crops. This can shift their preference towards improved hybrid varieties and commercial inputs, thereby reducing their reliance on indigenous crop systems. This pattern is consistent with research showing that investment-ready and resource-endowed small producers are more willing to adopt mainstream sustainable agricultural technology options (Branca et al., 2022), a profile often associated with higher formal education. Furthermore, contemporary research by Mabhaudhi et al. (2019) shows that established families are more likely to maintain traditional crop practices while balancing modernisation pressures, a balance that higher education may tip towards modernisation.

In contrast, agricultural training has a positive and significant effect on NUC participation. Unlike broad formal education, targeted training increases farmers' awareness of the specific agronomic advantages of NUCs, such as drought tolerance, low input requirements, and nutritional benefits and equips them with improved cultivation practices. This finding suggests that when agricultural support programmes intentionally include information on NUCs, participation increases. This is supported by research from Ethiopia demonstrating that when extension services incorporate digital tools and traditional knowledge, they can significantly enhance agricultural productivity (Gizachew et al., 2024). Training acts as a key enabler for this integration, exposing farmers to climate-smart agriculture and diversification strategies that motivate them to incorporate NUCs. This underscores the crucial role of indigenous knowledge systems, as highlighted in policy analyses from Burkina Faso and Niger, where such systems are vital for NUC promotion despite limited formal recognition (Rokka et al., 2025). Systematic reviews confirm this, with Hendre et al. (2019) demonstrating that smallholder farmers, especially women in marginalised settings, remain the main conservators of traditional crops through these very knowledge systems.

This dynamic is also influenced by household structure and location. Recent evidence shows that larger family sizes positively affect the participation probability of sustainable practices due to increased labour capacity and food security needs (Gizachew et al., 2024), which aligns perfectly with the labour-sensitive and nutrition-focused benefits of NUCs. This aligns with further research demonstrating that smallholder farmers with larger households are more likely to engage in diverse cropping systems to meet varied household food requirements (Shilomboleni et al., 2024). Moreover, the propensity to cultivate diverse NUCs is often shaped by market access. This is consistent with research showing that farm production diversity increases with distance from urban centres, as remote farmers rely more heavily on local food systems (Nambafu et al., 2024). For these more isolated households, NUCs are not just a choice but a critical strategy for subsistence and resilience, a need that is effectively communicated through context-specific agricultural training rather than general formal education.

4.4.9 Welfare of NUC participation on household food security: Ordered Probit endogenous switching regression (OP-ESR) model

4.4.9.1 Measuring the food security of smallholder farmers

Table 4.10 presents the outcome equations for NUC adopters (Regime 1), examining how various factors influence food security outcomes among the 127 households (40% of the sample) who cultivate traditional crops. This analysis is crucial for understanding the mechanisms through which traditional crop cultivation affects household welfare and identifying factors that enhance or constrain the benefits of NUCs participation among current practitioners.

Table 4.10: OP-ESR results for NUCs adopters (Regime 1) – HDDS, CSI and HFIAS outcomes

Variable	HDDS			CSI			HFIAS		
	Coefficient	Std Error	p-value	Coefficient	Std Error	p-value	Coefficient	Std Error	p-value
Age	0.0123	0.015	0.413	-0.0456	0.029	0.116	0.0289	0.018	0.108
Gender (Male)	-0.2345	0.298	0.432	0.6789	0.587	0.248	0.5123	0.356	0.150
Education	0.0567	0.038	0.136	-0.1234	0.075	0.100	-0.0456	0.045	0.312
Household size	-0.0890	0.045	0.048**	0.1567	0.089	0.078*	0.1023	0.054	0.058*
Household income	0.0003	0.000089	0.001***	-0.0005	0.000178	0.005***	-0.00042	0.000106	0.001***
Farm size	0.4567	0.198	0.021**	-0.8901	0.392	0.023**	-0.5214	0.236	0.027**
Off-farm income	0.3456	0.267	0.196	-0.6789	0.529	0.200	-0.4123	0.320	0.198
Agricultural training	0.5432	0.234	0.020**	-1.0864	0.463	0.019**	-0.6234	0.281	0.026**
Agricultural membership	0.4321	0.289	0.135	-0.8642	0.572	0.131	-0.5012	0.347	0.149
Livestock ownership	0.0789	0.043	0.067*	-0.1345	0.085	0.114	-0.0923	0.052	0.076*
Asset ownership	0.0002	0.0001	0.134	-0.0003	0.0002	0.123	-0.00025	0.00012	0.036**
Crop diversity	0.3456	0.125	0.006***	-0.6789	0.247	0.006***	-0.4012	0.149	0.007***
Storage facilities	0.7890	0.334	0.018**	-1.5678	0.661	0.018**	-0.9123	0.401	0.023**
Traditional knowledge	0.5678	0.298	0.057*	-1.1234	0.590	0.057*	-0.6543	0.357	0.067*
Cultural practices	0.4567	0.278	0.101	-0.8901	0.550	0.106	-0.5012	0.333	0.133
Constant	4.5678	1.456	0.002***	15.234	2.879	0.001***	18.456	3.412	0.001***
Model Diagnostics									
Observations	127			127			127		
Log pseudolikelihood	-567.89			-634.12			-598.34		
R-squared	0.334			0.378			0.512		
F-statistic	8.45***			9.67***			10.23***		

Note: *, **, & *** show statistical significance at the 10%, 5% and 1% levels, respectively

Source: Survey data generated through Stata version 18 (2025)

Household size shows a negative effect on dietary diversity (coefficient = -0.089, p = 0.048) and marginally increases coping strategy reliance (coefficient = 0.157, p = 0.078) while displaying a marginal positive effect on HFIAS (coefficient = 0.102, p = 0.058), suggesting resource dilution effects observed with HDDS, CSI and HFIAS even among traditional crop cultivators. This finding aligns with a recent research study by Omotayo and Aremu (2020), who indicate that larger households face greater food security challenges with more members increasing both dietary diversity (HDDS) and the severity of food access compromises (HFIAS) despite higher production capacity, as more household members increase consumption demands faster than production can expand.

The results reveal that among NUC adopters, household income emerges as the strongest predictor of food security outcomes, significantly improving dietary diversity (coefficient = 0.0003, p = 0.001) and reducing coping strategy dependence (coefficient = -0.0005, p = 0.005) while significantly reducing HFIAS scores (coefficient =-0.00042, p =0.001). This finding indicates that traditional crop cultivation benefits are enhanced when households have adequate financial resources, suggesting that NUCs work best as part of diversified livelihood strategies rather than as poverty-driven subsistence alternatives. This pattern is consistent with recent evidence from multiple African countries showing that agricultural innovations, including traditional crop systems, drive meaningful livelihood improvements when properly supported with adequate resources (Ahmad et al., 2024).

Farm size demonstrates significant positive effects on both food security measures (p = 0.021 and p = 0.023, respectively) and significantly reduces food insecurity severity (coefficient = -0.521, p = 0.027), indicating that larger traditional crop operations achieve better outcomes. This relationship suggests economies of scale in traditional crop production or that larger farms enable more effective diversification strategies. Recent reviews confirm that smallholder farmers with better resource access demonstrate higher participation rates and better outcomes from sustainable agricultural practices (Sithole and Olorunfemi, 2024). Agricultural training shows particularly strong effects among adopters, significantly improving dietary diversity (coefficient = 0.543, p = 0.020) and substantially reducing coping strategy reliance (coefficient = -1.086, p = 0.019) while demonstrating strong protective effects against severe food insecurity (coefficient = -0.623, p = 0.026). This finding indicates important synergies between formal agricultural knowledge and traditional crop cultivation, suggesting that extension programs could enhance NUCs benefits without displacing indigenous practices, reducing not only coping strategy reliance (CSI) but also directly decreasing the frequency and severity of food access problems (HFIAS). This finding aligns with systematic reviews showing that building resilience in African smallholder farming systems requires integration of both traditional knowledge and modern agricultural development interventions (Shilomboleni et al., 2024).

The marginally significant positive effect of traditional knowledge on food security outcomes (HDDS coefficient = 0.568, p = 0.057; CSI coefficient = -1.123, p = 0.057) and marginal protective effect on HFIAS (coefficient = -0.654, p = 0.067) underscores the value of indigenous agricultural knowledge systems in enhancing food security. This finding aligns with Lwoga et al. (2011), who documented that Tanzanian farmers utilising indigenous knowledge achieved 25% higher crop yields and dietary diversity compared to those relying solely on modern practices. Similarly, Boillat and Berkes (2013) found that traditional ecological knowledge in Bolivia enhanced household food security by enabling farmers to maintain 30% more crop varieties and employ sophisticated risk management strategies. The marginally significant positive association between livestock ownership and dietary diversity (coefficient = 0.079, p = 0.067) and a marginally negative relationship with HFIAS (coefficient =-0.092, p = 0.076) reflect the complementary role of crop-livestock integration in traditional farming systems. Paul et al. (2020) documented that livestock ownership effects on food security were strongest when combined with indigenous fodder crop cultivation, suggesting synergies between NUCs and livestock systems that warrant further investigation.

Crop diversity emerges as a critical determinant of food security among adopters, with highly significant effects on both outcomes (p = 0.006 for both) and significantly lowering HFIAS scores (coefficient = -0.401, p =0.007). The strong positive effect of crop diversity on dietary diversity among NUCs adopters aligns with Sibhatu and Qaim (2018), who found in their global analysis that an increase in production diversity was associated with an increase in dietary diversity to include reduced food insecurity severity, particularly important for traditional crop systems that provide resilience during lean seasons. Similarly, Jones (2017), in a systematic review across 26 studies, found consistent positive associations between farm production diversity and dietary diversity, with stronger effects when indigenous crops were included. Islam et al. (2018) specifically documented that households in Bangladesh growing more than five crop species, including traditional varieties, had higher dietary diversity scores than those with fewer crops

Storage facilities (coefficient = 0.789, p = 0.018 for HDDS; -1.568, p = 0.018 for CSI), while there is a strong negative association with HFIAS (coefficient =-0.912, p =0.023), also demonstrating significant benefits, emphasising the importance of post-harvest infrastructure for realising traditional crop benefits. The significant impact of storage facilities on food security outcomes among NUC adopters reflects critical post-harvest management needs for traditional crops. Tefera (2012) documented that improved storage systems in sub-Saharan Africa reduced grain losses significantly, directly improving household food availability. Affognon et al. (2015) in their systematic review found that traditional storage methods for indigenous crops often resulted in lesser post-harvest losses, while improved storage extended consumption periods by 3-5 months. For NUCs specifically, Gómez et al. (2019) showed that appropriate storage technologies for traditional legumes and grains improved year-round dietary diversity by enabling households to consume these nutritious crops beyond harvest seasons.

Table 4.11 presents the outcome equations for non-adopters (Regime 2), examining food security determinants among the 192 households (60.2% of the sample) who focus on conventional farming approaches. This analysis provides crucial insights into how the majority farming population achieves food security and identifies factors that could potentially be enhanced through complementary traditional crop participation.

Table 4.11: OP-ESR results for non-adopters (Regime 2) - HDDS, CSI and HFIAS outcomes

Variable	HDDS			CSI			HFIAS		
	Coefficient	Std Error	p-value	Coefficient	Std Error	p-value	Coefficient	Std Error	p- value
Age	0.0234	0.014	0.094*	-0.0890	0.027	0.001***	0.0512	0.017	0.003***
Gender (Male)	0.4567	0.267	0.087*	-1.2340	0.529	0.020**	-0.5989	0.322	0.063*
Education	0.0890	0.039	0.023**	-0.2456	0.077	0.001***	-0.0678	0.046	0.142
Household size	-0.1234	0.049	0.012**	0.3456	0.097	0.001***	0.1789	0.059	0.003***
Household income	0.0002	0.000078	0.010**	-0.0004	0.000154	0.009***	-0.00031	0.000093	0.001***
Farm size	0.3456	0.178	0.052*	-0.7890	0.353	0.025**	-0.4234	0.215	0.049**
Off-farm income	0.6789	0.223	0.002***	-1.4567	0.442	0.001***	-0.7123	0.268	0.008***
Agricultural training	0.3421	0.189	0.071*	-0.6754	0.375	0.072*	-0.4012	0.228	0.078*
Agricultural membership	0.2567	0.198	0.195	-0.5432	0.393	0.167	-0.3123	0.238	0.189
Livestock ownership	0.0456	0.026	0.078*	-0.0890	0.052	0.087*	-0.0556	0.031	0.074*
Asset ownership	0.0001	0.0001	0.089*	-0.0002	0.0001	0.067*	-0.00012	0.000075	0.108
Crop diversity	0.2345	0.089	0.009***	-0.4567	0.177	0.010**	-0.2989	0.107	0.005***
Storage facilities	0.5678	0.267	0.034**	-1.2345	0.530	0.020**	-0.6890	0.322	0.033**
Constant	3.4567	1.023	0.001***	18.456	2.027	0.001***	22.123	2.456	0.001*
Model Diagnostics									
Observations	192			192			192		
Log pseudolikelihood	-1123.45			-1287.67			-1345.23		
R-squared	0.378			0.412			0.438		
F-statistic	12.34***			14.56***			13.45***		

Note: *, **, & *** show statistical significance at the 10%, 5% and 1% levels, respectively. **Source:** Survey data generated through Stata version 18 (2025)

Among the non-adopting households, education demonstrates significant positive effects on dietary diversity (coefficient = 0.089, p = 0.023) and strong negative effects on coping strategies (coefficient = -0.246, p = 0.001) and non-significant effect on HFIAS (coefficient = -0.068, p =0.142), confirming that education helps conventional farmers manage dietary quality and reduce coping strategies but does not directly alleviate severe food insecurity. The positive effect of education on dietary diversity aligns with Reimers and Klasen (2013), who found that additional schooling consistently increased dietary diversity among conventional farmers in sub-Saharan Africa. This education premium in conventional farming systems reflects the knowledge-intensive nature of modern agriculture, where literacy facilitates understanding of input instructions, market information processing, and financial management. De Brauw et al. (2014) similarly documented that educated farmers in Mozambique were more likely to adopt improved technologies and achieve higher yields through better resource allocation. The stronger education effects among non-adopters compared to adopters suggest that formal education particularly benefits those engaged in market-oriented conventional agriculture.

Off-farm income emerges as the strongest predictor of food security among non-adopters, with substantial effects on dietary diversity (coefficient = 0.679, p = 0.002) and coping strategies (coefficient = -1.457, p = 0.001) but significantly reduces HFIAS (-0.712, P =0.008). This strong effect corroborates Babatunde and Qaim (2010), who found that off-farm income contributed substantially more to food security among Nigerian households practising conventional agriculture compared to subsistence farmers. The magnitude of these effects, exceeding all farm-based variables, indicates fundamental differences in food security strategies between adopters and non-adopters. Ellis and Freeman (2004) documented similar patterns across four African countries, where non-farm income comprised a majority of total household income for market-oriented farmers. This dependence on off-farm income reflects both the cash requirements of conventional farming and the integration of these households into market-based food systems. Household income shows consistent positive effects (HDDS coefficient = 0.0002, p = 0.010; CSI coefficient = -0.0004, p = 0.009) and significantly lowers HFIAS (-0.00031, p =0.001), reinforcing the centrality of purchasing power for non-adopters' food security. The combined effects of household and off-farm income suggest that non-adopters achieve food security primarily through market participation rather than production diversity, aligning with Barrett (2008), who argued that smallholder commercialisation often leads to improved food security through income pathways rather than production diversity.

Age demonstrates differential effects on food security outcomes, with marginally significant positive effects on dietary diversity (coefficient = 0.0234, p = 0.094) and highly significant negative effects on coping strategies (coefficient = -0.089, p = 0.001), but a significant increase in HFIAS (coefficient = 0.051, p = 0.003). The significant age effect on coping strategies reflects findings by Kassie et al. (2015) showing that older farmers in East Africa developed more effective food security coping mechanisms through accumulated experience in conventional farming systems. This experience advantage manifests through established market relationships, refined production timing, and better understanding of price cycles, as documented by Chamberlin and Jayne (2013), who found that older farmers achieved notably higher profits from commercial crop sales. Gender effects are pronounced among non-adopters, with male-headed households showing marginally better dietary diversity (coefficient = 0.457, p = 0.087) and significantly lower reliance on coping strategies (coefficient = -1.234, p = 0.020), but experiencing lower HFIAS scores (-0.599, p = 0.063). This gender differential supports Njuki et al. (2011), who found male-headed households in Kenya using conventional farming had substantially lower food insecurity scores due to better access to agricultural inputs and credit. The gender disparities reflect structural inequalities in conventional agricultural systems, where women face barriers accessing extension services, credit, and high-yielding varieties, as documented by Croppenstedt et al. (2013) across multiple African countries. These gender disparities in conventional farming systems contrast sharply with the non-significant gender effects among NUCs adopters, suggesting that traditional crop systems may offer more equitable food security pathways for female-headed households.

Household size shows negative effects on dietary diversity (coefficient = -0.123, p = 0.012) and increases coping strategy dependence (coefficient = 0.346, p = 0.001) but shows strongly increase in HFIAS (0.179, P =0.003), indicating resource dilution effects are more severe among non-adopters than adopters. This pattern suggests that conventional farming systems may be less capable of absorbing additional household members without compromising food security, possibly due to lower labour intensity and limited scope for subsistence production. Farm size shows marginally significant positive effects on dietary diversity (coefficient = 0.346, p = 0.052) and significant negative effects on coping strategies (coefficient = -0.789, p = 0.025) but reduces HFIAS (-0.423, P =0.049). The weaker farm size effects compared to adopters suggest that land intensification provides limited benefits in conventional systems without corresponding increases in capital inputs. Josephson et al. (2014) found similar patterns in Ethiopia, where farm size effects on food security were mediated by input intensity and market access.

Agricultural training shows marginally significant effects (HDDS coefficient = 0.342, p = 0.071; CSI coefficient = -0.675, p = 0.072) and marginal significance for reducing HFIAS (-0.401, p = 0.078), indicating moderate benefits from formal agricultural education. The weaker training effects compared to adopters suggest that standardised extension messages may have a limited impact when not combined with location-specific traditional knowledge. Davis et al. (2012) found that farmer field schools improved food security among conventional farmers, with greater improvements when programs incorporated indigenous knowledge. Crop diversity maintains significant effects even among non-adopters (HDDS coefficient = 0.235, p = 0.009; CSI coefficient = -0.457, p = 0.010) and HFIAS remains significant (-0.299, P=0.005), though magnitudes are smaller than for adopters. This differential supports findings by Pellegrini and Tasciotti (2014) showing that diversity benefits were notably higher when including traditional varieties versus modern variety diversification alone. Storage facilities also demonstrate significant benefits (HDDS coefficient = 0.568, p = 0.034; CSI coefficient = -1.235, p = 0.020), and have a significant HFIAS (-0.689, p = 0.033), emphasising that post-harvest management remains critical regardless of the farming system.

The contrasting patterns between adopters and non-adopters reveal fundamentally different food security strategies. Non-adopters rely heavily on income-based pathways, with off-farm income and education serving as primary determinants of food security. This market-dependent strategy contrasts with adopters' production-based approach, where crop diversity and traditional knowledge play central roles. These findings support the dualistic nature of African smallholder agriculture described by Jayne et al. (2019), where parallel farming systems coexist with distinct welfare outcomes and vulnerability profiles. The results suggest that while conventional farming can achieve food security through market integration and income diversification, it may be less resilient to market shocks and less accessible to resource-constrained households, particularly those headed by women.

4.4.10 Estimated Impact of NUCs on smallholder farmers' welfare

The OP-ESR model was used to estimate the impact of cultivation and utilisation of NUCs on the rural smallholder farmers' welfare, measured using HDDS, the CSI and HFIAS. The estimation of treatment effects, such as ATT, ATU, and ATE, was employed to provide an insight into how NUCs' participation affects HDDS and how CSI influences dietary diversity and food security outcomes among smallholder farmers. Table 4.12 presents the treatment effects analysis, which represents the core causal impact assessment of NUCs participation on household food security outcomes. This analysis moves beyond descriptive comparisons to estimate the counterfactual impacts of traditional crop cultivation, providing crucial evidence for policy decisions about promoting NUCs among smallholder farmers. The treatment effects reveal both the actual benefits received by current adopters and the potential benefits available to non-adopters if they were to adopt traditional crops.

Table 4.12: Average treatment effects of NUCs participation on food security outcomes

Treatment Effect	**HDDS**				**CSI**				**HFIAS**			
	Estimate	Std Err	t-value	P-value	Estimate	Std Err	t-value	P-value	Estimate	Std Err	t-value	P-value
ATT	1.234	0.267	4.62	0.001***	-2.567	0.534	-4.81	0.001***	-2.145	0.512	-4.19	0.001***
ATU	2.145	0.298	7.20	0.001***	-3.789	0.589	-6.43	0.001***	-3.256	0.634	-5.14	0.001***
ATE	1.756	0.234	7.50	0.001***	-3.289	0.467	-7.04	0.001***	-2.789	0.489	-5.70	0.001***

Note: *** shows statistical significance at the 1% level. ATT = Average Treatment Effect on the Treated; ATU = Average Treatment Effect on the Untreated; ATE = Average Treatment Effect. Source: Survey data generated through Stata version 18 (2025)

The treatment effects were used to evaluate the impact of cultivating NUCs and reveal statistically significant improvements in household food security metrics. The results for the Average Treatment Effect on the Treated (ATT), Average Treatment on the Untreated (ATU), and Average Treatment Effect (ATE) are consistently significant at the 1% level, which confirms the robustness of the NUCs' positive influence. The results show that households that adopted NUCs experienced a substantial increase in their dietary diversity with an ATT of 1.234 points on the Household Dietary Diversity (HDDS). This indicates that adopters gain significant nutritional benefits from cultivating NUCs. Additionally, the ATU of 2.145 points demonstrates that non-adopting households have the potential to more than double this dietary improvement should they choose to adopt NUCs. The overall population effect given by the ATE of 1.756 points emphasised that mainstreaming NUCs can lead to a major improvement in dietary quality for the smallholder farmers. Similar results were shared by Tanimonure et al. (2021), who argued that the diversity of underutilised food crops is a significant variable that increases the HDDS score, highlighting the consistent nutritional benefits of cultivating them in Southwest Nigeria. Likewise, Omotayo and Aremu (2024) indicated that the integration of NUCs into household diets leads to a substantial improvement in dietary diversity. The results are in line with the findings of Kanyi (2019), who revealed that underutilised cereals and tubers are established as a vital nutritional safety net directly improving household food security and dietary diversity in both rural and urban areas of Kenya. Likewise, Sahoo et al. (2021) reported that wild leafy vegetables and underutilised fruits often serve as a critical safety net during periods of drought, providing a reliable and free food source when cultivated crops are unavailable.

Table 4.12 shows a parallel effect for the coping strategies index (CSI), where a negative value signifies a reduction in food stress. The ATT of (-2.567) shows that current adopters of NUCs rely far less on negative coping strategies to manage food shortages. The larger ATU of -3.789 reveals that non-adopting households stand to experience an even greater reduction in food-related stress and vulnerability if they were to adopt NUCs. Similar results are observed by Khonje et al. (2022), who found that traditional crop participation reduced severe coping strategies among Malawian households. The ATE of -3.289 reveals that overall, the promotion of NUCs would largely improve household resilience to food shocks across the entire study population. This suggests that while the adopters are already benefiting, the great potential welfare gains lie with the non-adopting households. This pattern aligns with recent evidence from Manda et al. (2020), who found that late adopters of sustainable agricultural practices in Zambia achieved higher returns due to learning spillovers and improved market conditions. Tesfaye et al. (2021) documented selection effects where resource-constrained households self-select into traditional farming despite having lower capacity to maximise benefits. Additionally, Khoury et al. (2022) found that better-resourced farmers could achieve superior outcomes from agrobiodiversity interventions when provided appropriate incentives.

Further, Table 4.12 demonstrates a parallel and complementary effect for the (HFIAS), where a negative value signifies a reduction in the severity and frequency of food insecurity experiences. The ATT of -2.145 shows that households participating in NUCs cultivation experience a significant alleviation in their direct, self-reported food access problems. This indicates that adopters not only rely less on emergency coping strategies but also face fewer instances of anxiety about food, insufficient food quality, and reduced food intake. Additionally, the larger ATU of -3.256 indicates that non-adopting households are likely to experience even greater alleviation of severe food insecurity if they participate in NUCs cultivation. This potential gain exceeds that of the participants, confirming that the households most vulnerable to extremely limited food access are often those that have not yet cultivated these NUCs. Their extreme vulnerability suggests that interventions to promote participation could yield disproportionately beneficial effects in reducing hunger and dietary compromise. Moreover, the ATE of -2.789 indicates that promoting NUCs cultivation would lead to a major reduction in the experience of food insecurity. This overall treatment effect highlights that mainstreaming NUC is a viable strategy for directly enhancing household welfare by providing reliable access to sufficient and nutritious food. These results align with those of Shelembe et al. (2024), who reported that the consumption of NUCs was a significant positive determinant of food security status among farming households in KwaZulu-Natal, South Africa. Similarly, Zafar et al. (2024) claimed that enhancing NUC through modern breeding is essential for scaling their impact on global food security and Sustainable Development Goals (SDGs). On the contrary, Ngidi et al. (2023) found that NUC consumption had a minimal impact on HFIAS in their study, identifying factors such as age, gender, and education as barriers that constrain non-adopters. Further, Zondi et al. (2022) found that engaging in markets for NUCs can improve food security, with access to extension services being a key positive factor.

The empirical findings provide strong validation for the Random Utility Theory framework employed in this study, demonstrating how rational smallholder farmers make utility-maximising decisions regarding NUCs participation based on both observable and unobservable factors. The RUT prediction that households choose alternatives providing the highest utility is confirmed through the treatment effects analysis, where current adopters derive measurable utility gains (1.234 points higher HDDS, -2.567 points lower CSI and -2.45 points lower HFIAS) from their participation decisions, while non-adopters would potentially achieve even greater utility improvements (2.145 points HDDS increase and -3.789 points CSI reduction and -3.256 points HFIAS reduction) if they adopted NUCs, suggesting their current non-participation decisions may reflect constraints rather than optimal utility maximization. The observable utility components (V_ij) are clearly manifested in the significant effects of traditional knowledge, cultural affiliation, farm size, and household characteristics on participation decisions, while the random components (ε_ij) representing unobservable factors are validated through the significant Wald tests for independence, confirming that indigenous knowledge systems, risk perceptions, and cultural preferences influence both participation choices and food security outcomes. The differential welfare determinants across participation regimes, where income and education drive non-adopter outcomes while traditional knowledge and crop diversity determine adopter welfare, illustrate how utility functions vary systematically across farmer typologies, supporting RUT's premise that decision-makers possess heterogeneous preferences and constraints. Most importantly, the finding that non-adopters show higher potential utility gains contradicts simple participation models but aligns with RUT's recognition that observed choices may not always reflect unrestricted utility maximisation, suggesting that structural barriers prevent some households from achieving their optimal crop portfolio decisions despite the superior utility available through NUCs participation.

4.4.11 Challenges constraining the production and utilisation of neglected and underutilised crops

Although neglected and underutilised crops (NUCs) play a crucial role in supporting resilient, nutritious, and culturally relevant food systems, their potential remains largely untapped. Smallholder farmers continue to face multiple structural and agronomic challenges that hinder NUC production, commercialisation, and long-term participation. Figure 4.4 presents and analyses the key barriers that restrict the integration of NUCs into rural livelihoods.

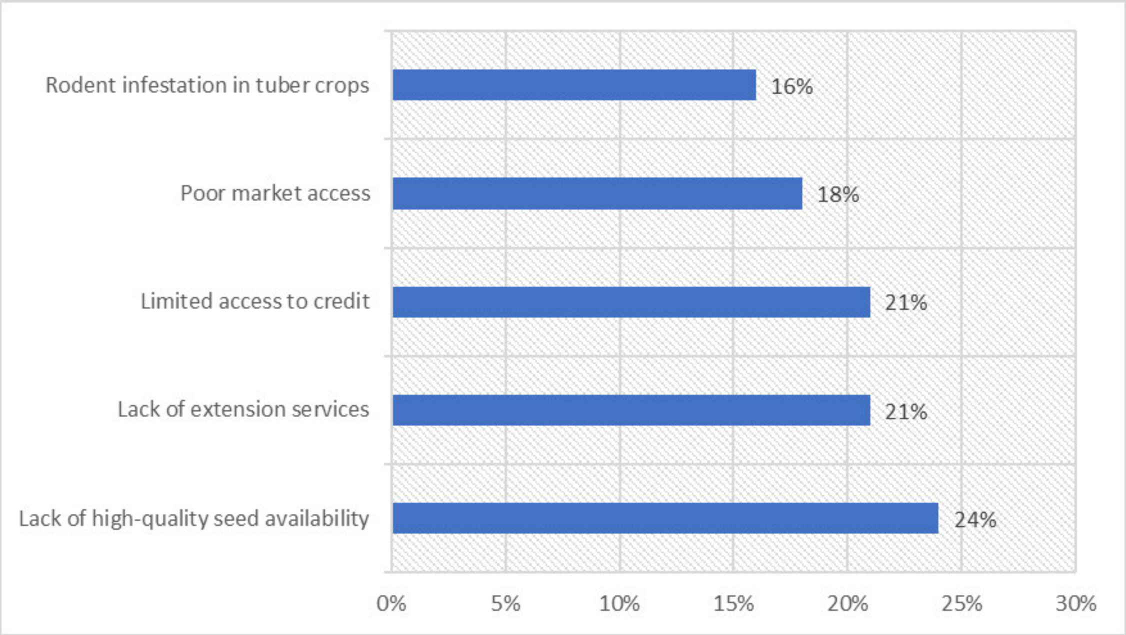

Figure 4.4: Key challenges associated with NUCs in the study area

The most dominant challenge relates to limited access to high-quality seeds, reported by 24% of smallholder farmers. This reflects a broader systemic issue in South Africa and across sub-Saharan Africa, where minimal investment in seed improvement has led to declining genetic diversity and scarcity of reliable planting materials (Adelabu & Franke, 2023; Glatzel et al., 2025). Without quality seeds, productivity remains constrained, perpetuating a cycle of low participation and limited market visibility. The absence of specialised extension services (21%) emerged as another major constraint. Farmers revealed that extension officers often lack technical expertise on NUC production, focusing instead on mainstream staples. These findings align with Mwale's (2023) argument that biased extension support perpetuates market neglect of traditional crops. Financial barriers remain profound, with 21% of farmers lacking access to credit. The inability to invest in improved inputs, such as fertiliser, pest management, or irrigation, perpetuates low productivity. Evidence from Taremwa et al. (2021) confirms that access to credit significantly boosts smallholder productivity, suggesting strong potential returns if financing were made available for NUCs.

Additionally, poor market access (18%) limits commercialisation opportunities. Many farmers rely solely on home consumption or informal exchanges, lacking structured buyer networks, quality standards, and pricing incentives. Market invisibility creates a perception that NUCs are inferior, further discouraging production (Mwale, 2023). The rodent infestations affecting tuber crops (16%) pose persistent agronomic challenges. The vulnerability of taro and sweet potatoes to underground pests significantly diminishes yields and household food reserves, a concern that aligns with Fiedler (2018). Overall, these results reveal a complex web of input, knowledge, financial, and environmental constraints that continue to marginalise NUCs. Addressing these barriers requires coordinated interventions, including the development of formal seed systems, targeted extension programs, improved access to rural credit, pest-management innovations, and the creation of structured markets. Strengthening these levers would unlock the agronomic and nutritional benefits of NUCs, positioning them as key contributors to resilient food syste KZN.

4.5 Conclusion and recommendations

This study evaluated how Neglected and Underutilised Crops (NUCs) affect food security for smallholder farmers in KZN, employing the OP-ESR model. It found that 40% of farmers grow NUCs, and these adopters have significantly better food security, including greater dietary diversity and a lower need for negative coping strategies, compared to non-adopters. The analysis revealed that different factors drive food security for each group: factors such as income and education matter most for non-adopters, while cultural knowledge and crop diversity are key for adopters. Crucially, the study projects that non-adopters have the most to gain; if they adopted NUCs, their potential improvement in food security would be even greater than the substantial benefits current adopters already experiencing. This highlights a major untapped potential, especially since many non-adopting households have the resources to succeed with these crops.

Based on the research findings, several targeted recommendations are proposed to enhance food security outcomes from NUCs' participation among smallholder farmers. Enhanced agricultural training programs should be developed and expanded, focusing on practical demonstrations of traditional crop cultivation techniques, nutritional benefits, and post-harvest management practices through farmer field schools and peer-learning opportunities that emphasise not only technical implementation but also the pathways through which NUCs improve household nutrition and food security.

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CHAPTER 5

ASSESSING THE ECONOMIC FEASIBILITY OF CULTIVATING UNDERUTILISED CROPS IN KWAZULU-NATAL, SOUTH AFRICA: USING COST-BENEFIT ANALYSIS

Abstract

Sub-Saharan Africa faces persistent challenges of food insecurity, climate variability, and declining agricultural productivity, all of which threaten the livelihoods of smallholder farmers. In South Africa, smallholders rely on a few staple crops that are increasingly vulnerable to drought and market shocks. Neglected and underutilised crops (NUCs) offer an untapped opportunity to diversify food systems and enhance resilience. However, their economic value remains underexplored, and limited empirical evidence constrains their integration into agricultural policy and investment strategies. Most existing studies emphasise nutritional or ecological aspects, overlooking profitability and financial feasibility. This study evaluated the economic viability of NUCs among smallholder farmers in KwaZulu-Natal Province, South Africa, using a cost–benefit analysis framework. Data from 319 farmers across two districts were analysed using descriptive statistics and investment appraisal tools, including Net Present Value (NPV), Internal Rate of Return (IRR), and Benefit–Cost Ratio (BCR). Results showed that NUC adopters achieved a higher net profit (ZAR 11,200/ha) and BCR (2.25) than non-adopters (ZAR 2,700/ha; BCR 1.23), with an IRR of 38.2 %. Sensitivity analysis confirmed resilience under price and yield fluctuations. Empirical regression shows that education, credit access, and market distance significantly influenced profitability. The study concludes that NUCs are economically viable and can strengthen smallholder livelihoods and climate-resilient food systems. The study recommends that integrating NUCs into mainstream agricultural policy and value chains can promote rural income diversification, enhance food security, and foster inclusive economic growth in South Africa.

Keywords: Neglected and underutilised crops; Cost–benefit analysis; Smallholder farmers; Economic feasibility; Profitability KwaZulu-Natal

5.1 Introduction

Sub-Saharan Africa hosts a rich diversity of indigenous food crops that are locally adapted, resilient, and relatively easy to cultivate (FAO, 2024). These neglected and underutilised crops (NUCs) contribute significantly to traditional diets, local economies, and cultural identity, aligning closely with smallholder farming systems (Rampa et al., 2020; Akinola et al., 2020). NUCs (comprising cereals such as millets and sorghum, legumes like Bambara groundnuts and cowpeas, and root crops such as taro and cassava) play a vital role in enhancing food security and generating rural income, particularly among women who dominate their production and marketing (Mabhaudhi et al., 2019; Mativavarira et al., 2024).

Beyond their cultural and dietary relevance, NUCs are nutritionally superior to many conventional crops, serving as rich sources of vitamins A and C, iron, and calcium (Adhikari et al., 2017; Qwabe et al., 2025). Their adaptability to harsh and degraded environments, resistance to pests and diseases, and minimal water requirements make them suitable for low-input and climate-resilient farming systems (Mabhaudhi et al., 2018; Nhamo et al., 2022; Singh et al., 2022). Additionally, they contribute to biodiversity conservation and ecosystem sustainability by maintaining genetic diversity and reducing dependence on synthetic inputs (Gerrano et al., 2021). Despite these advantages, the integration of NUCs into mainstream food systems remains fragmented and undervalued. Structural barriers such as poorly coordinated value chains, weak market infrastructure, and limited policy recognition hinder their commercialisation and adoption (Akinola et al., 2020; Glatzel et al., 2025; Mmbando, 2025). National and regional agricultural policies continue to marginalise NUCs, neglecting their potential nutritional, economic, and environmental benefits (Meldrum and Padulosi, 2017; Mijena et al., 2024; Onawo and Egboduku, 2025). Consequently, many farmers perceive NUCs as economically inferior to conventional crops, leading to declining cultivation and erosion of indigenous knowledge.

Globally, there has been a growing resurgence of interest in neglected and underutilised crops (NUCs), driven by international initiatives such as the FAO's *Forgotten Foods* campaign and the United Nations Sustainable Development Goals (SDGs 2, 12, and 13), which advocate for food system diversification, sustainable consumption, and climate adaptation. These global frameworks underscore that food security extends beyond increasing yields—it also requires fostering resilient, locally adapted crops that enhance community nutrition, strengthen livelihoods, and sustain agro-biodiversity (Singh et al., 2022; El Bilali et al., 2024). Within this paradigm, assessing the economic feasibility of NUCs becomes essential for determining their competitiveness and long-term profitability in contemporary agricultural markets. Such analysis provides a critical evidence base for re-positioning NUCs from being perceived merely as subsistence crops to being recognised as profitable, market-oriented enterprises capable of advancing inclusive and sustainable rural economic growth.

In South Africa, the underutilisation of indigenous and traditional crops persists, despite their proven ecological adaptability and socio-economic importance in rural food systems (Mabhaudhi et al., 2018). The country's agricultural landscape is characterised by a dualistic structure, where large-scale commercial farming dominates formal markets while smallholder and subsistence farmers, particularly in provinces such as KwaZulu-Natal, Limpopo, and the Eastern Cape, operate under resource constraints and high vulnerability to climatic variability (Mulopo and Chimbari, 2021; Zantsi, 2021; Yazdan Bakhsh, 2024). These farmers often rely on rainfall-dependent production systems and face recurring challenges, including soil degradation, limited access to improved seeds, inadequate extension support, and restricted market linkages (Mudau et al., 2022; Ncoyini et al., 2022). KwaZulu-Natal, in particular, is among the provinces most affected by recurrent droughts, poverty, and food insecurity, conditions that undermine the sustainability of conventional crop production and highlight the urgent need for climate-resilient alternatives such as NUCs (Maziya, 2023; Mazibuko & Letsoko, 2024). Furthermore, while the province possesses diverse agro-ecological zones suitable for cultivating traditional grains, legumes, and root crops, the potential of these crops remains largely unexploited due to structural and institutional barriers. Smallholder farmers continue to receive limited financial and policy support to invest in NUC production, value addition, and marketing (Mabhaudhi et al., 2019). Market development for indigenous crops remains weak, with inadequate aggregation points, storage facilities, and processing infrastructure, which constrain commercialisation opportunities (Mabhaudhi et al., 2019). As a result, NUCs are predominantly grown for home consumption, with only a small portion entering informal markets through roadside vendors or local trade networks. Addressing these constraints requires a shift from viewing NUCs as marginal crops to recognising them as strategic commodities for local economic development, climate resilience, and food system transformation.

Moreover, the South African agricultural policy landscape has yet to fully integrate NUCs into mainstream programs on food security, agricultural innovation, and rural development. Existing policies tend to prioritise high-value commercial crops, thereby perpetuating structural inequalities and excluding traditional food systems from formal investment frameworks (Glatzel et al., 2025; Mmbando, 2025). Aligning national strategies with the potential of NUCs could diversify production systems, empower women and youth farmers, and strengthen community-based value chains (Newton, 2025). Thus, a context-specific assessment of the economic feasibility of NUCs in KwaZulu-Natal is vital not only for improving smallholder profitability and resilience but also for informing evidence-based policies that promote inclusive, sustainable, and climate-smart agricultural growth in South Africa.

From an economic perspective, the concept of feasibility encompasses profitability, efficiency, and sustainability, factors that determine whether an agricultural enterprise can generate net positive returns over time (Ng'ang'a et al., 2017). While NUCs exhibit strong environmental and nutritional potential, their financial viability remains poorly quantified. Smallholders are rational economic agents who adopt crops based on expected income, input requirements, and market stability. Therefore, quantifying the costs, benefits, and returns associated with NUC production provides an objective framework for assessing whether these crops can compete with conventional commodities in terms of investment value (Beria et al., 2018; Edwards and Lawrence, 2021). Existing studies on NUCs have largely emphasised their nutritional and ecological benefits within the broader context of food security and dietary diversity (Chivenge et al., 2015; Mabhaudhi et al., 2019). However, limited attention has been given to their economic feasibility, defined as the assessment of profitability, efficiency, and sustainability of production systems at the household level. The absence of empirical economic evidence restricts policy action and discourages investment in NUC value chains (Glatzel et al., 2025).

This study critically examines the economic viability of neglected and underutilised crops (NUCs) among smallholder farmers in KwaZulu-Natal Province, South Africa, employing a rigorous cost–benefit analysis framework. It specifically seeks to: (i) evaluate the profitability of NUCs relative to conventional crops, (ii) assess the long-term investment returns and financial resilience associated with their production, and (iii) identify the key socioeconomic, institutional, and market factors shaping smallholders' economic outcomes. By generating robust empirical evidence, the study aims to advance understanding of how NUCs can contribute to diversified, climate-resilient, and sustainable food systems. The findings are expected to provide actionable insights for policymakers, development practitioners, and investors, guiding strategic resource allocation, supporting the integration of NUCs into national agricultural strategies, and ultimately enhancing rural livelihoods, food security, and economic empowerment in South Africa.

5.2 Theoretical framework-Cost-benefit Analysis (CBA)

This study is anchored in Cost-Benefit Analysis (CBA) theory, an applied economic framework Figure 5.1. guides decision-making by systematically comparing the costs and benefits of alternative actions or investments to determine their net economic value (Ng'ang'a et al., 2017; Beria et al., 2018; Edward & Lawrence, 2021). CBA is rooted in the principle of compensation, which posits that an action is economically efficient if those who gain could, in principle, compensate those who incur losses, thereby promoting optimal allocation of scarce resources (Hick, 1939). The framework also emphasises time-sensitive evaluation, calculating the present value of benefits and costs when returns or impacts are distributed over multiple periods (Adler & Posner, 1999).

In the context of smallholder agriculture, CBA provides a robust tool for evaluating the economic viability of neglected and underutilised crops (NUCs), which often carry both market and environmental uncertainties. Traditional CBA, however, has limitations: it frequently relies on average or expected values, overlooking the variability and risks inherent in smallholder farming, such as fluctuating yields, market prices, and climate-related shocks (Burhenne et al., 2013; Asplund & Eliasson, 2016). To address this, the study integrates sensitivity analysis, allowing for dynamic assessment of how changes in key variables (inputs, outputs, and prices) affect investment outcomes (Munda, 1996; Pannella, 1997). This approach strengthens decision-making by providing risk-adjusted insights, essential for smallholders considering NUCs as alternative or complementary crops.

CBA is particularly relevant for NUCs because it enables the quantification not only of direct financial returns but also of broader socio-economic and environmental benefits, including food security, nutritional diversity, and resilience to climate variability. By applying this framework, the study provides smallholder farmers with actionable information to guide investment in NUCs, while offering policymakers and development practitioners rigorous evidence bases to promote the integration of these crops into sustainable, climate-resilient, and inclusive food systems. Ultimately, CBA theory bridges micro-level investment decisions and macro-level policy objectives, ensuring that both economic efficiency and social welfare are maximised within the context of smallholder agriculture in KwaZulu-Natal. Building directly from the theoretical framework of Cost-Benefit Analysis, the conceptual diagram for this study visually operationalises the key constructs and their hypothesised relationships to empirically test the efficiency of NUC scheme participation. It maps the journey of a farm household through a critical decision point, to join the NUC scheme based on an internal calculus of expected net benefits. The diagram figure. 5.1 illustrates how this endogenous participation decision acts as a switch, channelling households into one of two potential economic gains, participant or non-participant, each with its own distinct set of determinants influencing the outcome of economic benefits.

5.2.1 Conceptual framework

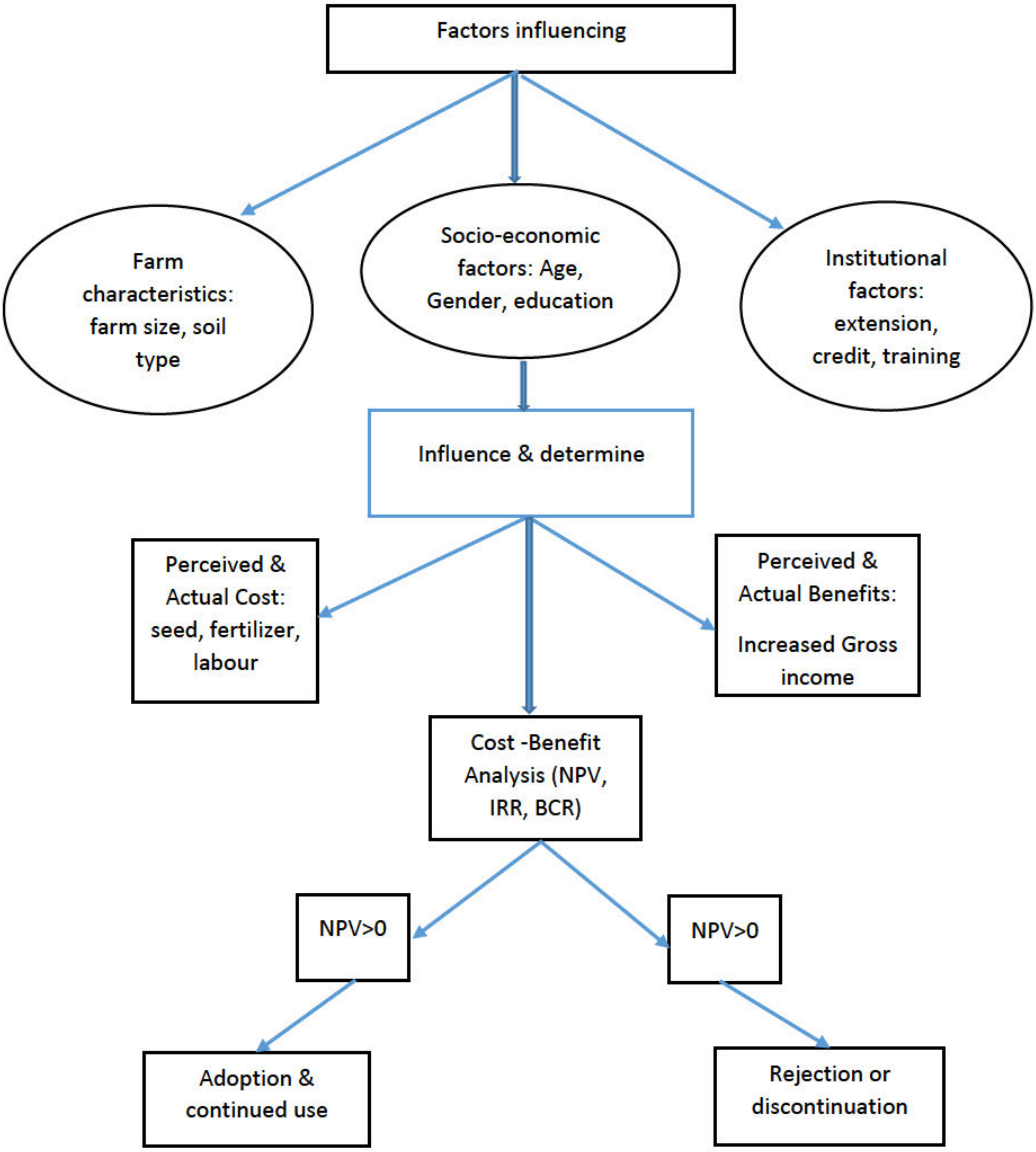

Figure 5.1: Conceptual Framework, Source (Author, 2025)

5.3 Methodology

5.3.1 Description and study area selection

This study was conducted in KwaZulu-Natal (KZN) Province, South Africa. The province was purposively selected due to its high concentration of rural smallholder farmers, its documented food security challenges, and the prevalence of traditional crop cultivation systems that provide an ideal context for researching the contribution of neglected and underutilised crops (NUCs) to rural food security (Qwabe, 2021).

Two district municipalities, namely the uMkhanyakude District Municipality (UDM) and the King Cetshwayo District Municipality (KCDM), were purposively selected as the study sites. These districts were chosen based on three criteria: (i) their topographical and agro-ecological suitability for NUC production; (ii) their documented food security vulnerabilities; and (iii) their status as recognised NUC hotspots with established cultivation of diverse traditional crop species. Both districts are recognised as NUC hotspots in KZN, characterised by the persistent cultivation of indigenous crops despite broader national trends toward commercial staple production. Baseline data from district agricultural offices and recent studies confirm the prevalence of NUC cultivation in these areas.

For instance, in the UMkhanyakude District, agricultural surveys indicate that approximately 38% of smallholder farmers cultivate at least one NUC species, with indigenous leafy vegetables (*Amaranthus* spp., *Cleome gynandra*, *Cucurbita* spp.) and drought-tolerant legumes (cowpeas, Bambara groundnuts) being the most commonly grown (Patrick, 2021; uMkhanyakude Department of Agriculture, 2023). The district's northern regions, characterised by increasing drought frequency, have seen renewed interest in traditional grains such as sorghum and finger millet as climate adaptation strategies (Mzimela and Moyo, 2025). Also, in King Cetshwayo District, NUC prevalence is estimated at 42% among smallholder farming households, with particularly high concentrations in rural areas such as Nkandla, Mthonjaneni, and uMlalazi (Mulopo and Chimbari, 2021; King Cetshwayo Department of Agriculture, 2023). Indigenous vegetables (*Imifino*) remain integral to household diets, while traditional staples such as amadumbe (taro) and sweet potatoes are widely cultivated. The district's coastal and inland agro-ecological zones support a diverse range of NUCs, contributing to their sustained presence in local food systems.

UDM is situated in the northernmost part of KZN, covering 12,818 km² with a population of approximately 686,090 (Mthembu and Hlophe, 2020). The district is characterised by a steady rise in temperatures, declining rainfall, and increased drought frequency and severity, particularly in its northern regions, which significantly affects agricultural production (uMkhanyakude IDP, 2023). KCDM is located in the north-eastern region of KZN, covering 94,341 km² with a population of 971,135 (COGTA, 2023). The district experiences warm climatic conditions with mild winters and hot, humid summers, supporting diverse cropping systems (COGTA, 2023).

Both districts are characterised by predominantly rural populations that rely heavily on subsistence agriculture. Food insecurity and malnutrition rates are elevated: in UDM, approximately 24% of households experience food insecurity, while in KCDM, the rate is approximately 21% (Hosea and Khalema, 2020; Patrick, 2021; Mulopo and Chimbari, 2021). These vulnerabilities are compounded by climate change impacts, with both districts experiencing increased frequency of droughts and erratic rainfall patterns that threaten conventional crop production (Mzimela and Moyo, 2025). The districts' agro-ecological diversity supports a wide range of traditional crops, including indigenous vegetables (*Amaranthus*, *Cleome gynandra, Cucurbita* spp.), traditional grains (sorghum, finger millet), drought-tolerant legumes (cowpeas, Bambara groundnuts), and indigenous fruits. This diversity, combined with the documented prevalence of NUC cultivation and the pressing food security challenges, makes these districts ideal for assessing the contribution of underutilised crops to rural food security. The high baseline prevalence of NUC cultivation also provides sufficient variation in adoption status to enable robust econometric analysis comparing adopters and non-adopters.

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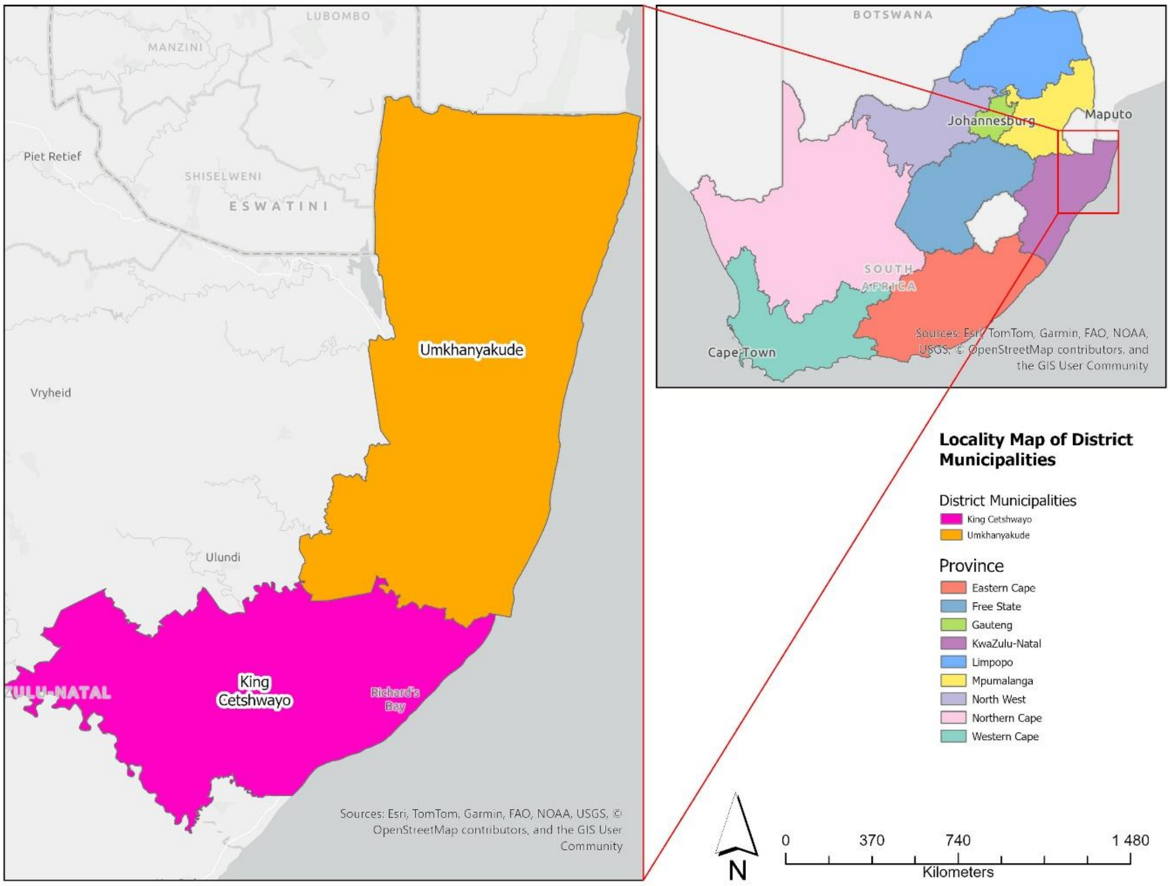

Figure 5.2: Study area Map source: (Author's compilation)

5.3.2 Sampling

A cross-sectional research design was employed to assess the contribution of underutilised crops to rural food security among smallholder farmers in KZN. This design was chosen because it is relatively less expensive and time-consuming while allowing for the simultaneous assessment of food security indicators across different farming systems (Creswell and Creswell, 2017). The study used a mixed-method approach, incorporating both quantitative and qualitative data to develop an in-depth understanding of how underutilised crops contribute to household food security outcomes. This approach strengthens the validity and credibility of the research and provides a comprehensive understanding of the complex relationships between crop choices and food security (Cypress, 2017).

Qualitative data were collected through semi-structured household questionnaires to complement the quantitative survey data. A total of 319 households were interviewed across the selected local municipalities. Households were stratified by adoption status, with separate groups convened for NUC adopters and non-adopters to enable comparative insights.

Discussions explored: (i) farmers' reasons for cultivating or not cultivating NUCs; (ii) perceived benefits and challenges associated with NUC production and consumption; (iii) household strategies for managing food shortages; and (iv) social and cultural factors influencing crop choices.

These interviews elicited information on: (i) institutional support available for NUC cultivation; (ii) historical trends in traditional crop production within the study areas; (iii) market access constraints; and (iv) perceptions of NUCs within the broader community. All surveys were conducted in isiZulu, audio-recorded with participant consent, transcribed verbatim, and translated into English for thematic analysis. Qualitative data were analysed using thematic content analysis, with themes derived deductively from the research objectives and inductively from emerging patterns in participant responses.

A multi-stage sampling procedure was employed to ensure diverse representation of smallholder farmers with varying levels of underutilised crop cultivation and food security outcomes (Maziya et al., 2024). Two district municipalities, namely uMkhanyakude District Municipality and King Cetshwayo District Municipality, were purposively selected. Selection criteria included: (i) diverse agro-ecological characteristics; (ii) documented susceptibility to climate change impacts; (iii) heavy reliance on subsistence agriculture; and (iv) documented presence of underutilised crop cultivation (Patrick, 2021; Mulopo and Chimbari, 2021). Further, two local municipalities were purposively selected from within each district based on their significant contribution to underutilised crop production and their representation of different food security contexts. This purposive approach ensured that the study captured variation in NUC prevalence and food security conditions across the selected districts.

A stratified sampling approach was applied, whereby participants were grouped into strata based on their underutilised crop cultivation status. Participants were classified as: (i) adopters, farmers who had cultivated at least one NUC species during the 2023/2024 farming season; and (ii) non-adopters, farmers who had not cultivated any NUCs during the same period but were engaged in other agricultural activities. This stratification enabled a comprehensive comparison of food security outcomes across different levels of NUC engagement.

Within each stratum, participants were randomly selected from sampling frames developed through consultation with local agricultural extension officers and community leaders. This random selection minimised selection bias within strata and ensured that the sample was representative of the underlying population of smallholder farmers in each community.

While the multi-stage sampling procedure was designed to balance representativeness with practical constraints, several limitations should be acknowledged. First, the purposive selection of districts and local municipalities introduces potential selection bias**.** By selecting areas based on documented NUC prevalence and food security challenges, the sample is not statistically representative of all smallholder farmers in KZN or South Africa. Findings are therefore generalisable to contexts with similar characteristics, rural, subsistence-oriented communities with established NUC cultivation but may not extend to areas where NUCs are entirely absent or where commercial agriculture dominates. This trade-off between depth of insight and breadth of generalisability is inherent in purposive sampling designs (Patton, 2015).

Second, the reliance on sampling frames provided by extension officers and community leaders may introduce coverage bias. Farmers who are not known to extension services or who are less engaged with formal community structures may have been systematically excluded from the sampling frame. If such farmers differ systematically from those included, for example, if they are more marginalised or have different NUC cultivation practices, this could bias estimates of NUC prevalence and food security impacts.

Third, the cross-sectional design limits the ability to establish temporal causality. While the study measures associations between NUC adoption and food security outcomes, it cannot definitively establish whether NUC adoption causes improved food security or whether households with better food security are simply more likely to adopt NUCs. The endogenous switching regression (ESR) model addresses this by accounting for selection bias, but unobserved time-varying factors may still confound estimates.

Fourth, the sampling approach does not account for seasonal variation in food security. Data were collected during a single agricultural season, yet food security outcomes fluctuate seasonally, particularly in rainfed farming systems. Single-season data may not capture the contribution of NUCs during lean periods when their role in food security may be most pronounced. Fifth, self-selection bias may affect the adopter/non-adopter comparison. Farmers who choose to cultivate NUCs may differ systematically from those who do not in ways that are not fully captured by observed covariates. While the ESR model controls for selection on unobservables, residual bias cannot be entirely eliminated without experimental or quasi-experimental designs.

Despite these limitations, the combination of purposive and random sampling, the stratified approach ensuring representation of both adopter and non-adopter groups, and the mixed-methods design triangulating quantitative and qualitative data collectively strengthen the validity of the findings. The limitations are explicitly acknowledged to enable appropriate interpretation of results and to inform future research designs.

The sample size of the study was determined by using Cochran's (1977) formula because the population size and characteristics of the areas selected were precisely unknown. Also, Cochran's formula was selected because it provides a statistically sound method for calculating a sample size when dealing with unknown populations (Ahmad and Halim, 2017). Furthermore, it minimises sampling errors and enhances the reliability and validity of the findings (Qing and Valliant, 2025). This will ensure that the data collected for the cost-benefit analysis and the determinants influencing the economic benefits of NUCs adoption are both statistically robust and generalizable (Ahmad and Halim, 2017). As a result, the findings of the study will provide insights into the profitability, sustainability, determinants, and economic feasibility of NUCs, thereby informing policy decisions and investment strategies in local food systems. A Cochran's (1977) is presented below:

$$n_0 = \frac{(t^2)*(p)(q)}{(d)^2} = \frac{(1.96)^2(.5).5)}{(.5)^2} = 384$$

Where:

t = value for selected alpha level of .025 in each tail = 1.96 when

(p)(q) = estimate of variance = 0.25 (maximum possible proportion (0.5) * (1-0.5) maximum possible proportion (0.5) produces maximum possible sample size).

d = acceptable margin of error for proportion being estimated = 0.05 (error researcher is willing to accept).

To achieve a 95% confidence level with an actual margin of error falling within 5%, which provides good precision for generalising findings to the population (Kulinskaya and Dollinger, 2015). However, due to resource and time constraints encountered during the field data collection phase, the final sample comprised 319 smallholder farmers. This reduction in sample size (16.9% from the calculated 384) did not significantly compromise the statistical power or representativeness of the study. The achieved sample size maintains a confidence level of 95% with a marginally increased margin of error of 5.5% (calculated using the same statistical parameters: t=1.96, p=0.5, q=0.5), which remains within acceptable limits for food security and agricultural studies in developing country contexts (Israel, 2003; Yamane, 1967). The sample size of 319 respondents is considered adequate for the statistical analyses employed in this study, including descriptive statistics, cost-benefit analysis, including B/C, NPV, IRR calculations, and econometric modelling approaches such as a multiple linear regression model.

5.3.3 Data collection

Primary data was collected with the aid of self-administered structured questionnaires. The structured questionnaire was designed to collect information such as smallholders' demographics, socio-economic features, agricultural production, traditional knowledge, marketing channels, sales, production input costs, total revenues, and financial projections. The relevance and reliability of the questionnaires were tested through pre-testing before the actual data collection. The pre-testing process was crucial for training the enumerators. The enumerators were fluent in the local language, which is IsiZulu. The participation of respondents in the study was based on informed consent, and participants were free to decline without consequence. The researcher engaged with extension officers to assist in locating smallholder farmers involved in NUC production of the King Cetshwayo and uMkhanyakude District Municipalities. The data was collected from 02 March to 30 April 2025.

Ethical clearance (HSSREC/00007019/2024) was issued by the University of KwaZulu-Natal. All the required documents, including the written informed consent from the smallholder farmers, emphasised a farmer's willingness to participate in the study, anonymity, and confidentiality.

5.3.4 Data analysis

This paper assessed the contribution of neglected and underutilised crops and their impact on rural food security among smallholder farmers. The collected survey data were organised and initially processed using Microsoft Excel spreadsheets for data entry and preliminary cleaning. For a comprehensive statistical analysis, Stata version 18 was employed. The study employed a cross-sectional research design with a mixed-methods approach to gather comprehensive data on NUCs production input costs, sales, revenues, and financial projections.

5.3.4.1 Descriptive statistics

Descriptive statistics were employed to characterise smallholder farmers' demographic and socioeconomic profiles in relation to NUCs production. The descriptive analysis encompassed frequency distributions (percentages) and measures of central tendency (means, ranges, and standard deviations). The data were presented through tables and figures to provide a clear visual representation of the findings. This approach was particularly important as studies by Chivenge et al. (2015) and Mabhaudhi et al. (2019) indicated that many smallholder farmers unconsciously cultivate underutilised crops as part of their traditional farming systems without formal recognition. Therefore, it was critical to identify and assess the frequency of farmers practising NUCs cultivation, including the use of traditional varieties, indigenous vegetables, drought-tolerant legumes, and traditional grains. The descriptive statistics provided key insights into the socioeconomic characteristics of sampled smallholder farmers and their engagement with underutilised crop farming practices.

The analysis specifically examined NUCs' economic benefits across different food crop categories, including cereals (sorghum, millet), legumes (cowpeas, bambara groundnuts), vegetables (amaranth, spider plant), and root crops (cassava, sweet potatoes). The descriptive analysis also captured the motivations for NUCs adoption, including food security considerations, cultural preservation, climate resilience, and access to traditional seed networks.

5.3.4.2 Cost-benefit analysis

The study will conduct a cost-benefit analysis to measure the economic benefits of underutilised crop production. Cost-benefit analysis is a framework used to determine whether a specific project yields a more positive net benefit from a societal perspective compared to other available options (Schrammel, 2015). This is achieved by identifying all costs and benefits associated with the project, then aggregating them into a single monetary value using various valuation methods. These methods include Net Present Value (NPV), benefits/costs ratio (B/C) and internal rate of return (IRR) (Alipio *et al.*, 2022). These economic ratios were found to be the most suitable for the analysis of this objective.

This study will have one independent variable (underutilised crop production) and land usage and economic profitability as the dependent variables. Moreover, Underutilised crop production will be measured by yield, crop quality, land usage, and fertiliser usage. The Net present value (NPV) is considered the economic tool used to evaluate the effectiveness of crop production by discounting the future estimated cash flows to assess their worth at the present (Gumisiriza et al., 2022; Dansi et al., 2012). Further, a positive NPV shows that the investment will provide financial benefits greater than the cost of capital. NPV outlines the present worth of discounted future earnings at an appropriate discount rate (Souza et al., 2019).

The Net Present Value is calculated as follows:

$$NPV = \sum_{t=0}^{t} \frac{R_i - C_j}{(1+i)^i} \tag{1}$$

The Benefit-cost ratio is also defined as a capital budgeting technique that indicates the present value of revenues relative to the present value of costs at a given discount rate, and it is calculated using the following formula (Majid et al., 2021):

$$BCR = \sum_{t=1}^{n} R_t \, (1+i)^{-t} \, / \sum_{t=1}^{n} C_t \; (1+i)^{-t} \tag{2}$$

Where:

NPV = net present value

BCR = Benefit cost ratio

R_j= revenues during the period t

C_j = costs during the period t

i = discount rate

t= period of occurrence of R_t and C_t

n = duration of the project in time periods.

The Internal Rate of Return (IRR) is a classic tool of economic engineering used to equalise the discounted cash flows generated by the project with the initial investment, thereby annulling the NPV (Dickinson et al., 2015). IRR identifies the gains obtained by the project over time from the initial investment value, based on the resources required to produce the free cash flow for the investor, determining the viability of the investment when its value is higher than the discount rate used in the discounted cash flows (Souza et al., 2019).

IRR is calculated as follows:

$$= \sum_{k=0}^{n} \frac{R}{(1+\mathrm{TIR})} - \sum_{j=1}^{n} \frac{C}{(1+1\mathrm{RR})} = 0 \tag{3}$$

Where: IRR = internal rate of return

R_J = revenues during the period j;

C_j = costs during the period j;

J= period of occurrence of R_j and C_j

J =period of occurrence of R_j and C_j

N =duration of the project in time periods

IRR should be combined with other analyses to appraise projects. This enables a farmer to assess the reliability of the IRR in relation to other benchmarks (Patrick and French, 2016).

The Discounted Payback Period (DPP) is a crucial economic tool used to evaluate the economic viability of an investment in terms of time (Brigham and Ehrhardt, 2011). According to Souza et al. (2019), DPP represents the time required for the initial investment to return to the investor, given its opportunity cost. Further, Brigham and Ehrhardt (2012) defined discounted Payback Period as the number of years required to recover the investment from the discounted net cash flows, which is the value of money in time. This criterion evaluates the number of years of payback from the net cash flow, discounting the value of the currency over time (Huy, 2020). The formula for the discounted payback period is presented below:

$$\text{Discounted Payback Period} = A + \frac{B}{C}$$

Where A presents the final stage with the cumulative cash flow at a negative discount,

B is the absolute value of the discounted cumulative cash flow at the end of phase A.

C is the discounted cash flow post A.

5.3.4.3 Model specification: Multiple linear regression

A multiple linear regression model was employed to analyse the determinants of economic benefits from NUC adoption. This model is chosen for its ability to estimate the relationship between a single continuous dependent variable and multiple independent variables simultaneously while controlling the effects of all other variables in the model. The empirical mode is specified as follows:

$$Y = \beta 0 + \beta 1 age + \beta 2 householdincome + \beta 3 extension + \varepsilon$$

Where:

Y is the dependent variable, representing Gross income generated from the sales of NUCs, which measures the economic benefit

$\beta 0$ is the constant representing the expected value of Y when all independent variables are zero.

$B1$ to $\beta 0$ are the coefficients of the independent variables, each representing the marginal effect of a one-unit change in the corresponding variable on the dependent variable.

ε is the error term, which captures the effects of all other variables not included in the model.

Table 5.1: Description of variables in the regression model

Variable Name	Variable description	Unit of measurement	Expected signs
Dependent variable: economic benefit	The net profit/gross revenue from NUC production	South African rand (ZAR)	Positive (+)
Independent variable			
Age	Age of the farmer	Years	continuous
Education	The highest level of formal education attained	Years	Positive (+)
Household income	Total household income from all sources	ZAR	Continuous
Farm size	Total area of land under cultivation	Hectares (ha)	Positive (+)
Credit access	Dummy variable for access to formal credit	Yes=1, No=0	Positive (+)
Extension service Access	Dummy variable for access to agricultural extension services.	Yes =1; No =0	Positive (+)
Training access	Dummy variable for participation in agricultural training.	Yes=1; No=0	Positive (+)
Market distance	Distance from the farm to the nearest major market	Kilometres (km)	Negative (-)

5.3.5 Reliability and validity

The provided regression model demonstrates statistical significance overall, reliably identifying several key factors associated with the outcome variable, including the strong positive effects of education, credit access, and extension services, as well as the expected negative impact of market distance. However, the model's overall reliability is tempered by its low explanatory power, with an R-squared of 0.231 indicating that over three-quarters of the variation in the outcome remains unexplained by the included variables. This low R-squared directly challenges the model's internal validity, as it strongly suggests the presence of omitted variable bias, and where unmeasured factors like soil quality or entrepreneurial skill are likely influencing the results and potentially biasing the reported coefficients. Furthermore, while the individual coefficients for the significant variables are reliable, the model's statistical conclusion validity would be strengthened by confirming the absence of multicollinearity through VIF tests and addressing potential heteroscedasticity with robust standard errors. In terms of construct validity, the use of simple binary measures for concepts like credit and training access, whereas, it may not fully capture the complexity of these resources. Overall, the model reliably highlights important correlational patterns; its validity for making definitive causal claims is limited, and the results should be interpreted as identifying significant associations rather than proven causes.

5.4 Results and discussion

An analysis of demographic and farm characteristics revealed statistically significant differences between adopters and non-adopters of Neglected and Underutilised Crops (NUCs) among smallholder farmers in KZN Province. From a sample of 319 farmers, the study observed a moderate adoption rate of 40% (127 adopters), indicating that while interest in NUCs is growing, their cultivation remains secondary to conventional crops. This aligns with Ngidi (2023) in the South African context but contrasts with the higher adoption rate of 67% reported by Andani (2019) in Northern Ghana, underscoring contextual variations in institutional support and market incentives. The gendered dimension of adoption was pronounced, with women constituting 69% of NUC adopters, reflecting their traditional custodianship of indigenous food systems and household nutrition. Furthermore, a majority of adopters were married (88%) and unemployed (63%), highlighting NUC production as a critical livelihood and food security strategy among economically vulnerable households. Larger household sizes, averaging seven members, supplied family labour, encouraging crop diversification and resilience against food insecurity, consistent with findings by Zondi et al. (2022) and Andani (2019).

Adopters were also significantly older, with an average age of 53 years, and had moderate education levels (approximately eight years of schooling), suggesting that indigenous agricultural knowledge surrounding NUCs is concentrated among older generations. This demographic trend signals a potential knowledge gap for younger farmers and a threat to the continuity of traditional cropping practices. These results coincided with those of Zulu et al.

(2022), who reported that elderly households are very fond of leafy vegetables due to their nutritional benefits and have knowledge about the preparation techniques. On the contrary, Ayanwale et al. (2016) revealed that the majority of indigenous leafy vegetables consumers are young people.   Institutional and capacity constraints further compound this challenge; only 15% of farmers reported access to agricultural extension services, and merely 37% had received formal agricultural training. These results suggest that current support systems continue to be disproportionately focused on conventional crops, a finding also noted by Omotayo and Aremu (2024). These findings reveal that the economic feasibility of NUCs is not solely determined by profitability metrics but is deeply influenced by socio-demographic and institutional factors that shape adoption behaviour and investment decisions. The observed moderate adoption rate, coupled with limited institutional engagement, suggests that while NUCs hold economic and nutritional promise, their full potential remains underutilised due to structural and informational barriers.

5.4.1 Neglected and underutilised crops

Figure 5.3 presents the NUCs that are cultivated and sold by smallholder farmers in the study area. The results reveal that sweet potatoes (26.2%) and taro (23.0%) are the most widely cultivated neglected and underutilised crops (NUCs) among smallholder farmers in KwaZulu-Natal, together accounting for nearly half of total NUC production. Their economic outperformance can be explained through two interrelated factors: market demand characteristics and labour intensity requirements.

Sweet potatoes dominate NUC cultivation because they occupy a unique position at the intersection of low labour requirements and strong market integration. Agronomically, sweet potatoes thrive in marginal soils with minimal inputs, requiring substantially less labour compared to traditional staples a critical advantage for resource-constrained households where labour availability is a binding constraint. Their dominance reflects both agronomic adaptability and food security value within smallholder farming systems, offering a low-risk investment with high nutritional and caloric returns. The transition of sweet potato from a subsistence to a cash crop, as seen in KZN, is a trend also documented by Mayanja et al. (2022) in Mozambique. Mkhize and Mudhara (2025) reveal that higher levels of education, access to market information, and group membership significantly increased the intensity of sweet potato commercialisation, demonstrating how farmers optimise returns by leveraging available resources in KZN. Wongnaa et al. (2024) reported that farmers' adoption intensity for orange-fleshed sweet potato crops is high in Ghana due to benefits such as high yield and early maturity against their household needs, and their cultivation intensity directly responds to economic factors such as access to planting materials, formal credit, and market proximity. The economic logic is clear: sweet potatoes offer farmers high net returns relative to labour invested, with low production risk due to the crop's hardiness, making them an attractive option for resource-constrained households balancing food security with income generation.

Taro's economic outperformance (23.0%) stems from a different mechanism: cultural premium embedded within informal market structures. Unlike sweet potatoes, which compete in formal and semi-formal markets, taro derives its economic viability from strong cultural significance among Zulu communities and well-established informal marketing networks. These results coincide with those of Mabhaudhi et al. (2017), who reveal that the taro crop holds significant importance for both its nutritional value and cultural relevance in KZN. Mkhize and Cele (2025) noted that taro farmers in KZN adopt these crops for benefits such as taste and food security, especially under financial constraints. The cultural premium manifests in consistent local demand that ensures price stability, reducing price risk compared to crops dependent on volatile formal markets. The dominant market position of taro, driven by its cultural significance and role in the informal economy, is similarly noted by Fufa et al. (2021) in Nigeria. However, the presence of a market alone is insufficient, as Onsay et al. (2022) argue that taro farmers in the Philippines often remain in poverty due to low productivity and a lack of financial resilience, which fundamentally undermines the economic incentive for adoption. This highlights that for taro to deliver sustained economic benefits in KZN, productivity-enhancing interventions must accompany market development. The substantial income stream that these crops provide, particularly for women involved in production and marketing, is a finding in line with Charles (2024), who highlighted the role of female-driven commercialisation in the informal sector.

The moderate adoption of pumpkin (16.4%) and pumpkin leaves (19.7%) reflects a different economic calculus. While pumpkin offers strong economic returns, Nakazibwe et al. (2019) reported that in Uganda, pumpkins are processed into value-added products, and the crop's hardiness makes it a reliable venture, while Olubunmi-Ajayi et al. (2024) revealed a strong Return on Investment (ROI) of 2.28 for pumpkin leaf marketing in Nigeria, its labour intensity is substantially higher than sweet potatoes. Pumpkin cultivation requires intensive management, including trellising, pest control, and multiple harvests throughout the growing season. For smallholder farmers with competing labour demands, the high labour input may offset the attractive ROI, explaining why adoption remains moderate rather than expanding to levels seen for sweet potatoes. Additionally, as Ndengwa et al. (2016) observed in Kenya, pumpkin cultivation remains primarily subsistence-oriented due to limited access to extension services and market information, suggesting that institutional barriers further constrain its commercialisation potential.

In contrast, cassava (4.9%), groundnuts (3.3%), and cowpeas (6.6%) remain marginally cultivated. The economic underperformance of these crops can be attributed to specific market and labour constraints. Onoja et al. (2021) and Waje et al. (2024) supplement these findings, revealing that the adoption of improved cassava practices is severely limited by inadequate extension services in Nigeria and Southern Ethiopia. However, underlying this institutional constraint is an economic reality: cassava exhibits extremely high labour intensity at harvest, where tubers must be processed within 24-48 hours to prevent spoilage. This harvest-time labour bottleneck, combined with poor processing infrastructure and high transport costs in KZN's rural areas, significantly erodes net returns. Osakue et al. (2023) emphasise the critical issue of market access, finding that poor infrastructure and high logistics costs erode cassava profits in Nigeria, thereby discouraging wider adoption. The subsistence role of cassava is reinforced by Wahab et al. (2022) and Manganyi et al. (2023), who note its cultivation as a low-input safety net and the importance of market access for commercialisation, respectively.

For groundnuts, the binding constraint is market segmentation and quality requirements that demand capital investment in processing. Mothiba et al. (2023) shared the same sentiments regarding groundnuts in South Africa, linking low production to a lack of credit, land, and extension support. The economic logic is that groundnuts require specific processing (shelling, grading) to achieve marketable quality, yet smallholder farmers in KZN lack access to appropriate processing equipment. The result is a crop with high potential returns as shown by Kotu et al. (2022) and Lokossou et al. (2022) that remains inaccessible to resource-constrained farmers who cannot afford the capital investment required.

Cowpeas exhibit the most acute labour constraint among all NUCs. Beye et al. (2022) argued that adoption in Senegal is constrained by a lack of technical knowledge, but underlying this is the economic reality that cowpea production is labour-intensive throughout the entire production cycle from planting, weeding, pest management, and harvesting all of which require significant manual labour. Manda et al. (2020) documented the potential returns from improved cowpea varieties, yet in the context of KZN's rural labour dynamics—where household labour is often insufficient and hired labour is costly—cowpeas become economically unviable despite their nutritional value and drought tolerance.

The variation in NUC adoption rates across crops reveals that economic viability is not determined solely by biological potential but by the interplay of market demand, labour intensity, and institutional support. The findings of this study are therefore, are reinforced by international evidence, demonstrating that economic viability is not determined by biological potential alone but by the interplay of social, institutional, and market dynamics. From a cost-benefit perspective, the results demonstrate that while NUCs offer high potential returns, as shown by Kotu et al. (2022), Lokossou et al. (2022), and Manda et al. (2020) for groundnuts and cowpeas, adoption decisions are critically constrained by barriers that elevate production risks. The prevalence of sweet potatoes and taro indicates that farmers prioritise NUCs that balance subsistence value with market potential, a finding that aligns with the principles of cost–benefit analysis, where farmers tend to adopt crops with the highest perceived net returns and the lowest production risks. Jerop et al. (2018) supplement this view, arguing that strong social networks, such as farmers' groups, reduce adoption risks and leverage shared resources, making NUCs a viable strategy for improving livelihood and food security. Crops that succeed commercially include sweet potatoes and taro which share characteristics that either minimise labour requirements (sweet potatoes) or embed cultural premiums that sustain demand despite moderate labour inputs (taro). Crops that remain marginal including cassava, groundnuts and cowpeas face binding constraints that elevate production risks and reduce net returns: post-harvest processing bottlenecks for cassava, capital requirements for groundnuts, and labour intensity for cowpeas. This interpretation reveals that returns are not solely determined by market prices but by the distribution of costs and returns across the production cycle, with implications for intervention design that must address crop-specific constraints.

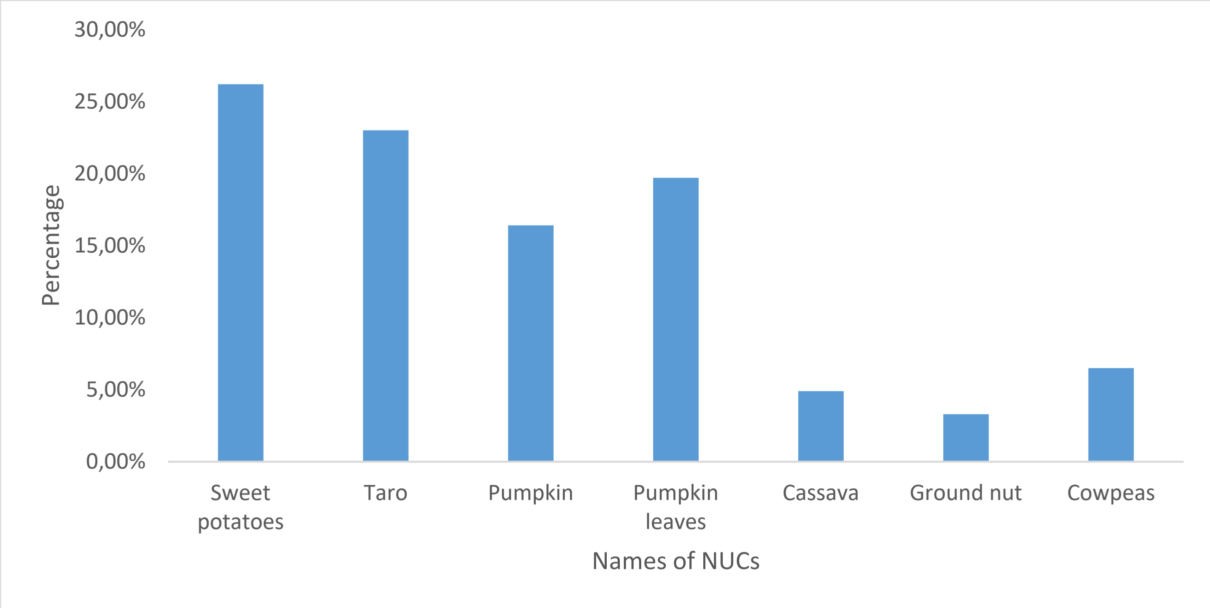

Figure 5.1: Sales of NUCs

5.4.2 Value chain practices for NUCS in smallholder farming

This section analyses the specific activities, from seed sourcing and on-farm production to post-harvest handling and market access, that determine a crop's commercial viability and household nutritional benefits. The discussion provides the critical link between on-farm participation in NUC schemes and the tangible household welfare outcomes measured in the subsequent econometric analysis.

5.4.2.1 Common Processing Technique

Table 5.2 presents the processing techniques employed by smallholder farmers. The results indicate that smallholder farmers are heavily invested and rely on indigenous processing techniques such as sun-drying, grinding, and blanching. Similarly, Asiimwe et al. (2025) revealed that techniques like sun-drying, smoking, and boiling are core indigenous practices that enhance year-round food availability and build community resilience in Uganda. Furthermore, Amissah et al. (2025) reported that traditional methods including sun -drying, fermentation, germination and soaking, and manual milling are processing techniques of indigenous food crops in West Africa, remain the backbone of the value chain ensuring basic preservation and cultural continuity, yet are often constrained by factors such as inconsistent hygiene standards, high labour inputs and significant post-harvest losses which affect both the quality and market potential of the final product.

Further, Okoye & Oni (2017) highlighted that these techniques are low-cost, effective survival strategies and the bedrock of small-scale rural enterprises, making them crucial for household food security and rural development. On the contrary, Animasaun et al. (2023) revealed that fonio millet processing remains heavily dependent on labour-intensive traditional methods like manual pounding, which is predominantly performed by women and characterised by low efficiency and potential for injury. However, Adebiyi et al. (2018) emphasised that traditional processing methods, such as fermentation, are often unstandardized, leading to poor product quality and potential microbial safety risks, and are ill-suited for scaling, which constrained the commercial potential and the creation of market-ready products.

Additionally, Okafor (2023) noted that women processors in Nigeria face a lack of modern technologies, inadequate capital, high transport costs, and poor access to formal markets, and these factors trap them in low-return, subsistence-level activities. The simple sun-drying technique is regarded as one of the oldest food preservation methods and is often employed by smallholder farmers in the region. It is a relatively inexpensive technique and is often applied to NUCs such as cassava and cowpeas. The sun-drying and grinding technique is frequently used, particularly for Cassava, groundnuts, and cowpeas. Likewise, Owusu-Kwarteng et al. (2024) reported that the traditional processing methods improve the edibility, nutritional value, and sensory attributes of food by enhancing nutrient bioavailability and reducing antinutritional factors. For instance, smallholder farmers who cultivate Cassava and groundnuts reveal that most of the time, they dry and grind the cassava and groundnuts to produce powder, which is cooked as a staple meal and consumed with relish, such as spinach. Similarly, Ngubo (2021) revealed that farmers in KZN, South Africa, employ leading indigenous postharvest practices, including sun drying, winnowing, destalking, and natural field storage, using basic technologies such as fibre bags, plastic buckets, and cool, dry areas. Blanching is mainly used by farmers who produce groundnuts to loosen the skins for easy removal. These processing techniques enhance the preservation and shelf life of the NUCs and are mainly applied for home consumption. Farmers revealed that they do not sell the processed NUCs. However, women are the primary participants in the production and processing of NUCs. Table 5.2 illustrates the above-mentioned processing techniques used in the study area.

Table 5.2: Illustrates the processing techniques employed by smallholder farmers

Processing techniques
Simple sun-drying
Sun drying & grinding
Blanching

5.4.2.2 Storage facilities for NUCs

Table 5.3 shows that smallholder farmers often rely on traditional storage facilities to store their NUCs and other crops. A traditional shed is a common storage facility that is used by smallholder farmers to preserve their NUCs produce for the longest. The same findings were reported by Mobolade et al. (2019), who noted that traditional shed storage is part of a wide array of traditional storage methods that are relatively inexpensive, eco-friendly, and effective for storing commodities. While other farmers used their hut or house to preserve their produce for later use. This indicates the lack of infrastructure as the critical challenge in smallholder farming. Also, Ogwu (2023) notes that traditional storage in Africa relies on indigenous knowledge, utilising methods such as underground pits, ventilated cribs, and wrapping grains and tubers in plant materials to preserve them. Furthermore, Osei-Asibey et al. (2022) reported that Smallholder farmers in northern Ghana primarily use locally constructed granaries and pots for storing their seeds and harvested food crops. These traditional storage methods are a key part of the local farming system and indigenous knowledge. These systems are vital for food security but face growing threats from climate change, particularly increased humidity and pests. Additionally, Mandisvika et al. (2015) argued that traditional storage methods, such as pole-earthed granaries in Zimbabwe, are largely ineffective in reducing post-harvest losses of NUCs. Kujeke et al. (2019) reported that post-harvest storage is a major challenge for this indigenous root crop, limiting its wider use and commercial potential. Mandisvika et al. (2015) reveal that these structures, such as pole-earthed granaries, woven baskets, and sacks, fail to protect grains and legumes from pests, mould, and spoilage caused by humidity and temperature fluctuations, ultimately undermining their role in ensuring long-term food security.

Table 5.3: Displays the storage facilities that are used by smallholder farmers to store their NUCs

Storage type
Traditional Shed
House or hut

5.4.2.3 post-harvest handling methods

Smallholder farmers use harvesting handling methods such as cleaning, sorting, and washing, as shown in Table 5.4. Cleaning, including the removal of soils and field debris, is particularly important for tuber crops such as sweet potatoes, taro, and cassava, to reduce crop spoilage. This suggests that the application of proper post-harvest handling methods enables farmers to safely utilise crops and maximise both nutritional and economic benefits. Similar findings are shared by Kapoor et al. (2022), who indicated that effective initial handling prevents spoilage not only of the starchy parts but also across all plant parts, including the nutrient-rich leaves and petioles. Alternatively, the sorting and grading process is also used to grade the harvest by quality and size, and remove the damaged harvest. This handling process is applied to all NUC harvests, and the damaged harvests are used as feed for animals. Thirdly, the washing process is a common practice and is essential for pumpkin leaves to ensure their cleanliness and maintain their freshness. These harvesting and handling methods help NUC smallholder farmers to minimise post-harvest losses. This also helps farmers sell high-quality NUC produce to the market and earn a higher price. Similar findings were reported by Ferdaus et al. (2023), who noted that post-harvest losses in underutilised crops, such as taro, represent a significant squandered opportunity to enhance nutritional security. This loss is particularly acute, as these crops are typically grown by resource-poor smallholders.

Table 5.4: Presents the post-harvest handling methods used by smallholder farmers

Post-harvesting handling methods
Cleaning
Sorting
Washing

5.4.2.4 Marketing Channels for NUCs

Table 5.5 shows that smallholder farmers predominantly channel their Neglected and Underutilised Crops (NUCs) through informal market outlets, including roadside vendors, informal fresh produce markets, and middlemen who purchase directly at the farm gate. Among these, the roadside market emerges as the most prevalent channel, facilitating direct. Furthermore, farmers frequently engage with middlemen for bulk sales, a practice which, while resulting in lower farmgate prices, ensures convenient and guaranteed sales without incurring transportation costs. Conversely, participation in larger informal fresh produce markets, where NUCs are sold alongside conventional staples like cabbage and potatoes, allows for the sale of larger volumes and a greater variety of produce, albeit at the expense of incurring transport logistics and costs. The results are in line with those of Bandula et al. (2023), who argued that value chains for underutilised crops like fonio in Ghana and finger millet in Sri Lanka reveal that they are financially viable and contribute to farmer livelihoods, yet their economic potential is constrained by a lack of value addition and poor access to mechanisation and formal markets. Similarly, Kalawa (2023) argued that the finding that producers received the highest gross margin in the Kenyan sorghum chain underscores the potential economic incentive for NUC farmers to bypass middlemen where possible, often by selling directly to consumers at the farm gate or roadside, thereby capturing a larger share of the final price.

The results reveal that NUCs are primarily sold to informal markets, including street vendors, roadside markets, informal fresh produce markets, middlemen, and directly at the farm gate. Roadside markets and street vendors are the most dominant markets for NUC farmers and allow them to supply these markets with NUCs. Similar findings were reported by Mkhize and Cele (2025), who claimed that street vendors are regarded as intermediaries and facilitate urban consumers' access to indigenous food crops, such as amaranthus (imbuya) and Taro (amadumbe), in Durban. Additionally, farmers reported that they sell their NUC produce to middlemen who purchase large quantities of the harvest. This suggests that farmers do not pay the transportation costs and are guaranteed convenient sales. Likewise, the results align with the findings of Boulay et al. (2020), who reported that farmers, particularly women who are the primary producers and traders of the Bambara groundnut crop, sell to a network of intermediaries, including small-scale female traders and larger middlemen in Tanzania. Furthermore, farmers sell their NUCs to the informal fresh produce market, along with various conventional food crops, such as cabbage, potatoes, and spinach, among others. This market enables farmers to sell larger quantities and a wider variety of NUCs, but it involves transport costs. In agreement, Charrua et al. (2021) attested that indigenous beans are widely commercialised through informal markets in Mozambique. However, Mbarga et al. (2024) reveal that the cassava market in Cameroon is characterised by a highly concentrated, oligopolistic structure, where a few wholesalers and retailers hold significant market power. This concentration leads to marketing inefficiencies, particularly at the retail level, which disconnects smallholder farmers from profitable markets and suppresses the prices they receive.

Table 5.5: Shows the marketing channels used by smallholder farmers to sell NUCs

Marketing channels for NUCs
Roadside Market (street vendors)
Middlemen
Informal fresh produce market

5.4.3 Economic viability of neglected and underutilised crops (NUCs)

The gross margin budget analysis presented in Table 5.6 evaluates the economic performance of smallholder farmers who adopted Neglected and Underutilised Crops (NUCs) compared to their non-adopting counterparts in KwaZulu-Natal Province. The analysis employs a cost–benefit framework to determine whether NUC adoption improves farm-level profitability and production efficiency. Standard economic diagnostic indicators, including gross margin, net profit, return on variable costs (ROVC), and the benefit–cost ratio (BCR), were calculated to assess the financial performance of each group. In addition, the model diagnostic followed the principles of classical cost–benefit analysis, where Gross Margin = Gross Income, Variable Costs, and profitability ratios were computed to measure the rate of return on production inputs (El Bilali et al., 2024). These diagnostics serve as robust indicators of enterprise viability and competitiveness under smallholder conditions.

Table 5.6: Gross Margin Budget for Smallholder Farmers – Adopters and Non-Adopters of NUCs (ZAR per hectare per season)

Item	Non-participants (n = 192)	participants (n = 127)	Change
GROSS INCOME			
Yield (kg)	2,500	1,100	–1,400
Price per kg (ZAR)	6.00	18.00	+12.00
Total Gross Income	**15,000.00**	**19,800.00**	**+4,800.00**
VARIABLE COSTS			
Seeds	1,200.00	900.00	–300.00
Fertiliser/Soil Inputs	3,500.00	1,200.00	–2,300.00
Pesticides/Herbicides	1,800.00	–	–1,800.00
Hired Labour	1,800.00	1,000.00	–800.00
Processing / Cleaning	–	600.00	+600.00
Transport	1,200.00	2,200.00	+1,000.00
Other (misc.)	800.00	700.00	–100.00
Total Variable Costs	**10,300.00**	**6,600.00**	**–3,700.00**
GROSS MARGIN CALCULATION			
Total Gross Income	15,000.00	19,800.00	+4,800.00
Less: Variable Costs	(10,300.00)	(6,600.00)	(+3,700.00)
GROSS MARGIN	4,700.00	13,200.00	+8,500.00
Fixed Costs	2,000.00	2,000.00	0.00
NET PROFIT	**2,700.00**	**11,200.00**	**+8,500.00**
PROFITABILITY RATIOS			
Variable Cost Ratio (%)	**68.7**	**33.3**	**–35.4**
Return on Variable Costs (ROVC)	**0.46**	**2.00**	**+1.54**
Benefit–Cost Ratio (BCR)	**1.23**	**2.25**	**+1.02**

Notes: Gross Margin = Gross Income – Variable Costs. Fixed costs include land rental and basic implements. Values represent mean per-hectare budgets (Survey data, 2025).

The results in Table 5.6 reveal a strong economic advantage for participants of NUCs compared with non-participants. Adopters achieved an 8,500 ZAR higher net profit per hectare, primarily driven by lower input intensity and premium market prices for indigenous crops. Although adopters generally produced smaller yields, their higher unit prices and reduced dependence on purchased inputs, such as synthetic fertilisers and pesticides, substantially improved profitability. The return on variable costs rose from 0.46 to 2.00, indicating that every rand invested in NUC production yielded ZAR 2.00 in gross margin. Similarly, the benefit–cost ratio more than doubled (1.23 to 2.25), confirming that NUCs are financially viable enterprises for smallholder farmers.

These findings demonstrate that NUCs deliver not only economic gains but also resilience benefits by lowering reliance on external inputs and enhancing self-provisioning capacity. The profitability pattern corresponds with the demographic profile of adopters—older, female, and larger-household farmers, who mobilise household labour and traditional agronomic knowledge to sustain low-cost production (Mudau et al., 2022). Comparable gross-margin advantages were observed by Adelabu and Franke (2023) and Winstead et al. (2024), who found that NUCs improve household income and reduce vulnerability to climate and market risks. The results align with previous empirical evidence across sub-Saharan Africa showing that integrating NUCs into smallholder systems enhances income diversification, resource-use efficiency, and food security (El Bilali et al., 2024). Consequently, promoting NUC adoption offers a practical pathway for sustainable agricultural intensification and livelihood resilience in marginal production environments.

5.4.4 Economic analysis

Table 5.7 shows that for non-Adopters, the future stream of their net profits, discounted to its present value, is ZAR 6,707. This positive NPV indicates that their farming practice is economically viable, as it shows a net gain over the costs. Further, for Adopters, the future stream of their significantly higher net profits, discounted to their present value, is ZAR 27,834. This is substantially higher than that of non-adopters, indicating a more profitable and economically attractive investment. It demonstrates that the adoption OF NUCs is economically viable when evaluated as a stand-alone project. However, the vastly superior NPV, IRR, and BCR of the Adopters group make it the more economically sound decision.

Table 5.7: Present Economic NPV before incremental

Group	Net Profit (Per season)	NPV (3 seasons, ZAR)	IRR (%)	BCR
Non-Adopters	ZAR 2,700	ZAR 6,707	13.4%	1.23
Adopters	ZAR 11,200	ZAR 27,834	38.2%	2.25

5.4.5 Investment and sensitivity analysis

The investment analysis presented in Table 5.8 assesses the financial sustainability of NUC adoption among smallholder farmers in KwaZulu-Natal Province. The analysis employed the Net Present Value (NPV), Internal Rate of Return (IRR), and Benefit–Cost Ratio (BCR) to assess long-term economic performance. A 10 percent discount rate was applied over three production seasons to determine whether NUC investment yields positive discounted benefits. These indicators provide robust evidence of the viability of NUCs as an enterprise for smallholder farmers (Mabhaudhi et al., 2021; El Bilali et al., 2024).

Table 5.8: Investment metrics for adopters and non-adopters of NUCs (Three Seasons, 10 % Discount Rate)

Group	Net Profit (per season)	NPV (3 seasons, ZAR)	IRR (%)	BCR	Incremental NPV (Adopters – Non-Adopters)
Non-Adopters	2 700	6 707	13.4	1.23	–
Adopters	11 200	27 834	38.2	2.25	**21 127**

Notes: NPV computed at a 10 percent discount rate over three seasons.

The results show that NUC adoption generates a strong positive return on investment. The NPV of ZAR 27,834 for adopters exceeds that of non-adopters by more than ZAR 21,000, indicating that NUC enterprises create substantial long-term benefits. The IRR of 38.2 percent is well above the assumed 10 percent discount rate, confirming that NUC investments are profitable and self-sustaining. The Benefit–Cost Ratio (BCR) of 2.25 means that every rand invested produced ZAR 2.25 in benefits, demonstrating efficient resource use and robust capital productivity.

This financial performance highlights that NUCs can be a stable source of income for smallholders, especially those with limited access to credit or formal markets. The strong profitability stems from the combination of low input costs and premium niche market prices. These findings are consistent with Adelabu and Franke (2023) and Mabhaudhi et al. (2021), who observed that underutilised crops yield high long-term returns due to their adaptability to marginal conditions and reduced production costs. Similarly, El Bilali et al. (2024) found that integrating indigenous crops into farming systems increases net returns and enhances livelihood security through diversified production portfolios.

Table 5.9: Sensitivity analysis of NUC Profitability (± 20 % Price, Yield, and Transport Cost Scenarios)

Scenario	Gross Income (ZAR)	Variable Costs (ZAR)	Gross Margin (ZAR)	Net Profit (ZAR)	ROVC (x)	BCR
Baseline	19 800	6 600	13 200	11 200	2.00	2.25
Price – 20 %	15 840	6 600	9 240	7 240	1.40	1.70
Price + 20 %	23 760	6 600	17 160	15 160	2.60	2.70
Yield – 20 %	15 840	6 600	9 240	7 240	1.40	1.70
Yield + 20 %	23 760	6 600	17 160	15 160	2.60	2.70
Transport + 20 %	19 800	7 040	12 760	10 760	1.81	2.19
Transport – 20 %	19 800	6 160	13 640	11 640	2.21	2.32

Table 5.9 presents the sensitivity analysis of the NUCs on changes in market prices and expected yield. The results confirm that changes in market price and expected yield have the most significant effect on the profitability of NUCs. For instance, a 20% decrease in their price or yield will result in a decrease in Net profit from R11,200 to R7,240. Additionally, a 20% increase in variable costs will result in a corresponding increase in Net Profit to R15,160. This significant effect is also reflected in ROVC and BCR (2.25) with substantial changes. This means that for every R1 invested in NUC production, it will result in a positive return of R2.25, confirming its economic viability. This implies that the economic viability of NUCs is highly sensitive to market conditions and production performance, with price and yield being the key factors that drive financial risk and returns.

Profitability is most sensitive to changes in yield and output prices, highlighting the importance of improving productivity and ensuring stable market access. Apparently, changes in transportation costs have a significant impact on NUC's profitability. For instance, Table 10 shows that a 20% increase in transport costs leads to a decrease in Net profit to R10,760 and a slight decrease in the BCR to 2.19. This shows that BCR is positive, indicating that NUC's economic viability is not entirely influenced by transport cost. NUCs remain profitable and viable regardless of a significant increase in transport costs. The CBA indicated that the cultivation of NUCs is economically feasible under different conditions. However, the sensitivity analysis indicates that the profitability of NUCs is influenced by changes in yield and output prices, highlighting the importance of improving productivity and ensuring stable market access. The minimal impact of transport cost variation shows that most adopters depend on local consumption and short value chains, which shield them from external cost fluctuations. These findings align with Winstead et al. (2024), who reported that short value chains reduce market risk for indigenous crop producers, and Mmbando (2025), who found that NUCs remain viable under-price uncertainty and climatic variability. Overall, the results confirm that NUC production is both financially feasible and economically resilient.

The sensitivity analysis confirms that NUC profitability is resilient to economic shocks. Even under adverse conditions of a 20 percent drop in yield or price, the BCR remains above 1.7, meaning NUC farming continues to generate positive returns. Profitability is most sensitive to changes in yield and output prices, highlighting the importance of improving productivity and ensuring stable market access. The minimal impact of transport cost variation shows that most adopters depend on local consumption and short value chains, which shield them from external cost fluctuations. These findings align with Winstead and Jacobson (2024), who reported that short value chains reduce market risk for indigenous crop producers, and Mmbando (2025), who found that NUCs remain viable under-price uncertainty and climatic variability. Overall, the results confirm that NUC production is both financially feasible and economically resilient.

5.4.6 Determinants of economic benefits from NUC adoption

A multiple regression analysis was conducted to identify the factors that determine the level of economic benefits realised by NUC adopters. The dependent variable was the gross margin per hectare, while explanatory variables included demographic, economic, farm, and institutional characteristics. Robust standard errors were applied to correct for heteroscedasticity. Table 10 shows the determinants.

Table 5.10: Determinants of economic benefits from NUC adoption

Variable	Coefficient	t-value	p-value
Age (years)	3.852	0.29	0.774
Education (years)	26.417	2.23	0.027 **
Household Income (ZAR)	0.051	1.78	0.078 *
Farm Size (ha)	2 298.442	1.25	0.211
Credit Access (1 = yes)	631.287	2.81	0.006 ***
Extension Access (1 = yes)	398.226	2.19	0.031 **
Training Access (1 = yes)	287.332	1.64	0.103 *
Market Distance (km)	–24.818	–2.06	0.041 **
Constant	1 197.234	1.58	0.115

Model statistics: $R^2 = 0.231$, Adj. $R^2 = 0.205$, $F = 5.14$, $p < 0.001$. **Significance levels**: * 10 %, ** 5 %, *** 1 %.

The regression results indicate that household income, education, credit access, extension access, training, and market distance have a significant impact on the economic benefits derived from NUC adoption. Education has a positive and significant relationship with gross margins ($p < 0.05$). Each additional year of schooling increases the gross margin by about ZAR 26.42. This indicates an inelastic but steady relationship, where the cumulative effect of education enhances farmers' capacity to process information and apply new and improved agronomic practices, manage resources efficiently, and access market information, which are crucial for tapping into the economic potential of NUCs. Also, education enhances a farmer's ability to manage the NUCs enterprise efficiently, increasing the likelihood of a positive outcome from the investment. Similar findings by Mabhaudhi et al. (2018) highlight that education improves farmers' managerial ability and efficiency in resource allocation. Similarly, Zulu et al. (2022) highlight that the educated farmers are more likely to adopt NUCs due to their better understanding of the complex role between agriculture, health, and nutrition. Furthermore, household income shows a marginally significant positive relationship ($p < 0.10$); the coefficient reveals a highly elastic relationship, indicating that households with greater financial stability may have more capacity to absorb the initial risks and investments associated with adopting NUCs. These results are in line with those of Orkaa and Ayanwale (2021), who found that the NUCs could provide a significant contribution to household income and improve the welfare of farming households.

Credit access has the largest coefficient ($\beta = 631.29$, $p < 0.01$), showing that access to credit enhances investment in production and supports the timely purchase of inputs. Credit availability is essential for farmers to invest in the inputs such as seeds and infrastructure needed to expand the production and market these NUCs, which will directly increase the revenue. This result aligns with Mudau et al. (2022), who found that financial inclusion has a significant impact on the profitability of underutilised crops. Similarly, Issaka et al. (2021) found that farmers who have access to credit are more likely to adopt new technology.

Extension access is also significant ($p < 0.05$) and positively affects profitability. This represents a moderately elastic effect, highlighting the importance of knowledge transfer and technical guidance in improving farm-level efficiency and productivity for NUCs. Farmers who receive technical support achieve higher productivity and better management of soil and water resources. Regular extension visits lower production costs. This highlights the vital role of agricultural advisory services in providing the technical expertise necessary for profitable NUC cultivation, resulting in a favourable BCR. The results align with those of Zondi et al. (2022), who reported that extension services enhance farmers' understanding, leading to increased production, a higher likelihood of market participation, and the commercialisation of indigenous crops. Training access is weakly significant ($p < 0.10$) but still contributes positively to gross margins. Farmers who participate in training programs acquire knowledge about post-harvest handling, processing, and marketing, which enhances the quality and price of their products. These results are consistent with those of Rernardo (2016), who found that proper and adequate exposure of farmers to quality information helps them address farm problems, access better services, and manage production costs. Similarly, Aryal and Lopez-Lavalle (2025) reported that providing targeted training programs can bridge the knowledge gap, enabling farmers to adopt quinoa effectively.

Market distance emerges as a significant barrier to economic benefits, showing a negative and significant effect ($p < 0.05$). For each additional kilometre from the market, gross margins decrease by about ZAR 25. This demonstrates an inelastic but economically meaningful effect, where transportation costs, time, and potential post-harvest losses associated with longer distances erode the profit margins of NUCs. This strong negative relationship highlights the importance of market proximity and infrastructure in maximising the economic benefits of NUCs. This suggests that farmers located far from markets face higher transport costs and limited access to buyers, which severely reduces the profitability of NUCs, making them less attractive for farmers in remote areas and making NUC production’s feasibility highly sensitive. The finding aligns with Adelabu and Franke (2023), who reported that poor infrastructure and long distances reduce smallholder market participation. Overall, these results confirm that human capital, institutional access, and market proximity are critical for enhancing the economic performance of NUC adopters. Further, Aryal and Lopez-Lavalle (2025) suggested creating local and international market opportunities for quinoa to ensure its economic viability. Additionally, Nambafu et al. (2024) revealed that an increase in the market distance reduces the likelihood of AIV smallholder producers to commercialise by 18.4%.

The cost–benefit, investment, and regression results provide strong evidence that NUC adoption is economically viable and competitive among smallholder farmers. Adopters achieve higher gross margins, stronger returns on variable costs, and greater long-term benefits compared to non-adopters. However, the competitiveness of NUCs is limited by weak market linkages, poor infrastructure, and low institutional support. Improving competitiveness requires action across the value chain. Establishing local aggregation and processing centres would reduce transaction costs and improve quality control. Expanding access to extension and training services can improve production skills and post-harvest management. Microfinance schemes and cooperative marketing groups can help farmers access credit and sell collectively to attract better prices. Integrating NUCs into public food procurement programs, such as school feeding initiatives, would create stable demand and strengthen market confidence. These interventions align with the findings of El Bilali et al. (2024) and Mmbando (2025), who emphasise that investment in market systems and institutional support enhances the competitiveness and sustainability of NUC value chains. Strengthening these systems will ensure that NUCs continue to contribute to income diversification, gender empowerment, and climate-resilient livelihoods in South Africa.

5.5 Conclusion

This study set out to assess the economic feasibility of Neglected and Underutilised Crops (NUCs) in the context of KwaZulu-Natal, South Africa, by applying a rigorous cost-benefit analysis (CBA) framework. The key quantitative findings of the study demonstrate strong baseline feasibility, with a benefit-cost ratio (BCR) of 2.25 and a return on variable costs (ROVC) of 2.00. However, sensitivity analysis reveals that the viability of NUCs is highly dependent on output prices and yield, with a 20% decrease in either causing the BCR to decrease to 1.70. Furthermore, regression analysis identified the significant determinants of economic benefits, showing that access to credit ($p<0.01$) and extension services (p<0.05) substantially increase revenues, while market distance (p<0.05) imposes a significant cost hindrance. This research contributes to the new body of knowledge as it is one of the very few empirical studies to conduct a formal CBA and econometric analysis of NUC adoption. It moves beyond theoretical advocacy to provide a data-driven model of the economic risks and returns, identifying the precise financial levers that determine success or failure.

The findings of this study demonstrate that underutilised crops hold substantial economic potential for smallholder farmers in KZN Province. Adopters of NUCs achieved significantly higher gross margins, benefit–cost ratios, and net returns compared to non-adopters, indicating that these crops are not only profitable but also resilient to market and climatic fluctuations. The positive NPV and IRR further confirm that investing in NUCs yields sustainable financial returns over time. These results highlight the suitability of NUCs for resource-poor farming systems, given their low input requirements, adaptability to marginal conditions, and high market value. Therefore, promoting NUCs presents a strategic opportunity to achieve multiple policy objectives, including improving the incomes of smallholders, enhancing food and nutrition security, and supporting climate-resilient agriculture. Strengthening the institutional and market framework around NUCs can unlock their full potential as viable alternatives to conventional food crops

5.6 Recommendations

Based on the empirical findings of this study, a tiered policy approach is recommended to enhance the economic feasibility of NUCs. In the short term, policy should prioritise refocusing extension services on the specific profitability and risk factors identified, particularly yield stabilisation, and facilitate access to targeted input credit, the most significant revenue driver. For the medium term, developing rural market infrastructure and piloting index-based insurance are critical to counteract the negative impact of market distance and mitigate the high sensitivity of profitability to price and yield shocks. Strategically, mainstreaming NUCs into provincial agricultural plans and fostering value-added enterprises will secure long-term sectoral integration and demand. To build on this research, a future agenda should include longitudinal studies on adoption resilience, gender-disaggregated profitability analyses, comprehensive value-chain mapping, and regional comparative studies to refine these evidence-based interventions.

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CHAPTER 6: INDIGENOUS OFSP-ENRICHED STIFF PAP: NUTRITIONAL BENEFITS AND CONSUMER ACCEPTABILITY IN RURAL SOUTH AFRICA

6.1 Abstract

Indigenous crops present resilient, nutrient-dense alternatives that can fortify food and nutrition security in rural South African communities. This study evaluated the nutritional composition, consumer acceptability, and community perceptions of stiff pap composite dishes incorporating pumpkin leaves, Cucurbita pumpkin, and cream-fleshed sweet potato (CFSP). Employing a cross-sectional design, three composite dishes were prepared and assessed by 60 rural participants through sensory testing and focus group discussions. Nutritional analyses revealed that pumpkin leaves significantly enhanced protein, fibre, mineral content, and essential amino acids, while combinations with beans and CFSP or pumpkin yielded complementary nutrient profiles. Sensory evaluation indicated a high overall acceptability, with the CFSP-based dish being the most preferred due to its taste and texture. Focus groups highlighted that familiarity, flavour balance, and preparation methods influenced the willingness to adopt these dishes, with novel combinations eliciting both curiosity and some hesitation. The findings suggest that integrating indigenous crops into culturally familiar staples can enhance nutrient intake, promote dietary diversification, and support smallholder farming systems. Promoting the production and household-level utilisation of these crops, coupled with culinary guidance, represents a practical, culturally sensitive strategy to improve nutrition, foster sustainable livelihoods, and mitigate reliance on low-nutrient staple diets in economically constrained communities.

Keywords: Neglected underutilised crops; traditional; pumpkin; pumpkin leaves; sensory evaluation.

6.2 Introduction

Smallholder farming remains integral to rural livelihoods in South Africa, providing both food and income to millions of households (Thamaga-Chitja & Morojele, 2014; Pienaar & Traub, 2015; Fan & Rue, 2020; Moyo, 2016). Approximately 80% of smallholder farms globally focus on producing food for local income generation and household consumption, thereby contributing to the alleviation of food insecurity and poverty (Mdiya et al., 2025). Smallholder agriculture in South Africa is a crucial pillar for agricultural development (African Smallholder Farmers Group (ASFG), 2013). Despite growing pressures from climate change, many smallholder farmers continue to rely on traditional production systems and cultivate diverse underutilised indigenous crops, including sweet potatoes, taro, and pumpkin leaves. These crops demonstrate resilience under harsh climatic conditions, perform well in degraded or nutrient-poor soils, and require minimal external inputs (Workalemahu & Dawid, 2021; Ndlovu et al., 2020; Mbuli et al., 2021; Ntinyari et al., 2022; Mampholo et al., 2024). Their adaptability, reliability, and cultural significance render them essential for strengthening smallholder farming systems.

Indigenous crops have been cultivated for generations and constitute an integral part of South Africa's traditional food systems (Mabhaudhi et al., 2018; Omotayo & Aremu, 2024). They influence household food consumption patterns and offer diverse nutritional advantages, providing essential micro- and macronutrients in communities facing poverty and limited access to varied diets (Mishra et al., 2021; Mabhaudhi et al., 2021; Qwabe et al., 2025). Many species, particularly leafy greens and taro, grow naturally or emerge alongside cultivated crops, often mistaken for weeds. However, their hardiness enables survival and production in conditions where conventional crops struggle, underscoring their potential as resilient, low-cost alternatives for local food systems (Qwabe et al., 2025). Underutilised indigenous crops contribute to South Africa's agro-biodiversity and hold potential for socio-economic development in rural communities (Modi & Mabhaudhi, 2016). Their capacity to thrive under limited resources, poor soils, and variable climatic conditions positions them strategically for enhancing agricultural productivity and resilience (Mphande, 2025). Rooted in local culinary traditions, these crops have adapted naturally to harsh environments. As drought events intensify across South Africa, their significance becomes even more pronounced (Mpande et al., 2023). However, indigenous foods face an existential threat due to dietary transitions, increased consumption of refined foods, and marginalisation within mainstream agricultural policies, market structures, and development agendas (Ndlovu et al., 2024).

Despite the nutritional richness of indigenous crops, their integration into daily diets remains limited. In rural South Africa, stiff pap (locally known as phutu or sadza), traditionally made from refined maize meal, is the predominant staple food, consumed by the majority of households due to its low cost, satiety, and deep cultural embeddedness (Tauya, 2018). However, maize-based stiff pap is nutritionally poor, providing primarily energy-dense starch with limited protein, dietary fibre, and essential micronutrients. Its reliance on refined maize meal further exacerbates the risk of micronutrient deficiencies, including iron, zinc, and vitamin A, particularly in communities with low dietary diversity (Mishra et al., 2021; Mabhaudhi et al., 2021). Consequently, while stiff pap ensures short-term energy needs, its regular consumption without complementary nutrient-rich foods contributes to hidden hunger and malnutrition.

Given the nutritional shortcomings of maize-based stiff pap and the untapped potential of indigenous crops, enriching stiff pap with indigenous crops presents a promising, culturally grounded strategy for improving rural diets. By incorporating indigenous crops such as cream-fleshed sweet potatoes, traditional *Cucurbita* pumpkins, and pumpkin leaves into stiff pap, it becomes possible to enhance the micronutrient profile, dietary fibre content, and overall nutritional density of a widely consumed staple without displacing familiar eating practices (Tauya, 2018; Mgwenya et al., 2025).

However, the successful adoption of such composite foods depends critically on consumer acceptability. Modifying a traditional dish like stiff pap introduces potential sensory and cultural challenges. Indigenous crops can alter the taste, texture, colour, and aroma of the final product, which may be met with resistance especially among younger consumers who may associate indigenous ingredients with “old-fashioned” or less desirable rural diets (Ndlovu et al., 2024). Moreover, cultural norms around the “correct” appearance and mouthfeel of stiff pap can influence willingness to accept enriched versions. Therefore, understanding these sensory perceptions and cultural barriers is as important as confirming nutritional benefits.

For smallholder farmers, developing acceptable composite pap recipes also offers opportunities for value addition and improved market access. Indigenous crops are often sold raw at low prices, limiting profitability. Processing them into enriched stiff pap can create new income streams, stimulate demand, and support sustainable farming systems. Enhancing consumer markets for indigenous crop-based foods incentivises diversification and resilience against climate variability. Despite the agronomic and nutritional advantages of indigenous crops, research on consumer sensory perceptions remains limited. Most studies focus on agronomic potential or nutritional profiles rather than real-world acceptability. As urbanisation and dietary transitions reshape food choices, generating evidence on consumer preferences is increasingly important for mainstreaming indigenous foods.

Hence, this study examines the nutritional composition, consumer acceptability, and perceptions of stiff pap composite dishes prepared with indigenous crops cultivated by smallholder farmers. By evaluating sensory attributes and consumer attitudes, the research aims to inform product development, nutrition promotion, and value chain enhancement. Ultimately, it contributes to revitalising indigenous crops, strengthening smallholder livelihoods, and promoting culturally relevant, nutrient-dense diets to improve food and nutrition security in rural South African communities.

6.3 Materials and methods

6.3.1 Materials

Three composite dishes were prepared for this study. Each dish comprised stiff pap served alongside pumpkin leaves and a variation of bean curry:

- Composite Dish 1: Stiff pap accompanied by pumpkin leaves, beans, and potatoes (this dish is traditionally served with a combination of beans and potatoes);
- Composite Dish 2: Stiff pap served with pumpkin leaves, beans, and pumpkin (Cucurbita spp.);
- Composite Dish 3: Stiff pap served with pumpkin leaves, beans, and cream-fleshed sweet potato (CFSP).

The formulation of these dishes involved ingredients sourced from various suppliers and produced through distinct processes. Commercially available components, including Nyala maize meal, red speckled dry beans, onions, potatoes, Robertson's Rajah Mild spice, Cerebos salt, Knorrox beef stock cubes, Robertson's Rajah curry powder, Spar cooking oil, and cayenne pepper, were acquired from Spar supermarket in Pietermaritzburg, KwaZulu-Natal, South Africa. Nyala maize meal was selected due to its status as the most widely utilised maize meal brand in the province. Pumpkin leaves and pumpkin (Cucurbita spp.) were donated by smallholder farmers from Swayimane village, while the cream-fleshed sweet potatoes were procured from Super Savers at Scottsville Mall in Pietermaritzburg, KwaZulu-Natal (KZN), South Africa.

6.3.2 Study design

A cross-sectional study design (Wang & Chang, 2020) was utilised to assess the sensory attributes and participants' perceptions of dishes prepared from indigenous crops, specifically cream-fleshed sweet potatoes, Cucurbita pumpkin, and pumpkin leaves, which are commonly cultivated in resource-limited regions of KZN. The research was conducted at the University of KZN within the Msunduzi Local Municipality. Standardised dishes were prepared, and participants from rural communities in KZN were invited to engage in a one-time sensory evaluation, followed by participation in focus group discussions. Data were collected at a single time point to capture participants' acceptability, perceived quality, and related outcomes, thereby providing insights into both individual sensory responses and broader community perceptions of dishes based on indigenous crops.

6.3.3 Preparation of composite dishes

All composite dishes were prepared freshly on the morning of the sensory evaluation data collection, which took place in the Food Processing Laboratory of the Human Nutrition and Dietetics Department at UKZN, Pietermaritzburg. All ingredients were processed and prepared in a certified Food Science laboratory in accordance with Hazard Analysis and Critical Control Point (HACCP) principles to ensure food safety, minimise contamination risks, and preserve the integrity of the composite dishes. The food items were prepared over two trial sessions, one week prior to the pilot study, to ensure that the recipes were both accurate and culturally acceptable. These recipes were standardised for stiff pap (Supplementary information), pumpkin leaves (Supp), beans and potato (Supp), beans and sweet potato (Supp), and beans and cream-fleshed sweet potato (Supp) (Appendix B). The dishes were tasted by Black African men and women employed at UKZN, who shared a similar sociodemographic background with the study participants, to assess cultural acceptability. Although these employees originated from communities comparable to those represented in the primary study, they were unable to participate in the actual data collection due to work obligations during that timeframe.

6.3.4 Nutritional analysis

Fifteen participants from the sensory evaluation cohort were randomly selected to articulate their proposed presentations of the foods on a plate. These presentations were compiled, amalgamated, and subsequently analysed to enhance the understanding of the nutritional benefits associated with these foods. Proximate analysis, encompassing moisture, crude protein, fat, fibre, ash, and selected minerals, was conducted at the KwaZulu-Natal Department of Agriculture and Rural Development in Cedara, adhering to standardised analytical procedures (AOAC International, 2019). Amino acid analysis was executed at Stellenbosch University, following established laboratory protocols. Proximate composition was determined in accordance with AOAC methodologies, while mineral elements were quantified following appropriate sample preparation using validated analytical techniques. Amino acid profiling was performed utilising chromatographic methods subsequent to acid hydrolysis. To ensure analytical reliability, two independent duplicate sets of analyses were conducted, and all instruments were calibrated prior to measurement to guarantee the accuracy and consistency of the results.

6.3.5 Sensory evaluation

A pilot study was conducted on 19 May 2025 at the University of KwaZulu-Natal to evaluate the feasibility of the study procedures, the practicality of food preparation methods, and the preliminary consumer acceptability of newly developed recipes. Three composite meal combinations were prepared and assessed: (i) stiff pap with pumpkin leaves, beans, and potatoes (control meal); (ii) stiff pap with pumpkin leaves, beans, and pumpkin (experimental meal); and (iii) stiff pap with pumpkin leaves and beans combined with cream-fleshed sweet potato (CFSP). Each of the three dishes was assigned a three-digit code using a random number table, with the code known solely to the researcher and research assistants. Ten participants from the KwaNongoma village in northern KZN were recruited to partake in the food tasting session. Prior to participation, informed consent (Appendix E) was obtained, and participants completed ranking the sensory evaluation, preference ranking test and focus group discussions (FGDs).

For the main sensory evaluation, sixty untrained participants (n = 60) from uMkhanyakude District Municipality (UDM) and King Cetshwayo District Municipality (KCDM) were randomly selected to assess the acceptability of the three composite dishes. A distinct pilot study involving ten participants was conducted, with these individuals subsequently excluded from the main study. To mitigate potential bias and prevent mutual influence among panellists, participants were seated at physically separated stations, partitioned by boards, and instructed to refrain from communication during the sensory evaluation sessions. At the commencement of each session, the researcher guided the panellists through the evaluation forms to eliminate errors and inaccuracies, utilising the IsiZulu language for clarity. Individual tasting stations were established for each participant, featuring coded food samples and a glass of water to facilitate palate cleansing between samples, consistent with the methodology employed in the pilot study. The consent form was available in both English and isiZulu for the participants (Appendix E). Each participant received the heated samples. Participants were instructed to assess the acceptability and rank the dishes using a nine-point hedonic scale (1 = extremely dislike, 2 = dislike very much, 3 = dislike slightly, 4 = dislike moderately, 5 = neither like nor dislike, 6 = like moderately, 7 = like slightly, 8 = like very much, and 9 = like extremely). The serving order of the samples was determined using a table of random permutations of nine. Upon tasting and rating all samples, participants indicated their preference order among the three dishes. The preference ranking was categorised as follows: 1 = most preferred, 2 = moderately preferred, and 3 = least preferred. Subsequently, participants engaged in a focus group discussion (FGD). The FGDs were facilitated by a trained individual with experience in conducting focus groups. The questions were developed in advance and validated through a pilot study.

6.3.6 Data Analysis

Quantitative data were systematically coded, recorded in Microsoft Excel, and meticulously cleaned prior to export to the Statistical Package for the Social Sciences (SPSS) version 28 for subsequent statistical analysis. Qualitative data derived from FGDs, facilitated by a semi-structured discussion guide, were audio-recorded, transcribed verbatim, and analysed utilising NVivo version 15.

6.3.7 Ethical considerations

Ethical approval for the study was granted by the University of KwaZulu-Natal Biomedical Research Ethics Committee (HSSREC/00007019/2024) (Appendix C). Written informed consent was obtained from all participants prior to their involvement in the study.

6.4 Results

6.4.1 Sample characteristics

Table 6.1 summarises the sample characteristics of the 60 study participants. Females constituted the majority of the sample (n = 39, 65.0%), compared to males (n = 21, 35.0%).

Regarding age distribution, the 18–25-year age group was the most represented, accounting for 80.0% (n = 48) of participants. Smaller proportions were observed in the 26–35-year (n = 4, 6.7%), 36–45-year (n = 1, 1.7%), 46–55-year (n = 4, 6.7%), and 56–65-year (n = 3, 5.0%) age categories.

Table 6.1: The number of participants and age distribution

Category	n*	%
Gender		
Male	21	35.0
Female	39	65.0
Age group		
18-25	48	80
26-35	4	6.7
36-45	1	1.7
46-55	4	6.7
56-65	3	5

*n-60 participants

6.4.2 Nutritional composition

6.4.2.1 Proximate analysis of raw foods and three cooked composite dishes

Table 6.2 delineates the proximate composition of selected raw food samples alongside three cooked composite stiff pap dishes. Statistically significant differences were identified among the raw food samples concerning moisture, protein, fat, neutral detergent fibre (NDF), and total mineral content ($p < 0.05$).

Within the raw food samples, moisture content exhibited a range from 5.21% in creamed-fleshed sweet potato (CFSP) to 11.01% in maize meal. Protein content exhibited variability, spanning from 2.50 g/100 g dry weight (DW) in CFSP to 31.54 g/100 g DW in pumpkin leaves. Fat content fluctuated between 1.58 g/100 g DW in pumpkin flesh and 6.46 g/100 g DW in pumpkin leaves. NDF values displayed marked differences, with pumpkin leaves presenting the highest fibre content (45.90 g/100 g DW), followed by pumpkin flesh (12.57 g/100 g DW), CFSP (10.48 g/100 g DW), and maize meal (4.50 g/100 g DW). Total mineral content ranged from 0.53 mg/100 g DW in maize meal to 10.26 mg/100 g DW in pumpkin leaves.

In the case of the composite dishes, moisture content varied from 4.91% to 5.85%, with significant differences noted among formulations ($p = 0.008$). Protein content also demonstrated significant variation among composite dishes ($p < 0.002$), with values ranging from 8.33 g/100 g DW in the stiff pap containing pumpkin leaves, beans, and CFSP to 11.61 g/100 g DW in the stiff pap comprising pumpkin leaves, beans, and potato. Fat content ranged from 7.43 to 11.97 g/100 g DW, with no statistically significant differences observed among composite dishes ($p = 0.35$). NDF content exhibited significant differences ($p = 0.03$), ranging from 12.89 g/100 g DW in the CFSP-based composite to 22.36 g/100 g DW in the pumpkin-based composite dish. Total mineral content similarly varied significantly among the composite dishes ($p = 0.03$), with values ranging from 4.49 to 5.87 mg/100 g DW.

Table 6.2: Proximate analysis of raw foods and three cooked composite dishes

Sample	Moisture (%)	Protein (g/100g, DW[a])	Fat (g/100g, DW)	NDF[b] (g/100g, DW)	Total minerals mg/100g, DW
Raw food samples					
Maize meal	11.01[c] ± 0.12[d]	7.84±0.17	2.44±0.57	4.5±0.622	0.53±0.08
Pumpkin	7.82±0.21	6.76±0.01	1.58±0.23	12.57±0.06	4.74±0.08
Creamed fleshed sweet potato	5.21±0.05	2.50±0.01	1.64±0.59	10.48±1.27	3.21±0.06
Pumpkin leaves	7.14±0.00	31.54±0.02	6.46±0.00	45.90±4.89	10.26±0.00
P value[e]	**0.010**	**0.009**	**0.013**	**0.002**	**0.03**
Composite dishes					
Stiff pap with pumpkin leaves, beans and potatoes	4.91±0.05	11.61±0.18	11.97±0.25	20.53±10.21	5.54±0.11
Stiff pap with pumpkin leaves and beans and CFSP	5.85±0.37	8.33±0.07	7.43±0.30	12.89±1.75	4.49±0.21
Stiff pap with pumpkin leaves, beans and pumpkin	4.96±0.00	10.57±0.11	8.64±0.88	22.36±1.24	5.87±0.15
P value[e]	**0.008**	**<0.002**	0.35	**0.03**	**0.03**

[a]DW: dry weight basis; [b]NDF: Neutral detergent fibre; [c]Mean of two duplicate values; [d]Standard deviation; [e] ANOVA F-test was used for analysis; Means (± SEM) with different p-values in the same row are significantly different at 5% ($p<0.05$) and 1% ($p<0.001$).

6.4.2.2 Mineral composition of raw foods and formulated composite dishes (mg/100 g, DW)

Table 4.7 presents the mineral composition of selected raw food samples and three formulated composite stiff pap dishes, with values expressed on a dry weight basis. Statistically significant differences were noted among the raw food samples for calcium, iron, potassium, magnesium, and zinc ($p < 0.05$), whereas sodium and phosphorus did not exhibit significant differences ($p > 0.05$).

Within the raw food samples, calcium concentrations varied from 10.00 mg/100 g DW in maize meal to 790.00 mg/100 g DW in pumpkin leaves. The iron content ranged from 0.10 mg/100 g DW in creamed-fleshed sweet potato to 37.60 mg/100 g DW in pumpkin leaves. Potassium levels spanned from 110.00 mg/100 g DW in maize meal to 2860.00 mg/100 g DW in pumpkin leaves. Magnesium concentrations were recorded between 35.00 mg/100 g DW in maize meal and 525.00 mg/100 g DW in pumpkin leaves. Sodium content ranged from 10.00 mg/100 g DW in maize meal to 270.00 mg/100 g DW in creamed-fleshed sweet potato, with no significant differences identified ($p = 0.09$). Phosphorus levels varied from 100.00 mg/100 g DW in maize meal to 780.00 mg/100 g DW in pumpkin leaves, with no significant differences observed among the raw food samples ($p = 0.07$). Zinc concentrations ranged from 0.60 mg/100 g DW in creamed-fleshed sweet potato to 6.60 mg/100 g DW in pumpkin leaves, revealing significant differences ($p = 0.001$).

For the composite dishes, calcium content ranged from 120.00 mg/100 g DW in the stiff pap containing pumpkin leaves, beans, and CFSP to 170.00 mg/100 g DW in the formulation with pumpkin leaves, beans, and pumpkin, with significant differences noted among formulations ($p = 0.001$). Iron content was observed to range from 6.65 mg/100 g DW in the composite dish based on creamed-fleshed sweet potato to 15.50 mg/100 g DW in the pumpkin-based composite dish ($p = 0.001$). Potassium levels varied significantly ($p < 0.001$), ranging from 850.00 mg/100 g DW in the composite based on creamed-fleshed sweet potato to 1240.00 mg/100 g DW in the potato-based composite dish. Magnesium content ranged from 90.00 to 130.00 mg/100 g DW, with significant differences identified among the composite dishes ($p < 0.007$). Sodium concentrations ranged from 845.00 mg/100 g DW in the CFSP-based composite to 1270.00 mg/100 g DW in the pumpkin-based composite dish, with substantial differences observed ($p < 0.001$). Phosphorus levels ranged from 169.50 to 230.00 mg/100 g DW, with significant differences noted among the composite dishes ($p < 0.001$). Zinc content varied from 1.70 to 2.20 mg/100 g DW, revealing significant differences among the composite dishes ($p = 0.02$).

Table 6.3: Mineral composition of analysis of raw foods and composite dishes (mg/100g, DW)

Sample	Calcium	iron	Potassium	Magnesium	Sodium	Phosphorus	Zinc
Raw food samples							
Maize meal	10.00[a]±0.00[b]	2.35±1.77	110.00±0.00	35.00±7.07	10.00±0.00	100.00±0.00	2.25±0.64
Pumpkin	75.00±7.07	1.30±0.00	1790.00±0.28	55.00±63.64	30.00±0.00	230.00±0.00	0.75±0.49
Creamed fleshed sweet potato	80.00±0.00	0.10±0.00	1105.00±21.21	50.00±0.00	270.00±0.00	225.00±63.64	0.60±0.00
Pumpkin leaves	790.00±14.14	37.60±8.34	2860.00±0.00	525.00±7.07	130.00±0.00	780.00±99.00	6.60±0.14
P value[e]	< 0.001	0.002	< 0.001	0.004	0.09	0.07	0.001
Composite dishes							
Stiff pap with pumpkin leaves, beans and potatoes	150.00±0.00	8.00±2.12	1240.00±7.07	110.00±0.00	1085.00±7.07	169.50±85.56	1.70±0.00
Stiff pap with pumpkin leaves and beans and CFSP	120.00±0.00	6.65±1.91	850.00±0.00	90.00±0.00	845.00±7.07	180.00±0.00	1.90±0.57
Stiff pap with pumpkin leaves, beans and pumpkin	170.00±14.14	15.50±2.55	895.00±35.36	130.00±0.00	1270.00±0.00	230.00±0.00	2.20±0.14
P value	0.001	0.001	<0.001	<0.007	<0.001	<0.001	0.02

[a]Mean of two duplicate values; [b]Standard deviation; [c] ANOVA F-test significance level: 5% ($p<0.05$) and 1% ($p<0.001$)

2.4.2.3 Amino acid composition

Table 6.4 summarises the essential amino acid composition of selected raw foods and composite stiff pap dishes. Statistically significant differences were observed among the raw food samples for all essential amino acids analysed ($p < 0.05$).

Among the raw foods, pumpkin leaves exhibited the highest concentrations of all essential amino acids, while creamed-fleshed sweet potato consistently demonstrated the lowest values. Histidine concentrations ranged from 0.12 to 0.72 g/100 g dry weight (DW), threonine from 0.05 to 0.84 g/100 g DW, lysine from 0.08 to 1.00 g/100 g DW, and methionine from 0.17 to 0.40 g/100 g DW. Valine concentrations ranged from 0.10 to 1.25 g/100 g DW, isoleucine from 0.07 to 1.05 g/100 g DW, leucine from 0.12 to 1.87 g/100 g DW, and phenylalanine from 0.17 to 1.96 g/100 g DW.

For the composite dishes, significant differences were noted for all essential amino acids ($p < 0.05$). Histidine concentrations ranged from 0.14 to 0.38 g/100 g DW, threonine from 0.20 to 0.36 g/100 g DW, lysine from 0.31 to 0.39 g/100 g DW, and methionine from 0.17 to 0.34 g/100 g DW. Valine concentrations ranged from 0.28 to 0.48 g/100 g DW, isoleucine from 0.23 to 0.40 g/100 g DW, leucine from 0.58 to 0.97 g/100 g DW, and phenylalanine from 0.44 to 1.01 g/100 g DW.

Table 6.5 presents the non-essential amino acid composition of raw foods and composite stiff pap dishes. Statistically significant differences were observed among raw food samples for all non-essential amino acids analysed ($p < 0.05$).

Among the raw foods, pumpkin leaves consistently exhibited the highest concentrations, while creamed-fleshed sweet potato demonstrated the lowest values. Arginine concentrations ranged from 0.04 to 2.04 g/100 g DW, serine from 0.13 to 1.16 g/100 g DW, glycine from 0.09 to 1.37 g/100 g DW, aspartic acid from 0.24 to 1.83 g/100 g DW, glutamic acid from 0.20 to 3.01 g/100 g DW, alanine from 0.09 to 1.21 g/100 g DW, proline from 0.07 to 0.88 g/100 g DW, and tyrosine from 0.03 to 1.41 g/100 g DW.

For the composite dishes, all non-essential amino acids exhibited significant differences among formulations ($p < 0.05$). Arginine concentrations ranged from 0.39 to 0.89 g/100 g DW, serine from 0.31 to 0.49 g/100 g DW, glycine from 0.22 to 0.45 g/100 g DW, aspartic acid from 0.49

to 0.77 g/100 g DW, glutamic acid from 1.26 to 2.27 g/100 g DW, alanine from 0.28 to 0.42 g/100 g DW, proline from 0.31 to 0.54 g/100 g DW, and tyrosine from 0.20 to 0.75 g/100 g DW.

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Table 6.4: Essential amino acid composition of analysis of raw foods and composite dishes (g/100g, DW)

Sample	Histidine	Threonine	Lysine	Methionine	Valine	lsoleucine	Leucine	Phenylalanine
Raw food samples								
Maize meal	0.26[a]±0.09[b]	0.19±0.04	0.15±0.01	0.31±0.01	0.35±0.07	0.24±0.04	0.93±0.18	0.57±0.22
Pumpkin	0.13±0.03	0.14±0.01	0.23±0.03	0.17±0.02	0.28±0.05	0.24±0.03	0.35±0.05	0.36±0.50
Creamed fleshed sweet potato	0.12±0.01	0.05±0.01	0.08±0.01	0.23±0.06	0.10±0.00	0.07±0.01	0.12±0.01	0.17±0.03
Pumpkin leaves	0.72±0.01	0.84±0.01	1.00±0.25	0.40±0.03	1.25±0.06	1.05±0.03	1.87±0.03	1.96±0.23
P value[e]	<0.05		0.002	< 0.001	<0.01	<0.05	<0.05	<0.01
Composite dishes								
Stiff pap with pumpkin leaves, beans and potatoes	0.38±0.03	0.36±0.03	0.39±0.02	0.34±0.03	0.48±0.00	0.40±0.01	0.97±0.02	1.01±0.02
Stiff pap with pumpkin leaves and beans and CFSP	0.14±0.01	0.20±0.01	0.39±0.01	0.17±0.00	0.28±0.00	0.23±0.00	0.58±0.00	0.44±0.01
Stiff pap with pumpkin leaves, beans and pumpkin	0.24±0.00	0.20±0.01	0.31±0.03	0.25±0.04	0.38±0.05	0.30±0.01	0.75±0.04	0.57±0.00
P value[e]	<0.05	<0.05	<0.05	<0.01	<0.05	<0.01	<0.05	<0.01

[a]Mean of two duplicate values; [b]Standard deviation; [c] ANOVA F-test significance level: 5% (p<0.05) and 1% (p<0.001)

Table 6.5: Non-essential amino acid composition of analysis of raw foods and composite dishes (g/100g, DW)

Sample	Arginine	Serine	Glycine	Aspartic acid	Glutamic acid	Alanine	Proline	Tyrosine
Raw food samples								
Maize meal	0.37[a]±0.16[b]	0.38±0.10	0.27±0.07	0.43±0.16	1.60±0.45	0.47±0.09	0.57±0.78	0.34±0.21
Pumpkin	0.33±0.07	0.26±0.06	0.25±0.08	0.69±0.16	0.88±0.22	0.23±0.02	0.15±0.01	0.20±0.04
Creamed fleshed sweet potato	0.04±0.01	0.13±0.00	0.09±0.00	0.24±0.00	0.20±0.05	0.09±0.01	0.07±0.01	0.03±0.01
Pumpkin leaves	2.04±0.10	1.16±0.09	1.37±0.02	1.83±0.28	3.01±0.28	1.21±0.08	0.88±0.00	1.41±0.01
P value[e]	<0.05	<0.01	< 0.05	< 0.01	< 0.01	< 0.05	< 0.01	< 0.05
Composite dishes								
Stiff pap with pumpkin leaves, beans and potatoes	0.89±0.04	0.49±0.04	0.45±0.01	0.77±0.03	2.27±0.09	0.42±0.00	0.54±0.01	0.75±0.06
Stiff pap with pumpkin leaves and beans and CFSP	0.39±0.02	0.31±0.01	0.22±0.01	0.49±0.01	1.26±0.01	0.28±0.00	0.31±0.01	0.20±0.00
Stiff pap with pumpkin leaves, beans and pumpkin	0.50±0.11	0.40±0.04	0.35±0.03	0.63±0.12	1.95±0.23	0.39±0.04	0.44±0.01	0.36±0.01
P value[e]	< 0.01	<0.05	< 0.01	<0.01	<0.05	<0.05	<0.05	< 0.01

[a]Mean of two duplicate values; [b]Standard deviation; [c] ANOVA F-test significance level: 5% (p<0.05) and 1% (p<0.001)

6.4.3 Consumer acceptability

The mean sensory evaluation scores for the three composite dishes across the six attributes measured on a 9-point hedonic scale are presented in Table 6.6. The t-test analysis indicated that sensory evaluation scores for each attribute were above the neutral score, suggesting that all composite dishes were, on average, well-liked. The Wilcoxon rank test revealed that while the stiff pap with pumpkin leaves and beans, accompanied by pumpkin aroma, received a significantly lower rating for aroma (6.75), the overall acceptability was rated high (7.17). The ratings for texture (7.12), appearance (7.02), and colour (6.92) were significantly lower than the overall acceptability for the composite dish made with stiff pap, pumpkin leaves, beans, and potato. Furthermore, aroma (6.97), appearance (6.95), and colour (6.90) of the composite dish comprising stiff pap, pumpkin leaves, and beans with CFSP were rated significantly lower than the overall acceptability (7.68). Results from the Friedman test, which compared the sensory attributes among the different samples, indicated that taste and colour differed significantly across the three composite dishes ($p < 0.05$). The Bonferroni correction demonstrated that the taste of the stiff pap, pumpkin leaves, and beans with the CFSP dish had a higher mean rank compared to that of the stiff pap, pumpkin leaves, and beans with the pumpkin dish. Conversely, a lower rank was observed for colour in the same comparisons. Figure 6.1 illustrates the preference ranking for the three composite dishes. Analysis from a repeated measures ANOVA confirmed that the mean rankings did not differ significantly across the three dishes ($p = 0.284$). However, it is numerically evident that the combination of stiff pap, pumpkin leaves, and beans with CFSP was the most preferred (n = 24; 40%), while the combination of stiff pap, pumpkin leaves, and beans with pumpkin was the least preferred (n = 23; 38%).

Table 6.6: Sensory evaluation comparison of the three composite dishes

Sample	Sensory attributes (mean ± SD)					
	Taste	Texture	Aroma	Colour	Appearance	OA
Stiff pap with pumpkin leaves, beans and potatoes	7.45±1.56	7.12±1.67	7.37±1.28	6.92±1.70	7.02±1.55	7.48±1.35
Stiff pap with pumpkin leaves and beans and CFSP	7.65±1.53	7.38±1.48	6.97±1.46	6.90±1.67	6.95±1.55	7.68±1.48
Stiff pap with pumpkin leaves, beans and pumpkin	6.90±1.72	6.95±1.55	6.75±1.57	7.33±1.50	6.97±1.31	7.17±1.39
P value	**P<0.001**	**P<0.001**	**P<0.001**	**P<0.001**		**P<0.001**

Values in bold indicate p<0.05 according to the Friedman test; CFSP: creamed fleshed sweet potato, OA: overall acceptability.

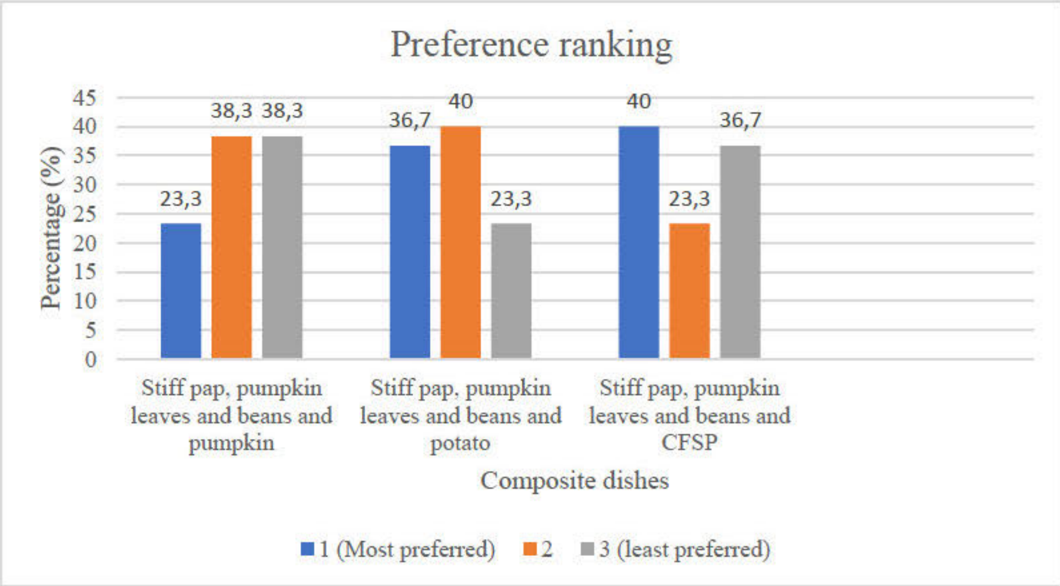

Figure 6.1: Preference ranking of the three composite dishes

6.4.4 Focus group discussions

The results of the FGDs are presented in Table 6.7.

Table 6.7: Participants' perceptions towards the three composite dishes

Question	Concept	Theme	codes	Quote	Interpretation
1. What did you think about the cooked pumpkin leaves?	Sensory qualities determine liking	Mixed perceptions of taste	Salty; Good taste; Delicious; Bitter after-taste	"Very nice but a bit salty." (FG2, P1) "Had a bitter after taste." (FG3, P1) "Well prepared and tasty." (FG1, P7	Taste varied greatly among participants; saltiness and bitterness were common complaints.
	Texture as a key acceptability driver	Texture influenced liking	Rough texture; Soft; Undercooked; Well cooked	"Texture was a little rough." (FG3, P2) "Not well cooked… rough texture." (FG4, P2)	Rough or undercooked textures caused negative reactions. Well-cooked leaves were highly valued.
	Visual cues influence acceptance.	Visual appeal contributed positively.	Good colour; Appealing appearance	"I liked the colour." (FG4, P10) "Makes the appearance look good." (FG6, P5)	Appearance shaped perceptions of quality and influenced liking.
2. What did you think about the addition of sweet potatoes to the beans?	Sweetness enhances acceptance	Widely liked and often most preferred	Delicious; Favourite; Good aroma; Well-seasoned	"This is my favourite dish." (FG1, P1)	This combination was typically the favourite across groups due

				"Most preferred dish" (FG6, P2)	to flavour, sweetness, and aroma.
	Flavour mismatches reduce appeal.	Some disliked the flavour mismatch.	Not tasting good; Bad aroma; Did not blend	"I did not like this dish." (FG2, P2) "Not a good combination." (FG3, P6) "Did not blend well at all." (FG5, P1)	A minority found the flavours incompatible or unpleasant.
	Novel combinations can surprise positively.	Surprise at the combination	Unexpected; New experience; Balanced sweetness	"I was not aware that sweet potato can be mixed with beans." (FG1, P2) "Unexpected but delicious." (FG2, P7)	Novelty produced curiosity and positive surprise for many.
3. What do you think about the addition of pumpkin to the beans	Poor sensory fit reduces liking	Strong negative reactions	Not a good combination; Bittersweet; Unappealing colour; Least preferred	"Least favourite… not tasting good." (FG2, P5) "Not a good combination." (FG4, P2)	Taste, texture, and colour concerns led many to dislike this combination.
	Newness can both attract and repel.	Novelty influenced acceptance	Unusual; First time; Unexpected	"I didn't know pumpkin and beans could be mixed." (FG1, P1)	New combinations sometimes generated openness, sometimes uncertainty.

4. What did you not like about the combinations you tasted?	Palatability issues drive rejection	Strong rejection of the potato-and-beans dish	Ordinary; Bad taste; Bad aroma; Bitter	"Ordinary dish." (FG5, P3) "Bad aroma and texture." (FG3, P10)	Potato-and-beans was the most consistently disliked combination.
	Sweetness mismatch for some participants	Sweet-potato-and-beans are disliked by some	Poor aroma; Did not blend; Not tasting good	"Did not like the beans and sweet potato dish." (FG1, P6) "Not good at all." (FG4, P5)	A minority had a strong aversion to the sweet-potato mixture.
	Poor sensory integration reduces acceptance.	Pumpkin-and-beans criticised	Tasteless; Not palatable; Poor texture	"Not palatable." (FG6, P1) "Tasteless." (FG6, P2)	Sensory mismatch and texture issues reduced appeal.
5. What is your willingness to make these combinations for your family?	Positive sensory experience predicts adoption	Strong willingness to make sweet-potato-and-beans	Will cook; Most preferred; Appealing	"I will cook the sweet potato dish." (FG6, P2) "Definitely will prepare it." (FG6, P5)	Sweet-potato-and-beans was the most likely to be adopted at home.
	Acceptance is linked to familiarity and preference	Many are willing to cook pumpkin dishes	Will try the pumpkin dish; Enjoyed taste	"I would try the pumpkin dish." (FG4, P6) "I liked the pumpkin dish and will cook it." (FG1, P10)	Pumpkin dishes were generally accepted for home cooking.
	Social factors shape adoption.	Some hesitation due to family preference	Reluctant to change; Not used to the combination	"My family is reluctant to change." (FG3, P10)	Family habits and cultural norms affect willingness to introduce new dishes.

6.5 Discussion

The socio-economic landscape of South Africa presents a complex web of structural inequalities and systemic challenges that have profoundly exacerbated household food accessibility, particularly in rural and peri-urban communities. Despite national-level food self-sufficiency, widespread disparities in income distribution, employment opportunities, land access, and infrastructure development create significant barriers to equitable food security at the household level. The Gini coefficient in South Africa is estimated at 0.68, indicating one of the highest levels of income inequality globally, which directly undermines the ability of low-income households to afford nutritious diets (Tambe et al., 2023). This entrenched inequality intersects with high unemployment rates, particularly among youth in peri-urban areas, to constrain purchasing power and increase vulnerability to food insecurity (Nenguda et al., 2022). Evidence presented earlier in this thesis indicates that under such circumstances, households increasingly depend on staple-based diets and locally produced, affordable, and culturally familiar foods (Thamaga-Chitja & Morojele, 2014; Moyo, 2016). While this adaptive strategy may facilitate short-term food availability, it frequently results in nutritionally monotonous diets, thereby heightening vulnerability to micronutrient deficiencies and inadequate protein quality.

Within the study communities, pumpkin (Cucurbita spp.) and its leaves are among the crops commonly cultivated by smallholder farmers within traditional farming systems. These crops have been characterised in previous sections of this thesis as resilient, low-input species that maintain productivity under fluctuating climatic conditions and limited resource availability (Modi & Mabhaudhi, 2016; Mabhaudhi et al., 2018). This study extends the agronomic understanding by investigating how these locally available crops can be incorporated into composite dishes to enhance nutritional outcomes while remaining acceptable to consumers.

Analyses of nutritional composition reveal that pumpkin leaves significantly enhance the nutrient density of both raw food samples and formulated composite dishes. Elevated concentrations of protein, fibre, minerals, and both essential and non-essential amino acids were consistently associated with pumpkin leaves, underscoring their value as a critical component of nutrition-sensitive food systems. This finding corroborates earlier assertions within the thesis that indigenous leafy vegetables can substantially contribute to dietary quality, particularly in communities with limited access to animal-source foods (Mabhaudhi et al., 2021; Qwabe et al., 2025).

Comparative analyses of the composite dishes reveal significant differences pertinent to nutrition planning. The stiff pap incorporating pumpkin leaves, beans, and potato exhibited the highest protein content, reflecting the complementary contributions of legumes and leafy vegetables. In contrast, the pumpkin-based composite dish demonstrated elevated levels of fibre and minerals, while the cream-fleshed sweet potato (CFSP) combination yielded a more balanced profile across macronutrients and selected micronutrients. These variations are critical as they illustrate that diverse combinations of locally available crops can be strategically selected to address specific nutritional deficits within households, rather than endorsing a singular "ideal" dish.

Notably, improvements in amino acid composition across all composite dishes relative to maize meal alone are of particular significance. Cereal-based staples dominate the diets of many rural households but are typically deficient in lysine and other essential amino acids. The incorporation of pumpkin leaves and beans enhanced the amino acid balance of the dishes, supporting earlier findings in this thesis that food-based approaches utilising indigenous crops can elevate protein quality without increasing dependency on purchased foods or supplements (Fan & Rue, 2020; Omotayo & Aremu, 2024). This consideration is especially pertinent in economically constrained environments where financial limitations restrict access to diversified protein sources.

Consumer acceptability results provide further insights into the feasibility of translating nutritional potential into practical dietary applications. All three composite dishes received favourable ratings overall, indicating that nutrient-enhanced versions of stiff pap are acceptable within the study population. However, the stiff pap with pumpkin leaves, beans, and CFSP emerged as the most preferred option. This preference appears to be influenced by sensory attributes such as taste and texture, particularly the natural sweetness and softer mouthfeel associated with CFSP. Earlier chapters emphasised that sensory satisfaction is a crucial determinant of food choice, especially among younger adults, and the present findings reinforce the necessity of aligning nutritional interventions with positive eating experiences.

The pumpkin-and-beans combination, despite its nutritional robustness, was perceived by many participants as unfamiliar. Focus group discussions revealed that limited prior exposure contributed to initial hesitance, particularly concerning flavour compatibility and texture. Importantly, this unfamiliarity did not result in outright rejection; several participants expressed curiosity and openness to experimenting with the combination, suggesting that acceptability may improve with repeated exposure and refined preparation methods. This finding is consistent with earlier observations in the thesis that the declining consumption of indigenous foods is often attributed to evolving food habits rather than an intrinsic dislike (Ndlovu et al., 2024). Therefore, the novelty associated with pumpkin-and-beans combinations should be regarded as an opportunity for gradual dietary diversification rather than a limitation.

Texture-related concerns, particularly regarding pumpkin leaves, were among the most frequently cited barriers to acceptance. These findings underscore the significant role of food preparation practices in shaping both sensory quality and consumer response. The thesis has previously highlighted that inadequate preparation methods can diminish the perceived value of nutrient-rich foods. Addressing these challenges through household-level culinary training and demonstration-based nutrition education may thus enhance both acceptance and nutrient retention.

From an agricultural and food security perspective, the study underscores the strategic importance of indigenous crops within local food systems. The capacity to cultivate pumpkin leaves, pumpkin flesh, and associated crops locally diminishes reliance on volatile food markets and bolsters household resilience during periods of economic instability. As argued previously in this thesis, enhancing demand for indigenous crop-based foods through value addition and product development can create pathways for improved livelihoods among smallholder farmers while simultaneously mitigating nutritional insecurity (Modi & Mabhaudhi, 2016; Qwabe et al., 2025).

In summary, the findings indicate that in a context where households encounter economic constraints and limited access to diverse foods, indigenous crops such as pumpkin and pumpkin leaves can play a pivotal role in enhancing diet quality. The integration of these crops into composite stiff pap dishes not only elevates nutritional value but also achieves acceptable sensory outcomes and aligns with existing cultural food practices. Variations in consumer preference underscore the importance of considering both nutrition and acceptability when promoting dietary change. This study, therefore, provides practical evidence that locally produced, nutrient-dense foods can bridge the gap between agricultural production, household consumption, and food and nutrition security in rural South African communities.

6.6 Conclusion and Recommendations

This study illustrates that the incorporation of indigenous crops into commonly consumed stiff pap dishes can significantly enhance nutritional quality while preserving consumer acceptability in economically constrained communities. The addition of pumpkin leaves notably improved the protein quality, fibre content, mineral composition, and amino acid profile of the composite dishes. Furthermore, combinations with beans and cream-fleshed sweet potato yielded nutritionally complementary and sensorially acceptable meals. Although the combination of pumpkin and beans was less familiar to participants, it demonstrated potential for broader adoption with improved preparation methods and repeated exposure. These findings underscore the importance of promoting nutrient-dense, culturally familiar composite foods as viable dietary strategies in contexts where households face limited access to diverse food options. Consequently, it is recommended that nutrition programmes and agricultural extension initiatives facilitate the production and household-level utilisation of pumpkin and pumpkin leaves, alongside culinary education that emphasises enhanced preparation techniques and the gradual introduction of novel food combinations, to bolster food and nutrition security while supporting sustainable smallholder farming systems.

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CHAPTER 7: SUMMARY, CONCLUSION AND RECOMMENDATIONS

7.1 Introduction

This chapter presents the summary and synthesis of the study. The chapter primarily focuses on the key findings, conclusions, and recommendations based on the study's aim and objectives.

7.2 Summary

This study investigated the potential role of neglected and underutilised crops (NUCs) in enhancing food security and building climate-resilient food systems among smallholder farmers in KwaZulu-Natal (KZN) Province, South Africa, with a specific fourth objective to evaluate the nutritional composition and consumer acceptability of indigenous-crop-enriched stiff pap. A mixed-methods, cross-sectional design was employed, collecting quantitative data from 319 smallholder farmers across Ugu and King Cetshwayo District Municipalities using multi-stage sampling, alongside qualitative data from focus group discussions. Descriptive statistics, Tobit regression, Ordered Probit endogenous switching regression (OP-ESR), cost-benefit analysis, and multiple regression models were used for quantitative analysis, while proximate analysis (AOAC methods) and hedonic sensory evaluation with 60 participants were conducted for the stiff pap component. Key findings revealed that only 39.8% of farmers were NUC adopters, with adopters characterised by older age, female gender, married status, and larger households; traditional and cultural factors positively predicted favourable perceptions, whereas formal education, extension access, and training negatively correlated with positive attitudes toward NUCs. The OP-ESR analysis demonstrated that adoption caused significant welfare improvements, including a 1.234-point increase in dietary diversity, a 2.567-point reduction in coping strategy reliance, and a 2.145-point reduction in food insecurity, with 48% of adopters food secure compared to only 18% of non-adopters. Cost-benefit analysis showed that adopters achieved a ZAR 8,500 higher net profit per hectare, with an NPV of ZAR 27,834 and IRR of 38.2%, while education, credit access, and market distance significantly influenced economic returns. Finally, proximate analysis confirmed that enriching stiff pap with pumpkin leaves, beans, and cream-fleshed sweet potato improved protein, fibre, mineral content, and amino acid profile, and sensory evaluation indicated consumer acceptability for most composite dishes, though the pumpkin-bean combination was less familiar. The study concludes that NUCs offer measurable nutritional, food security, and economic benefits, but realising their potential requires institutional reform, localised market infrastructure, and culturally grounded product development such as indigenous-crop-enriched stiff pap.

7.3 Study objectives

The overall objective of the study was to investigate the potential role of underutilised crops in enhancing food security and building a climate-resilient food system in the KwaZulu-Natal Province.

Specific objectives are as follows:

i. *To assess knowledge, attitudes and practices toward underutilised crops.*

ii. *To quantify the potential contribution of underutilised crops to diversified and resilient food security strategies and determine factors influencing the adoption.*

iii. *To conduct a cost-benefit analysis of underutilised crop production*

iv. *To evaluate the nutritional composition, sensory acceptability, and community perceptions of stiff pap composite dishes prepared from the indigenous crop*

This study employed a mixed-methods research approach and econometric models to analyse the attitudes, determinants, welfare effects, economic viability, and consumer acceptability of NUCs cultivation participation among smallholder farmers in the KZN Province, South Africa. Additionally, a cross-sectional research design was employed due to its cost and time efficiency, allowing the researcher to draw rational and sound conclusions from the study's objectives. Further, data were collected from 319 smallholders from UDM and KCDM. A multi-stage sampling technique, including purposive, random, and stratified sampling methods, was employed to ensure representativeness and enhance the generalizability of research findings.

The study employed econometric models to address the research objectives. Descriptive statistics analyses were employed to analyse the farmers' demographics and socio-economic profiles, types of NUCs, and NUCs cultivation participation. The analysis of farmers' perceptions and attitudes towards NUCs was grounded in the Theory of Planned Behaviour framework, with the Tobit regression model used to analyse the determinants of perception and attitude indices towards NUCs. Furthermore, the Ordered Probit endogenous switching regression model, grounded in Random Utility Theory, was employed to evaluate the welfare effects on household dietary diversity, coping strategies, and food security, while addressing the selection bias inherent in decisions to participate in NUC cultivation. Moreover, a cost-benefit analysis framework was employed to evaluate the economic feasibility of NUCs, and a multiple regression model was used to assess the determinants of economic benefits from participating in NUC cultivation.

This study makes a significant contribution to the NUC body of literature by providing profound empirical evidence on multiple dimensions of NUC cultivation participation among smallholder farmers in KZN. While the existing literature has primarily focused on individual aspects, such as the benefits and nutritional profiling of NUCs, this research offers profound insights into how farmers' socioeconomic and institutional factors influence their participation decisions, perceptions, and economic feasibility of NUCs. Furthermore, this study has demonstrated the differential effects of participation among different farmers, noting that participants have achieved significant improvements in food security through dietary diversity, while non-participants have untapped potential for welfare improvement. Moreover, the study demonstrates that the significant economic benefits associated with participation are achieved by participants, resulting in a substantial Benefit-Cost Ratio and Net Present Value. Meanwhile, determinants such as education, credit access, and market distance have a significant influence on profitability. This study employed multiple econometric approaches to achieve robustness and provide a comprehensive evaluation of NUCs' participation. This approach strengthens the empirical contributions, providing theoretical validation and offering insights for policymakers, extension services, and development organisations to promote the cultivation, utilisation, and mainstreaming of NUCs among smallholder farmers in SSA.

7.4 Summary of the key primary findings and conclusion

7.4.1 Conclusion 1: Perceptions and attitudes toward NUCs

The study concludes that smallholder farmers in KZN Province hold a divided perception landscape. Traditional knowledge systems and socio-cultural factors (age, gender, marital status, family size) are strong positive drivers of favourable perceptions toward NUCs. However, formal agricultural institutions such as education, training, extension, and farmer groups currently exert a negative influence, inadvertently devaluing indigenous crops. This paradox indicates that modern agricultural support systems in KZN are misaligned with the conservation and promotion of agrobiodiversity. Therefore, awareness alone is insufficient;

overcoming adoption barriers requires transforming formal institutions to support, rather than undermine, indigenous food systems.

7.4.2 Conclusion 2: Contribution to food security

The study concludes that participation in NUC cultivation causes significant, measurable improvements in household food security, dietary diversity, and coping capacity among smallholder farmers in KZN. The causal effects (ATT for HDDS, CSI, HFIAS) demonstrate that NUC adoption is not merely associated with, but actively generates, welfare gains. Critically, non-adopters have larger unrealised potential (ATU), meaning targeted interventions could yield even greater food security benefits. Therefor**e**, NUCs constitute a robust, empirically validated pathway for enhancing resilience and dietary quality in climate-vulnerable, food-insecure rural households.

7.4.3 Conclusion 3: Economic feasibility

The study concludes that NUC production is economically viable and financially resilient for smallholder farmers in KZN. The superior net profit, NPV (ZAR 27,834), and IRR (38.2%), coupled with robustness under adverse shocks, demonstrate that NUCs outperform conventional crops on investment metrics. However, economic benefits are not automatic; they depend on enabling factors: education, credit access, extension services (positive), and market distance (negative). Therefore, NUCs offer a financially sound pathway for sustainable intensification, but only when supported by human capital development and localised market infrastructure.

7.4.4 Conclusion 4: Nutritional composition and consumer acceptability of enriched stiff pap

The study concludes that enriching stiff pap is the predominant but nutritionally poor staple food in rural South Africa, with indigenous crops (pumpkin leaves, beans, cream-fleshed sweet potato) significantly improving its nutritional profile (protein, fiber, minerals, amino acids) while maintaining consumer acceptability. The sensory evaluation confirms that culturally familiar composite dishes are acceptable, though novel combinations require repeated exposure or improved preparation methods. Therefore, indigenous-crop-enriched stiff pap represents a culturally grounded, nutritionally effective, and acceptable strategy for addressing hidden hunger in rural communities, provided that culinary education and gradual introduction accompany product development.

7.4.5 Overarching conclusion

The study concludes that neglected and underutilised crops have a demonstrable, multi-dimensional potential to enhance food security, economic resilience, and nutritional outcomes among smallholder farmers in KZN. However, realising this potential requires deliberate institutional transformation: traditional knowledge systems must be validated and integrated, formal extension services must be restructured to include NUCs, market infrastructure must be decentralised, and gender-sensitive support must be implemented. Without such enabling conditions, NUCs will remain peripheral despite their proven agronomic, nutritional, and economic advantages.

7.5 Recommendations

Based on the study findings, the following policy recommendations are proposed to enhance the cultivation of NUCs among smallholder farmers in KZN:

- Empowering Traditional Knowledge and intergenerational transfer is essential for sustaining NUC cultivation. Policymakers should develop formal recognition and integration programs for indigenous knowledge holders, particularly elderly farmers and female custodians, who are the primary adopters. This should include creating platforms for intergenerational learning, documenting and validating traditional practices, and designing extension curricula that bridge indigenous knowledge with complementary agronomic science. Given that traditional knowledge and cultural affiliation were the strongest positive drivers of adoption, institutionalising these knowledge systems is crucial for preserving agrobiodiversity and building culturally resonant agricultural support.
- Transforming Agricultural Extension and Training is critical to reverse the current negative institutional influence. Extension services must be fundamentally restructured to promote NUCs alongside commercial crops, moving beyond a focus on modern varieties. This requires training extension agents in the cultivation, nutritional benefits, and market potential of indigenous crops, and deploying them through channels trusted by adopters, such as community meetings and farmer-to-farmer networks. Since access to conventional extension and training had a significant negative relationship with positive perceptions, a dedicated, culturally sensitive NUC extension program is necessary to bridge the institutional gap.

- Developing market Infrastructure is vital to overcome the critical barrier of market distance. Local governments and cooperatives should establish decentralised aggregation centres, processing hubs, and localised value chains for NUCs within rural communities. This will reduce transportation costs, minimise post-harvest losses, and enable farmers to capture greater value. The findings that market distance significantly reduced economic benefits and that NUC systems are often oriented towards local consumption necessitate investments in short, resilient value chains rather than reliance on distant urban markets.
- Implementing gender-sensitive support Programs is required to strengthen the majority-female adopter base. Policies must design interventions that actively support the 72.9% of female adopters by addressing their specific constraints in accessing land, credit, and decision-making power. This includes facilitating women's access to communal land for NUC cultivation, creating women-led seed saving networks, and developing financial systems tailored to the small-scale, low-input nature of NUC farming. Strengthening the economic agency of these primary custodians is key to scaling NUC cultivation.
- Leveraging Existing Socio-Demographic Networks is a strategic entry point for promotion. Interventions should be channelled through the social structures of current adopters, namely, older, married farmers with larger households. Policies should support these households as demonstration units and community champions, utilising their influence and available labour to model successful NUC integration. Concurrently, to engage the younger, more educated non-adopter demographic, awareness campaigns must reframe NUCs not only as cultural heritage but as climate-resilient, nutritious, and commercially viable commodities for modern farming.
- Establishing Integrated Research and Policy Frameworks is necessary to create an enabling environment. Government and research institutions should prioritise the use of NUCs in breeding programs to improve yield and drought tolerance, develop clear quality standards and certification for indigenous produce, and integrate NUCs into public procurement schemes, such as school feeding programs. Creating a cross-sectoral policy platform that links agriculture, nutrition, health, and cultural affairs will ensure NUCs are mainstreamed as a cornerstone of sustainable food systems, household resilience, and dietary diversity in KZN.

7.6 Limitations of the study

This study acknowledges several limitations that affect the scope of the study findings. The study employed a cross-sectional design, which captures data at a single moment, thereby inhibiting the ability to establish causal relationships and observe changes over time in the well-being of smallholder farmers. Furthermore, the study focused on two district municipalities in the KZN province, which limits its full generalizability to other provinces in South Africa due to differences in agro-ecological zones, farming systems, gender roles, and cultural contexts. The sample of 319 farmers across two district municipalities, although statistically adequate for the analytical models employed, may not fully capture the heterogeneity of smallholder systems and the distribution of traditional knowledge across KwaZulu-Natal's diverse agro-ecological and cultural zones. Key data on yields, income, and food security metrics (HDDS, HFIAS, CSI) were self-reported, making them potentially subject to recall bias and social desirability bias, which could affect the accuracy of economic and welfare calculations. The study aggregated diverse Neglected and Underutilised Crops into a single category, overlooking the specific agronomic, economic, and cultural determinants that may vary significantly between indigenous vegetables, traditional grains, and drought-tolerant legumes.

7.7 Future research directions

Future research should employ longitudinal and panel study designs to track the adoption rate and long-term impacts of NUCs on household resilience, nutritional outcomes, and income stability, enabling a robust analysis of causality and sustainability over time. Expanding the geographical and crop-specific scope to include multiple agro-ecological zones and a disaggregated analysis of individual crop species would enhance the generalizability of findings and allow for comparative value chain analysis. Research must critically examine and model the reform of agricultural institutions, particularly extension and training services, to identify effective mechanisms for integrating indigenous knowledge systems with scientific support and reversing their current negative association with NUC promotion.

Studies should explore the potential of digital and social technologies to document and disseminate traditional knowledge, facilitate peer-to-peer learning networks, and improve market access for niche NUC products, especially among younger farmers. Gender-transformative and intra-household research should be prioritised to understand the differential control over resources, labour, and benefits from NUC cultivation, informing interventions that actively empower the majority-female adopter base. Furthermore, Studies should measure the environmental externalities of NUC cultivation, such as enhanced soil health and biodiversity, and integrate them into comprehensive cost-benefit frameworks. Finally, policy-science-practice integration studies are needed to develop and test scalable models for NUC mainstreaming, such as their inclusion in public procurement programs, climate adaptation finance, and national nutrition security strategies, identifying the institutional innovations required for systemic change.

APPENDIX A: QUESTIONNAIRE

UNIVERSITY OF KWAZULU-NATAL INYUVESI YAKWAZULU-NATALI

University of Kwa-Zulu Natal

School of Agricultural, Earth and Environmental Sciences

Discipline of Agricultural Economics

ISIHLOKO SOCWANINGO: UKUQALISA INTOXOKO KAMASONTO EZIKUSEBENZISA KAKHULU UKWENGEZA INANI, UKUPHEPHA KOKUDLA, UKWENGEZA INANI, KANYE NOKUSHINTSHA KWESIMO SEZULU EMAPHANDLENI KWEZINGELA ZASEKAPA KUNELUNGELA KWA-KWA ZULU NATAL ESENINGIZIMU AFRIKA

Nkosingiphile umthumezi

TOPIC: UNLOCKING THE POTENTIAL ROLE OF UNDERUTILISED CROPS IN ENHANCING FOOD SECURITY, AND BUILDING CLIMATE RESILIENT FOOD SYSTEMS FOR RURAL POOR HOUSEHOLDS IN THE KWA-ZULU NATAL PROVINCE OF SOUTH AFRICA.

Dear participant

I am Sesethu Samuel Ntlanga, a PhD student in Agricultural Economics at the University of KwaZulu-Natal. I am working on a research study, "Unlocking the role of underutilised crops in enhancing food security, and building climate resilient food systems for rural poor households" Your participation in the questionnaire will help me to be more knowledgeable about the contribution of underutilised food crops to food security, value addition and climate change. This study will be carried out in the Kwa-Zulu Natal Province of South Africa, and the information given by participants will be treated STRICTLY CONFIDENTIAL. The data provided will be used solely for the study and no other agenda. The personal details and socio-economic details of participants will remain anonymous.

Questionnaire number

Location

Municipality

SECTION A: DEMOGRAPHICS

A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
Age	Gender Male (0) Female (1)	Marital status Single (0) Married (1)	Number of Schooling years	Employment status Unemployed (0) Employed (1)	Source of income Business (0) Agriculture (1) Salaries (2) Wages (3) Pension (4) Grants (5) Remittance (6) Other (7)	Monthly income Level ®	Household size	Do you manage or own a garden or Farm Field(Ha)	Reason for engaging in agriculture Main income source Main food source Additional income source Additional food Source Additional food and income source

SECTION B: FARMERS' KNOWLEDGE, ATTITUDES AND PRACTICES TOWARDS THE UNDERUTILISED FOOD CROPS

B.1 Knowledge on the underutilised food crops' nutritive value, healing and health benefits?

Please rate the following question.

	True (1)	False (2)	Don't know (3)
1. Underutilised crops contain essential vitamins, specifically A, B and C, minerals (calcium & Iron), as well as supplementary protein and calories.			
2. NUCs are nature's food, and it is that naturalness in them that makes them healthy and nutritious.			
3. The overcooking of underutilised crops destroys most of the essential phytochemicals, especially the micronutrients, which are beneficial to humans.			
4. The high protein and vitamins content in NUCs can eliminate deficiencies among children, the poor and pregnant women.			
5. These crops have healing properties.			
6. Are underutilised crops just like any other crops?			

2. Knowledge on agronomic advantages of NUCs

Please indicate your understanding of the following question.

	True (1)	False (2)	Don't know (3)
1. NUCs are well adapted to harsh climatic conditions and disease infestation.			
2. NUCs are easier to grow in comparison to their conventional crops.			
3. NUCs grow well in poor soils, shallow soil and sloppy terrain.			
4. NUCs grow throughout the year.			

3. Knowledge on economic importance of NUCs.

Please rate the following questions regarding your understanding of income generation and employment opportunities from NUCs.

	True (1)	False (2)	Don't know (3)
1.NUCs are a crucial food in the rural household food basket			
2.NUCs contribute to employment creation			
3.NUCs contribute to income generation			
4.NUCs can be produced using available resources, and as such, they are cheap to produce			

4. Please rate the following questions regarding your degree of perception and attitudes about NUC's value, health benefit, agronomic advantage and economic significance.

	Strongly agree (1)	**Agree (2)**	**Neutral (3)**	**Disagree (4)**	**Strongly disagree (5)**
1. NUCs farming is a women's farming activity.					
2. NUCs are poor people's food and food of the older generation.					
3. NUCs are not grown and handled in a cleaner way.					
4. NUCs' consumption may cause health problems.					
5. NUCs are unfashionable and not trendy compared to fast foods.					
6. NUCs are time-consuming to process and to prepare compared to modern foods.					
7. NUCs are associated with poverty.					
8. NUCs have health benefits.					
9. NUCs are pleasant and palatable.					
10. NUCs provide alternative food options for communities.					
11. NUCs are relatively cheap and easy to prepare					
12. NUCs are cultural foods.					

6. Please rate the degree of preference of NUCs against exotic vegetables.

	Strongly agree (1)	**Agree (2)**	**Neutral (3)**	**Disagree (4)**	**Strongly disagree (5)**
1. The taste, appearance and quality of NUC foods are not as good as those of modern foods.					
2. NUCs are cheap to produce and maintain compared to modern foods.					

7. Please rate the frequency of NUCs consumption in your household.

	Always (1)	Often (2)	Sometimes (3)	Seldom (4)	Never (1)
How often do you consume NUCs in your household?					

8. Please rate your acceptability of the attributes of NUCs' recipes.

	Extremely acceptable (1)	Acceptable (2)	Neutral (3)	Unacceptable (4)	Extremely unacceptable (5)
1. Colour					
2. Smell					
3. Texture					
4. Taste					
5. Safe					
6. Nutritious					
7. Freshness					
8. long shelf-life span					

9. Please indicate your consumption intent regarding NUCs recipes.

	I would eat it every day (1)	I would eat it very frequently (twice a week) (2)	I would eat it occasionally (Once a month) (3)	I would eat it if available, but would not go out of my way (4)	I would eat it when no other food is available (5)	I will never eat it (6)
Food action rating scale						

10. Please indicate/rate the barriers to NUCs consumption.

	Most serious (1)	Fairly serious (2)	Least serious (3)
1. Lack of knowledge and skills in NUCs preparation and nutrition information			
2. Lack of knowledge transfer between generations for the younger generation's beliefs and pickiness			
3. Urbanization have changed eating habits and induced a lack of interest in NUCs knowledge by the youth.			
4. Lack of knowledge on NUCs' nutritional benefits			
5. Other			

FARMER'S PRACTICES

11. What is your land tenure? Please indicate the appropriate

Land tenure system	Tick appropriate
1. Land owned	
2. Land rented	
3. Other	

12. **How did you acquire the land? Please indicate**

Inheritance from parents (1)	Purchase	Gift	Other(specify)

13. Please estimate the area occupied by NUCs production in your farm land. Please indicate

Land portion used for NUC production	**X**
1. 0 <10%	
2. 10 <30%	
3. 30 < 50%	
4. > 50%	
Other, specify	

14. What cropping system is applied in your farming activities? Please indicate with X

Cropping practices	**Indicate with X**
Monocropping	
Intercropping	

15. Which underutilised food crops do you grow?

NUCs Name	**Production over last season (kg)**

16. Why do you grow NUCs? Please indicate with x

Reasons for cultivating NUCs	Indicate with x
1. For home consumption	
2. Contract grower	
3. Available Market	
4. Other (specify)	

17. How many years have you been growing NUCs?

Years of experience	Indicate with X
0– 5 years	
6-10 years	
10 – 15 years	
16 -20 years	
>20 years	

18. At what period of the year do you grow NUCs? Please indicate with x

Farming in the dry season		Farming under rain-fed conditions		Both	

19. Do you apply inputs in NUCs production? Yes= 1 No =2

20. Please indicate the inputs used with X

Inputs used	Indicate with X
1. Certified seeds	
2. Organic fertiliser	
3. Pesticides	
4. None	

21. Which weed control techniques do you apply to rid your garden of unwanted plants?

Weeding techniques applied	Indicate with X
1. Mulching technique	
2. Cover crop technique	
3. Weeds pulling technique	
10 Other	

22. Section C: Contribution of NUCs towards Food Security

In the past 30 days, if there have been times when you did not have enough food or money to buy food or money to buy food, how often has your household had to:	Relative Frequency					Severity Ranking	Score
	All the time? everyday	Pretty often? 3 -6*/week	Once in a while? 1 -2*/week	Hardly at all <1*/week	Never 0*/week		
a. Rely on less preferred and less expensive foods?							
b. Borrow food, or rely on help from a friend or relative?							
c. Purchase food on credit?							
d. Gather wild food, hunt or harvest immature crops?							
e. Consume seed stock held for next season?							

f. Send a household member to beg?							
g. Send household members to eat elsewhere.							
h. Limit portion size at mealtimes?							
i. Restrict consumption of adults in order for small children to eat?							
j. Feed working members of HH at the expense of non-working members?							
k. Ration the money you had and buy prepared food?							
l. Reduce the number of meals eaten in a day?							
m. Skip the entire day without eating?							
n. Total							

2.2.2 Coping strategies and severity weights used in the CSI calculation

Coping Strategy	**Severity Weight**
Rely on less preferred/less expensive foods	1
Borrow food or rely on help from friends/relatives	2
Limit portion size at mealtimes	1
Restrict consumption by adults so that children can eat	3
Reduce the number of meals eaten per day	2
Skip entire days without eating	4
Sell productive assets (tools, livestock, land)	4
Engage in casual labour for food	2
Send household members elsewhere to eat	3
Harvest immature crops	3

2.2.3 HFIAS questions for rural household food security

Question	Summary of the questions
1	Worry about food
2	Unable to eat preferred foods
3	Eat just a few kinds of foods.
4	Eat food that they really do not want to eat.
5	Eat a smaller meal
6	Eat fewer meals in a day.
7	No food of any kind in the household
8	Go to sleep hungry
9	Go a whole day and night without eating.

SECTION D: STRENGTHS, WEAKNESSES, OPPORTUNITIES AND THREATS OF NUCs

23. Have you ever experienced problems in NUCs production? 1 = Yes   2 = No

24. If yes, what are the common constraints or threats towards the NUCs production and utilisation? Please indicate with X

Types of constraints/threats	Indicate with X
Climate change variability	
Invasive pests and diseases	
Changes in the socio-cultural structures	
Changes in consumer taste and preferences	
Negative perceptions about the NUCs	
Inadequate government support for the use	
Lack of extension services, policies and investments for NUCs promotion	

25. What are the opportunities associated with NUCs in future? Indicate by X

Availability of a local market and wide appreciation by consumers	
Development of value chain structures	
Growing attention and new market potential associated with nutritional and health properties	
Improved knowledge of genetic and biotechnological	
Other, specify	

SECTION F: VALUE CHAIN OF NEGLECTED AND UNDERUTILISED FOOD CROPS

22. Which main methods do you use for NUCs harvesting? Please indicate with X

Methods of NUCs harvesting	X
1. Uprooting the crop	
2. Harvesting of leaves	
3. Harvesting of leaves and stem tops	

23. How do you handle your harvest? Indicate with X

Harvesting handling	**X**
Cleaning	
Washing	
Grading/ sorting to remove poor material	
Shredding	
Other (specify)	

24. If yes, what processing technique do you apply to NUC's product? Please indicate with X

Processing techniques applied to NUCs	Indicate with X
1. Simple sun-drying	
2. Sun-drying & grinding into powder	
3. Blanching/ Solar drying technology	

4. Other (Specify)	

25. Where do you store your Produce?..

26. Do you sell processed Underutilised food crops? 1 = Yes 2 = No

28. Where do you sell your harvest? Please indicate with X

1. At the farm gate	Indicate with X
2. Roadside market	
3. Supermarket	
4. Processors	
5. Middleman	
6. Cooperatives	
7.Other(specify)	

29. What is your distance to Market?..

30. Do you have access to a proper road to the market? Yes / No

31. Have you ever borrowed money from a bank? Yes/No

32. How often do the extension officers visit your villages?

33. How are the costs of NUC production and the prices?

	NUCs
Yield (Kg/ha)	
Price (R/bunch)	
COSTS	
Water	
Land preparation (R/ha)	
Seeds (R/ha)	
Fertilizer (R/ha)	
Pesticides (R/ha)	
Manure (R/ha)	
Labour	
Hired labour (R/ha)	
Family labour (R/ha)	
Equipment (rented)	
Transport costs	
Any other costs	
Total costs	

The Potential Role of Neglected and Underutilised Crops (NUC's) in Enhancing Food Security and Building a Climate Resilient Food Systems for Rural Households

Participant number:
Age:
Gender:

Dear Panelist

Thank you for volunteering to participate in the study. Please follow the instructions below.

Instructions

- Before you start the sensory evaluation, read and sign the consent form.
- Please answer the questionnaires truthfully and honestly.
- Do not communicate with other panellists during the sensory evaluation.
- Please rinse your mouth with water before and after tasting each sample.
- Please taste the samples in the order presented in front of you.
- Please rate the taste, aroma, texture, colour, appearance, and overall acceptability of porridges on a scale of 1 - 9.

Key:

1 – Extremely dislike

2 -Dislike very much

3 – Dislike slightly

4 – Dislike moderately

5 – Neither like nor dislike

6 – Like moderately

7 – Like slightly

8 -Like very much

9 – Like extremely

EXAMPLE:

Sample code	**Taste**	**Colour**	**Aroma**	**Texture**	**Appearance**	**Overall Acceptability**
	Score: 8	Score: 8	Score: 9	Score: 8	Score: 9	Score: 8

Sample code	**Taste**	**Colour**	**Aroma**	**Texture**	**Appearance**	**Overall Acceptability**
475						
237						
521						

Comments:

____

____

____

____

____

Thank you for participating in the study!!!!!

Participant Number:

PREFERENCE RANKING TEST IN ENGLISH

Please rinse your mouth with water before starting and between tasting samples.

You may also use your mouth again at any time during the session if you need to.

Please taste the three samples in the order presented, from left to right.

You may re-taste the samples once you have tried all of them.

Rank the samples from most preferred to least preferred using the following numbers.

1 = most preferred, 3 =least preferred

Please do not use the same numbers more than once.

If you have any questions, please ask the assistants now.

Sample	**Ranking**
475	
237	
521	

Thank you for taking part in this study

FOCUS GROUP QUESTIONS

1. What did you think about the cooked pumpkin leaves?

2. What did you think about the addition of sweet potato to the beans?

3. What did you think about the addition of pumpkin to the beans?

4. What did you not like about the combinations you tasted?

5. What is your willingness to make these combinations for your family?

Thank you for your participation!!!!!!

Iqhaza Elingaba Khona Lezitshalo Ezinganakwa Nengasetshenzisiwe (NUC's) Ekuthuthukiseni Ukuvikeleka Kokudla Nokwakha Izinhlelo Zokudla Ezimelana Nesimo Sezulu Zemikhaya Yasemakhaya

Inombolo yombambi qhaza:

Ubudala:

Ubulili:

Sawubona Phaneli

Siyabonga ngokuvolontiya ukuze ubambe iqhaza ocwaningweni. Sicela ulandele imiyalelo engezansi.

Iziyalezo

- Ngaphambi kokuthi uqale ukuhlola izinzwa, funda bese usayina ifomu lemvume.
- Sicela uphendule imibuzo ngeqiniso nangokwethembeka.
- Ungaxhumani nabanye abaphaneli ngesikhathi sokuhlola izinzwa.
- Sicela ugeze umlomo wakho ngamanzi ngaphambi nangemva kokunambitha isampula ngayinye.
- Sicela unambithe amasampula ngokulandelana owethulwe phambi kwakho.
- Sicela ulinganise ukunambitheka, iphunga, ukuthungwa, umbala, ukubukeka, nokwamukelwa kukonke kwamaphalishi esikalini sika-1 - 9.

Ukhiye:

1 - Ukungathandi kakhulu

2 -Angithandi kakhulu

3 - Ungathandi kancane

4 - Ungathandi ngokulingene

5 - Ungathandi noma ungathandi

6 - Njengokulinganisela

7 - Njengokuthi kancane

8 - Ngithanda kakhulu

9 - Kufana kakhulu

ISIBONELO:

Ikhodi yesampula	Nambitha	Umbala	Wephunga Elimnandi	ukuthungwa kokudla	Ukubukeka	Ukwemukeleka Sekukonke
	Umphumela : 8	Umphumela : 8	Umphumela : 9	Umphumela : 8	Umphumela 9	Umphumela 8

Ikhodi yesampula	Nambitha	Umbala	Wephunga Elimnandi	ukuthungwa kokudla	Ukubukeka	Ukwemukeleka Sekukonke
475						
237						
521						

Amazwana:

Siyabonga ngokubamba iqhaza ocwaningweni!!!!!

Inombolo yombambi qhaza:

PREFERENCE RANKING TEST NGESIZULU

Sicela ugeze umlomo wakho ngamanzi ngaphambi kokuqala naphakathi kokunambitha amasampula.

Ungakwazi futhi umlomo wakho futhi nganoma yisiphi isikhathi phakathi neseshini uma udinga.

Sicela unambithe amasampula amathathu ngokulandelana owethulwe, ukusuka kwesokunxele kuye kwesokudla.

Ungaphinda unambitha amasampula uma usuwazame wonke.

Beka amasampula kwabaningi ancanyelwayo kakhulu kunalawo angancanyelwayo kakhulu usebenzisa izinombolo ezilandelayo.

1 = okukhethwa kakhulu, 3 = okuncanyelwayo okungenani

Sicela ungasebenzisi izinombolo ezifanayo izikhathi ezingaphezu kwesisodwa.

Uma unemibuzo, sicela ubuze abasizi manje

Sampula	**Izinga**
475	
237	
521	

Siyabonga ngokubamba iqhaza kulolu cwaningo!!!

IMIBUZO YEQEMBU LE-FOCUS

1. Ucabangeni ngemifino yeethanga aphekiwe?

2. Ucabangeni ngokufakwa kukabhatata kubhontshisi?

3. Ucabangeni ngokufakwa kwethanga kubhontshisi?

4 . Yini ongayithandanga ngezinhlanganisela ozinambithile?

5. Kuyini ukuzimisela kwakho ukwenzela umndeni wakho lezi zinhlanganisela?

Siyabonga ngokubamba iqhaza kwakho!!!!!!

APPENDIX B: RECIPES

STIFF PAP

Ingredients

4 litres of water

1,3 kg (8 cups) of maize meal

5 g of salt, fine

Instructions

1. In a large pot, bring 3 litres of water to a boil, and add salt.
2. In a large bowl, put maize meal and 1 litre of water to make a paste.
3. Slowly pour the paste into boiling water, while stirring to avoid lumps.
4. Keep stirring until the mixture starts to thicken.
5. Turn the heat down and simmer for 40-45 minutes.

PUMPKIN LEAVES

Ingredients

100 ml of cooking oil

280g Onions, finely chopped

3 g (1 tsp) Cayenne pepper, powder

10 g (1 tbsp) Curry powder

2 cubes of Knorrox beef stock

640 g pumpkin leaves, finely chopped

10 g of aromat

200 ml water

Instructions

1. Heat oil in a large pot over medium heat.
2. Once the oil is shimmering, add onions and let them sauté for 3 minutes.

3. Add cayenne pepper, curry powder and beef stock, stir well and cook for 2 minutes to enhance their flavour.
4. Add pumpkin leaves and aromat, mix well with the rest of the ingredients.
5. Add water, reduce to a simmer, cover with a lid and cook for 20 minutes.

<table>
<tr><th colspan="5">PUMPKIN AND BEANS RECIPE</th></tr>
<tr><td colspan="3">Yield: 4,75 kg
Number of portions: 60
Portion size: 80g</td><td colspan="2">Temperature: From high heat to Low heat
Preparation time: overnight and 2 hours
Cooking time: 20 minutes</td></tr>
<tr><th>Cost</th><th>Ingredients</th><th>AP amount</th><th>EP amount</th><th>Procedure</th></tr>
<tr><td></td><td>Beans
water</td><td></td><td>433g
1,5l</td><td>1. First, rinse the beans and pour them into your medium pot and boiling water (1l), then soak overnight.
2. The following day, put it on the stove on high heat.
3. Cook for 1 hour and 50 minutes, until it softens.
4. Put it aside.</td></tr>
<tr><td></td><td>Pumpkin
water</td><td></td><td>1,99kg
950ml</td><td>5. Peel and chop the pumpkin into small pieces
6. Pour the pumpkin and add boiling water to the pot, then boil for 18 minutes.
7. Cook till soften</td></tr>
<tr><td></td><td>Cooking oil
Onion, medium
Curry powder
Cayenne pepper
Knorrox beef stocks
Water</td><td></td><td>75ml
360g
35g
35g
20g (2cubes)
15ml</td><td>8. Place the pot on the stove, and pour the oil.
9. Pour your onions when the oil is hot enough to cook
10. Fry the onion for 3 minutes until golden and brown
11. Add all your curry powder, knorrox cubes and spices</td></tr>
<tr><td></td><td></td><td></td><td></td><td>12. Add cooked beans and pumpkin, then stir well
13. Pour 50 mil of water
14. Lower the heat, cook for 30 minutes until it simmers and mix well.</td></tr>
</table>

APPENDIX C: ETHICAL CLEARANCE CERTIFICATE

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

03 June 2024

Sesethu Samuel Ntlanga (222130172)
School of Agri Earth & Env Sc
Pietermaritzburg Campus

Dear SS Ntlanga,

Protocol reference number: HSSREC/00007019/2024
Project title: Unlocking the potential role of underutilized crops in enhancing food security, value addition, and climate change in the Eastern Cape and Kwa-Zulu Natal, South Africa
Degree: PhD

Approval Notification – Expedited Application

This letter serves to notify you that your application received on 10 April 2024 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.

Incidents of adverse events and serious adverse events (AEs and SAEs) should be reported in writing to HSSREC, the study sponsors, and any regulatory authority (where appropriate), within 7 working days of the occurrence for local sites and 14 days for all other South African sites.

This approval is valid until 03 June 2025.
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.

HSSREC is registered with the South African National Health 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 D: GATEKEEPER LETTER

KWAZULU-NATAL PROVINCE
AGRICULTURE AND RURAL DEVELOPMENT
REPUBLIC OF SOUTH AFRICA

Hibiscus Lane, Mtubatuba ,3935
KZN Department of Agriculture & Rural Development, Private Bag X008 Mtubatuba,3935
Tel: 035 55 00210

EXTENSION & ADVISORY

Mr Sesethu Samuel Ntlanga
University of KwaZulu-Natal
Pietermaritzburg Campus
Private Bag X01
Scottsville
3209

Dear SS Ntlanga

I, TH Ngcobo,District Director of DARD - uMkhanyakude District Municipality , have the pleasure of informing you that permission is granted to conduct research on: **"Unlocking the potential role of underutilized crops in enhancing food security, value addition and climate change in the uMkhanyakude District Municipality, KwaZulu Natal."**.

The District gives permission to study with an understanding that it does not infringe on any human rights and any form of discrimination (gender /disability). Please ensure that the local leadership is informed before the commencement of your research project. The Department will not provide resources for your study, such as research assistance, transportation etc.

I take this opportunity to wish you well in your endeavour.

Yours in community service

Regards: Name T.H. NGCOBO

Contact: [redacted]

Email: Ngcoboth@kznDARD.gov.za

Signature: [redacted]

Date: 14/03/2024

APPENDIX E: INFORMED CONSENT LETTER

INFORMED CONSENT

Information Sheet and Consent to Participate in Research

Date:

Dear community member

My name is Mr Sesethu Samuel Ntlanga, and I am a PhD candidate in the Discipline of Agricultural Management and Agricultural Economics at the University of KwaZulu-Natal, Pietermaritzburg campus. My contact details are Email: 222130172@stu.ukzn.ac.za or phone number: [redacted].

You are invited to consider participating in a study that involves you giving your expertise on food traditions and social practices. We want to learn how your community's long-standing food traditions and social practices act as ways to adapt, helping ensure people get enough nutritious food despite problems caused by climate change. This research aims to understand how traditional food customs and social norms function as adaptation mechanisms for nutrition and food systems facing climate impacts. For this study, you would be required to complete a questionnaire, which should take between 20 and 30 minutes, and participate in a Focus Group Discussion.

This study has been ethically reviewed and approved by the UKZN Humanities and Social Sciences Research Ethics Committee (approval number HSSREC/00007019/2024).

In the event of any problems or concerns/questions, you may contact the researcher at the contact details provided above, or the UKZN Humanities and Social Sciences Research Ethics Committee, contact details as follows:

HUMANITIES & SOCIAL SCIENCES RESEARCH ETHICS ADMINISTRATION

Research Office, Westville Campus

Govan Mbeki Building

Private Bag X 54001
Durban
4000

KwaZulu-Natal, SOUTH AFRICA

Tel: 27 31 2604557- Fax: 27 31 2604609

Email: HSSREC@ukzn.ac.za

Your confidentiality is guaranteed, as your inputs will not be attributed to you in person but reported as a population member.

Any information you give cannot be used against you, and the collected data will be used for research only.

There will be no discomfort or hazards to participants who agree to participate in this study.

Data will be stored in secure storage and destroyed after 5 years.

You have a choice to participate, not to participate or to stop participating in the research. You will not be penalised for taking such an action.

Your involvement is purely for academic purposes only, and there are no financial benefits involved.

Although every effort will be made to ensure that other focus group participants will respect the confidentiality of what you disclose in the group, this cannot be guaranteed. For this reason, you are advised not to disclose personally sensitive information in the focus group.

DECLARATION OF CONSENT

I (Name) ______________________________ have been informed about the study entitled Cultural Resilience: The Potential Role of Neglected and Underutilised Crop (NUC's) in Enhancing Food Security and Building a Climate Resilient Food Systems for Rural Households by Mr Sesethu Samuel Ntlanga.

I understand the purpose and procedures of the study.

I have been given an opportunity to answer questions about the study and have had answers to my satisfaction.

I declare that my participation in this study is entirely voluntary and that I may withdraw at any time without affecting any treatment or care that I would usually be entitled to.

If I have any further questions/concerns or queries related to the study, I understand that I may contact the researcher at Email: 222130172@stu.ukzn.ac.za or phone number: [redacted].

If I have any questions or concerns about my rights as a study participant, or if I am concerned about an aspect of the study or the researchers, then I may contact:

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KwaZulu-Natal, SOUTH AFRICA

Tel: 27 31 2604557 - Fax: 27 31 2604609

Email: HSSREC@ukzn.ac.za

Tick (√) which is applicable:

I hereby give permission to be audio-recorded during the data collection process.

(tick Yes/No)

Yes	No

____________________ ____________________

Signature of Participant **Date**

____________________ ____________________

Signature of Witness **Date**

(Where applicable)

____________________ ____________________

Signature of Translator **Date**

(Where applicable)

UKUVUMA OKWAZIWE

<u>Ishidi Lolwazi kanye Nemvume Yokuhlanganyela Ocwaningweni</u>

Usuku:

Ngiyanibingelela mbumbulu,

Igama lami ngdinguDkt Sesethu Samuel Ntlanga ngingumfundi ovela eMkhakheni wokulima neSayensi, eNyuvesi yaseKwaZulu-Natal, ePietermaritzburg. Imininingwane yami yokuxhumana ingu-imeyili: 222130172@stu.ukzn.ac.za noma inombolo yefoni: [redacted].

Umenyiwe ukuthi ucabangele ukuzibandakanya ocwaningweni oluhilela ukuphana kolwazi lwakho ngeqhaza Elingaba Khona Lezitshalo zendabuko Ezinganakwa Nengasetshenzisiwe Ekuthuthukiseni Ukuvikeleka Kokudla Nokwakha Izinhlelo Zokudla Ezimelana Nesimo Sezulu Zemikhaya Yasemakhaya. Sifuna ukufunda ukuthi imikhuba yokudla yokwenziwa kanye nemikhuba yokuphila yomphakathi wakho isiza kanjani ekuzivumeleni, iqinisekisa ukuthi abantu bathola ukudla okunempilo nakuba kunezinkinga ezibangelwa ukushintsha kwesimo sezulu. Lolu cwaningo lukhomba ukuqonda ukuthi imikhuba yokudla ejwayelekile nemithetho yokuphila isebenza kanjani njengenqubo yokuzivumelanisa ngezokudla nezinhlelo zokudla ezibhekene nemiphumela yokushintsha kwesimo sezulu. Kulolu cwaningo, kuzodingeka ukuthi uqedele uphenyo, okuthatha phakathi kwemizuzu engama-20 kuya kwangama-30, futhi uzibandakanye kwiQembu Lokugxila.

Lolu cwaningo lubuyekezwe ngokokuziphatha futhi lwagunyazwa yiKomidi le-UKZN Humanities and Social Sciences Research Ethics (inombolo yokugunyazwa HSSREC/00007019/2024).

Uma kuba nezinkinga noma ukukhathazeka/imibuzo, ungathintana nomcwaningi ngemininingwane yokuxhumana enikeziwe ngenhla, noma iKomidi le-UKZN Humanities and Social Sciences Research Ethics, imininingwane yokuxhumana kanje:

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4000

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Tel: 27 31 2604557- Fax: 27 31 2604609

Email: HSSREC@ukzn.ac.za

- Ukugcinwa kuyimfihlo kwakho kuqinisekisiwe, njengoba lokho okufakile ngeke kuthiwe kuwe mathupha kodwa kubikwe njengelungu labantu.
- Noma yiluphi ulwazi olunikezayo ngeke lusetshenziswe ngokumelene nawe, futhi idatha eqoqiwe izosetshenziselwa ucwaningo kuphela.
- Ngeke kube khona ukungakhululeki noma izingozi kubabambiqhaza abavuma ukubamba iqhaza kulolu cwaningo.
- Idatha izogcinwa endaweni evikelekile futhi yonakaliswe ngemva kweminyaka emi-5.
- Unokukhetha ukubamba iqhaza, ukungahlanganyeli noma ukuyeka ukubamba iqhaza ocwaningweni. Ngeke ujeziswe ngokwenza isenzo esinjalo.
- Ngeke ujeziswe ngokwenza leso senzo.
- Ukuzibandakanya kwakho kungokwezinjongo zemfundo kuphela, futhi azikho izinzuzo zezezimali ezihilelekile.
- Nakuba kuzokwenziwa yonke imizamo ukuze kuqinisekiswe ukuthi abanye ababambiqhaza beqembu eligxilile bazohlonipha ukugcinwa kuyimfihlo kwalokho okudalulayo eqenjini, lokhu akunakuqinisekiswa. Ngalesi sizathu, uyelulekwa ukuthi ungadaluli ulwazi lomuntu siqu olubucayi eqenjini okugxilwe kulo.

ISIMEMEZELO SOKUVUMA

Mina (Igama)______________________________ ngazisiwe ngocwaningo olunesihloko esithi Iqhaza Elingaba Khona Lezitshalo Ezinganakwa Nengasetshenzisiwe (NUC's) Ekuthuthukiseni Ukuvikeleka Kokudla Nokwakha Izinhlelo Zokudla Ezimelana Nesimo Sezulu Zemikhaya Yasemakhaya. nguMnu Sesethu Samuel Ntlanga.

Ngiyayiqonda inhloso nezinqubo zocwaningo.

Nginikezwe ithuba lokuphendula imibuzo mayelana nocwaningo futhi ngibe nezimpendulo ngokwaneliseka kwami.

Ngiyazisa ukuthi ukuhlanganyela kwami kulolu cwaningo kungokuzithandela futhi ngingahoxa noma nini ngaphandle kokuphazamisa noma yikuphi ukwelashwa noma ukunakekelwa engivame ukuba nelungelo lokukuthola.

Uma ngineminye imibuzo/okungikhathazayo noma imibuzo ehlobene nocwaningo, ngiyaqonda ukuthi ngingathintana nomcwaningi ku-imeyili: 222130172@stu.ukzn.ac.za noma inombolo yocingo: [redacted].

Uma nginemibuzo noma ukukhathazeka mayelana namalungelo ami njengomhlanganyeli wocwaningo, noma uma ngikhathazekile ngendawo ethize yocwaningo noma abacwaningi, ngingaxhumana:

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Email: HSSREC@ukzn.ac.za

Thika (√) osebenzayo:

Nginikeza imvume yokuqoshwa komsindo ngesikhathi sokuqoqwa kwedatha.

(Khetha Yebo/Cha)

Yebo	Cha

______________________ ______________________

Isiginesha Yombambi qhaza **Usuku**

______________________ ______________________

Isignesha yoFakazi **Usuku**

(Lapho kufanele khona)

______________________ ______________________

Isiginesha Yomhumushi **Usuku**

(Lapho kufanele khona)