

**IMPACT OF LAND DEGRADATION ON AGRICULTURAL PRODUCTIVITY AND  
HOUSEHOLD FOOD SECURITY: EVIDENCE FROM SMALLHOLDER FARMERS  
IN A SEMI-ARID REGION OF SOUTH AFRICA**

**by**

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## ABSTRACT

Land degradation is a global concern with far-reaching implications for both developed and developing nations, particularly in the context of climate change. However, there remains a critical gap in research and policy regarding the relationship between socioeconomics, land quality, and soil health. Existing studies often rely on remote sensing data to raise awareness but are ambiguous to guide sustainable development approaches grounded in socio-economic development. To address this knowledge gap, the study surveyed 256 smallholder farmers using a structured questionnaire developed in line with the Food and Agriculture Organization (FAO) Land Degradation Assessment in Drylands (LADA) framework, complemented by various analytical tools and statistical models. The research aimed to understand the drivers and consequences of land degradation on agricultural productivity and food security in semi-arid regions particularly the Sekhukhune District Municipality. The research went beyond immediate agricultural effects by examining socio-economic impacts and coping strategies of smallholder farmers. The study examined how smallholder farmers choose strategies to adapt to the impacts of land degradation and further explored factors influencing decision making.

To understand this, the study utilised an integrated analytical approach that combined descriptive statistics with binary logistic regression, multivariate probit (MVP), multiple linear regression (MLR), propensity score matching (PSM), ordinal logistic regression (OLR), and structural equation modelling (SEM). Agricultural productivity is assessed through an Agricultural Land Productivity Index (ALPI) adapted from the Alkire-Foster counting approach. Food security is measured with the Household Food Insecurity Access Scale (HFIAS) technique. The study began by examining the dominant forms of land degradation prevalent in the Sekhukhune District Municipality and found that they primarily manifest in the form of water erosion (36.8%), soil compaction (28.1%), topsoil loss (26.6%), waterlogging (25.0%), and wind erosion (24.6%), however, a strong co-movement observed among water erosion, topsoil loss, and compaction was observed. Additional forms of degradation identified included invasive species, vegetation degradation, and salinity, which together exacerbate the decline in soil and ecosystem health. These processes are intensified by unsustainable agricultural practices, deforestation, and mining activities, which collectively diminish arable land, deplete essential soil nutrients, and aggravate water scarcity.

The study also examined farmers' coping and adaptation strategies employed to mitigate its adverse effects. The study found that adoption of coping strategies varies greatly in the area, conservation tillage is adopted at (28.4%), crop diversification (19.7%), and use of crop residues (15.8%) lead, while mulching, crop rotation, organic manure, and fertiliser use remain marginal. Results from the logistic regression model indicate that household size ( $p < 0.01$ ), education ( $p < 0.05$ ), and participation in land-care projects ( $p < 0.10$ ) significantly enhance the likelihood of adopting coping strategies. The multivariate probit (MVP) model confirms the existence of complementarities among strategies such as

conservation tillage combined with residue retention and crop diversification suggesting that farmers employ integrated rather than isolated responses. Regarding exposure to degradation, the Probit model highlights the significant roles of age, gender, land ownership, access to information, and adoption of sustainable land management (SLM) (*model*  $R^2 = 0.27$ ). Older, male-headed, and tenure-secure households are less likely to experience degradation, while SLM adoption significantly reduces exposure. Interestingly, the positive coefficient on access to information implies persistent quality gaps in extension delivery and knowledge dissemination.

Additionally, the study evaluated the impacts of land degradation on agricultural productivity and household food security. Results from the Propensity Score Matching (PSM) model estimate an Average Treatment Effect on the Treated (ATT) of -0.824, implying an average 82.4% reduction in agricultural productivity among affected households. Land degradation further worsens welfare outcomes, as households experiencing degradation are 25.5% more likely to be food insecure ( $p = 0.053$ ). Findings from the Ordinal Logistic Regression (OLR) model identify land degradation, low income, limited education, and insecure land rights as significant predictors of heightened food insecurity. Conversely, the adoption of sustainable land management (SLM) practices exhibits a strong protective effect, mitigating the negative impacts of degradation on both productivity and food access.

The Structural Equation Model (SEM) clarifies the underlying mechanisms: land degradation indirectly increases food insecurity through its negative impact on agricultural productivity, while a modest positive direct pathway suggests that social grants and relief interventions may temporarily buffer households against acute food shortages, though they fail to address the structural risks driving vulnerability.

These results indicate the need for increased awareness among smallholder farmers regarding the impacts of land degradation and the importance of adopting sustainable land management practices. These findings are also of importance for policy development and implementation. In South Africa, communal and grazing areas face significant land degradation challenges driven by historical land systems, mining, climate change, overgrazing, and unsustainable practices, compounded by erosion and deforestation. A wide-ranging approach is recommended, including sustainable farming practices, equitable resource access, education, land distribution, reforestation, and improved land management.

The study recommends holistic, informed policy interventions addressing the root causes of land degradation, promoting sustainable land management, improving rural education and resource access, and enhancing adaptation to environmental changes. Policymakers should encourage the adoption of Sustainable Land Management technologies, particularly among non-adopters, focusing on gender and youth integration. Capacity-building programs, advocacy, and enhanced extension staff skills are crucial elements. Additionally, government support for extension services and technology dissemination can

influence adoption decisions, ultimately enhancing resilience and food security in the face of land degradation challenges.

This research further critiqued the existing literature for neglecting ecological mechanisms, climate change interactions, and socio-economic factors contributing to land degradation, particularly in developing countries. Recognizing land degradation's severe impacts, global initiatives like the United Nations Convention to Combat Desertification and Sustainable Development Goals aim to combat it. Furthermore, the study identifies areas for further research, such as long-term impact assessment, climate change resilience strategies, economic valuation, gender and youth inclusion, policy implementation, community-based initiatives, capacity-building, and interdisciplinary approaches, to comprehensively address the complex challenges of land degradation and food security.

**Key words:** *smallholder farmers; land degradation; agricultural productivity; food security; sustainable land management practices; multivariate probit; propensity score matching; structural equation modelling; South Africa.*

## DECLARATION 1: PLAGARISM

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Date: 19 November 2025

As the candidate 's supervisor, I agree to the submission of this dissertation.



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Supervisor: Prof Maxwell Mudhara

Date: 24/11/2025

## DECLARATION 2: PUBLICATIONS AND MANUSCRIPTS

Details of publication manuscripts that form part and/or include research presented in this dissertation.

**Publication manuscript 1:** Budaza, N., Mudhara, M., & Mwenge Kahinda, J.-M: A Review of the Land Degradation-Livelihood Nexus: Emerging Issues and Gaps Land Use Policy (In preparation).

**Publication manuscript 2:**

Budaza, N., Mudhara, M., & Mwenge Kahinda, J.-M.2025. *Smallholder farmers' adaptation strategies to the effects of land degradation in Sekhukhune District Municipality, Limpopo, South Africa.* Journal of Land Degradation & Development. (Revision submitted).

**Publication manuscript 3:**

Budaza, N., Mudhara, M & Mwenge Kahinda, J.-M. *Impacts of Land Degradation on Agricultural Productivity of Smallholder Farmers in Sekhukhune District Municipality, Limpopo, South Africa.* (In preparation).

**Publication manuscript 4**

Budaza, N., Mudhara, M. & Mwenge Kahinda, J.-M. *Impacts of Land Degradation on Household Food Security of Smallholder Farming Households in Sekhukhune District Municipality, Limpopo, South Africa.* Target journal: *Sustainability*. (In preparation).

## **DEDICATION**

I dedicate this work wholeheartedly to my grandmother, Ms Nosayinethi Budaza, whose love, encouragement, and support have been a guiding light in my life. It is through her guidance and presence that I have found the courage to pursue my academic endeavours and strive for excellence. This dedication is a testament to her profound impact on shaping the person I am today, and I am forever grateful for her unconditional love and support.

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## LIST OF ABBREVIATIONS AND ACRONYMS

AF	Alkire-Foster
DDP	District Development Plan
DEA	Department of Environmental Affairs
DFFE	Department of Forestry, Fisheries, and the Environment
DRAPA	Drought Resilient and Prepared Africa
ELD	Economics of Land Degradation
FAO	Food and Agriculture Organisation
GSDM	Greater Sekhukhune District Municipality
HFIAP	Household Food Insecurity Access Prevalence
HFIAS	Household Food Insecurity Access Scale
HHD	Household Head
HHS	Household Size
IFAD	International Fund for Agricultural Development
IIA	Independence Of Irrelevant Alternatives
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	International Panel on Climate Change
MEAs	Multilateral Environmental Agreements
NAP	National Action Programme
NDP	National Development Plan
PSM	Propensity Score Matching
SANBI	South African National Biodiversity Institute
SDGs	Sustainable Development Goals
SLM	Sustainable Land Management
UNCCD	United Nations Convention to Combat Desertification
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change

## CHAPTER 1: INTRODUCTION

### 1.1 Background

The significance of land as a foundational element in agricultural production cannot be overstated, a fact highlighted by classical political economists and esteemed researchers such as Mazzucato et al. (2023), Baker & Conning (2023), Meyfroidt et al. (2024). Land assumes a pivotal role as it serves as the primary source of food production and the provider of invaluable ecosystem services, as emphasized by Pereira et al. (2024) and Scown et al. (2020). The well-being of our planet depends on the effective functioning of ecosystems, making it a critical component in our pursuit of Sustainable Development Goals (SDGs), a sentiment shared by Avtar et al. (2020), DeClerck et al. (2016), Wu et al. (2020), von Braun et al. (2021), and Viana et al. (2022). However, our world grapples with an urgent environmental crisis known as "land degradation". This pressing issue is propelled by various factors, including land conversion, the abandonment of agricultural fields, and soil overexploitation in agriculture, climate change and population growth (Zingore et al., 2021; Montanarella et al., 2016). The consequences of these are far-reaching, leading to the depletion of productive soil, which in turn adversely affects agriculture, water resources, biodiversity, and the delicate balance of ecosystems.

Owing to the complex and multifaceted nature of land degradation that spans various agro-ecological zones, the diverse range of its causative factors can be attributed to several elements. These include climatic conditions such as drought and land use practices (Gomiero, 2016; Tamene et al., 2021). Additionally, contributing to this complex issue are inadequate land tenure arrangements, elevated levels of poverty, rapid population growth, and deficiencies in institutional governance (Abdi & Aulakh, 2017). The complex interplay of these factors presents substantial global challenges, notably encompassing concerns related to food security, water scarcity, and carbon sequestration, (Hossain et al., 2020; Perović et al., 2023; Das et al., 2023).

In recent years, a growing sense of urgency has emerged to tackle the pressing problem of land degradation, primarily due to its escalating and far-reaching impacts on critical aspects such as food security, biodiversity, climate change, and socio-economic well-being. As a result, global efforts to combat land degradation have intensified over the past three decades, supported by a range of international strategies and policy frameworks. These include the United Nations Convention to Combat Desertification (UNCCD), the integration of land-related priorities within the Sustainable Development Goals (SDGs) particularly Goal 15: Life on Land as well as the formulation of National and Regional Action Plans (NAPs and RAPs) and the promotion of sustainable land management (SLM) practices (Akhtar-Schuster et al., 2017). Since the UNCCD was established in 1994, local and regional governments (LRGs) have gained growing recognition as key actors in the implementation and localisation of land restoration interventions (UN-Habitat, 2020). This role was reaffirmed at UNCCD

COP16 in 2024, where LRGs were acknowledged as essential in addressing desertification, land degradation and drought (DLDD) due to their proximity to affected communities and their ability to bridge urban-rural development challenges (UNCCD, 2024). In addition, major global platforms such as the Group of Twenty (G20) Summit have increasingly prioritised land restoration and resilience-building initiatives as part of broader climate and development agendas (G20, 2024). These initiatives collectively reflect a serious commitment of international organisations, governments, and communities worldwide to combat land degradation and advance the cause of sustainable land use practices (DFFE, 2025; Sanz et al., 2017; Fuso et al., 2019).

At their core these initiatives are firmly rooted in the pursuit of multifaceted strategies, policies, and practices that facilitate sustainable land management (UNCCD, 2021). This encompasses a comprehensive approach that spans various facets of land stewardship, including the restoration of degraded areas to their former ecological vitality. Simultaneously, these endeavours emphasize the development of resilience-building measures that can effectively counteract the adverse consequences of desertification and land degradation (UNCCD, 2021). In essence, these global initiatives serve as a beacon of hope, rallying nations and communities to pool their resources, knowledge, and expertise in pursuit of a shared vision: a world where the relentless march of land degradation is halted and reversed, where drought-stricken regions find renewed hope, and where environmental sustainability and poverty reduction walk hand in hand toward a brighter future.

The United Nations Convention to Combat Desertification Conference of the Parties (UNCCD COP13), held in September 2017 in Ordos, China, marked a significant turning point in the global effort to combat land degradation and promote sustainable land management (UNCCD, 2017). At this momentous event, countries from around the world united to achieve a crucial milestone - the adoption of a comprehensive global roadmap known as the UNCCD 2018-2030 Strategic Framework (UNCCD, 2017). This framework represents a shared commitment among nations to pursue the ambitious goal of Land Degradation Neutrality (LDN) over the next decade and beyond. The LDN, at the heart of the UNCCD 2018-2030 Strategic Framework, carries profound implications (UNCCD, 2017). Its primary objectives are nothing short of transformative. First and foremost, it seeks to reverse the degradation of vast expanses of land, thereby restoring their productivity and ecological vitality (Chasek and Downie, 2020). This monumental endeavour is not only about the environment; it is also about the people. The Land Degradation Neutrality initiative LDN aims to enhance the livelihoods of over 1.3 billion people who are directly affected by land degradation, offering them a chance for a better quality of life and economic well-being.

Crucially, the LDN agenda acknowledges the critical role that land plays in mitigating the adverse impacts of drought on vulnerable populations (Chasek and Downie, 2020). By restoring and sustainably managing land, it becomes a buffer against the harsh effects of water scarcity, safeguarding food and

water resources for those who are most at risk. Within the UNCCD 2018-2030 Strategic Framework, the promotion of sustainable land management emerges as a cornerstone strategic objective (UNCCD, 2017). This emphasis on sustainability underscores the importance of not only halting land degradation but also ensuring that the restored land remains healthy and productive over the long term. Furthermore, the framework places a strong emphasis on the welfare of individuals and communities affected by land degradation (UNCCD, 2017). It recognizes the interconnectedness of land health and human well-being, prioritizing actions that improve livelihoods and promote economic opportunities for those grappling with the consequences of degraded land.

## **1.2 Research problem**

Recent assessments indicate that approximately 1.5 million hectares of land in South Africa are affected by land degradation, leading to declining soil fertility, reduced agricultural productivity, and the loss of key ecosystem services such as water, biodiversity support and carbon sequestration (SANBI, 2023). Soil degradation imposes substantial economic costs on South Africa, including increased dam sedimentation and higher water treatment expenses, which collectively amount to billions of rand annually (Department of Water and Sanitation, 2021; Schulze et al., 2019). For instance, nutrient depletion and erosion contribute significantly to reduced soil fertility and increased expenditure on remediation and agricultural inputs (DAFF, 2020). Food production per capita is declining, and agricultural and food imports are rising, potentially exacerbated by future climate change, which could force marginal agriculture out of production, leading to further job losses and livelihood erosion (World Bank, 2023). Clearly, land degradation poses a significant threat to the country's economic growth and development. In conjunction with declining land productivity due to degradation these indicators raise serious concerns regarding sustainable food provision.

Several research studies (e.g. FAO & ITPS, 2015; Nkonya et al., 2016; Masipa, 2017; Turpie et al., 2021) have consistently emphasized the pressing need to address land degradation issues in Southern Africa. Despite the UNCCD and the South African government recognizing and prioritizing the problem since 2004, a significant knowledge gap persists concerning the complete scope of the impact of land degradation on both agricultural productivity and socio-economic development. This knowledge gap becomes even more crucial in the context of global existential challenges, as it underscores the detrimental effects of land degradation on global food security. Regionally, only a limited number of studies (Gupta, 2019; Drechsel et al., 2019; Tully et al., 2015; Nkonya et al. 2016), have managed to generate empirical evidence regarding the link between land degradation and food security.

When it comes to rural communities in South Africa, there is a noticeable research dearth in substantiating this linkage, hindering the development and implementation of effective strategies to mitigate the adverse consequences of land degradation. To bridge this knowledge gap, it is essential to

undertake studies and assessments that specifically focus on understanding these impacts. Given the intricate and site-specific nature of land degradation and its influence on food security, establishing direct causal relationships remains a complex challenge. Therefore, it is imperative to broaden the examination of land degradation's social impacts beyond its immediate effects on food production to comprehensively address these interconnected challenges. Sekhukhune District in the Limpopo Province provides a compelling context for examining the interplay between land degradation and agricultural productivity. Recent analyses show that approximately 11.6% of the area is degraded by human-induced processes (e.g., overgrazing, poor rangeland management), while 41.4% is affected by rainfall variability and drought-driven degradation (Kgaphola et al., 2023). These degradation dynamics coincide with the district's dominance of small-scale, rain-fed agriculture, shallow soils, and limited irrigation infrastructure conditions that heighten vulnerability to yield declines and livelihood shocks. Such characteristics make Sekhukhune an appropriate case study area for investigating how degraded land undermines productivity and, ultimately, household food security.

### **1.3 Research aim and objectives**

The main aim of this study was to examine the impact of land degradation to agricultural productivity and household food security of smallholder farming households in Sekhukhune District Municipality, South Africa. The study synthesises existing literature to examine the complex relationships between land degradation, land-based livelihood activities, and household well-being. It investigates the factors influencing farmers' choice of coping strategies and further quantify the extent to which land degradation affects both agricultural output and food security at the household level.

#### **1.3.1 Sub-objectives**

The above-stated aim was achieved by addressing the following specific objectives:

- To critically analyse the relationships between land degradation, land-based human activities, and their environmental and socio-economic impacts.
- To explore the factors that influence farmers' decisions to adopt coping strategies for land degradation and further evaluate the key drivers that shape the selection of specific coping strategies by farmers in semi-arid South Africa.
- To quantify the impacts of land degradation on agricultural productivity of smallholder farmers in semi-arid South Africa.
- To quantify the impact of land degradation to household food security of smallholder farmers in semi-arid South Africa.

### **1.3.2 Research questions**

- 1. Causal linkages between land degradation and smallholder farmers' activities and well-being**
  - What are the specific land-based activities most affected by land degradation in the Greater Sekhukhune District?
  - How do these activities contribute to or mitigate the impacts of land degradation on smallholder farmers' well-being?
  - How does land degradation affect farmers' income, crop yields, livestock production, and dietary diversity in this region?
- 2. Factors influencing adoption of coping strategies**
  - What socio-economic, environmental, and institutional factors motivate or hinder smallholder farmers from adopting coping strategies?
  - How do these factors influence the selection of specific coping strategies to address land degradation?
- 3. Impact on agricultural productivity**
  - How does land degradation affect agricultural productivity, including crop yields and livestock production, among smallholder farmers?
- 4. Impact on household food security**
  - To what extent does land degradation affect household food security?
  - How are food availability, access, and utilization influenced by land degradation in smallholder farming households?

### **1.4 Envisaged contribution to the body of knowledge**

The issue of land degradation and its implications for food security and local socio-economic conditions have gained increasing attention in recent years. One key area of concern is how changes in land quality affect agricultural productivity and food security. The degradation of soil leads to lower crop yields and increased production costs, thereby undermining food production and availability. These consequences ripple through rural households, perpetuating a cycle of poverty and compromising livelihoods (Peprah et al., 2017; Etongo et al., 2023). However, there remains a critical gap in research and policy attention regarding the relationship between human well-being, land quality, and soil health. While studies (e.g. AbdelRahman, 2023; Hou, 2023; Rahman et al., 2022; Sonderegger & Pfister, 2021), on land degradation often rely on remote sensing data to raise awareness, these approaches may not provide the information required to identify sustainable land management interventions at the local level. In the

Greater Sekhukhune District Municipality, researchers such as Nzuza et al. (2022), Kgaphola et al. (2023), Mugari (2025) and DFFE (2024), have assessed and mapped patterns of land degradation, further examining land use and land cover changes as well as the barriers to implementing sustainable land management (SLM) practices in the area. While these studies provide valuable insights, they predominantly rely on remote sensing data and spatial analyses, with limited or absent linkages between specific land degradation indicators and their measurable impacts on agricultural productivity. This gap underscores the need for empirical studies that rigorously quantify these relationships to inform evidence-based mitigation strategies. Consequently, it is imperative to explore the complex interplay between land quality, agricultural productivity, and household food security to support the development of integrated policies and targeted interventions aimed at safeguarding food systems and rural livelihoods.

While land degradation exacerbates the vulnerability of smallholder farming systems to climate change, there is limited in-depth analysis of the underlying decision-making processes regarding coping strategies and the multifaceted factors influencing adoption of these land degradation strategies. Socio-economic differences within smallholder communities have received limited attention, hence, there is a need for more detailed analysis to understand how land degradation differentially affects various farmer groups. This study aims to fill these gaps by providing a comprehensive, household-level analysis of the impacts of land degradation on agricultural productivity and food security in the Greater Sekhukhune District Municipality. By integrating quantitative data on land degradation indicators with socio-economic assessments, this research will offer a nuanced understanding of the complex interplay between land quality, agricultural productivity, and food security.

### **1.5 Delineation and limitations**

The key purpose of this study is to examine the impacts of land degradation on the agricultural productivity and food security of smallholder farming households in the semi-arid regions of South Africa. The research centres on the specific context of semi-arid areas and aims to elucidate the intricate relationship between land degradation, agricultural activities and household food security. However, it is critical to acknowledge certain delineations and limitations inherent to this study. In this study, it should be noted that measurement of total productivity is assessed through total farm output and all the variations in quantitative outcomes are considered, therefore this study is not focusing on alterations in the chemical properties of soil over time. While this approach effectively reflects fluctuations in agricultural yield, it does not provide insight into underlying shifts in soil health, nutrient dynamics, or related biophysical processes that critically influence long-term productivity.

## 1.6 Organisation of the thesis

This thesis is structured into six distinct chapters that are largely presented in form of research articles as presented below.

Chapter one contextualises the context of this study and further discusses the research problem, including the objectives of the overall study. This chapter serves as a foundational framework upon which this research is built. Furthermore, this chapter delves into the global including South Africa's policy landscape by examining the policy adoptions and initiatives undertaken in response to the complex interplay between land degradation and food security.

Chapter two - **A Review of the Land Degradation-Livelihood Nexus: Emerging Issues and Gaps** undertakes a thorough exploration of the existing body of literature surrounding the topics of land degradation, agricultural productivity and food security. It critically evaluates and synthesizes relevant studies, offering insights into the broader theoretical frameworks and empirical investigations within the field.

Chapter three - **Smallholder Farmers' Choice of Adaptation Strategies to the Effects of Land Degradation in Sekhukhune District Municipality, Limpopo, South Africa** explores various factors that influence farmers' decisions to adopt specific land management practices as a means of mitigating land degradation. This empirical exploration delves into the intricacies of decision-making processes and offers a deeper understanding of the drivers and constraints that shape farmers' choices in the semi-arid region of Sekhukhune District Municipality, South Africa.

Chapter four - **The impact of Land degradation to Agricultural Productivity of Smallholder Farmers in Semi-Arid Region of South Africa** dissects the intricate web of causal linkages between the land degradation, land-based activities and associated impacts on the smallholder farmers' agricultural productivity in the semi-arid region of Sekhukhune District Municipality, South Africa.

Chapter five - **The Impact of Land Degradation on Household Food Security in Semi-Arid Region of South Africa** extends the inquiry to assess the tangible consequences of land degradation on food security. Through rigorous analysis, this chapter elucidates the impacts of deteriorating soil quality on crop yield and the potential ramifications for the overall well-being of the population.

Chapter six presents the implications emanating from the research. The chapter also offers pragmatic policy recommendations derived from the research findings. Moreover, it suggests potential avenues for further research, acknowledging the evolving nature of the subject matter.

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## **CHAPTER 2: A REVIEW OF LAND DEGRADATION-LIVELIHOOD NEXUS: EMERGING ISSUES AND GAPS**

### **2.1 Introduction**

Land degradation is a pressing global environmental concern that transcends geographical boundaries (Chakma et al., 2022), affecting both developed and developing nations alike (Rehman et al., 2022). This phenomenon encompasses a range of processes, including soil erosion (Bhatnagar, 2022), deforestation (Sofo et al., 2020), desertification (Kumar et al., 2023), and the depletion of soil fertility (Pani, 2020), all of which have profound impacts on ecosystems and human livelihoods (Abdulmalik, K. and Zewide, 2021). Considering these environmental transformations, the relationship between land degradation and human livelihoods has become a subject of intense scrutiny (Halbac-Cotoara-Zamfir et al., 2020). As arable land diminishes and natural resources become scarcer (Barbier, 2021; Maja and Ayano, 2021), the interplay between land degradation and livelihoods has attracted the attention of a wide array of stakeholders, researchers, policymakers, and environmentalists (Jendoubi et al., 2020; Xie et al., 2020; Owonikoko, and Momodu, 2020).

The consequences of land degradation are complex. For communities dependent on agriculture, declining soil fertility can result in reduced crop yields and, consequently, food insecurity (Chimwamurombe and Mataranyika, 2021; Smith et al., 2020). The loss of forested areas can disrupt ecosystems and limit opportunities for sustainable livelihoods, including non-timber forest product harvesting (Sheppard et al., 2020; Ehara et al., 2023; de Mello et al., 2020). Moreover, the expansion of desertified regions poses a direct threat to the pastoral communities that rely on these lands for their livestock (Stringer et al., 2021). As the global society grapples with the challenges of environmental degradation and climate change, an understanding of how land degradation affects human livelihoods is paramount. This review aims to synthesise the current state of research, consolidating insights from various studies, and shedding light on the evolving dynamics of the land degradation-livelihood nexus. By elucidating these complexities, it seeks to contribute to the broader dialogue on sustainable land management, resilience building, and the development of policies that can address the profound consequences of land degradation while fostering the well-being of communities around the world.

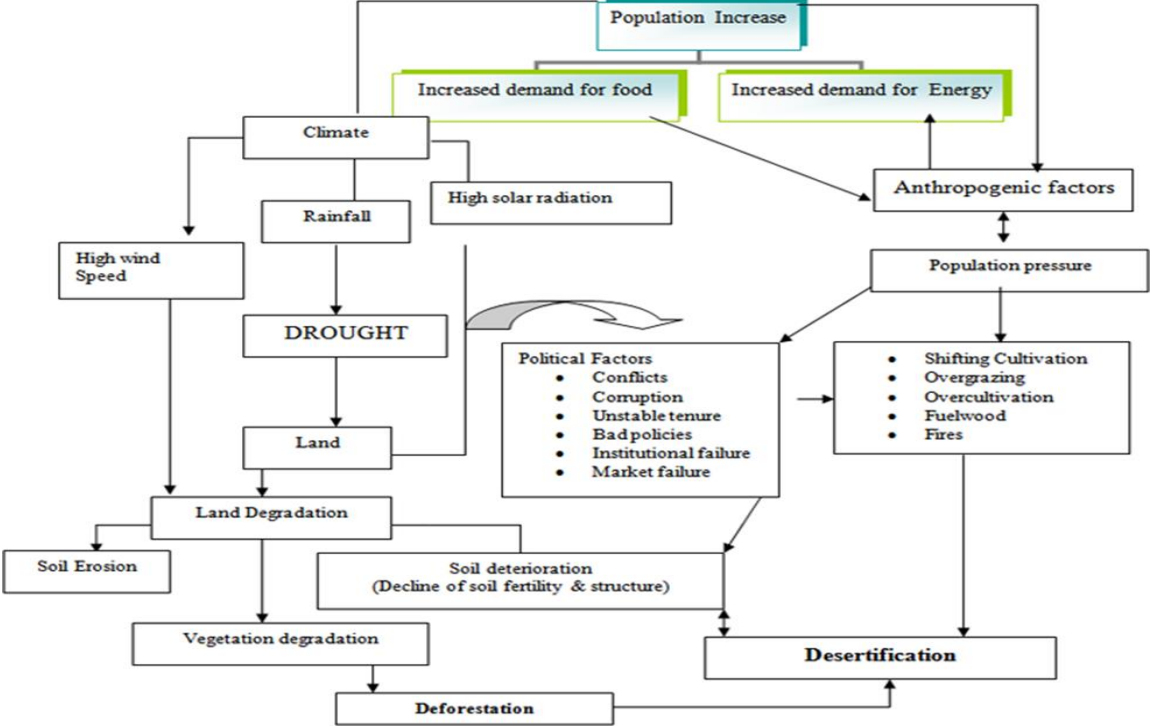
### **2.2 Land degradation: contextualisation**

According to Castro-Koshy and Le Roux, 2020, the definition of land degradation mainly depends on the issue or subject that needs emphasis. For this study, this concept is used and defined from an agricultural perspective. In this perspective, scholars usually describe land degradation as a loss of physical, chemical, and biological productivity due to unsustainable land use management such as

overgrazing, poor farming practices, deforestation, climate change (Bhadwal et al., 2019; Montanarella and Panagos, 2021; Nkonya et al., 2016).

**2.2.1 Natural and anthropogenic causes of land degradation**

According to Nkonya et al., (2016), the three main, interconnected groups of factors that contribute to land degradation: (i) institutional factors that govern more general land use policies, (ii) socio-economic factors that influence the demand for and management of land, and (iii) biophysical factors that determine how land is used. The key primary drivers of land degradation include land use, climate change, population growth and urbanisation (Dragović & Vulević, 2020) as shown in figure 2.1 below. Several scholars argue that land degradation is caused by a multitude of factors, driven by both natural and human-induced forces (Briassoulis, 2019; Eswaran et al., 2019). These include unsustainable land management practices, such as improper agricultural techniques and excessive use of agrochemicals, which contributes to soil erosion, nutrient depletion, and degradation. Deforestation and the loss of vegetation cover significantly impact ecosystems and accelerate land degradation processes. Several human activities, such as agriculture expansion and urbanization, are major drivers of deforestation, leading to the destruction of natural habitats and disrupting ecological balance. For instance, overgrazing, particularly in arid and semi-arid regions, leads to soil compaction and the deterioration of rangelands (Behmanesh et al., 2016).



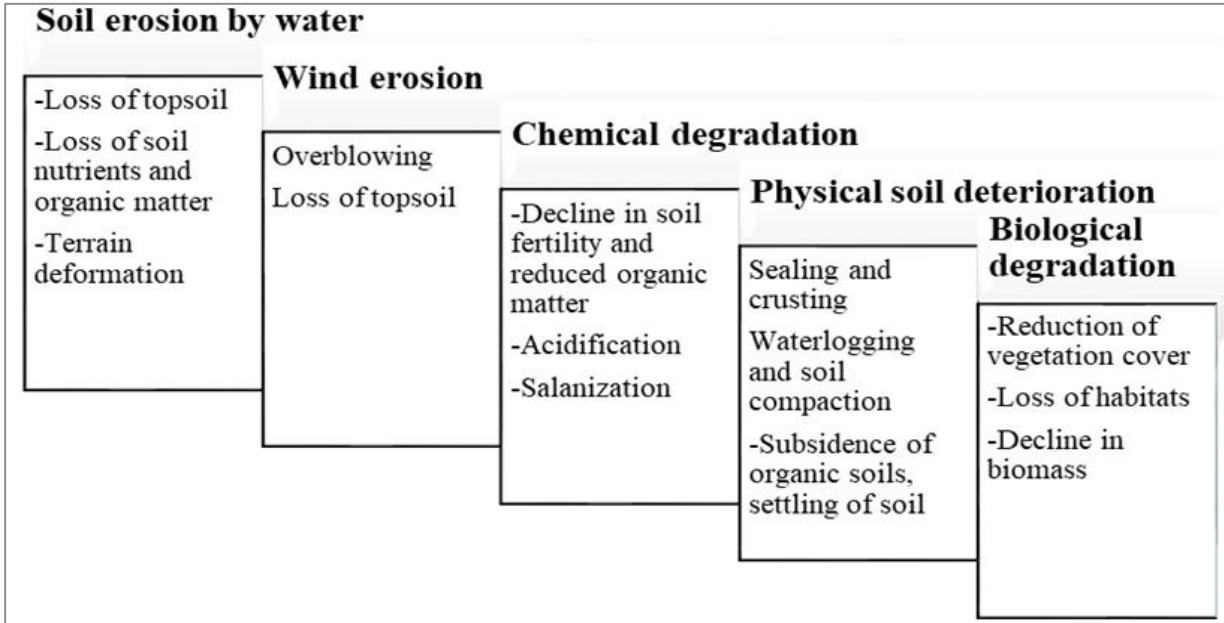
**Figure 2.1: Synergistic factors contributing to land degradation**

Adapted from Abdi et al., 2013.

Climate change, with its associated shifts in rainfall patterns and increased frequency of extreme weather events, intensifies erosion and affects soil quality. The growing global population, along with urbanization and the increasing demand for food and resources, puts pressure on land resources, leading to land conversion and unsustainable land use practices. Socio-economic factors, including poverty, limited access to resources, and weak governance systems, also contribute to land degradation. Furthermore, infrastructure development and mining activities can disrupt natural drainage patterns and cause land disturbance. However, understanding these causes and drivers is crucial for developing effective strategies to mitigate land degradation and promote sustainable land management practices.

**2.2.2 Types of land degradation**

Conceptually, there are four types of land degradation: (i) physical; (ii) chemical; (iii) biological; and (iv) ecological factors. Figure 2.2 below presents different types of degradation and their indicators.



**Figure 2.2: Types of degradation and their indicators**

Source: Adapted from FAO & UNEP (2022)

**2.2.3 Soil water erosion**

Soil water erosion transpires when the bare-sloped soil surface is exposed to rainfall, and the rainfall intensity exceeds the rate of soil intake, or infiltration rate, leading to soil-surface runoff (Wang, 2023). Holz et al., (2015) described two processes of soil water erosion i.e., detachment of soil particles, the tearing loose of soil particles: and transportation of detached soil particles by splash or flowing water. Soil water erosion is one of the principal mechanisms of land degradation because sometimes it leads to sheet and rill as well as gully erosion (Firoozi & Firoozi, 2024; AbdelRahman, 2023). According to

Tarrolli et al., (2019), soil water erosion on cultivated land poses the biggest threat to soil resources due to topographic, edaphic, and climate conditions. Soil erosion is a major threat to the soil resource, soil fertility, productivity, and, lastly, to food and fibre production (Addis et al., 2016).

#### **2.2.4 Wind erosion**

In various parts of the world, wind erosion stands as the primary contributor to both soil degradation and air pollution, particularly in arid and semi-arid regions where dry and loose soil particles are easily carried away by wind (García-Ruiz et al., 2015; Lackóová et al., 2021; Wu et al., 2022; Weeraratna, 2022). This form of erosion has detrimental effects on the land, it leads to the loss of topsoil, which is rich in essential nutrients and organic matter crucial for plant growth (Vos et al., 2022). As a result, agricultural productivity declines, and the natural ecosystem functions are compromised. Wind erosion also degrades the soil structure, breaking down soil aggregates and causing compaction, which reduces water infiltration and increases surface runoff (Balasubramanian, 2017). Bhattacharyya et al. (2022) elucidated that the phenomenon of wind erosion exerts a direct influence on crop yield by inflicting detrimental effects on the crops themselves, primarily through mechanisms such as abrasion, burial, and dust deposition. These physical interactions between the wind and crops lead to physical damage and subsequent reduction in crop productivity.

#### **2.2.5 Soil chemical degradation**

The chemical properties of soils are crucial factors influencing plant productivity and growth. Nutrient content, soil pH, and cation exchange capacity are among the key chemical properties that directly impact a plant's ability to thrive (Efretuei et al., 2023; Ntalo et al., 2022). Essential nutrients, such as nitrogen, phosphorus, potassium, and micronutrients, are vital for plant development and healthy yields (Kihara et al., 2017). The soil's pH level plays a significant role in nutrient availability and can influence the plant's ability to uptake essential elements. Furthermore, the cation exchange capacity of the soil affects its ability to retain and exchange essential ions required for plant growth (Kumar et al., 2021; Vargas-Rojas et al., 2022). Nonetheless, chemical degradation of soil stands as the second most prevalent type of soil degradation, posing a significant threat to soil resources due to its capacity to diminish their capabilities (Tetteh, 2015).

#### **2.2.6 Physical deterioration of soil**

Physical deterioration of soil encompasses a range of adverse effects, including the breakdown of soil structure, dispersion of soil particles, closure of pores, compression and heightened density, consolidation, compaction leading to restricted root penetration, reduced infiltration, waterlogging, runoff, and accelerated erosion (Adão et al., 2025; Xing et al., 2025). Soil physical properties i.e., soil

texture and soil structure play a key role in determining soil suitability for agricultural production (Sainju et al., 2022; Ye et al., 2024; Blanco-Sepúlveda et al., 2024; Souza Cruz et al., 2024; Karki et al., 2025). Soil texture and structure are the key physical properties of soil that control organic matter and soil nutrient dynamics of the soil. Soil texture affects the soil's ability to hold nutrients and water, while soil structure affects aeration, water holding capacity, drainage, and penetration of roots (Phogat et al., 2015). Physical properties of the soil are very important for agricultural production, for instance, the amount and rate of water, oxygen, and nutrient absorption by plants depend on the ability of the roots to absorb the soil solution as well as the ability of the soil to supply it to the roots. Some soil properties, such as low hydraulic conductivity, can limit the free supply of water and oxygen to the roots and negatively affect the agricultural yield (Almendro-Candel, et al., 2018).

### **2.2.7 Biological degradation**

Biological degradation refers to the deterioration of soil quality caused by living organisms such as bacteria, fungi, insects, and other microorganisms. Soil microorganisms are known for playing a central role in nutrient cycling, decomposition of wastes and residuals, and detoxification of pollutant compounds in the environment, therefore degradation/ depletion of these organisms results in loss of biomass, loss of habitat and loss of vegetation cover which leads to bare soils that are highly susceptible to erosion (Lal, 2015; Lia et al., 2021). Biological degradation is known as the most serious form of soil degradation as it affects the life of the crops (Lal, 2015).

## **2.3 Unpacking the land degradation-livelihood nexus**

Land degradation is an increasingly critical issue that demands urgent attention and action (United Nations Convention to Combat Desertification & Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, 2025). This complex problem, driven by factors such as deforestation, soil erosion, overgrazing, and unsustainable agricultural practices, poses a severe threat to global food security, ecological stability, and the livelihoods of millions of people worldwide (Lal, 2015). It is disheartening to note that the rate of land degradation continues to outpace efforts to mitigate its impacts. One of the key challenges in addressing land degradation is the inherent interconnectedness of its drivers and consequences.

Land degradation is not a standalone issue but rather a symptom of broader problems like climate change, poverty, and inadequate land management practices (UNCCD, 2019). Unfortunately, policy responses and mitigation strategies often lack the required depth and holistic perspective needed to tackle these interconnected challenges effectively. To address land degradation comprehensively, it is essential to adopt an interdisciplinary approach that considers not only ecological factors but also socio-economic, cultural, and political dimensions (Turner et al., 2016).

The land degradation-livelihood nexus is a critical and complex issue that has far-reaching consequences for both the environment and human societies (UNCCD, 2019). This nexus refers to the interconnected relationship between the degradation of land resources and its impact on the livelihoods of communities dependent on these resources (Reed et al., 2017). While it is crucial to address this issue to ensure sustainable development (Drechsel et al., 2015), there are several challenges that must be considered.

Firstly, land degradation often stems from unsustainable land-use practices, such as deforestation, overgrazing, and improper agricultural methods (FAO, 2015). These activities can lead to soil erosion, loss of biodiversity, and reduced agricultural productivity (IPBES, 2019). Consequently, the livelihoods of communities relying on these lands are severely impacted, as their primary source of income and sustenance deteriorates. Secondly, the land degradation-livelihood nexus is exacerbated by climate change (IPCC, 2014). Rising temperatures, erratic rainfall patterns, and extreme weather events can intensify land degradation processes (UNCCD, 2019). Vulnerable communities, particularly in developing countries, face increased challenges in maintaining their livelihoods, as they are often ill-equipped to adapt to these changing conditions (IPCC, 2014).

Moreover, the nexus is often characterised by a vicious cycle (Reed et al., 2017). Impoverished communities, lacking alternative livelihood options, continue to exploit their degraded lands, further exacerbating the problem. This cycle of land degradation and poverty becomes self-reinforcing, making it difficult to break the chain without targeted interventions and support (Drechsel et al., 2015). Again, the issue of land degradation is not limited to rural areas (FAO, 2015). Urban expansion and industrialisation can also contribute to land degradation through processes like urban sprawl, pollution, and habitat destruction (IPBES, 2019). This impacts both rural and urban livelihoods, as resources become scarcer and competition for land increases (UNCCD, 2019). This underscores the complexity of the land degradation-livelihood nexus in the sense that addressing it requires a multifaceted approach that considers social, economic, and environmental factors (IPCC, 2014) to mitigate against its associated impacts.

#### **2.4 Previous studies exploring the land degradation-livelihood nexus: key findings**

The concept of the land degradation-livelihood nexus is a fundamental and multidimensional framework that illuminates the complex interplay between environmental changes, particularly land degradation, and human livelihoods (Gambo, 2024). It recognizes that the health of ecosystems and the well-being of people are intricately linked, and any degradation of the land can have far-reaching consequences for communities, especially those heavily dependent on agriculture and natural resources for their sustenance. A ground-breaking study conducted by Bai et al. (2013) has been instrumental in establishing an understanding of this complex relationship, shedding light on the profound implications

it holds for societies around the world. The study offers a foundational framework that encompasses various critical aspects of the land degradation-livelihood nexus.

The study highlights that a significant portion of land degradation results from human activities, such as deforestation, overgrazing, inappropriate agricultural practices, and urbanisation. These activities often deplete the land's natural resources, leading to soil erosion, reduced fertility, and ultimately land degradation. Further, the research emphasizes that the impact of land degradation is most pronounced in rural and agrarian societies where livelihoods are complexly linked to the land. In these communities, agriculture, livestock rearing, and other natural resource-based activities often serve as the primary sources of income and sustenance.

Bai et al. (2013) delve into the direct and indirect effects of land degradation on rural livelihoods. The direct effects include reduced crop yields, lower livestock productivity, and diminished access to clean water. Indirect effects encompass the socio-economic consequences, such as increased poverty, food insecurity, and migration as people seek alternative livelihoods. More interestingly, the study elucidates the existence of feedback loops within the land degradation-livelihood nexus. For instance, as land degradation worsens, it can drive farmers to adopt more unsustainable practices in a desperate attempt to secure their livelihoods, exacerbating the problem.

## **2.5 Impact of land degradation on agricultural productivity**

A key strength of the literature is its consistent demonstration of the negative correlation between land degradation and agricultural productivity. Numerous studies (e.g. Bai et al., 2013; Lal, 2015) from various regions provide compelling evidence that soil erosion, nutrient depletion, salinization, and other forms of land degradation significantly reduce crop yields. This global consensus highlights the widespread nature of the problem, emphasizing its importance in the context of global food security. However, a common limitation in the literature is the lack of a standardized framework for quantifying the impact of land degradation on agricultural productivity (Vågen et al., 2016). Different studies employ varying methodologies and indicators, making it challenging to compare findings across regions and ecosystems. This lack of consistency hinders policymakers' ability to develop targeted strategies for mitigating land degradation's effects on agriculture.

Additionally, while the literature effectively identifies the negative consequences, it often falls short in exploring the mechanisms through which land degradation affects agricultural productivity. A more in-depth analysis of the ecological processes, such as changes in soil structure, microbial activity, and nutrient cycling, would provide a better understanding of how land degradation directly impacts crop yields. Moreover, the literature generally underemphasizes the interaction between land degradation and climate change. Land degradation can exacerbate the effects of climate change on agriculture by

increasing vulnerability to extreme weather events and reducing soil resilience (Lal, 2015; IPCC, 2019). A more comprehensive examination of this nexus is essential for crafting effective adaptation strategies.

Furthermore, the literature predominantly focuses on the agronomic aspects of land degradation, often overlooking the socio-economic dimensions. Sustainable land management practices, while vital, may not be adopted if they do not align with the economic interests of farmers or if access to resources is unequal (Nkonya et al., 2016). Moreover, there is a need to pay greater attention to the societal inequalities and disparities in access to resources that underlie land degradation issues. Poverty, for example, can force marginalized communities to resort to unsustainable land-use practices, such as slash-and-burn agriculture or illegal logging, which exacerbate degradation (Nkonya et al., 2016).

Land tenure systems and property rights also play a significant role, as insecure land tenure can discourage investments in sustainable land management, and often disadvantaged groups, particularly women, have limited access to land and resources. To address these challenges effectively, a more holistic approach to land degradation research is imperative through consideration of the human dimensions, including social, cultural, and economic factors, and actively engage with local communities to design context-specific, socially equitable, and economically viable solutions.

Numerous studies in South Africa (e.g. Nezomba et al., 2017; Mngqawa et al., 2016) have shown that land degradation, including soil erosion, nutrient depletion, and declining soil quality, has a detrimental impact on agricultural productivity. This includes both smallholder and commercial farming systems. The consequences of land degradation are particularly severe in regions with fragile ecosystems, leading to reduced crop yields, increased vulnerability to climate variability, and heightened food security risks. The negative correlation between land degradation and agricultural productivity underscores the urgent need for sustainable land management practices in the country.

A common limitation in the literature is the lack of a comprehensive and standardized assessment of the extent and severity of land degradation across South Africa's diverse agro-ecological zones (Blignaut et al., 2015; Le Roux et al., 2021). Variations in land degradation patterns and drivers across regions demand tailored strategies and interventions. Additionally, while some studies acknowledge the role of socio-economic factors, such as land tenure systems and access to resources in driving land degradation, there is a need for more in-depth research that explores the human dimensions of the problem, considering issues of poverty, inequality, and the impact on marginalized communities.

## **2.6 Impacts of land degradation on food security**

According to the Food and Agriculture Organization (1996), food security entails not only the availability of food but also its accessibility, utilization and stability. Recent studies reaffirm this broader definition Mirzabaev et al. (2023) define food security as “physical, social and economic access to sufficient, safe and nutritious food that meets dietary needs and food preferences for an active and healthy life,” while Saccone & Vallino, (2025) integrate the four core dimensions (availability, access, utilization, stability) into their analytical framework. This comprehensive definition underscores the importance of not just having enough food but also ensuring its safety, nutritional adequacy, and consistent accessibility. However, the global challenge of land degradation compounds the complexities associated with achieving food security, particularly among the most vulnerable populations in developing countries (Gomiero, 2016; Kopittke et al., 2019).

In many developing nations, rural communities depend heavily on agriculture as their primary source of income and sustenance (International Fund for Agricultural Development [IFAD], 2020). These communities often lack diversification in their livelihoods, leaving them highly dependent on the productivity of their agricultural lands. Land degradation, manifested through processes like soil erosion, nutrient depletion, and other factors, directly impacts the capacity of these lands to produce sufficient crops. Consequently, crop yields decline, and the quantity of food available to these communities diminishes (Nyanga et al., 2020).

The adverse effects of land degradation on food security extend beyond immediate crop yield reductions and price hikes (UNCCD, 2020). Land degradation can disrupt traditional farming practices, forcing communities to adapt to new, potentially less sustainable agricultural methods (Ogega et al., 2020). These adaptations can be resource-intensive and may require investments in technology, training, and infrastructure, further straining the already limited resources of vulnerable populations (Tittonell et al., 2016).

Land degradation also contributes to the escalation of food prices (UNEP, 2017). As agricultural land's productivity decreases due to soil degradation, farmers may struggle to meet their production targets (Lal, 2015). This supply shortfall can lead to higher prices for agricultural products, affecting the affordability of food for both rural and urban populations (Fan and Rue, 2020). Vulnerable communities in developing countries, often living on limited incomes, bear the brunt of these rising food prices, intensifying the challenge of accessing nutritious meals regularly (Headey et al., 2010). In addition, soil degradation also impacts the nutritional quality of available food. Nutrient depletion in the soil can result in reduced nutrient content in crops, affecting the overall nutritional value of the food supply (Silver et al., 2021). This can lead to malnutrition and related health issues among affected populations, exacerbating the food security crisis (Padhani et al., 2022).

## **2.7 Linkages between land degradation, agricultural productivity, and food security**

The interlink between land degradation and agricultural productivity is a multifaceted and intricate relationship, influenced by a plethora of interconnected factors. Soil properties, ground slope, vegetation cover, and rainfall patterns, among others, all play pivotal roles in this dynamic interplay (Wang et al., 2023). The fundamental significance of soil health in the sustainability of agricultural systems cannot be overstated (Eswaran et al., 2019; Gupta, 2019). However, soil faces various degradation processes, including erosion (water, wind, and tillage), compaction, declining soil organic carbon, biodiversity loss, salinization, sodification, and contamination by pollutants (Slayi et al., 2024). Among these, soil erosion stands out as a critical threat to soil fertility and productivity, as it erodes the chemical and biological components essential for plant growth and biodiversity, endangering agriculture's long-term viability in many regions (Teku & Derbib, 2025; Li et al., 2025; Panagos et al., 2021).

Soil degradation directly translates into a decline in soil quality and productivity, with significant consequences for agriculture. The impacts of soil erosion encompass both on-site effects within the farmland and off-site effects beyond agriculture (Borrelli et al., 2018). Among these, the most pressing on-site effect is the loss of soil productivity, which hampers the ability of farmers to sustain their livelihoods and produce enough food to meet growing global demands. According to the FAO (2021), land degradation results in reduced average crop yields, greater yield variability and diminished total factor productivity all of which translate into economic costs such as income losses, higher production expenses and reduced consumption.

The economic ramifications of soil degradation extend beyond direct agricultural losses. Changes in land value emerge as another critical facet of this relationship. Studies like that of Gide et al. (2024), employ the Hedonic price model, which is typically used to estimate the market value of environmental or ecosystem services influencing home prices, to demonstrate that the value of agricultural land is closely tied to its productivity, spatial location, and environmental susceptibility. However, quantifying the complex relationships between land degradation and agricultural productivity has proven to be a challenging endeavour (Chaudhry et al., 2024; Bigelow et al., 2020).

The relationship between soil degradation and food security is a global concern that has persisted over the decades. While some argue that land degradation does not pose a direct threat to global food security, it is undeniably a critical issue in regions where soils are fragile, property rights are insecure, and farmers have limited access to information and markets (Ahmed, 2025). However, empirical evidence (e.g. Utuk

& Daniel, 2015)) suggests that significant proportions of both irrigated and rain-fed lands in Asia and Africa have experienced substantial losses in productive potential, with dire consequences for food security. The looming spectre of food insecurity and malnutrition, particularly in South Asia and Sub-Saharan Africa, underscores the urgency of addressing land degradation as a central component of sustainable development (Abdi et al., 2024). Considering the existing literature, the complex link between soil erosion and declining agricultural productivity remains undeniable, demanding continued attention and intervention.

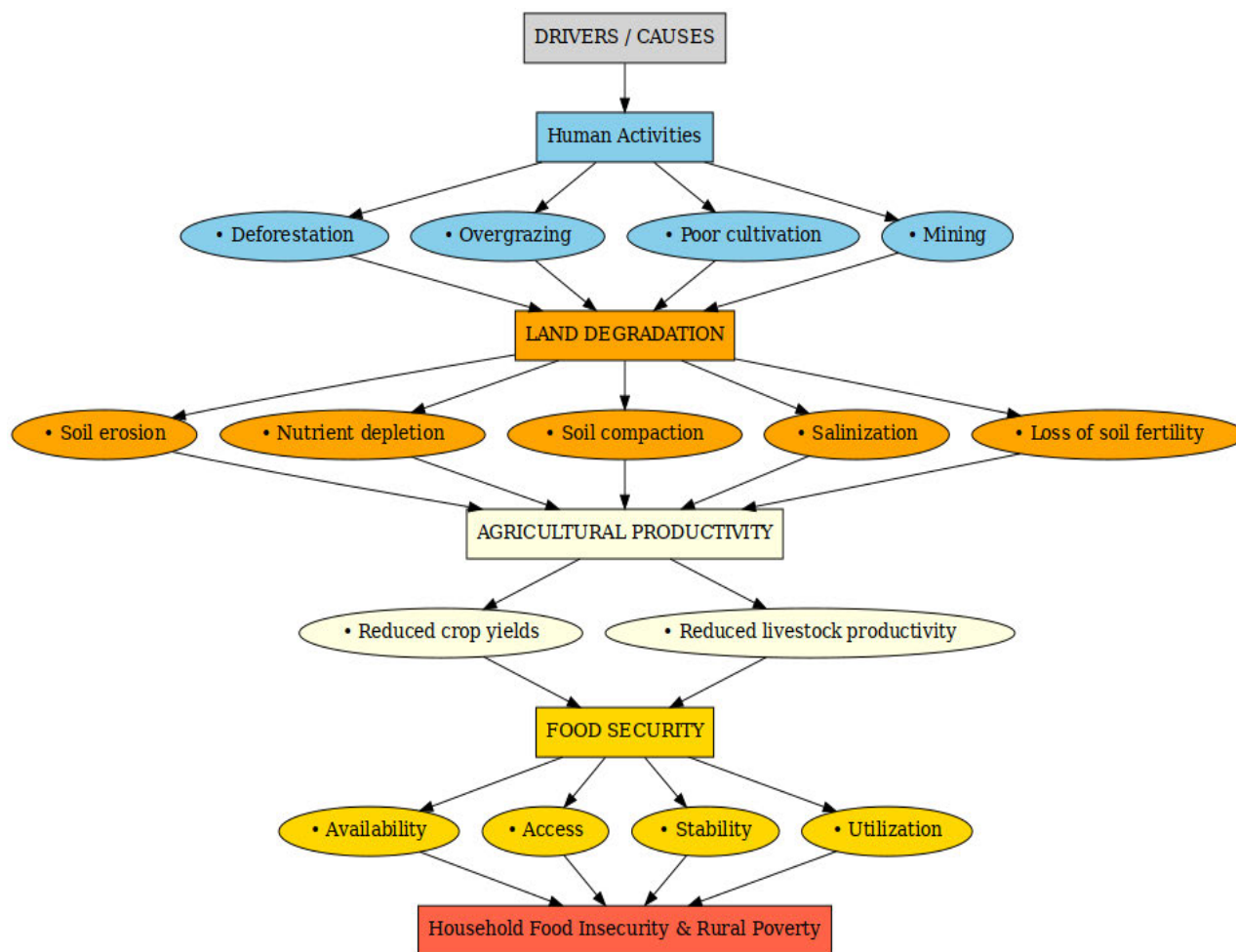
### **2.7.1 Conceptual Framework**

Figure 2.3 presents the conceptual framework illustrating the dynamic pathways through which land degradation influences agricultural productivity and, ultimately, household food security. Land degradation manifests through interrelated processes such as soil erosion, nutrient depletion, salinization, compaction, and other human-induced activities including deforestation, overgrazing, and unsustainable agricultural practices. Collectively, these processes undermine the land's productive capacity, reducing its ability to sustain crop yields and support resilient farming systems.

In the conceptual framework agricultural productivity serves as a mediating variable that translates the biophysical consequences of land degradation into socioeconomic outcomes. When productivity declines, household food security becomes increasingly threatened due to reduced crop availability, income losses, and increased vulnerability to the effects.

To mitigate these adverse effects, coping strategies such as crop diversification and rotation, soil and water conservation, agroforestry, organic farming, and community-based resource management function as moderating mechanisms. Their effectiveness, however, depends heavily on the socio-economic and institutional context in which farmers operate. Factors such as access to resources, education, land tenure security, market access, and the presence of enabling policies, subsidies, and extension services shape the adoption and success of these coping strategies. Consequently, the framework conceptualizes a multi-layered interaction in which land degradation acts as the primary driver, agricultural productivity serves as the mediator, and household food security represents the ultimate outcome, all moderated by socio-economic, institutional, and adaptive dimensions.

Therefore, the nexus between land degradation, agricultural productivity, and household food security is intricate and influenced by a multitude of factors. Mitigating the adverse effects of land degradation requires coordinated efforts that encompass institutional reforms and community empowerment.



**Figure 2.3: Conceptual Framework**

## 2.8 Agriculture and land degradation in South Africa

The smallholder farming sector in South Africa continues to occupy a central and prioritized position within the country’s developmental agenda. It is consistently supported through initiatives focused on infrastructure development, grant and operational funding, access to production inputs, credit facilities, and agricultural extension services aimed at enhancing productivity and rural livelihoods. Recent policy frameworks such as the National Policy on Comprehensive Producer Development Support (2022) and the Agricultural and Agro-Processing Master Plan (AAMP, 2023) reflect government commitment to empowering small-scale and emerging farmers as a pathway to inclusive growth, job creation, and food security (Mugari et al., 2025; Tantoh & McKay, 2023; Department of Agriculture, Land Reform and Rural Development [DALRRD], 2023).

In the Greater Sekhukhune District Municipality, a significant proportion of smallholder farmers fall into the category of disadvantaged individuals. These farmers are not integrated into the mainstream agricultural practices; they operate on small plots of land located in densely populated and semi-arid regions. Their farming activities are characterised by low productivity levels, limited access to land,

inadequate availability of agricultural inputs, and notably, constrained access to credit facilities (District Development Plan (DDP), 2022). Moreover, they are vulnerable to land degradation and its associated consequences.

In South Africa, the primary drivers of land degradation stem from historical land tenure systems that were previously in place, alongside mining activities in specific regions, and the encroachment of woody plants which is a consequence of climate change, overgrazing, and unsustainable land management practices, exacerbated by a high population-to-land ratio (Mani et al., 2021). One key factor highlighted by researchers in this regard is South Africa's dual land tenure system, which is often identified as a fundamental driver of land degradation.

This system comprises two main components: private ownership and communal land ownership overseen by traditional councils (Clark &Page, 2019; Phalatse, 2022; Mawere et al., 2021). Its origins can be traced back to the 1913 Land Act, which allocated most of the freehold land to large-scale commercial white farmers, laying the foundation for the current system (Walker, 2017; Moyo, 2017). However, the roots of land dispossession from indigenous communities by colonial powers extend far back into history (Boisen, 2017; Adhikari, 2020; Laband, 2020). The resulting disparities in land use patterns between freehold and communal land areas have contributed to variations in the causes and patterns of land degradation (Von Maltitz et al., 2019). Communal areas often face challenges like overgrazing, soil erosion, wood harvesting, and reduced agricultural productivity.

As a result, land degradation is becoming increasingly severe particularly in communal and grazing areas of South Africa. Both sheet and gully erosion now extend over approximately 0.72 million hectares of the country's land, with their prevalence on the rise. The most prevalent issue is water erosion, which impacts over 70% of the nation's territory. Wind erosion poses a significant threat as well, with around 25% of South Africa highly susceptible; approximately 2.2 million hectares experienced severe wind erosion (Van Tol et al., 2023). This already substantial figure has more than doubled due to the dry period leading up to 2013-2015 (Department of Environmental Affairs (DEA), 2016). As a result, the yield gap has continually increased, deteriorating up to less than 25% of potential attainable yield while the per capita food production has also continued to decrease (Raimi et al., 2017).

Despite South Africa's participation in international efforts to combat land degradation since 1994, soil erosion remains a major problem. According to the LADA-2010 assessment, approximately 32.7% of cultivated areas in South Africa are moderately to very severely degraded (Lindeque and Koegelenberg, 2015, cited in von Maltitz et al., 2019). The top two classes of land degradation, severe and very severe, account for a significant portion of the total cultivated land area. This ongoing issue underscores the need for all-inclusive strategies to address both land degradation and poverty while promoting sustainable land management.

The relationship between land degradation and poverty in South Africa is complex and intertwined. The natural environment serves as a primary source of livelihood for many rural communities, making their well-being closely linked to the state of the environment. Land degradation further exacerbates poverty by reducing agricultural productivity and the availability of natural resources. The academic discourse on land degradation in South Africa reveals a diversity of definitions and perspectives, reflecting the complex nature of the problem (Dlamini et al., 2014; Palmer & Bennett, 2013, cited in Mani et al., 2021). The historical context of colonialism has left a legacy of land dispossession and resource exploitation, contributing to the present-day challenges of environmental degradation in the country.

## **2.9 A discussion of the emerging issues and gaps from the literature**

While the section 2.7 above synthesised existing evidence on the interconnected pathways linking land degradation, agricultural productivity, and food security, it is equally important to acknowledge the limitations and unresolved questions within this body of research. Although the literature provides substantial empirical support for the degradation-productivity-food security nexus, several emerging issues and gaps remain underexplored. The following section critically examines these gaps to highlight areas where further research and methodological refinement are needed, thereby positioning the current study within the broader scholarly discourse.

The land degradation-livelihood nexus represents a multifaceted issue at the intersection of human activity, environmental health and socio-economic systems. Addressing it requires a comprehensive and interdisciplinary approaches that combine environmental restoration, socio-economic empowerment, and institutional reform. Current literature emphasises that sustainable land management (SLM) should be embedded within broader livelihood and climate adaptation strategies to ensure long-term resilience, particularly among smallholder farmers in fragile ecosystems (FAO,2023); IPCC, 2023) Policymakers, researchers, and local communities must join hands to develop sustainable land management practices, create alternative livelihood opportunities, and bolster resilience in the face of climate change. Additionally, equitable land tenure systems are necessary to ensure marginalised communities have secure access to land resources, contributing to a more sustainable and just future (Drechsel et al., 2015).

The literature review on the impact of land degradation on agricultural productivity and food security offers a comprehensive view of a complex and pressing global issue. This critical literature review assessed the strengths and limitations of existing research in this field. A key strength in this body of literature is the consensus regarding the adverse effects of land degradation on agricultural productivity and food security (Wang et al. 2023; Lal, 2015). Multiple studies (e.g Gao et al., 2025; Song et al., 2025; Tefera et al., 2024; Yaseen et al., 2025) from different regions consistently demonstrate that land degradation, including soil erosion, nutrient depletion, and loss of arable land, has a detrimental impact

on crop yields. This global consensus underscores the universality of the problem and its significance in addressing global food security challenges. However, several gaps and emerging issues persist.

One common limitation in the literature is the lack of a standardized framework for assessing the impact of land degradation. As a result, studies often rely on different methodologies and indicators, making it challenging to compare findings across regions and ecosystems (D'Acunto et al., 2024; Herrick et al., 2025; Nandi, 2025; Vagen et al., 2016). This lack of consistency can hinder policymakers' ability to develop targeted strategies for mitigating land degradation's effects on agriculture. Another notable shortcoming is the insufficient attention given to the role of climate change in exacerbating land degradation. While some studies (e.g. (Farah et al., 2025; Oishy et al., 2025; Bai et al., 2018)) acknowledge the interaction between climate change and land degradation, there is a need for more in-depth research exploring the synergistic effects of these two factors. This gap is particularly critical in the context of a changing climate where extreme weather events and altered precipitation patterns can intensify land degradation processes (Intergovernmental Panel on Climate Change [IPCC], 2023).

Furthermore, while many studies emphasise the importance of sustainable land management practices in mitigating land degradation, there is a dearth of research that delves into the practical implementation and scalability of such practices (Haregeweyn et al., 2023; Tadesse, 2023). Policymakers and practitioners require actionable recommendations and case studies showcasing successful interventions that can be applied on a global scale. Additionally, the literature often falls short in addressing the human dimensions of land degradation, such as the socio-economic factors driving unsustainable land use practices (Turner et al., 2016; Nkonya et al., 2016). A more holistic approach should consider the socio-economic drivers, as well as the cultural and political factors that influence land management decision. Therefore, future research should prioritise integrated frameworks that combine biophysical, socio-economic, and institutional indicators to capture the full extent of degradation impacts on agricultural productivity and household food security.

## **2.10 Conclusions and recommendations**

The concept of the land degradation-livelihood nexus highlights the critical importance of understanding the intricate connections between environmental changes and human well-being. It serves as a cornerstone for addressing one of the most pressing challenges ensuring that as we meet the needs of a growing global population, we do so sustainably, without compromising the health of the land and the livelihoods of vulnerable communities. The land degradation-livelihood nexus is a critical issue that demands immediate attention and concerted efforts. Failure to address this nexus can have dire consequences for both the environment and vulnerable communities, making it imperative to prioritize sustainable land management and livelihood development.

As such, research should prioritize standardisation of methodologies, explore the climate-land degradation nexus, provide actionable solutions, and consider the broader socio-economic and political contexts within which land degradation occurs. A comprehensive approach that addresses these limitations will be vital in crafting effective strategies for enhancing agricultural productivity and food security in the face of land degradation. The research underscores the need for informed policy interventions that address the root causes of land degradation while also supporting affected communities. These policies should aim to promote sustainable land management practices, enhance access to education and resources for rural populations, and facilitate adaptation to changing environmental conditions.

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### **CHAPTER 3: SMALLHOLDER FARMERS' CHOICE OF ADAPTATION STRATEGIES TO MITIGATE THE EFFECTS OF LAND DEGRADATION IN SEMI-ARID SOUTH AFRICA**

#### **Abstract**

Understanding how smallholder farmers adapt and cope with land degradation is crucial for evaluating their vulnerability and resilience at the local level. This study aimed to identify the coping and adaptation strategies smallholder farmers currently used in an area affected by land degradation, with a focus on their vulnerability and adaptive methods. A cross-sectional survey of 256 smallholder farming households was conducted using structured questionnaires developed in line with the Land Degradation Assessment in Drylands (LADA) framework. Data were analysed using Binary Logistic Regression, Propensity Score Matching (PSM), and Multivariate Probit Models to identify causal effects and determinants of coping strategies, while diagnostic tests were performed to confirm model robustness.

Results revealed that 51.2% of households experienced land degradation, mainly due to water erosion (36.8%), soil compaction (28.1%) and topsoil loss (26.6%). The Binary Logistic Regression model showed that household size ( $p < 0.01$ ), education level ( $p < 0.05$ ) and participation in land care projects ( $p < 0.10$ ) significantly increased the likelihood of adopting land degradation coping strategies. The Multivariate Probit Model indicated that female-headed households were more likely to adopt mulching and conservation tillage, while farm size and household size significantly influenced crop rotation and diversification decisions. PSM results confirmed that land degradation reduced agricultural productivity by 0.824 units and household food security by 0.254 units among affected households compared to similar unaffected households. Model validity was confirmed using Pseudo  $R^2$ , Likelihood Ratio Chi-square and VIF tests.

The study concludes that land degradation significantly undermines agricultural productivity and food security, necessitating targeted and context-specific interventions. Policy recommendations include strengthening gender-responsive extension support, scaling up land care programmes, and promoting affordable sustainable land management practices such as mulching, conservation tillage and crop residue use. These findings provide empirical evidence to guide rural development policy, agricultural planning and land rehabilitation strategies in semi-arid regions of South Africa.

**Keywords:** Land Degradation; Coping Strategies, Agricultural Productivity, Food Security, Multivariate Probit Model, PSM, Smallholder Farmers, Limpopo.

### 3.1 Introduction

Land degradation undermines global efforts to achieve sustainable development by compromising ecosystem functions and rural livelihoods (Hussan et al., 2021; Lal, 2018, 2019). In South Africa, mounting economic pressures and unsustainable production methods have intensified land and soil deterioration manifested through physical displacement, nutrient depletion, and loss of organic matter, thereby threatening both biodiversity and food security (Shackleton, 2020; Mani et al., 2021; Caon & Vargas, 2017). Estimates suggest that up to 70 percent of South African soils suffer from erosion, salinization, or fertility loss, a figure that is particularly alarming given the predominance of rain-fed agriculture among smallholder farmers (DFFE, 2021; Shackleton, 2020). Within southeastern Limpopo's Sekhukhune District Municipality, rapid land-use change, overgrazing, and shifting rainfall patterns have accelerated soil erosion and sedimentation of water bodies, exacerbating water scarcity and nutrient decline (Nzuza et al., 2020; Sepuru & Dube, 2018; Dutta, 2016; Hurni et al., 2015). While some researchers emphasize technological interventions such as contour ploughing and terracing to curb erosion (Mohammed et al., 2020; Balasubramanian, 2017), others argue that socio-institutional factors (e.g., land tenure security, extension services) are equally critical in determining whether such practices are adopted and maintained (Rahut & Ali, 2017; Bello et al., 2021).

Smallholder farmers' responses to land degradation span immediate coping mechanisms such as fallowing and off-farm labour to longer-term adaptive strategies, including crop diversification, agroforestry, and community-based resource management (Abid et al., 2016; Singh & Singh, 2017). Coping mechanisms are short-term actions farmers take immediately following land-degradation shocks, and contrast with adaptive capacity, which refers to the longer-term ability of farming systems and livelihoods to adjust to changing environmental conditions and foresee future risks. However, debate persists over the extent to which these practices transcend short-term survival tactics and contribute to true resilience: some studies suggest that without supportive policy frameworks (e.g., risk management, biodiversity conservation), adaptation measures remain reactive and unsustainable (Jia et al., 2022). Moreover, research on farmers' perceptions of degradation and risk often reveals a disconnect between local beliefs and biophysical assessments, pointing to a critical gap in understanding how subjective risk appraisal shapes adoption of adaptation measures (Chisadza et al., 2023; Mugari et al., 2025; Abid et al., 2015). Despite growing literature on adaptation in semi-arid African contexts, little is known about the interplay between socio-economic drivers, institutional support, and farmers' own risk perceptions in Sekhukhune. Specifically, the factors that influence both the selection and sustained use of land-degradation coping strategies remain under-researched. This study therefore aims to (i) identify the socio-demographic, economic, and environmental determinants guiding farmers' adoption of soil-conservation practices; and (ii) unpack how perceptions of land degradation risks inform their choice of coping and adaptive strategies in Sekhukhune District Municipality. By addressing these gaps, the study

seeks to inform more nuanced, locally grounded interventions that bolster smallholder resilience against ongoing land degradation.

## **3.2 Study area and methodology**

### **3.2.1 Study area**

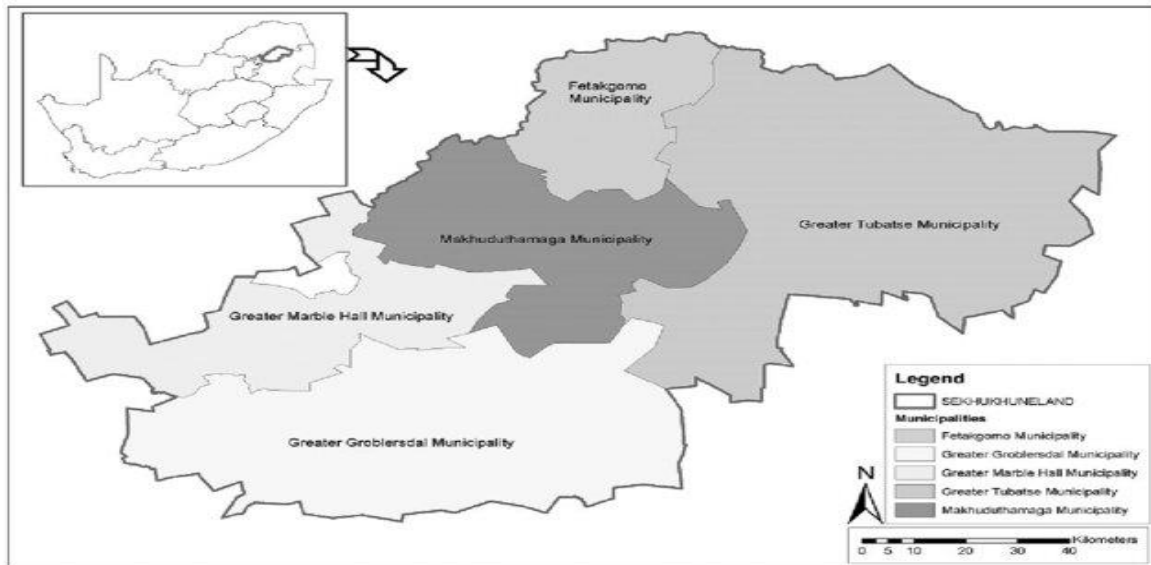
The study was conducted in the Greater Sekhukhune District Municipality (GSDM), one of the five districts of Limpopo Province, South Africa (Latitude: -24° 49' 59.99" S; Longitude: 29° 49' 59.99" E) as shown in Figure 3.1 below. GSDM comprises five local municipalities: Elias Motsoaledi, Ephraim Mogale, Fetakgomo-Tubatse, Greater Tubatse, and Makhuduthamaga (Stats SA, 2022). The district covers an area of approximately 13,528 km<sup>2</sup> and consists of 117 wards and 764 villages, making it predominantly rural (Limpopo Provincial Government, 2021).

According to the latest census data, GSDM had a total population of 1.19 million in 2020, representing about 20% of Limpopo Province's population. The district experienced the highest annual population growth rate in the province at approximately 1.2% between 2009 and 2019 (Stats SA, 2022). Poverty remains a key challenge in the district, with an estimated 689,310 individuals living below the upper-bound poverty line in 2019/2020 (Limpopo Socio-Economic Review and Outlook, 2021).

Unemployment levels are also significantly high. In 2020, GSDM recorded 93,900 unemployed individuals, accounting for 28.17% of Limpopo's total unemployed population (Stats SA Quarterly Labour Force Survey, 2021). These socio-economic conditions have implications for household resilience and agricultural livelihoods, particularly in the context of land degradation and climate variability.

Economically, agriculture, mining, and community services are the primary contributors to GSDM's GDP (Limpopo Economic Development Agency, 2021). Mining is the largest sector, projected to grow at an average of 5.64% annually, from R12.4 billion to R16.3 billion by 2023 (Khoza & Ngyende, 2016; SEDA Limpopo Mining Report, 2022). Agriculture, though less dominant in GDP contribution, remains crucial for rural livelihoods, with most households engaged in subsistence or smallholder farming.

GSDM's water resources and landscapes are characterized by semi-arid conditions, with high dependence on surface and groundwater for domestic and agricultural use. Water availability is frequently constrained due to low and erratic rainfall, which exacerbates the impact of land degradation on local farming systems (Department of Water and Sanitation, 2020).



**Figure 3.1: The Greater Sekhukhune District Municipality (GSDM) and its four local municipalities**

Agriculture, mining, and community services are the primary sectors in Sekhukhune District that contribute to the district's economic growth. Mining is the district's largest contributor to the economy, and it is expected to expand the fastest, at an average of 5.64 per cent per year, from R 12.4 billion to R 16.3 billion in 2023 (Khoza & Ngyende, 2016). In terms of water landscapes, Sekhukhune is widely regarded as a water-scarce location, with the low ground and surface water reserves. GSDM has an annual precipitation of 684 mm, the majority of which falls during the summer months (October and March) (Department of Cooperative Governance, 2018). Sekhukhune District was selected purposively due to its high exposure to both biophysical and socio-economic stressors relevant to the study's objectives. Spatial analyses indicate that human-induced degradation affects about 11.59% of the district, while climate-induced degradation accounts for around 41.41% of the land area (Kgaphola et al., 2023); this level of degradation is among the highest in the semi-arid zones of Limpopo. Agriculture in the district is characterised by predominantly rain-fed systems, limited access to mechanisation and irrigation, and high reliance on communal grazing lands all of which exacerbate productivity risks in degraded landscapes. Given this convergence of degradation, productivity vulnerability, and livelihood dependence, Sekhukhune offers a rigorous empirical setting for testing the proposed conceptual framework linking land degradation, agricultural productivity and household food security.

### 3.2.2 Data collection

A questionnaire was developed following the guidelines of the FAO on land degradation impact assessments. It consisted of five sections and included questions relating to demographic information, and socioeconomic, institutional, and biophysical variables. In this study, a non-probability technique, convenience sampling was employed to select 256 smallholder farmers in the GSDM, based on their

accessibility and willingness to contribute to the study. The target population was defined as all smallholder and subsistence farming households within the Sekhukhune District Municipality. According to the District Development Plan (2022), the district comprises approximately 764 villages with a significant proportion of households engaged in small-scale agriculture. The sample frame was therefore informed by these parameters.

In this study, a non-probability technique, convenience sampling was employed to select the smallholder farmers in the GSDM, based on their accessibility and willingness to contribute to the study. The sample size was determined using Yamane's formula, considering the total population size due to the unknown number of affected farming households and the predominance of smallholder and subsistence farmers in the study areas. The formula, as determined by Yamane (Umar Wachiko, B., 2021) is as follows.

$$n = \frac{N}{1 + N \times e^2} \dots\dots\dots 1$$

*where: n = sample size, N = total HHDs and e = significance level. The smallest statistically admissible number of responders for a population larger than 1 000 000, at a 95% confidence level, is above 200.*

However, for this study, the aim was to target approximately 300 farmers from the Sekhukhune District Municipality. Ultimately, 256 farmers who expressed their willingness to participate in the survey were included. Data collection was conducted using a structured questionnaire that was guided by the FAO technical guide for land degradation. The structured questionnaire provided a systematic and standardised approach to collecting data on various aspects related to land degradation. By following the guidelines outlined in the FAO technical guide, the researchers ensured that the questionnaire covered relevant topics and incorporated appropriate indicators to establish the linkages between land-based activities, land degradation, and associated impacts of agriculture. This approach helped to ensure consistency in data collection and facilitated the analysis and interpretation of the results.

**3.2.3 Data analysis**

Data entry, data sorting, coding and validation as well as analysis were conducted through STATA software. The study made use of descriptive statistics to capture smallholder farmers' socio-economic characteristics and the adaptation strategies used by these farmers in the study area. The binary logistic model and the multivariate probit model were used to determine factors driving adoption of land degradation coping strategies and the choice of the coping strategies, respectively.

**3.2.3.1 Binary logistic model**

A binary logistic model was used in this research to examine factors that influence farmers' decisions to adopt or not adopt land degradation adaptation measures. According to Atube et al. (2021), a binary

logistic model specification is employed to model land degradation adaptation strategies of farmers involving dummy dependent variables with binary choices. The logistic distribution function for the decision on adopting adaptation measures can be specified as:

$$\text{Logit (P)} = \log \left( \frac{P}{1-P} \right) \quad 1.$$

Let:  $P_i = P_r \left( \frac{Y=1}{X=x_i} \right)$ , then the model can be written as:

$$P_r \left( y = \frac{1}{x} \right) = \frac{\exp^{x'b}}{1 + \exp^{x'b}} ; = \log \left( \frac{P_i}{1-P_i} \right) = \text{Logit} (P_i) = \beta_0 + \beta_i X_i + \varepsilon \quad 2.$$

where;  $P_i$  is a probability of deciding to adopt adaptation strategies (dependent variable),  $X_i$ 's are the independent variables,  $\beta_0$  is the intercept and  $\beta_i$  is the regression coefficient;  $\varepsilon$  is referred to as the error term or disturbance since it incorporates various factors that influence farmers decisions to regarding adoption of land degradation practices. Table 1 below shows the variables used in the model.

The specification of the binary model above serves as an initial step in identifying whether a farmer decides to adopt any adaptation strategies, or otherwise. This decision is key as it sets the foundation for the ultimate choice a farmer makes, which is modelled through a Multivariate Probit Regression (MVP) as specified in the section that follows.

### 3.2.3.2 Multivariate Probit Regression

To lessen the impact of shocks, farmers use a variety of coping mechanisms simultaneously to reduce risk (Coulibaly et al., 2015; Ricart, et al., 2022). Therefore, the methodology of this study is multivariate, and it incorporates socio-economic factors thus enabling an understanding of the role of socio-economic factors in farmers' choices of appropriate strategies. A Multivariate Probit (MVP) regression model was run to assess the determinants of households' choice of different land degradation coping strategies. The multivariate probit (MVP) model is grounded in random utility theory, in the sense that each decision-maker is assumed to face a set of possible coping or adaptation strategies and to select the strategies that maximise expected utility. Because households often adopt several strategies at once rather than a single option, the MVP framework allows these discrete choices to be modelled jointly, capturing the correlation across decisions and the shared unobserved factors that drive them (Gebre et al., 2023; Kabote et al., 2024; Dawid & Boka, 2025).

**Table 1: Variables used in the binary logistic regression model**

Variable	Explanation	Type of measurement	Exp. sign	Theoretical Justification
<b>Treatment variable</b>				
Adoption	Decision to adopt land degradation coping strategies	Binary: 1=Yes, 0=Otherwise		Indicating whether the coping strategies are adopted or not.
<b>Independent variable</b>				
Age	Age of household head	Ordinal: 0=less than 60, 1=more than 60	+/-	Older people might have more experience but could be less open to new practices or vice versa.
Gender	Gender of household head	Ordinal: 1=male, 0=female	+/-	Gender might have an influence in decision-making and resource access.
MaritalStat	Marital status	Ordinal: 1=married, 0=not married	+	Married people are more likely to adopt coping strategies due to family responsibilities.
HHSize	Household size	Ordinal: 0=less than 5 years, 1=more than 5	+	Larger households can provide more labour for implementation.
EducLevel	Level of education	Ordinal: 0=less than grade 9, 1 more than grade 9	+/-	Education may improve understanding, though effects can vary.
EmplStatus	Employment status	Ordinal: 1=employed, 1=not employed	+/-	Employment affects income and time, influencing adoption capacity.
HHDInc	Total household income	Ordinal: 0=less than R2000, 1=more than R2000	+/-	Income supports investment in strategies but may not be the sole factor.
FarmSize	Farm size	Ordinal: 0=less than 3, 1=more than 3	-	Larger farms may require different and expensive strategies.
LandOwn	Land ownership	Ordinal: 1=individual, 1=no	+/-	Ownership can encourage investment, though effects are context dependent.
ProdType	Type of production	Ordinal: 1=mixed farming, 1=no	+/-	Mixed systems may be more adaptable to various strategies.
LivOwn	Livestock ownership	Binary: 1=yes, 2=no	+/-	Affects available resources and operational decisions.
AdopterLD	Adoption of land degradation practices	Binary: 1=yes, 2=no	+/-	Previous adoption may shape current perceptions and decisions.
AccInfo	Access to information	Binary: 1=yes, 2=no	+	Information enhances awareness and informed decision-making.

Source: Author compilation

The utility model assumes that each option has distinct attributes that influence a farmer's choice over another alternative and assumes that the utility is derived by choosing several alternatives. The individual selects the option with the greatest utility. The utility of an alternative is determined by its attributes (Cascetta, 2020). The utility random model is described below as applied by Feleke et al.,

(2016). Assuming that  $U_j$  is the expected utility that a farmer will gain from adopting coping strategy ( $j$ ) whereas  $U_k$  is the expected utility for not choosing coping strategy  $j$  but rather  $k$ . The linear random utility model of coping with effects of land degradation by choosing  $j^{\text{th}}$  coping strategy ( $U_j$ ) can be expressed as a function of explanatory variables  $X_i$  as shown below.

$$U_{ij} = x_i \beta_j + \mu_j \quad 3.$$

The linear random utility model for  $i^{\text{th}}$  farmer who does not use  $j^{\text{th}}$  coping strategy, but rather  $k^{\text{th}}$  coping strategy is given by:

$$U_{ik} = x_i \beta_k + \mu_k \quad 4.$$

Where  $x_i$  is a vector of explanatory variables  $\beta_j$  and  $\beta_k$  are vectors of parameters for choosing  $j^{\text{th}}$  and  $k^{\text{th}}$  coping strategy, respectively,  $\mu_j$  and  $\mu_k$  are error terms for choosing  $j^{\text{th}}$  and  $k^{\text{th}}$  coping strategy, respectively. According to Gujarati (2006), to the error terms in the above equations are assumed to be normally independently and identically distributed. If a farmer chooses to adopt  $j^{\text{th}}$  coping strategy, then the expected utility that the farmer gets is greater than the expected utility for not using that strategy and according to Falco et al., (2011), a farmer chooses coping strategy  $j$  over strategy  $k$  if and only if the expected utility from coping strategy  $j$  is greater than that of  $k$  as expressed in equation 3.

$$U_{ij} = x_i \beta_j + \mu_j > U_{ik} = x_i \beta_k + \mu_k \quad 5.$$

Following Mihiretu et al. (2019) and Piya et al. (2012), the MVP model assumes that each subject has  $J$  distinct binary responses. Let  $i=1 \dots n$  be the independent observations,  $j=1 \dots J$  be the available options of binary responses, and  $X_i$  be a matrix of covariates composed of any discrete or continuous variables.

Let  $Y_{ij} = Y_{i1} \dots Y_{ij}$  denote the  $J$ -dimensional vector of observed binary responses taking values  $\{0;1\}$  on the  $i^{\text{th}}$  household and denote a  $J$ -variate normal vector of latent variables such that:

$$Z_{ij} = X_i \beta + \varepsilon \quad \varepsilon_i \beta \quad i = 1 \dots n \quad 6.$$

Where  $\beta = \beta_1 \dots \beta_j$  is a matrix of unknown regression coefficient,  $\varepsilon_i$  is a vector of residual error distributed as multivariate normal distribution with zero means and unitary variance;  $\varepsilon_i \sim N(0, \Sigma)$ , where  $\Sigma$  is the variance-covariance matrix. The off-diagonal elements in the correlation matrix,  $P_{kj} = P_{jk}$  represent the unobserved correlation between the stochastic components of  $k^{\text{th}}$  and  $j^{\text{th}}$  options (Mullahy, 2016; Moss & Grønneberg, 2023). The relationship between  $Z_{ij}$  and  $Y_{ij}$  is:

$$Y_{ij} = \begin{cases} 1 & \text{if } Z_{ij} > 0 \\ 0 & \text{otherwise} \end{cases} \quad i = 1 \dots n \text{ and } j = 1 \dots J \quad 7.$$

The likelihood of the observed discrete data is then obtained by integrating over the latent variables:

$$Z : P(Y_{ij} = \frac{1}{x_{i\beta}} \Sigma \int A_{i1} \Phi_T(Z_{ij} = \frac{1}{x_{i\beta}} \Sigma) dZ_{ij} \quad 8.$$

Where,  $A_{i1}$  is the interval  $(0, \infty)$  if  $Y_{ij} = 1$ , and the interval  $(-\infty, 0)$  otherwise and,  $\int A_{i1} \Phi_T(Z_{ij} = \frac{1}{x_{i\beta}} \Sigma) dZ_{ij}$  is the is the probability density function of the standard normal distribution. Since the coefficient estimates from MVP regression show the direction of influence rather than the magnitude (Mullahy, 2017), to interpret the effects of explanatory variables on the probabilities, marginal effects were derived as follows:

$$\partial_{ij} = \frac{\partial P_{ij}}{\partial x_i} P_{ij} [\beta_j - \sum_{k=0}^j P_{kj} \beta_k] = P_{ij} [\beta_j - \beta] \quad 9.$$

Where  $\partial_{ij}$ -denotes the marginal effect of the explanatory variable on the probability that alternative  $j$  is chosen. According to Nega et al. (2025), the marginal effects measure the expected change in probability of a particular choice with respect to a unit change in an explanatory variable. The multivariate probit (MVP) regression model was suitable for this study since it simultaneously models the influence of the set of explanatory variables on each of the coping strategies, while allowing the unobserved factors (error terms) to be freely correlated (Wandera et al.,2024;).

The selected land degradation coping strategies adopted by farmers were used as the dependent variables, while farmers' socio-economic characteristics were used as the explanatory variables for the model as described in Table 2 and Table 3, respectively. Table 3 is the socio-economic characteristics that were used as the explanatory variables in the model.

### 3.2.3.3 Structural Equation Modelling (SEM)

To assess the direct and indirect effects of land degradation (LD) on household food security (FS) through agricultural productivity (AP), a structural equation model (SEM) was developed and used. This approach allowed simultaneous estimation of multiple interrelated equations, thereby capturing both the mediated and direct pathways among the key variables.

Land degradation (LD) was treated as an exogenous binary variable (1 = experienced, 0 = not experienced). Agricultural productivity (AP) served as the mediating variable, while household food security (FS) was modelled as the endogenous outcome variable. Food security was measured using an ordered index, with additional robustness checks treating it as a latent construct. Control variables such as age, gender, education, and employment status of the household head were included to account for socio-economic heterogeneity.

**Table 2: Description of dependent variables used in the Multivariate Probit model**

<b>Coping strategy</b>	<b>Description of strategy and measurement</b>	<b>Mean</b>	<b>Std. dev</b>
Practice mulching	Dummy = 1 if household practices mulching; 0 = otherwise	0.019	0.138
Practice crop rotation	Dummy = 1 if household practices crop rotation; 0 = otherwise	0.058	0.235
Use of manure	Dummy = 1 if household uses organic manure; 0 = otherwise	0.019	0.138
Use of fertilisers	Dummy = 1 if household uses fertilisers; 0 = otherwise	0.019	0.138
Conservation tillage	Dummy = 1 if household practices conservation tillage; 0 = otherwise	0.203	0.403
Crop diversification	Dummy = 1 if household practices crop diversification; 0 = otherwise	0.141	0.348
Use of crop residues	Dummy = 1 if household uses crop residues; 0 = otherwise	0.113	0.318
Practice afforestation	Dummy = 1 if household practices afforestation; 0 = otherwise	0.070	0.256
Construct wind breaks	Dummy = 1 if household constructs windbreaks; 0 = otherwise	0.070	0.256

Source: Author compilation

The model was estimated using robust maximum likelihood (ML) to ensure reliable parameter estimates under potential deviations from multivariate normality. Model fit was evaluated using multiple goodness-of-fit indices, including the Chi-square ( $\chi^2$ ) statistic, Comparative Fit Index (CFI), Tucker Lewis Index (TLI), and Root Mean Square Error of Approximation (RMSEA).

The structural relationships were defined as follows:

- AP ← LD and AP ← controls
- FS ← AP and FS ← LD

**Table 3: Description of explanatory variables used in the Multivariate Probit Model**

<b>Variable</b>	<b>Description</b>	<b>Type of Measurement</b>	<b>Expected Sign</b>
Age	Age of household head	Ordinal: 0 = less than 60 years, 1 = 60 years or older	+/-
Gender	Gender of household head	Dummy: 1 = male, 0 = female	+
Marital Stat	Marital status	Dummy: 1 = married, 0 = not married	+
HHSize	Household size	Ordinal: 0 = $\leq 5$ members, 1 = $> 5$ member	+/-
EducLevel	Educational attainment of household head	Ordinal: 0 = less than grade 9, 1 = grade 9 or higher	+/-
EmplStatus	Employment status of household head	Dummy: 1 = employed, 0 = not employed	+/-
HHDInc	Total household monthly income	Ordinal: 0 = $\leq$ R2000, 1 = $>$ R2000	-
FarmSize	Size of agricultural land owned or operated	Ordinal: 0 = $\leq 3$ hectares, 1 = $> 3$ hectare	+/-
LandOwn	Ownership of agricultural land	Dummy: 1 = individually owned, 0 = not owned	+/-
ProdType	Type of agricultural production	Dummy: 1 = mixed farming, 0 = otherwise	+/-
LivOwn	Ownership of livestock	Binary: 1 = yes, 0 = no	+/-
AccInfo	Access to agricultural information or extension	Binary: 1 = yes, 0 = no	+/-

Source: Author compilation

This specification allows for the estimation of the indirect pathway (LD  $\rightarrow$  AP  $\rightarrow$  FS) and the direct pathway (LD  $\rightarrow$  FS). The indirect path quantifies the effect of land degradation transmitted through changes in agricultural productivity, while the direct path captures additional influences, such as income transfers or external assistance. The SEM approach complements the Propensity Score Matching (PSM) and Ordered Logistic Regression (OLR) models by quantifying the mediating role of productivity and providing an integrated understanding of how land degradation affects household food security. Fit indices and standardized coefficients are fully presented in Chapter 5.

### **3.3 Results and discussion**

#### **3.3.1 Socio-economic information of the farmers**

Various scholars underscore the significance of farmers' socio-economic attributes in the realm of agriculture, as these factors play a pivotal role in shaping individual attitudes and behaviours (Meijer et al., 2015; Patil and Babus, 2018;). Within the scope of this study, farmers were categorized based on various socio-economic parameters, including gender, age, marital status, household leadership, household size, educational attainment, employment status, household earnings, and income origins. Notably, the findings stemming from the analysis of data collected from 256 respondents revealed that a majority of households, constituting 56 percent ( $n = 143$ ), were headed by women.

Regarding age distribution, the youngest group in the sample, comprising individuals aged 20 to 30 years, constituted 2 percent, whereas those falling within the age bracket of 31 to 40 years accounted for 20.3 percent of the surveyed population. The majority of respondents, comprising 27.0 percent, fell within the age range of 41 to 60 years. The descriptive statistics unveiled additional insights into the educational background of the farmers. Approximately 16.4 percent of the surveyed farmers had not undergone formal education. Those who had completed primary school education constituted 29.7 percent of the farming community, while 39.5 percent had attained a secondary level of education. Furthermore, the study revealed that 14.5 percent of the respondents had successfully pursued tertiary education. The income structure of the participants also emerged as a critical aspect of the investigation. Results indicated that social grants, encompassing provisions such as old age, child support, and disability grants, represented the predominant source of income for respondents, contributing to a substantial 59.0 percent of the total household income. Pension and remittance income contributed approximately 22.0 percent to the overall income, while full-time employment accounted for 8.0 percent. Notably, income derived from farming activities contributed to approximately 11.0 percent of the total household income.

#### **3.3.2 Strategies used by smallholder farmers to cope with land degradation**

The farmers were probed by adoption of coping strategies to mitigate the impacts of land degradation on their farms. The findings of this analysis are depicted in Table 4 below. Generally, the results show a worrisome situation with lower adoption of the coping strategies, suggesting underlying institutional and socio-economic factors that could drive the option to adopt, and the choice farmers make on the available strategies. An exploration of these possible drivers will be empirically assessed in the sections below.

**Table 4: Coping strategies used in the study area**

<b>Coping strategy</b>	<b><i>n</i></b>	<b>Proportion (%)</b>
Practice conservation tillage	52	28.4
Practice crop diversification	36	19.7
Use of crop residues	29	15.8
Construct wind breaks	18	9.8
Practice afforestation	18	9.8
Practice crop rotation	15	8.2

*Note: Multiple responses were allowed; totals may exceed 100%.*

Source: survey data, 2022

Among the coping strategies to minimize land degradation, some had low adoption rates, while conservation tillage 28.4%, crop diversification (19.7%), and use of crop residues (15.8%) were more commonly practiced by farmers. This pattern is based on conservation tillage is one of the principles of minimizing soil disturbance, using surface crop residues, and mixed cropping. These are some of the old traditional methods that have a rich history in South African rural agriculture; their reputation may be owing to their low cost and simplicity. Furthermore, it has always been argued that mixed cropping is superior to mono-cropping since it prevents crop failure, especially in adverse environments (Makuvaro et al., 2018).

The low adoption rates of mulching 2.7%, crop rotation (8.2%), and the use of organic manure (2.7%) among smallholder farmers in Sekhukhune District reflect a combination of informational, institutional, and resource-based constraints. First, these practices, while agronomically beneficial, are often not well integrated into local extension services or farmer training programs. This lack of exposure contributes to limited awareness and technical understanding of how and when to apply such methods effectively (Rahut & Ali, 2017; Abid et al., 2016). Second, mulching and organic manure use require specific inputs (e.g., crop residues, livestock manure) that may not be readily available to households with small landholdings, few livestock, or competing uses for biomass (e.g., fodder or fuel) (Shackleton, 2020). Additionally, some farmers perceive mulching to increase pest infestation, particularly under humid conditions, leading to reluctance in its application. Third, practices like crop rotation demand planning, land security, and diversity of seed types all of which are constrained under conditions of small plot sizes, communal land systems, and limited access to quality inputs (Bello et al., 2021; Mohammed et al., 2020). For many resource-poor farmers, the immediate need to secure household food supply outweighs longer-term soil management goals, making the adoption of these strategies less feasible.

Finally, a mismatch between traditional knowledge systems and introduced conservation agriculture practices can create scepticism or resistance among older or less formally educated farmers (Abid et al., 2015).

### 3.4 Factors influencing household decisions to adapt to land degradation

This study examines the likelihood of various factors significantly influencing farmers' decisions to adopt adaptation measures on their farms. The logistic regression compares the coefficients to the probability of an event happening or not happening and limits them to values between 0 and 1. If all other variables are held constant, the odds ratio and predicted probability of the independent variables demonstrate their influence on the likelihood of adopting adaptation strategies. Therefore, Table 5 below illustrates the results of the model.

**Table 5: Factors influencing farmers' decisions to adopt or not adopt.**

Variable	Coef.	St. Err.	p-value
Participation in land care projects	0.331	0.207	0.077*
Access to information	0.699	0.296	0.397
Agric. production type	0.726	0.222	0.295
Farm size	0.783	0.117	0.100
Livestock ownership	0.897	0.371	0.793
Gender of HH head	0.925	0.364	0.842
Age of HH head	0.962	0.165	0.822
HHD income	0.996	0.088	0.962
Employment status	1.068	0.199	0.723
Land ownership	1.125	0.561	0.814
HHD Size	1.175	0.068	0.005***
Marital status	0.620	0.202	0.143
Education level	1.606	0.366	0.038**
Constant	2.219	4.386	0.687
Pseudo r-squared		0.113	
Chi-square		23.881	
Prob. > chi2		0.032	
Number of obs.		256	

\*\*\*  $p < .01$ , \*\*  $p < .05$ , \*  $p < .1$

Source: survey data, 2022

### **3.4.1 Household size**

One of the key factors affecting the adoption of natural resource management practices is resource allocation within households (Hörner and Wollni, 2021). Efficient allocation of resources like labour, capital ensures optimal productivity (Restuccia, 2016). The study found household size to have a statistically significant positive effect on farmers' decisions to adopt coping strategies at the 1% level ( $p = 0.005$ ). Specifically, a one-person increase in household size is associated with an increase in the probability of adopting land degradation coping strategies by approximately 0.5% percentage points, holding other factors constant. This suggests that larger households are likely to have more available labour, which facilitates the adoption of adaptive measures to mitigate land degradation. Generally, larger families make available more labour that can actively engage in work, facilitating the adoption of adaptive measures against vulnerabilities. The result of this study which shows a positive and statistically significant relationship between household size and the adoption of land degradation practices at the 1% significance level is consistent with various studies (e.g. Wale et al., 2022) on the climate change problem, which show that the likelihood of adapting to climate change is always higher with large households than with small household due to greater labour availability. However, the allocation of labour and other resources may not always favour sustainable land management, particularly in households where competing needs such as food production and livelihoods are a priority.

On the other hand, household size can influence the dissemination and adoption of land degradation practices through its impact on education and access to information. Larger households may have more individuals who can potentially access agricultural extension services and training programs, thus increasing their likelihood of adopting sustainable practices. In some regions, land is divided among family members, with smaller plots allocated to each member in larger households. This fragmentation can hinder the adoption of land degradation practices, as smaller landholdings may not provide sufficient incentive for investments in sustainable practices (Su et al., 2024). Notably, the impact of household size may change over time due to evolving socio-economic conditions and policies, making it an important area for ongoing investigation and policy development towards sustainable land care strategies.

### **3.4.2 Education level of household head**

A positive and significant relationship has been observed at the 5% level ( $p= 0.038$ ), suggesting that a 1-year increase in the level of education of a farmer increases their odds of adopting land degradation strategies by 1.606 times. Previous studies (e.g., Dongdong et al., 2022; Padhan, 2023; Demisse et al., 2024; Aryal et al., 2025) also reiterate that educational attainment is associated with enhanced ability to cope with disasters. Households that have high levels of education have better information about risks/shocks and how to avoid or mitigate against these shocks unlike those households' heads with low

or without education. Education plays a multifaceted role in shaping the adoption of sustainable land management practices. Firstly, it equips individuals with enhanced decision-making skills, enabling them to critically assess the long-term implications of their land management choices, considering both environmental and economic factors (Deininger et al., 2010). Moreover, educated landowners are more inclined to consider the advantages of sustainable practices, recognizing the potential benefits they offer.

Secondly, education empowers individuals and communities to become effective advocates for policies and initiatives that promote sustainable land management, facilitating their engagement with policymakers and their ability to push for regulations and incentives that encourage conservation practices (Cailleux, 2025; Zhang et al., 2023). Thirdly, education fosters a culture of innovation and experimentation, making educated farmers more likely to embrace and implement innovative, sustainable land management technologies and approaches. However, it is crucial to acknowledge that educational attainment alone may not guarantee practice adoption; socio-economic factors, resource accessibility, and cultural norms also exert significant influence on decision-making in this context.

### **3.4.3 Participation in land care projects**

The positive, albeit marginally significant, association between participation in land-care projects and the adoption of coping strategies ( $\beta = 0.331$ ,  $p = 0.077$ ) lends empirical support to theoretical propositions that participatory approaches foster adaptive capacity through mechanisms of social learning, knowledge exchange, and collective action.

Consistent with Rogers' diffusion of innovations theory, this indicates that farmer participation in demonstrations, peer-learning networks and digital knowledge-sharing platforms significantly enhances exposure to innovation, supports adoption and reinforces the perceived attributes of new practices (Sarku et al. 2025; Zondo & Ndoro, 2023; Park et al. 2021). Participation in land-care or sustainable land management projects has been shown to increase farmers' access to extension services, demonstration plots and knowledge on key soil conservation practices. For instance, Hailu et al. (2024) found that conservation tillage and residue retention markedly improve soil moisture and nutrient status in degraded agricultural systems. Frank et al. (2024) further show that practices such as improved tillage, residue management and agroforestry/afforestation provide co-benefits in productivity and carbon sequestration. Moreover, large-scale SLWM interventions such as those reviewed in the SAWAP programme indicate that farmer participation in land-care frameworks enhances access to relevant information and peer-learning networks (World Bank/AFR100, 2023).

However, the modest strength of the relationship implies that participation alone may be insufficient to drive substantial behavioural change. This suggests the presence of contextual and enabling conditions such as access to financial resources, extension support, and institutional incentives that mediate the translation of knowledge into sustained practice. In other words, while participatory frameworks can

catalyse awareness and capacity development, their effectiveness depends on the broader socio-economic and institutional environment in which farmers operate. Strengthening these complementary factors could therefore amplify the transformative potential of participatory land-care programmes in promoting resilient adaptation and sustainable land management. From a policy perspective, these findings justify continued investment in extension and land care programs, but it also suggests the need to strengthen these interventions. Enhancing incentive structures (e.g., input subsidies for conservation tools, access to microcredit) and reducing adoption barriers (e.g., secure land tenure, infrastructure) could amplify the effect size. Integrating participatory approaches with livelihood diversification programs may also yield more robust and sustained outcomes.

### **3.5 Determinants of a farmer's choice to use a specific adaptation strategy**

The estimated coefficients of the Multivariate Probit regression model are presented in Table 6. The null hypothesis for test of independence in the model was rejected since the likelihood ratio test (*Log likelihood* = -889.28; Prob >  $\chi^2$  = 0.00) of independence of error terms was significant implying that there is mutual interdependence among the coping strategies thereby justifying the use of the model. Furthermore, the model has a pseudo  $R^2$  of 0.274, indicating that 27.4% per cent of the variation in the dependent variable is due to variations in the independent variables and that confirming households' choice of adaptation strategies could be attributed to fitted covariates, and thus the model appeared to have performed very well. Table 7 shows the Breusch-Pagan test of independence is significant, implying that the residuals of the nine variables in the model are not independent of each other. The correlation coefficients of the error terms are significant (Pr = 0.000), indicating that they are correlated, indicating that there are complementarities between the different coping strategies being used by the farmers. The results support the interdependence between the different coping strategies which may be due to complementarity in the different coping strategies, as well as the omitted household-specific and other factors that influence adoption of coping strategies. For example, the conservation tillage, which farmers are using is based on the principles of minimizing soil disturbance, using surface crop residues, and mixed cropping. The latter are coping strategies that farmers also use and are linked to the conservation tillage.

**Table 6: Determinants of a farmer's choice to use a specific adaptation strategy**

Variable	Mulching	Crop rotation	Use of organic manure	Use of fertilizer's	Conservation tillage	Crop diversification	Use of crop residues	Afforestation	Construction of windbreaks
	Coeff. (P>t)	Coeff.( P>t)	Coeff. (P>t)	Coeff (.P>t)	Coeff.(P>t)	Coeff. (P>t)	Coeff. (P>t)	Coeff.(P>t)	Coeff. (P>t)
Age	0.06 (0.398)	0.002 (0.838)	0.002 (0.748)	0.002 (0.741)	0.009 (0.594)	-0.022 (0.232)	-0.013 (0.433)	0.017 (0.204)	0.011 (0.412)
Gender	-0.031 (0.085) *	0.038 (0.211)	0.007 (0.692)	-0.021 (0.237)	-0.446 (0.000) ***	0.027 (0.549)	-0.028 (0.491)	0.015 (0.645)	-0.028 (0.388)
Marital status	0.008 (0.507)	-0.005 (0.832)	0.003 (0.834)	0.001 (0.929)	-0.005 (0.866)	-0.041 (0.201)	-0.009 (0.745)	-0.029 (0.203)	-0.019 (0.414)
Household size	0.004 (0.207)	0.010 (0.032) **	-0.002 (0.426)	0.003 (0.224)	-0.011 (0.088)*	0.018 (0.011) **	0.018 (0.004) ***	0.013 (0.009) ***	0.022 (0.000) ***
Level of education	0.006 (0.538)	0.007 (0.652)	-0.003 (0.751)	-0.013 (0.186)	-0.003 (0.886)	0.019 (0.427)	0.038 (0.081)*	0.014 (0.422)	0.017 (0.322)
Household income	-0.001 (0.786)	-0.004 (0.540)	0.002 (0.631)	-0.006 (0.103)	0.005 (0.598)	0.000 (0.993)	-0.013 (0.124)	-0.008 (0.265)	-0.000 (0.956)
Farm size	0.000 (0.346)	0.002 (0.004) ***	-0.000 (0.595)	0.000 (0.818)	-0.000 (0.885)	-0.002 (0.101)	0.001 (0.490)	0.000 (0.613)	-0.001 (0.116)
Land ownership	-0.017 (0.422)	0.028 (0.445)	0.002 (0.926)	-0.004 (0.845)	0.067 (0.200)	-0.070 (0.196)	0.024 (0.621)	-0.083 (0.035) **	-0.052 (0.181)
Type of production	-0.025 (0.057) *	-0.004 (0.871)	0.002 (0.877)	0.029 (0.029) **	0.025 (0.424)	-0.014 (0.661)	-0.015 (0.626)	-0.014 (0.546)	-0.001 (0.969)
Access to information	0.006 (0.575)	0.020 (0.499)	0.002 (0.917)	0.020 (0.253)	0.020 (0.644)	-0.048 (0.281)	-0.048 (0.234)	-0.044 (0.178)	-0.045 (0.159)
_cons	0.015 (0.831)	-0.174 (0.134)	0.009 (0.904)	-0.023 (0.739)	0.713 (0.000) ***	0.229 (0.182)	0.097 (0.538)	0.033 (0.793)	0.037 (0.766)
Number of obs	256		Wald chi2	35					
Log likelihood	-889.28		Prob > chi2	0.000					
Pseudo R <sup>2</sup>	0.274		*** $p < .01$ , ** $p < .05$ , * $p < .1$						

Source: survey data, 2022

**Table 7: Correlation matrix of residuals**

	<b>Mulching practices</b>	<b>Crop rotation practices</b>	<b>Manure use</b>	<b>Fertiliser use</b>	<b>Conservation tillage</b>	<b>Crop diversification</b>	<b>Afforestation</b>	<b>Afforestation</b>	<b>Windbreak construction</b>
Mulching practices	1.0000								
Crop rotation practices	0.2043	1.0000							
Manure use	0.4061	0.2264	1.0000						
Fertiliser use	0.1934	0.2046	0.1949	1.0000					
Conservation tillage	-0.0658	0.0864	-0.0008	-0.0420	1.0000				
Crop diversification	0.1067	0.1864	0.1188	0.0250	-0.1268	1.0000			
Crop residue use	0.1148	0.3139	0.0573	0.0282	-0.1030	0.4046	1.0000		
Afforestation	0.0438	0.0937	-0.0292	-0.0555	-0.1227	0.3908	0.3600	1.0000	
Windbreak construction	0.0488	-0.0251	-0.0292	-0.0585	-0.1529	0.2833	0.1994	0.5601	1.0000
Breusch–Pagan test of independence: $\chi^2(36) = 392.248$ , Pr = 0.0000									

Source: survey data, 2022

### 3.5.1 Gender of household head

Table 6 shows that the gender of the household head significantly influences the adoption of mulching and conservation tillage, with female-headed households more likely to adopt these practices ( $p = 0.085$  and  $p = 0.000$ , respectively). This trend reflects established gender dynamics in rural South African agriculture, where women often take primary responsibility for farming activities due to male migration to urban areas for employment (Shackleton, 2020). As a result, women are more directly engaged in land preparation, planting, and soil management, making them more attuned to the benefits of soil conservation practices such as mulching and conservation tillage. Moreover, female farmers frequently participate in community-based agricultural groups and land care initiatives, which serve as key platforms for accessing training, extension support, and practical demonstrations of sustainable techniques. Their increased involvement in these networks enhances awareness and capacity to adopt low-cost, labour-intensive practices, particularly when they align with household food security goals. Thus, the higher adoption rates among female-headed households may reflect both necessities, due to their direct role in farm labour and opportunity, through improved access to information and training tailored to their roles in subsistence agriculture.

### 3.5.2 Household size

Household size is positively and significantly associated with crop rotation (0.010), crop diversification (0.018) at the 5% level; use of crop residues (0.018), afforestation (0.013), construction of wind breaks (0.023) at the 1% level and negatively with conservation tillage (0.011) at the 10% level. Generally, this confirms the importance of household size on the choice of coping strategies farmers used, as more labour is needed when implementing these strategies. This suggests that households with many members provide an opportunity to split the workforce (Mequannt et al., 2020), which is beneficial when implementing the land degradation coping strategies. Generally, larger families make available more labour that can actively engage in work, facilitating the adoption of adaptive measures against vulnerabilities.

This assumption is consistent with various studies (e.g. Wale et al., 2022) on the climate change problem, which shows that the likelihood of adapting to climate change is always higher with large households than with small households due to greater labour availability. This suggests that households with many members provide an opportunity to split the workforce (Mequannt et al., 2020), which is beneficial when implementing the land degradation coping strategies. Generally, larger families make available more labour that can actively engage in work, facilitating the adoption of adaptive measures against vulnerabilities. This assumption is consistent with various studies (e.g. Wale et al., 2022) on the climate change problem, which shows that the likelihood of adapting to climate change is always higher with large households than with small households due to greater labour availability.

### **3.5.3 Level of education**

Education improves awareness of the effects of soil degradation and adaptation options to be employed. In this study, the level of education is positively and significantly associated with the adoption of crop residue use ( $p = 0.081$ ). The positive coefficient (0.038) implies that, as farmers move from lower to higher levels of education, the probability of adopting crop residue use increases. Since education is a key determinant of new technology adoption, more educated farmers may be better positioned to understand and apply soil conservation techniques (O'Donoghue & Heanue, 2018). These results align with the findings of Bedeke et al. (2019), who observed that farmers with higher educational attainment are more likely to recognize the benefits of crop residue use in maintaining soil organic matter and fertility.

These results, however, conflict with the fact that this is a long-standing agricultural production strategy used by rural households for decades. For example, some studies (e.g. (Valbuena et al., 2015; Kumar et al., 2015; Duncan et al., 2016) highlight historic development of this technique among uneducated rural farmers, indicating that they always viewed it as a strategic resource within mixed farming systems.

### **3.5.4 Farm size**

Farm size is positively and significantly associated with the adoption of crop rotation practices ( $p = 0.004$ ). The coefficient of 0.002 suggests that, with an increase in farm size (e.g., moving from smaller to larger landholding categories), the probability of adopting crop rotation practices increases. This implies that smallholder farmers with larger landholdings are more likely to adopt this practice, as farm size reflects greater access to natural and financial capital, which supports the adoption of improved agricultural technologies (Mequannt et al., 2020; Pauline, 2015). However, Martey and Kuwornu (2021) found that farm size positively influenced the adoption of mineral fertilizer and negatively influenced mulch and manure.

### **3.5.5 Land ownership**

Recent studies continue to emphasize that household asset endowments particularly land play a decisive role in shaping farmers' capacity to adopt coping and adaptive strategies in response to land degradation and climate stress. Secure land tenure and ownership not only enhance the willingness to invest in long-term land-improving practices but also determine the type and intensity of adaptation adopted (Olumba et al., 2024; Murken & Gornott, 2022). Similarly, empirical evidence from Namibia, South Africa, and Ghana highlights that access to productive assets such as land enables households to diversify their livelihood strategies, implement soil and water conservation measures, and sustain productivity under environmental stress (Ntombela et al., 2024; Amankwah et al., 2025).

The results of this study indicate that, land ownership is significantly and negatively associated with the adoption of afforestation as a coping strategy for land degradation ( $p = 0.035$ ). These results perhaps suggest that if a household individually owns land, then they understand the value of preserving trees and thus would not cut them down, unlike a common land where any member can cut trees down. This therefore implies they may not need to implement afforestation since they already have trees on their land. The negative coefficient (-0.083) indicates that individually owned land is associated with a lower probability of adopting afforestation. However, some earlier work (e.g., Lokshin & Yemtsov, 2004) found no significant link between land ownership and coping-strategy choice, but more recent evidence tends to find positive associations especially for long-term practices or secure tenure arrangements (Diendéré & Wadio, 2023; Adéchian, & Baco, 2025; Szmurlo, & Wesley Burnett, 2024)

### **3.5.6 Type of production**

The type of production that farmers are engaged in can determine the different coping strategies, and the choice that farmers make. In this case, a household that practised mixed farming had reduced use of mulching as a coping strategy by 0.025 at the 5% significance level ( $p = 0.057$ ). This could be explained by the fact that these households are using other strategies to ensure they minimise the destruction of the land. For example, households could be using fertilisers as a coping strategy. In this case, we see that the more a household practise mixed farming, the more they adopt use of fertiliser use on their farm by 0.0289 times to sustain the soils ( $p = 0.029$  at the 5% level). Similar findings were observed by Martey and Kuwornu (2021) who found that simultaneous production of livestock and crops positively influenced the adoption of mineral fertilizer and negatively influenced mulch and manure.

### **3.6 Conclusions and recommendations**

This study, based on a survey of 256 farming households in the SDM area, investigated how farmers are adapting to minimize the impacts of climate change. The adoption decisions and strategies employed were analysed using logistic and multivariate probit models. The decision to adopt coping strategies for land degradation is influenced by household size, level of education, and participation in land care projects. Larger families are more capable of actively engaging in work, making it easier to adopt adaptive measures against climate change impacts. Education enhances the ability to cope with disasters by providing better access to information about risks and mitigation strategies. Participation in land care projects equips farmers with knowledge and skills for sustainable resource management.

The choice of coping strategies is significantly influenced by the gender of the household head, as women are often responsible for agricultural work in rural areas and have better access to information and participation in land care projects. Household size also plays a role, as larger households have more available labour for implementing adaptive measures. Education increases awareness of land

degradation effects and adaptation options. Additionally, access to larger land areas and secure land tenure motivates experimentation with new technologies and sustainable practices, and mixed farming enhances diversification and resilience.

These findings have key policy implications, especially for farmers who have not yet adopted coping strategies. Targeted training programs on climate change adaptation and sustainable land management (SLM) must be prioritized. Promoting SLM through workshops, farmer field schools, and awareness campaigns, particularly aimed at female farmers and those with limited resources can significantly enhance adoption rates. To improve the effectiveness of extension services, the government should support the deployment of mobile agricultural advisory units that can reach remote areas, provide climate-smart agricultural tips via mobile platforms (e.g., SMS or WhatsApp), and encourage peer-led training where experienced adopters mentor neighbouring farmers. Strengthening community-based extension groups and integrating local knowledge systems into training modules will also help foster trust and uptake. Given the ongoing uncertainty and variability of climate impacts, SLM interventions should emphasize long-term capacity building through accessible, context-specific education and reliable information dissemination. Investing in the recruitment and upskilling of extension officers, particularly in participatory and gender-sensitive methods will be essential to influence adoption decisions among smallholder farmers.

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## CHAPTER 4: IMPACTS OF LAND DEGRADATION TO AGRICULTURAL PRODUCTIVITY IN SEMI-ARID SOUTH AFRICA

### Abstract

Land degradation poses a significant threat to agricultural productivity and rural livelihoods in semi-arid regions of developing countries like South Africa. This issue encompasses ecological complexities like soil erosion, nutrient depletion, and deforestation, worsened by unsustainable land practices and climate variability, aggravating food insecurity and limiting economic opportunities. Smallholder farmers, while striving for livelihoods, sometimes inadvertently contribute to degradation, raising concerns about agricultural sector resilience. To address this, this research study was conducted in Sekhukhune District Municipality to understand the impacts of land degradation on agricultural productivity. Primary data was collected from 256 smallholder farming households using a questionnaire covering various aspects. Analytical tools including descriptive statistics, correlation analysis, propensity score matching and multiple linear regression were employed to assess land degradation, its drivers, and impacts on agricultural productivity.

The results of the study indicate that over half of smallholder households experience land degradation, primarily through water erosion 36.8%, soil compaction (28.1%), and topsoil loss (26.6%). These challenges, intensified by unsustainable agricultural practices and mining activities, threaten economic and environmental stability. Multiple regression and propensity score matching analyses show that land degradation significantly reduces agricultural productivity by an average of 82.4% in affected households. In addition, probit model further reveals that socio-economic factors such as age, gender, land ownership, access to information, and adoption of sustainable land management practices significantly influence the likelihood of experiencing land degradation. The study recommends a wide-ranging approach involving sustainable farming practices, resource access, education, equitable land distribution, reforestation, and improved land management to address these challenges of land degradation effectively in Sekhukhune District Municipality.

**Keywords:** *Land degradation; land-based practices; livelihoods; agricultural productivity; South Africa*

## **4.1 Introduction**

The semi-arid regions of South Africa, characterized by erratic rainfall patterns and fragile ecosystems, are home to a significant population of smallholder farmers who rely heavily on agriculture as their primary source of livelihood (Dube et al., 2021). These areas are particularly vulnerable to the adverse impacts of climate change and land degradation (Archer et al., 2021). Land degradation, which encompasses processes such as soil erosion, salinization, desertification, and loss of soil fertility, has emerged as a critical environmental and socio-economic challenge in these regions (Swanepoel, 2021). The phenomenon of land degradation is driven by a multitude of factors, including unsustainable land management practices, deforestation, overgrazing, and climate variability (Tshikolomo et al., 2022). This gloomy spectre is haunting the agricultural landscapes of South Africa, casting challenges over the nation's agricultural productivity, due to the dwindling yet already limited arable land available to smallholder farmers (Giller et al., 2021). Moreover, smallholder farmers, who often possess limited resources and access to modern farming techniques, are disproportionately affected by land degradation (Mavhura and Mushure, 2019).

As a nation heavily reliant on agriculture to sustain its growing population and economy, the implications of land degradation extend far beyond mere soil erosion or loss of natural beauty (FAO, 2019). South Africa's agricultural sector, once a bastion of productivity and prosperity, now faces an existential threat as land degradation continues (World Bank, 2017). Furthermore, as a nation grappling with socio-economic disparities and historical inequalities, the consequences of land degradation in South Africa are not uniform (Mudavanhu et al., 2017). Vulnerable populations, often located in rural and marginalized areas, bear the brunt of this crisis, facing increased food insecurity and decreased access to economic opportunities (Omotayo et al., 2022; van der Ploeg and Schneider, 2022).

## **4.2 Context of the study**

The impacts of land degradation on agricultural productivity in South Africa is a multifaceted and pressing issue (UNCCD, 2019). This problem encompasses several key dimensions. Firstly, it confronts the ecological complexity of land degradation, encompassing various processes such as soil erosion, nutrient depletion, desertification, and deforestation (FAO, 2017). Comprehending the intricate interactions and synergies among these forms of degradation and their cumulative impact on agricultural productivity and food security is a formidable challenge (Ngarava, 2020). Secondly, the research problem delves into the deeply ingrained socio-economic disparities within South Africa's historical context. Vulnerable populations, particularly those residing in rural and marginalized areas, confront disproportionately severe consequences because of land degradation (Mabhaudhi et al., 2019).

Furthermore, the problem grapples with the sustainability of strategies to combat land degradation, raising concerns about the long-term effectiveness and adaptability of adopted strategies (Mabhaudhi et al., 2019). Rigorous examination of these aspects is vital to ensure the resilience of South Africa's agricultural sector. Lastly, the research problem underscores the complex interplay between climate change and land degradation and their compounded effects on agricultural productivity and food security (Reynolds et al., 2020). This complex relationship, exacerbated by climate change, introduces an additional layer of urgency and uncertainty to the land degradation challenge (Mabhaudhi et al., 2019; Reynolds et al., 2020).

While land degradation threatens agricultural productivity, the quest for livelihood sustenance often drives smallholder farmers to engage in land-use practices that contribute to degradation (Wambugu, 2018). This dynamic relationship warrants a research approach that explores the linkages between land degradation and smallholder livelihoods in semi-arid South Africa (Kgaphola et al., 2023). Given that the interplay between land degradation, land-based activities, and livelihoods is complex, this research aims to dissect the intricate web of causal linkages between the land degradation, land-based activities and associated impacts on the smallholder farmers' well-being.

### **4.3 Study area and methodology**

#### **4.3.1 Study area**

The study was conducted in Sekhukhune District Municipality (SDM), one of the five districts in the Limpopo Province of South Africa. SDM covers a vast rural area with five local municipalities, 117 wards, and 764 villages, comprising approximately 1.19 million people, making up around 20% of the province's total population. However, the district faces significant socio-economic challenges, including high poverty rates and rising unemployment. In 2020, over 93,900 people were unemployed in Sekhukhune, accounting for 28.17% of Limpopo Province's total unemployed population. The district's economy is primarily driven by agriculture, mining, and community services, with mining being the largest contributor. Despite being water-scarce, Sekhukhune relies on various water sources, including groundwater, rivers, and dams, with an annual precipitation of 684 mm, mainly falling during the summer months (October to March) (Khoza & Ngyende, 2016; Sekhukhune District Municipality, 2018; Department of Cooperative Governance, 2018).

Land degradation in the Sekhukhune District Municipality of South Africa is a pressing environmental issue that has significant implications for both the local communities and the broader ecosystem. This region, located in the north-eastern part of South Africa, is characterized by a diverse landscape that includes both rural and urban areas. Several types of land degradation are evident in Sekhukhune District Municipality, and addressing these challenges is crucial for sustainable land management and the well-

being of its inhabitants. Some of the key types of land degradation in this area are briefly discussed below:

- *Soil erosion:* Soil erosion is a widespread problem in Sekhukhune District, primarily caused by unsustainable agricultural practices, deforestation, and improper land management. The removal of vegetation, such as trees and grasslands, leaves the soil vulnerable to erosion by wind and water. This leads to a loss of fertile topsoil, reduced agricultural productivity, and increased sedimentation in rivers and dams.
- *Desertification:* The district is susceptible to desertification due to its arid and semi-arid climate. Prolonged droughts, overgrazing by livestock, and land clearing for agriculture contribute to the expansion of desert-like conditions. Desertification threatens the livelihoods of local communities who depend on agriculture and grazing lands.
- *Mining activities:* Sekhukhune District is rich in mineral resources, particularly platinum, which has led to extensive mining operations. Mining activities have resulted in land degradation through habitat destruction, soil contamination, and water pollution. Abandoned mines can also leave behind hazardous pits and spoil heaps.
- *Urbanization and infrastructure development:* Rapid urbanization and infrastructure development in towns like Burgersfort and Groblersdal have resulted in increased land degradation. This includes the conversion of natural land into paved surfaces, buildings, and roads, which disrupts ecosystems and decreases the availability of arable land.
- *Wetland degradation:* Wetlands in the district play a critical role in regulating water flow and supporting biodiversity. However, wetland degradation occurs due to drainage for agriculture, urbanization, and pollution. This impacts the availability of water resources and threatens the survival of wetland-dependent species.
- *Deforestation:* The cutting down of trees for firewood, timber, and land clearing contributes to deforestation in Sekhukhune District. This leads to the loss of vital ecosystems, soil erosion, and reduced water retention capacity in forests.
- *Overgrazing:* Livestock overgrazing is a significant issue in many rural areas of the district. Overstocking and improper management of grazing lands result in soil compaction, reduced vegetation cover, and soil degradation.
- *Invasive species:* Invasive plant species, such as prosopis (mesquite), have proliferated in parts of the district. These invasive species outcompete native vegetation, degrade soil quality, and disrupt ecosystems.

### **4.3.2 Data collection**

A questionnaire was developed in accordance with the Food and Agriculture Organisation (FAO) guidelines for assessing the impacts of land degradation. This questionnaire, composed in English, consisted of five sections covering demographic details, socio-economic factors, institutional aspects, and biophysical variables, as well as the land degradation indicators, land-based activities (e.g., farming practices), and livelihood outcomes (e.g., agricultural productivity and food security measures). In this study, a non-probability technique, convenience sampling was employed to select 256 smallholder farmers in the GSDM, selected based on their accessibility and willingness to contribute to the study. The sample size was determined using Yamane's formula as cited by (Umar & Wachiko, B., 2021), considering the total population size due to the unknown number of farming households and the predominance of smallholder and subsistence farmers in the study areas.

### **4.3.2 Ethical Considerations**

This study adhered to the fundamental ethical principles of social science research such as respect, informed consent, privacy and confidentiality.

In addition to upholding these foundational ethical values, the research process was marked by a commitment to transparent communication and ongoing ethical vigilance. Regular engagement with the CSIR Research Ethics Committee (REC) ensured that all procedures remained consistent with approved protocols and that any emergent concerns were addressed promptly and appropriately. This proactive approach fostered a research environment grounded in integrity, mutual respect, and accountability, setting a clear framework for the ethical treatment of participants throughout the study.

Ethical clearance for the project was formally granted by the Council for Scientific and Industrial Research (CSIR) Research Ethics Committee (REC) under Reference Number: REF 227/2017. The CSIR served as the lead institution for the project and confirmed that the ethical approval validity for this protocol was extended for one additional year, subject to compliance with the conditions specified by the REC.

In line with the approval, the researcher remained within the approved procedures and protocols, adhered to all national legislation and institutional guidelines governing research involving human participants, and submitted progress reports as required by the REC. Any new or unexpected ethical issues that arose during the course of the study were to be reported to the REC, consistent with standard ethical governance procedures.

#### **4.3.2.1 Informed Consent and Respect for Participants**

Participants were fully informed about the purpose and objectives of the study, which examined the *impact of land degradation on agricultural productivity and food security among smallholder households in the Greater Sekhukhune District Municipality, Limpopo Province, South Africa*. Before data collection, each participant received a detailed explanation of the study's intent, the data collection process, and their rights as participants.

Participation was entirely voluntary, and respondents were informed that they could withdraw at any point without penalty. The principle of autonomy and respect was observed through written and verbal informed consent, ensuring participants understood their roles and the voluntary nature of their involvement. Cultural sensitivity and respect for indigenous knowledge systems were also emphasized, recognising the importance of trust, reciprocity, and social capital in rural community engagement (FAO, 2015; Turner et al., 2016).

#### **4.3.2.2 Privacy, Confidentiality, and Anonymity**

All personal and identifying information obtained from participants was treated as strictly confidential. No names or personal identifiers were used in transcripts, analyses, or publications. Participants were coded numerically to preserve anonymity.

Data collected including photographs, and questionnaire responses were securely stored. Access was restricted to the researcher and authorized supervisors. Upon completion, a final report was submitted to the REC as required by the conditions of ethical approval.

Each questionnaire included a confidentiality statement assuring participants that:

“The information captured in this questionnaire is confidential and will be used solely for academic research purposes by a student at the University of KwaZulu-Natal in collaboration with the Council for Scientific and Industrial Research. Participation is voluntary, and you may withdraw at any stage without any adverse consequence. Your contribution is highly appreciated and will help inform sustainable solutions to land degradation and food insecurity challenges.”

#### **4.3.2.3 Institutional Oversight and Ethical Accountability**

As stipulated in the CSIR's extension letter for Protocol REF 227/2017, the researcher was required to:

- Remain within the procedures and protocols approved by the REC.
- Submit bi-annual progress reports.
- Notify the REC of any adverse events or emerging ethical issues; and

- Submit a final report confirming of compliance with all ethical standards.

These measures ensured continuous oversight, transparency, and accountability throughout the research process, reinforcing the integrity and credibility of the study.

### **4.3.3 Data analysis**

A combination of analytical tools was used to assess the land degradation and the perceived impacts in the study area. In addition, a correlation analysis was also conducted to determine the main drivers of land degradation, as well as the linkages between the land degradation types. Further to that, an empirical assessment was also conducted to explore the impact of land degradation on agricultural productivity. Agricultural productivity was used as a proxy for livelihood outcomes in this study, based on its established role in reflecting the well-being and resilience of rural households. In predominantly agrarian communities, where livelihoods are heavily dependent on land-based activities, a decline in agricultural productivity due to land degradation can directly affect household income, food availability, and overall livelihood security (Barbier & Hochard, 2018; Msipa et al., 2025; Petrescu-Mag et al., 2024). The Sustainable Livelihoods Framework also highlights agricultural productivity as a key determinant of livelihood outcomes such as food security, increased income, and reduced vulnerability (Kiconco et al., 2025). Therefore, assessing changes in agricultural productivity offers a valid and practical approach to understanding the broader implications of land degradation on rural livelihoods. In this study, it was envisioned that an impact on the agricultural productivity will consequently have an influence on the food security status of the household, hence the following chapter (chapter 5) assess the envisioned impacts.

#### **4.3.3.1 Descriptive statistics**

The descriptive statistics in the form of histograms were used to describe the types of land degradation in the study area, as well as the perceived impacts emanating from these caused.

#### **4.3.3.2 Dependent Variable: Agricultural Productivity**

Agricultural productivity in this study was measured using a composite Agricultural Land Productivity Index (ALPI), constructed based on the Alkire and Foster (AF) multidimensional methodology. Originally developed for poverty analysis, this “counting approach” is adaptable to ordinal data and allows the inclusion of multiple dimensions.

A set of 11 indicators ( $d$ ) was determined prior, and allocated to 10 broad dimensions ( $T$ ), each of which had an equal weight  $w$  Table 8. According to the weight of the dimension, the indicators were each

given an equal weighting so that the weight allocated to indicator  $j$ , where  $j = (1, 2, \dots, d)$ , as shown in Equation 1 below:

$$w_j^d = \frac{1}{T} \times \frac{1}{d}$$

1

**Table 8: Dimensions, indicators and assigned weights to determine productivity index.**

Dimension (T)	Indicator (d)	Measurement of impact	Weights
Loss of seedlings $\frac{1}{10} * \frac{1}{1} = \frac{1}{10}$	Seedling loss	1=loss of seedling; 0=otherwise	$\frac{1}{10}$
Reduce soil nutrients and organic matter $\frac{1}{10} * \frac{1}{1} = \frac{1}{10}$	Soil nutrients	1=reduced soil nutrients and organic matter; 0=otherwise	$\frac{1}{10}$
Reduce root depth and water retention $\frac{1}{10} * \frac{1}{1} = \frac{1}{10}$	Root depth & water retention	1=reduced root depth and water retention; 0=otherwise	$\frac{1}{10}$
Reduce farm output $\frac{1}{10} * \frac{1}{2} = \frac{1}{20}$	Reduced income	1=reduction in income; 0=otherwise	$\frac{1}{20}$
	Farm output	1=few products to sell; 0=otherwise	$\frac{1}{20}$
Reduced farm size $\frac{1}{10} * \frac{1}{1} = \frac{1}{10}$	Farm size	1=food shortage; 0=otherwise	$\frac{1}{10}$
Migration due to reduced farm size $\frac{1}{10} * \frac{1}{1} = \frac{1}{10}$	Migration	1=migration due to reduced farm size; 0=otherwise	$\frac{1}{10}$
Loss of vegetation cover $\frac{1}{10} * \frac{1}{1} = \frac{1}{10}$	Vegetation cover loss	1=loss of vegetation cover; 0=otherwise	$\frac{1}{10}$
Loss of palatable species for livestock $\frac{1}{10} * \frac{1}{1} = \frac{1}{10}$	Palatability	1=spending more money buying livestock feed due to poor grazing land; 0=otherwise	$\frac{1}{10}$
Reduced grazing land $\frac{1}{10} * \frac{1}{1} = \frac{1}{10}$	Grazing land	1=reduced grazing land; 0=otherwise	$\frac{1}{10}$
Encroachment by alien invasive species $\frac{1}{10} * \frac{1}{1} = \frac{1}{10}$	Invasive species	1=more time spent working on farm activities; 0=otherwise	$\frac{1}{10}$

Source: Author determination

The scores from all indicators were summed to generate an overall Agricultural Productivity Index for each household. This index ranged between 0 and 1.

$$\text{Agricultural Productivity Index}_i = \sum_{j=1}^{11} w_j^d x_{ij}$$

8

Where:  $X_{ij}$  is the response of household  $i$  to indicator  $j$  (1 to 10)  $W_j^d$  is the weight of indicator  $J$  :  
After computation of the agricultural land productivity index, households were categorised into two groups.

- 1 = experience impact of land degradation (land productivity index > 0)
- 0 = household did not experience impact of land degradation (land productivity index=0).

It is important to note that, although the Agricultural Productivity Index (API) was originally computed as a continuous variable ranging from 0 to 1, the index was then transformed into a binary variable. Households with an API greater than 0 as outlined above were coded as (experienced impact of land degradation), and those with an API equal to 0 were coded as (no impact).

#### 4.3.3.3 The Pearson Correlation Coefficient

The Pearson Correlation Coefficient, often denoted as "r," is a statistical measure that quantifies the strength and direction of the linear relationship between variables, with the coefficient ranging from -1 to 1, where.

- $r = 1$  indicates a perfect positive linear relationship.
- $r = -1$  indicates a perfect negative linear relationship and
- $r = 0$  indicates no linear relationship.

A correlation analysis was performed to examine the strength and direction of existing associations between land degradation and associated causes of this land degradation. Furthermore, this analysis also examined whether one cause exacerbates the other type of land degradation in the study area.

The specification is as presented below:

$$r = \frac{\sum(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum(X_i - \bar{X})^2 \sum(Y_i - \bar{Y})^2}}$$

9

where  $X_i$  and  $Y_i$  are data points of X and Y;  $\bar{X}$  and  $\bar{Y}$  are the means of the X and Y variables, respectively. The coefficients are interpreted as follows:

- Positive r values ( $r > 0$ ) indicate a positive linear relationship, meaning that as one variable increases, the other tends to increase.
- Negative r values ( $r < 0$ ) indicate a negative linear relationship, suggesting that as one variable increases, the other tends to decrease.
- An r value of 0 suggests no linear relationship, but it does not rule out other types of associations, such as non-linear or curvilinear relationships.

#### 4.3.3.4 Multiple linear regression model

The Multiple linear regression was used to model the linkages between land degradation and agricultural productivity. In this context, the multiple predictor variables (factors contributing to land degradation) and a response variable (agricultural productivity) were determined. The multiple linear regression equation is specified as below:

$$API_i = \beta_0 + \beta_1 * X_{1i} + \beta_2 X_{2i} + \dots + \beta_k X_{ki} + \epsilon_i \quad 10$$

Where  $API_i$  is the agricultural productivity index for the household  $i$ ;  $\beta_0$  is the intercept;  $\beta_1, \beta_2, \beta_3, \dots, \beta_n$  are the coefficients representing the impact of each predictor variable on agricultural productivity index;  $X_1, X_2, X_3, \dots, X_n$  are the values of the predictor variables;  $\epsilon$  represents the error term, accounting for unexplained variation in agricultural productivity index.

#### 4.3.3.5 Probit of a household experiencing land degradation.

Land degradation is influenced by a range of proximate and underlying factors. The proximate causes primarily include bio-physical conditions such as soil erosion, waterlogging, and vegetation loss, which were analysed using Multiple Linear Regression (MLR) to assess their impact on agricultural productivity. In contrast, the underlying causes are largely socio-economic in nature. To further investigate the influence of socio-economic factors on the likelihood of a household experiencing land degradation, a probit regression model was employed. This model is appropriate given the binary outcome variable, indicating whether a household experiences land degradation or not as presented, refer to Table 9 below. The probit model facilitates the estimation of the probability that socio-economic variables affect land degradation, thereby providing a comprehensive understanding of both environmental and human determinants. The probit model equation is specified below:

$$Y_i = \begin{cases} 1, & \text{if } API_i > 1 \\ 0, & \text{if } API_i = 0 \end{cases}$$

$$Y_i = 1 \text{ as: } P(Y_i = 1|X_i) = \phi(X_i\beta) = \phi(\beta_0 + \beta_1X_{1i} + \beta_2X_{2i} + \dots + \beta_kX_{ki})$$

Where  $Y_i = 1$  is function of the socio-economic variables;  $\beta_0$  is the intercept;  $\beta_1, \beta_2, \dots, \beta_n$  are the coefficients representing the impact of each predictor variable;  $X_1, X_2, \dots, X_n$  are the values of the predictor variables;  $\varepsilon$  represents the error term, accounting for unexplained variation in agricultural productivity index.

#### 4.3.3.6 Propensity Score Matching: impact of land degradation to agricultural productivity

The Propensity Score Matching (PSM) method was used to assess the casual effect of land degradation on agricultural productivity among smallholder farmers. Following Ngarava et al. (2018), this method estimated the treatment effect by comparing households experiencing land degradation (treatment group) with those that did not (control group). For a household  $j$  (where  $j = 1, 2, 3, \dots, j$  and  $j$  denotes the total population of households), the impact of land degradation ( $LD_j = 1$ ) on agricultural productivity outcomes  $AP_j(LD_j)$  is separated from the impact of not experiencing land degradation ( $LD_j = 0$ ), which serves as the counterfactual. This represents the difference between the outcomes when land degradation is experienced.

$$\tau_i = AP_j(1) - AP_j(0) \quad 11$$

Where: AP = outcome variables related to agricultural productivity

$AP_j(1) = \text{Productivity if the household experienced land degradation}$

$AP_j(0) = \text{Productivity if the household does not experience land degradation}$

The impact  $\tau_i$  is unobservable, since a household has experienced land degradation or has not, but never both. The average population effect is estimated through the average treatment effect of the treated (ATT):

$$\tau_{ATT} = E[\tau|LD = 1] = E[AP_j(1)|LD = 1] - E[AP_j(0)|LD = 1] \quad 12$$

The method subtracts the unobserved effect of experiencing land degradation  $E[AP_j(0)|LD = 1]$  had they been observed  $E[AP_j(0)|LD = 1]$ ;

$$E[AP_j(1)|LD = 1] - E[AP_j(0)|LD = 0] = \tau_{ATT} + E[AP_j(0)|LD = 1] - E[AP_j(0)|LD = 0] \quad 13$$

The impact under investigation is in the right-hand side of equation 13 with  $E[AP_j(0)|LD = 1] - E[AP_j(0)|LD = 0]$  representing selection bias. Therefore, it is important to eliminate the selection bias and obtain an unbiased estimate.

The true impact,  $\tau_{ATT}$ , is achieved when:

$$\Pr(X) = \Pr(LD = 1|X) \quad 14$$

Irrespective of experiencing the impact of land degradation, households with similar propensity scores shared similar unobservable characteristics through the balancing assumption  $D \perp X | \Pr(X)$ . Experiencing the impact of land degradation is as good as random, after controlling household characteristics as implied by the conditional independence assumption in  $AP(0), AP(1) \perp LD | X, \forall X$ . Probability of experiencing impact of land degradation has enough overlap in the characteristics with households who did not experience impacts, for each X vector, finding adequate matches ensured through the common support assumption in  $0 < [\Pr(X) = \Pr(LD = 1|X)] < 1$ .

The resulting PSM, through a probit regression estimator for ATT is generalised as:

$$\tau_{ATT}^{PSM} = E_{\Pr(X)|CL=1} \{E[AP(1)|LD = 1, \Pr(X)] - E[AP(0)|LD = 0, \Pr(X)]\} \quad 15$$

**Table 9: Variables used with agricultural productivity index**

Variable	Type	Description	Theoretical Justification
<b>Dependent Variable</b>			
Agricultural productivity Index (API)	Continues (0-1)	A composite index reflecting the degree of the decline in agricultural productivity due to land degradation.	Land degradation often results in yield decline due to soil fertility loss and reduced water retention capacity (FAO, 2015).
	Binary (1 = Yes, 0 = No)	Whether the household experienced a decline in agricultural productivity	
<b>Predictor variables: land degradation indicators</b>			
Water erosion	Binary (1 = Yes, 0 = No)	Water-induced removal of topsoil from farmland	Erosion depletes nutrients and arable depth (Awoonor et al., 2024)
Wind erosion	Binary (1 = Yes, 0 = No)	Wind-induced soil loss on the farm	Removes fine particles and organic matter (Ball et al., 2025).
Topsoil loss	Binary (1 = Yes, 0 = No)	General loss of the topsoil layer	Topsoil is crucial for crop growth because it holds most soil nutrients, and its loss reduces productivity.
Waterlogging	Binary (1 = Yes, 0 = No)	Presence of excess water on farmland	Limits respiration and raises disease risk (Zhou et al., 2025)
Soil compaction	Binary (1 = Yes, 0 = No)	Compacted soil structure on farmland	Reduces infiltration and root penetration (Sturm et al., 2025).
Alien species	Binary (1 = Yes, 0 = No)	Invasion by non-native plant species	Competing for resources, degrading soil Xiang et al., 2024)
Vegetation degradation	Binary (1 = Yes, 0 = No)	Loss or degradation of vegetative cover	Increases erosion risk and reduces organic input
Soil salinity	Binary (1 = Yes, 0 = No)	Presence of saline soil conditions	Disrupts water uptake, causes drought stress (El-Ramady et al., 2024).
<b>Control variables: socio-economic factors</b>			
Age of household head	Continuous	Age of the primary decision-maker in the household	May bring experience, but age can reduce productivity (Tani, 2022).
Education level	Ordinal	Education of household head	Higher education improves farming knowledge (Ferreira, 2018; Paltasingh & Goyari, 2018).
Land size owned	Continuous	Total land area cultivated by the household	Larger size can enable diversification (Dillon & Barrett, 2017)
Household size	Continuous	Total number of household members	More labour potential, but higher consumption (Tennhardt et al., 2024).
Access to extension services	Binary (1 = Yes, 0 = No)	Whether household had contact with agricultural extension agents	Promotes adoption of good practices

## 4.4 Results and discussion

### 4.4.1 Types of perceived farm-level land degradation

The dominating types of land degradation as perceived by the smallholder farmers (Table 10) are gullies (36.8%), soil compaction (28.1%) and sheet erosion (loss of topsoil) (26.6%).

**Table 10: Perceived indicators of farmland degradation**

Perceived indicators of farmland degradation	n	Proportion (%)” (%)	Rank
Water erosion (including gullies)	94	<b>36.8%</b>	<b>1</b>
Soil compaction	72	28.1%	2
Sheet erosion (loss of topsoil)	69	26.6%	3
Waterlogging	64	25.0%	4
Wind erosion	63	24.6%	5
Bush encroachment and alien invasive species	58	22.3%	6
Vegetation degradation	47	18.4%	7
Salinity	31	12.1%	8
<b>Parameter</b>			
Household experienced land degradation (%)	51.2%		
Household did not experience land degradation (%)	48.8%		

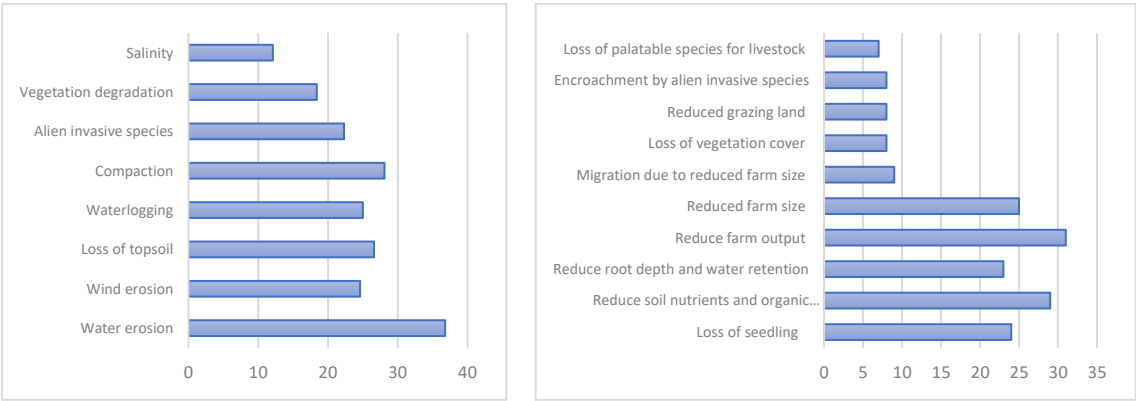
Source: survey data, 2022

In general, 51.2% of households perceived experienced land degradation compared to 48.8% who indicated that they did not experience land degradation. The results highlight several key indicators of farmland degradation based on respondents' perceptions, with water erosion, including gullies, being the most prevalent at 36.8%, followed by soil compaction at 28.1%, sheet erosion at 26.6%, and waterlogging at 25.0%. Wind erosion and bush encroachment, including alien invasive species, are also significant, reported by 24.6% and 22.3% of respondents, respectively. Additionally, vegetation degradation (18.4%) and salinity (12.1%) are identified as contributing factors. These findings underscore the complex nature of farmland degradation, emphasising an urgent need for sustainable land management strategies to address soil erosion, water management, invasive species control, and sustainable land use practices to mitigate further degradation and promote agricultural sustainability.

The key informant interviews and discussions with local pastoralists reveal that various factors are the primary drivers of land use and land cover change (LULCC) contributing to land degradation. These include inappropriate grazing management systems/overgrazing, governance issues, inadequate soil management, deforestation, removal of natural vegetation, settlement encroachment on cropland, and soil erosion. Integrating traditional and modern systems through coordinated land use plans and knowledge sharing could mitigate land degradation (Kgaphola et al., 2023a). Additionally, discussions with traditional authorities highlight declining rainfall, increasing droughts, shrinking wetlands, and water scarcity, exacerbated by sand mining and soil erosion. Settlement encroachments, driven by population growth and poverty, have intensified pressure on rangelands, leading to overgrazing and the proliferation of gullies and invasive species. Declining crop production, attributed to factors like poor livestock management and inadequate farming techniques, underscores the need for information dissemination and sustainable agricultural practices (Kgaphola et al., 2023a). Governance challenges, including loss of control over land use by tribal councils, further exacerbate degradation, necessitating interventions such as tree planting, dam maintenance, and rangeland management.

**4.4.2 Land degradation and perceived impacts in Sekhukhune District**

Figure 4.1 below shows the type of land degradation that the smallholder farmers in the study area have experienced, as well as the perceived impacts caused by these different types of land degradation.



**Figure 4.1: Types of land degradation and perceived impact**

Source: survey data, 2022

The common types of land degradation prevalent in Sekhukhune District manifest themselves in the form of water erosion, compaction, and loss of topsoil water logging and wind erosion. Other types of degradation types include invasive species, vegetation degradation and salinity concerns. Largely, these types of land degradation led to soil erosion, with detrimental effects on the land-based activities.

As seen in the table above, the impacts of the land degradation in the study area are largely associated with reduced farm output which could be linked to the impacts on the soil nutrients and organic matter. Also linked to reduced farm output could be reduced farm size as a result of land degradation, given the already limited arable land available to smallholder farmers (Makate et al., 2019). Again, another significant impact relates to the loss of the seedlings, perhaps due to soil erosion because of these land degradation types in the study area.

Soil erosion in Sekhukhune is driven primarily by unsustainable agricultural practices, deforestation, and mining activities, and poses a dire threat to the region's food security and economic stability (Kgaphola et a.,2023). This complex challenge significantly affects agricultural productivity by diminishing the available arable land, depleting topsoil nutrients, and exacerbating water-related issues (Diop et al., 2022). Addressing this pressing issue necessitates a holistic approach that encompasses sustainable farming practices, reforestation efforts to restore protective vegetation, and enhanced land management techniques (Cunningham et al., 2015). Effective implementation of these strategies, fostered through collaboration among government bodies, local communities, and non-governmental organisations, is crucial to mitigating the devastating consequences of soil erosion and securing the region's long-term well-being (Webb et al., 2017; Peri et al., 2016).

**4.4.3 Impact of land degradation on agricultural productivity**

Table 11 below demonstrates the significant adverse effect of land degradation on agricultural productivity, with clear disparities observed between affected and unaffected households.

**Table 11: Descriptive Analysis of the impact of land degradation on agricultural productivity**

Land degradation parameter	Agricultural productivity		
	No impact	Impact	Total
Household experienced land degradation (%)	11 (8.4%)	120 (91.6%)	<b>100%</b>
Household did not experience land degradation (%)	119 (95.2%)	6 (4.8%)	<b>100%</b>
<b>Total</b>	<b>130</b> <b>(50.8%)</b>	<b>126</b> <b>(49.2%)</b>	<b>100%</b>

Source: survey data, 2022

Among households affected by land degradation, 91.6% reported a significant negative impact on agricultural productivity, while only 8.4% observed no effect. In contrast, 95.2% of households not experiencing land degradation reported no impact, with only 4.8% acknowledging some effect. These figures highlight a strong association between land degradation and reduced agricultural productivity.

However, caution is needed when interpreting these results due to potential variations in how land degradation is defined and measured, as well as possible reporting biases. Furthermore, the absence of specific details on the mechanisms of degradation and available mitigation strategies limits the depth of understanding, underscoring the need for targeted strategies to effectively address land degradation and promote sustainable agricultural practices.

#### 4.5 Land degradation and its causes in the Sekhukhune District

The results of the Pearson Correlation Coefficient ( $r$ ) are as presented in Table 12. As shown in the table, land degradation in the study area is largely driven by water erosion (0.744), compaction (0.611), loss of topsoil (0.593), waterlogging (0.564) and wind erosion (0.558).

**Table 12: Pearson's correlation of the land degradation types**

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Land degradation	1.000								
(2) Water erosion	0.744*	1.000							
(3) Wind erosion	0.558*	0.430*	1.000						
(4) Topsoil loss	0.593*	0.597*	0.532*	1.000					
(5) Waterlogging	0.564*	0.459*	0.466*	0.381*	1.000				
(6) Compaction	0.611*	0.551*	0.570*	0.462*	0.482*	1.000			
(7) Alien species	0.529*	0.381*	0.557*	0.512*	0.420*	0.450*	1.000		
(8) Vegetation degradation	0.463*	0.413*	0.408*	0.462*	0.146*	0.377*	0.346*	1.000	
(9) Salinity	0.363*	0.338*	0.261*	0.260*	0.173*	0.434*	0.171*	0.319*	1.000

\*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$

Source: survey data, 2022

A strong correlation between water erosion and topsoil loss (0.597) as well as compaction (0.551) is observed, suggesting that water erosion largely contributes to loss of topsoil and compaction. Water erosion can contribute to both topsoil loss and soil compaction through a complex interplay of processes. When rainfall or runoff moves over unprotected or poorly managed soil surfaces, it can detach and transport soil particles, primarily from the topsoil layer rich in organic matter and nutrients, leading to topsoil loss. Simultaneously, the erosive force of water can compact the remaining soil as it pounds the surface and forces soil particles to settle closely together. Over time, this compaction reduces soil structure, diminishing pore space and impeding water infiltration, exacerbating erosion and furthering topsoil loss. In this way, water erosion not only directly removes valuable topsoil but also indirectly contributes to compaction, which in turn hinders soil health and fertility, making effective erosion control and soil conservation practices crucial for sustainable land management.

Wind erosion is also associated with increased invasion of alien species (0.557) and soil compaction (0.570). Wind erosion can facilitate the invasion of alien (non-native) species and exacerbate soil compaction through interconnected mechanisms. When wind erosion strips away the topsoil, it creates disturbed and barren surfaces, leaving the soil exposed to colonisation by invasive plant species, which often have aggressive growth strategies and adapt well to disturbed habitats. These invasive plants can, in turn, contribute to soil compaction by sending down deep and dense root systems that further reduce soil porosity and structure. Consequently, the loss of native vegetation due to wind erosion not only paves the way for invasive species to establish themselves but also intensifies soil compaction, creating a challenging environment for both native ecosystems and agricultural productivity. This highlights the importance of managing wind erosion to preserve soil quality and biodiversity.

The other notable association was observed between waterlogging, which influences soil compaction (0.482) and invasion by alien species (0.420). Waterlogging occurs when the soil becomes saturated with water, leading to reduced oxygen availability in the root zone. Compaction can exacerbate waterlogging by restricting drainage and creating conditions conducive to water accumulation. In waterlogged soil, native vegetation may struggle to thrive, creating an opportunity for invasive alien species that are more tolerant of these adverse conditions to establish themselves. These invasive species can further contribute to compaction by forming dense root mats that hinder water infiltration and exacerbate waterlogging. Thus, the combination of waterlogging and compaction can create a feedback loop that not only suppresses native vegetation, but also creates an ecological niche for invasive species, posing challenges for ecosystem health and management. Effective strategies to mitigate this cycle include soil aeration, native species restoration, and invasive species control.

#### **4.6 Land-based activities in Sekhukhune District in the context of land degradation**

Agricultural land-based activities in Sekhukhune Municipality, South Africa, are inextricably linked to the critical issue of land degradation, and a multifaceted perspective on this challenge is critical (Mafora, 2014). The region grapples with a trio of significant issues: soil erosion, deforestation, and unsustainable farming practices. Firstly, soil erosion, stemming from improper land management techniques like overgrazing and deforestation, stands out as a pressing concern (Bhatnagar, 2022; Dragović and Vulević, 2020). These practices strip away the protective vegetation cover, rendering the land vulnerable to erosion by wind and water, ultimately leading to the depletion of topsoil and reduced agricultural productivity (Kibret et al., 2023; Paudyal et al., 2019).

Secondly, unsustainable farming practices, exemplified by mono-cropping and the excessive use of pesticides and fertilizers, are contributing factors to land degradation in Sekhukhune. Mono-cropping depletes the soil of vital nutrients and elevates the risk of pest infestations, while the excessive application of chemical inputs can disrupt soil ecosystems and compromise water quality (Sanoullah et al., 2020; Meena and Lal, 2018). Compounding these issues is the limited access to modern agricultural technology and insufficient training among local farmers, making the adoption of sustainable practices an uphill encounter (Asare-Nuamah et al., 2019).

Furthermore, the socio-economic context of Sekhukhune plays a pivotal role in exacerbating land degradation. Poverty and land tenure complexities often drive individuals towards unsustainable farming methods as they grapple with economic hardship (Tiemann and Douxchamps, 2023). To address these challenges posed by land degradation in Sekhukhune, a comprehensive approach is imperative. This approach should encompass sustainable farming techniques, improved access to resources, and education (Piñeiro et al., 2020), as well as the promotion of equitable land distribution (Barrios et al., 2020). The active involvement of local communities and robust government support are crucial components of any strategy aimed at fostering environmentally responsible agricultural practices and mitigating the detrimental effects of land degradation in this region (Roy et al., 2023).

#### **4.7 Empirical analysis: Impact of land degradation on agricultural productivity**

The results of multiple regression analysis assessed how the various land degradation indicators (independent variables) jointly affect the agricultural productivity Sekhukhune District Municipality. The dependent variable used in this model is Agricultural Productivity Index (API), a composite measure scale between 0 and 1. The result of this analysis is shown in Table 13 below.

According to the results, five (5) land degradation indicators were found to have a statistically significant and a positive association with the decline in agricultural productivity. These include water erosion,

wind erosion, topsoil loss, water logging, and vegetation degradation. These land degradation types were also common in the study area as discussed in the descriptive analysis. The model explains approximately 57.4% of the variation in agricultural productivity ( $R^2 = 0.574$ ), indicating a reasonably strong fit for cross-sectional data. The F-statistic ( $F = 36.805$ ,  $p < 0.001$ ) confirms the overall significance of the model.

**Table 13: Impact of land degradation on agricultural productivity: Multiple Linear Regression**

<b>Variable</b>	<b>Coef.</b>	<b>St. errs.</b>	<b>t-value</b>
Water erosion	0.361***	0.061	5.95
Wind erosion	0.117*	0.068	1.71
Topsoil loss	0.113*	0.067	1.69
Water logging	0.241***	0.06	3.99
Compaction	0.031	0.066	0.47
Alien species	0.107	0.065	1.65
Vegetation degradation	0.127*	0.065	1.95
Salinity	0.099	0.073	1.36
Production type	0.034	0.031	1.08
Constant	0.119**	0.056	2.13
<b>Mean dependent var</b>	0.492	<b>Sd dependent var</b>	0.501
<b>R-squared</b>	0.574	<b>Number of obs</b>	256
<b>F-test</b>	36.805	<b>Prob &gt; f</b>	0.000
<b>Akaike crit. (aic)</b>	173.192	<b>Bayesian crit. (bic)</b>	208.644

\*\*\*  $p < .01$ , \*\*  $p < .05$ , \*  $p < .1$ ,  $p > 0.1$  (Not Significant)

Source: survey data, 2022

#### 4.7.1 Water erosion and impact on agricultural productivity

The results as depicted in Table 13 shows that water erosion impacts on agricultural productivity. A positive coefficient of 0.361 at the 1% significant level suggests that a marginal occurrence of soil erosion is associated with enhanced impact on agricultural productivity because of loss of topsoil. The loss of fertile topsoil due to erosion represents a direct threat to crop cultivation. Water erosion's impact on agricultural productivity and its ripple effect on environmental sustainability is a concern (Iwuchukwu et al., 2023). This process involves raindrops and runoff dislodging soil particles, carrying away valuable nutrients, and ultimately leading to the degradation of arable land. This not only compromises immediate yields but also undermines the long-term viability of agricultural systems (Raza et al., 2021). These findings collectively underscore a need for effective soil conservation measures to counteract soil loss and maintain agricultural productivity.

#### **4.7.2 Wind erosion and impact on agricultural productivity**

Wind erosion was also found to have an impact on agricultural productivity as confirmed by a significant and positive coefficient of 0.117 at the 10% level, suggesting that a marginal increase in wind erosion moments increases the impact on agricultural productivity. Wind erosion poses a formidable challenge to agricultural productivity, with implications for both local farmers (Kulkarni, 2021). Primarily, wind erosion leads to the loss of topsoil, which constitutes the essential foundation for plant growth and nutrient retention (Weeraratna, 2022). As wind currents pick up and transport soil particles over long distances, it depletes soil depth, organic matter, and crucial nutrients, ultimately rendering the land infertile and unproductive (Bimbraw, 2021). This erosion reduces crop yields, necessitating substantial investments by farmers in soil restoration efforts, including soil amendments and crop rotation, to sustain agricultural productivity. Consequently, wind erosion imposes a considerable economic burden on farmers and compromises the overall efficiency of the agricultural sector.

#### **4.7.3 Topsoil loss and impact on agricultural productivity**

As shown in Table 13, the coefficient for topsoil loss is positive (0.113) and statistically significant at the 10% level. The loss of topsoil is indeed a critical issue with far-reaching consequences for agriculture, and environmental sustainability. Topsoil, as the essential layer rich in organic matter and vital nutrients for plant growth, plays a pivotal role in agricultural productivity (Gurmu, 2019). Erosion due to factors like water and wind erosion, deforestation, and unsustainable farming practices contributes to the accelerated depletion of this precious resource (Gupta, 2019), leading to adverse effects on agricultural productivity (Hossain et al., 2020). Erosion results in a depletion of crucial soil nutrients, making the land less fertile and less capable of sustaining healthy crop yields (Singh and Chaudhary, 2023). As topsoil erodes or degrades, essential elements like nitrogen, phosphorus, and potassium are lost, necessitating increased fertilizer application.

This over-reliance on fertilizers can exacerbate environmental issues, such as water pollution and nutrient runoff, further complicating the sustainability of agricultural practices (Gweyi-Onyango and Ntinyari, 2022). Additionally, topsoil acts as a buffer against environmental stresses, including temperature fluctuations and moisture retention, making it a crucial defence against the impacts of climate change (Mukhtar et al., 2023). The loss of this buffering capacity can render crops more vulnerable to extreme weather events, drought, and other climatic challenges (Gambetta et al., 2020). Furthermore, the consequences of topsoil loss extend beyond the immediate impact on crop production. The erosion and degradation of topsoil contribute to environmental degradation, reduce overall soil quality, and increase the risk of desertification (Smith et al., 2020) with long-term consequences on agricultural productivity.

#### **4.7.4 Water logging and impact on agricultural productivity**

A marginal increase in the occurrence of water logging impacts on agricultural productivity by 0.241 times at the 1% significant level as it causes diminishing crop yields. Excess water in the root zone limits the supply of oxygen, which is crucial for respiration and nutrient absorption in plants (Bhattacharya and Bhattacharya, 2021). Consequently, crops suffer from reduced photosynthesis, stunted growth, and decreased overall productivity. Additionally, waterlogging creates favourable conditions for soil pathogens and diseases, further harming plant health and exacerbating yield losses (Molnárová et al., 2023). The environmental consequences of waterlogging extend beyond crop loss. The prolonged presence of water in fields can lead to soil degradation, salinization, and the leaching of valuable nutrients, affecting soil quality and long-term agricultural sustainability (Malik and Dechmi, 2020). The development of waterlogged areas can also disrupt local ecosystems and lead to the loss of biodiversity, thus having an impact on agricultural activities in the long run.

#### **4.7.5 Vegetation degradation and impact on agricultural productivity**

The degradation of natural vegetation has far-reaching implications for agricultural productivity and ecosystem stability. Vegetation plays a crucial role in maintaining soil health, regulating local climate patterns, and supporting biodiversity. When vegetation is degraded or removed, the adverse impacts on agriculture become evident. A key mechanism is the loss of valuable ecosystem services, such as soil erosion control, nutrient cycling, and pest regulation, all of which are essential for sustaining productive farmland (Li et al., 2025; Jiang et al., 2025; Zhi et al., 2025; Kanianska, 2024). In this context, a marginal occurrence of vegetation degradation positively and significantly impacts agricultural productivity by a coefficient of 0.127 significant at the 10% level. Vegetation plays a key role in maintaining soil stability, regulating microclimates, and supporting biodiversity. Loss or degradation of vegetation disrupts these ecosystem services, leading to increased soil erosion, reduced water retention, and heightened vulnerability to drought. Additionally, degradation impairs natural pest regulation, potentially increasing pest populations and the need for pesticides, thereby increasing production costs and environmental risks. These effects collectively undermine agricultural sustainability and productivity (Li et al., 2025; Tschardt et al., 2022; D'Odorico et al., 2019).

Vegetation degradation also affects agricultural ecosystems through altered microclimates and disruptions in natural pest regulation mechanisms. Intact vegetation can provide shade and buffer extreme temperatures, creating more stable microclimatic conditions for crops (Perfecto et al., 2019). Additionally, diverse ecosystems tend to support natural predators that help control pests. As vegetation degradation reduces biodiversity and disrupts habitat connectivity, the balance between pests and their natural enemies is disrupted, potentially leading to increased pest pressures and the need for greater

pesticide use in agriculture (Tschardt et al., 2022). This can result in both economic and environmental costs, impacting the long-term sustainability of agricultural systems.

#### **4.8 Probit of household experiencing land degradation**

The drivers of land degradation vary from place to place and are generally grouped into two proximate and underlying causes. The proximate causes are natural factors such as bio-physical conditions, topographic and climatic conditions, and inappropriate land management practices, whereas the underlying factors are mostly anthropogenic, which include population growth, land tenure, and other socio-economic and policy-related factors (Belay and Mengistu, 2019) Generally, land degradation in the GSDM is mostly influenced by climatic drivers (41.4%), rainfall in this case, and less so by anthropogenic ones (11.6%) (Kgaphola et al., 2023b).

The current study focused on the socio-economic factors and their influence on a household experiencing land degradation. The analysis as shown in Table 14 below, depicting the maximum likelihood estimates of the probit model. The model is strongly significant at 1%, suggesting that at least one of the explanatory variables explained perceived land degradation in the study area. Significant explanatory variables jointly accounted for 27.4% of the variation in the perceived land degradation. It also indicated that five explanatory variables out of thirteen explanatory variables included in the model significantly influenced a household experiencing degradation. These factors included age, gender, land ownership, access to information and adoption of methods/ techniques to reduce the degree of degradation largely influenced a household experiencing land degradation.

##### **4.8.1 Age of the farmer**

The results indicate that an increase in the farmer's age is likely to reduce the likelihood of land degradation by 0.181 at the 5% significance level. This trend can be attributed to the fact that as farmers age, they gain more experience, improving their ability to manage and implement sustainable land management practices effectively. The findings of this study align with previous research suggesting a relationship between the age of the farmer and the likelihood of land degradation, Yu et al. (2023) demonstrate that older farmers tend to adopt ecological restoration technologies more readily because they possess experiential knowledge of soil fertility dynamics and are motivated to preserve land productivity for future generations. Similarly, Tong et al. (2024) found that while ageing may reduce physical labour capacity, it often enhances managerial efficiency and environmental awareness, leading to more deliberate and sustainable farming practices. In the same vein, Msipa et al. (2025) report that experienced farmers are generally more proactive in implementing land rehabilitation measures and maintaining soil cover, having witnessed firsthand the adverse impacts of neglect and overexploitation. However, other studies (e.g. Sithole & Olorunfemi, 2024; Moges and Taye, 2017) found a positive

relationship between age and land degradation in various parts of the developing world, suggesting that older farmers may fail to adopt adequate land degradation control measures.

**Table 14: Probit of a household experiencing land degradation.**

Parameter	$\beta$	Std err	z	$P >  z $
Age	-0.18105	0.086463	-2.09	0.036**
Gender	-0.330026	0.1905331	-1.73	0.083***
Marital status	-0.0290957	0.1335978	-0.22	0.828
Household size	-0.0137281	0.155858	-0.09	0.930
Level of education	0.0645116	0.1012714	0.64	0.524
Employment status	-0.0290957	0.1335978	-0.22	0.828
Household income	-0.0261992	0.0390417	-0.67	0.502
Farm size	-0.0752815	0.0672049	-1.12	0.263
Land ownership	-0.45783	0.1756611	-2.61	0.009*
Type of production	0.0352178	0.1367084	0.26	0.797
Livestock ownership	-.02056792	0.1958047	-1.05	0.294
Adoption of sustainable land management practices	-1.971629	0.3387692	-5.82	0.000*
Access to information	0.7642525	0.1912524	4.00	0.000*
Constant	2.43113	0.9544259	2.55	0.011
Model summary				
Number of obs.	256			
LR chi2(13)	97.12			
R <sup>2</sup>	0.2738			
Prob. > chi2	0.0000			
Log likelihood	128.81315			

Source: survey data, 2022

#### 4.8.2 Gender of household head

The gender of the household head significantly influences farmland degradation, reflecting the socio-economic differences between male- and female-headed households. In this study, male-headed households were found to be less likely to experience land degradation, with a unit increase in male-headed households reducing the likelihood of land degradation by 0.330. Male-headed households are more likely to adopt sustainable land management technologies compared to their female counterparts (Kirui and Mirzabaev, 2015; Ewunetu et al., 2021).

Generally, male household heads tend to have greater access to resources, information, and financial support, allowing them to implement soil conservation practices more effectively than female-headed households. However, it is important to acknowledge the critical role that women play in land

conservation and management (Elias, 2024; Kouandou, 2025), despite facing significant barriers to active participation in decision-making processes concerning land degradation and associated issues (Aguilar et al., 2022).

#### **4.8.3 Land ownership**

The study findings show that an increase in individual land ownership reduces the likelihood of experiencing land degradation by 0.458, with a p-value of 0.009 at the 1% significance level. This suggests that individual ownership provides farmers with the incentive to invest in labour-intensive land management practices aimed at reducing land degradation and its impacts (Nkonya et al., 2016; Heger et al., 2020; Issahaku & Abdulai, 2020). In contrast, Barbier (2020) argues that private land ownership may sometimes lead to resource depletion as individuals seek to maximise their private benefits from the land.

Other forms of land ownership, such as communal land, are often seen as vulnerable due to the challenges in making collective decisions for sustainable management of common resources, as highlighted in the "tragedy of the commons" theory (Hardin, 2018). According to Hardin's argument, common land resources, without proper regulation, can lead to overuse, such as overgrazing, which in turn accelerates land degradation. This is also reflected in Musvoto et al.'s (2022) study, which identifies overgrazing as a primary contributor to soil erosion and degradation in the GSDM. On the other hand, Barbier (2020) proposes that commons can be successfully managed by local communities when they are able to self-organise and create mechanisms that deter free-riding behaviours.

#### **4.8.4 Access to information**

Access to information related to agricultural knowledge, technology, training, and land management practices enables farmers to recognize the value of their land and apply conservation measures using the knowledge and skills gained (; Nigussie et al., 2017). However, in this study, increased access to information was associated with an increased likelihood of experiencing land degradation, with a positive coefficient at the 10% significance level (p-value = 0.000). This could be attributed to various factors, such as the quality, capacity, and orientation of information providers, as well as limited access to extension services, which may promote unsustainable land management practices (Nkonya et al., 2016).

This finding echoes Nzuzza et al. (2021) study, which links unsustainable land-use practices to soil erosion and loss of vegetation cover as prominent types of land degradation. Therefore, promoting awareness, training, and providing material support for best land management practices is crucial for mitigating land degradation.

#### **4.8.5 Adoption of sustainable land management practices**

The marginal increase in the adoption of sustainable land management practices was found to significantly reduce the likelihood of a household experiencing land degradation, with a marginal increase in adoption reducing the likelihood by 1.972 times ( $p$ -value = 0.000). In this study, 80.5% of farmers reported adopting some form of sustainable land management practice. Previous research suggests that farmers who are heavily dependent on land resources for their livelihoods are more likely to be impacted by land degradation and thus have a strong incentive to adopt sustainable practices that mitigate its effects (Teku & Derbib, 2025; Mugari et al., 2025; Kirui, 2016).

Commonly adopted practices in the study area include conservation tillage (20.3%), crop diversification (14.1%), and the use of crop residues (11.3%). However, it is important to note that the ability of farmers to manage their land sustainably is often influenced by institutional factors such as land ownership titles (Abab et al., 2023), as well as policies that consider farmer heterogeneity (Nigussie et al., 2017). One of the least adopted practices in the study area was fertiliser use (2.0%), which may be related to the high poverty levels in the region. Poor farmers are often unable to afford productivity-enhancing inputs such as fertilisers, which may exacerbate natural resource degradation. The lack of complementary resources such as financial, human, and physical capital limits farmers' capacity to invest in land management, thereby increasing the prevalence of land degradation and its associated impacts (Nkonya et al., 2016).

#### **4.9 Impact of land degradation on agricultural productivity: PSM approach**

The results of the Propensity Score Matching (PSM) reveal a significant adverse impact of land degradation on agricultural productivity. The average treatment effect on the treated (*ATT*) was estimated at -0.824, indicating that households affected by land degradation experience an average decline of 82.4% in agricultural productivity compared to their unaffected counterparts. This effect is statistically significant, with a  $z$ -value of -14.374 and a ( $p=0.000$ ), underscoring the robustness of the result and confirming that the observed difference is highly unlikely to have occurred by chance. The strong statistical significance ( $p = 0.000$ ) highlights the urgent need to address land degradation to maintain or improve agricultural output. This finding aligns with extensive empirical evidence (Barbier & Hochard, 2018), which shows land degradation reduces crop yields, lowers livestock output, and increases input requirements. These findings emphasize the urgent need to combat land degradation to protect agricultural productivity.

#### **4.10 Conclusions and recommendations**

The semi-arid regions of South Africa are a crucial hub for smallholder farmers, heavily dependent on agriculture. However, land degradation poses a complex and pressing challenge, with soil erosion, desertification, and declining fertility at its core. The issue is compounded by ecological complexities, including soil erosion, nutrient depletion, and deforestation, making it challenging to gauge their cumulative impact on agriculture. Unsustainable land practices, deforestation, and climate variability exacerbate these problems. Furthermore, land degradation intersects with profound socio-economic disparities, disproportionately affecting vulnerable rural populations, and leading to heightened poverty and limited economic opportunities. Smallholder farmers, despite striving for livelihoods, often inadvertently contribute to degradation, risking productivity. The effectiveness of strategies to combat land degradation and enhance agricultural sector resilience raises critical questions, necessitating research to uncover the intricate connections.

Sekhukhune District grapples with a range of land degradation challenges, including water and wind erosion, compaction, topsoil loss, waterlogging, and invasive species, all culminating in soil erosion with profound implications for land-based activities. These issues manifest in reduced farm output, potentially linked to the depletion of nutrients and organic matter. Unsustainable agricultural practices, deforestation, and mining activities exacerbate these challenges diminishes arable land by depleting topsoil nutrients, and worsening water-related problems. Water erosion is strongly correlated with topsoil loss and compaction, playing a significant role in these processes, while wind erosion contributes to compaction and invasive species invasion, further compounding the issue.

Agricultural activities in South Africa's Sekhukhune Municipality are intrinsically tied to the pressing challenge of land degradation, encompassing soil erosion, deforestation, and unsustainable farming practices. Soil erosion, driven by improper land management like deforestation and overgrazing, exposes land to wind and water erosion, depleting topsoil and reducing agricultural productivity. Unsustainable farming practices, such as mono-cropping and excessive chemical use, further exacerbate land degradation by depleting nutrients, inviting pests, and compromising soil and water quality. Limited access to modern farming technology and training compounds the issue. Socio-economic factors, including poverty and land tenure complexities, also drive unsustainable practices.

Various forms of erosion, such as water and wind erosion, have a substantial impact on agricultural productivity in Sekhukhune District Municipality. Water erosion, closely linked to topsoil loss, poses immediate and long-term threats to crop cultivation by dislodging soil particles and carrying away vital nutrients. Wind erosion also leads to topsoil loss and reduced soil fertility, imposing economic burdens on farmers. The loss of topsoil exacerbates the reliance on fertilizers, contributing to environmental problems and making crops more susceptible to climate change effects. Additionally, waterlogging

diminishes crop yields due to oxygen deprivation, while vegetation degradation disrupts critical ecosystem services, further compromising agricultural sustainability. The study recommends a need for approaches, involving sustainable farming practices, resource access, education, equitable land distribution, reforestation, and improved land management. Collaboration among government bodies, local communities, and NGOs is pivotal for effective implementation and long-term well-being in Sekhukhune District.

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## CHAPTER 5: THE IMPACT OF LAND DEGRADATION ON HOUSEHOLD FOOD SECURITY IN A SEMI-ARID REGION OF SOUTH AFRICA

### Abstract

Food security remains a critical development challenge in many parts of sub-Saharan Africa, particularly in the semi-arid regions where climatic variability, poor infrastructure, and environmental degradation converge to threaten rural livelihoods. Among the key environmental stressors, land degradation stands out as a persistent and worsening threat, undermining both agricultural productivity and the socio-economic stability of households that rely on the land for survival. Although global research on land degradation is extensive, localized studies remain limited, often hindering the development of effective and context specific policy responses. In South Africa, worsening food insecurity and declining agricultural productivity are increasingly linked to land degradation.

This study investigates the impacts of land degradation on food security of smallholder farmers in the GSDM, Limpopo Province. Data were collected from 256 farmers using structured questionnaires aligned with the FAO's technical guide on land degradation assessment. Analytical methods included Probit regression, Propensity Score Matching (PSM), and Ordinal Logistic Regression.

Findings indicate that 51.2% of households reported experiencing land degradation, predominantly due to water erosion and gullies (36.8%), soil compaction (28.1%), and topsoil loss (26.6%). Key drivers of degradation included age, gender, land ownership, and access to information. Among affected households, 91.6% reported declines in agricultural productivity, while 53.4% experienced food insecurity. PSM results confirmed that land degradation significantly reduced agricultural productivity (reduction factor: 0.824) and food security (reduction factor: 0.254).

These findings highlight the urgent need for context-specific strategies that promote sustainable land management among smallholder farmers. Targeted policy interventions, capacity-building programs, and the adoption of appropriate technologies are essential to enhance resilience, improve rural livelihoods, and mitigate the effects of land degradation.

**Key words:** *land degradation, agricultural productivity, food security; Propensity Score Matching.*

## 5.1 Introduction

Food security remains a critical development challenge in many parts of sub-Saharan Africa, particularly in the semi-arid regions where climatic variability, poor infrastructure, and environmental degradation converge to threaten rural livelihoods (FAO, 2023; Smith & Jones, 2016). Among the key environmental stressors, land degradation stands out as a persistent and worsening threat, undermining both agricultural productivity and the socio-economic stability of households that rely on the land for survival (UNCCD, 2022; FAO, 2023; World Bank, 2023; UNEP, 2024). Land degradation is defined as the impairment in the land's ability to provide ecosystem services leading to a decline in biological and economic productivity, (Nzuza et al., 2021a). Semi-arid regions, characterised by low rainfall and fragile ecosystems, are particularly susceptible to land degradation (Gupta, 2019). The degradation process, driven by poor soil fertility and unsustainable land use, significantly threatens agricultural output and socio-economic development, especially in Southern Africa (Li, et al., 2023).

Land degradation negatively affects agricultural productivity through processes such as soil erosion, nutrient depletion, and desertification (Hamdy & Aly, 2014). Degraded land loses its ability to sustain healthy plant growth, resulting in lower crop yields and heightened food insecurity (Gomiero, 2016; Smith et al., 2020; AbdelRahman, 2023). Reduced crop production leads to increased food prices and decreased access to adequate and nutritious food, particularly among vulnerable populations (Sawadogo, 2021). Furthermore, rural communities reliant on agriculture for income and sustenance face greater poverty risks when land degradation limits productivity (Gupta, 2019). Beyond economic consequences, land degradation exacerbates environmental issues such as deforestation, biodiversity loss, and increased greenhouse gas emissions, further disrupting agricultural systems (Cohn et al., 2017; Jamshidi et al., 2019).

While global studies have acknowledged these challenges (Garcia-Ruiz et al., 2017; Panagos et al., 2018; Sartori et al., 2019), their findings may not fully apply to local contexts. Relying solely on global trends to assess the impacts of land degradation on poverty and food and nutrition security at the local level can lead to inaccurate conclusions. Although South Africa is considered food secure at the national level, significant disparities persist at the household level, particularly among rural and smallholder communities, due to factors such as unemployment, income disparities, climate change, and fluctuating agricultural production. This research aims to contribute to the ongoing discourse on land degradation's effects on smallholder farmers and provide recommendations to enhance resilience and adaptive capacity at local level.

## **5.2 Theoretical Framework**

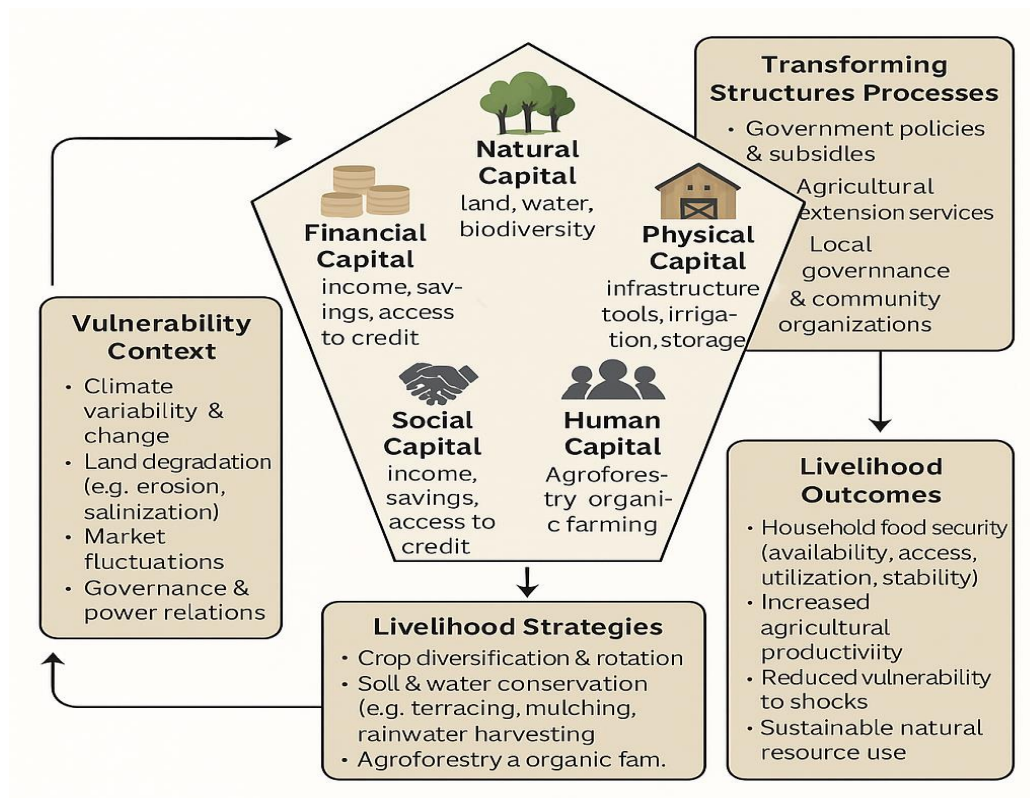
### **5.2.1 Sustainable Livelihood Framework**

To develop the theoretical framework for the impacts of land degradation to agricultural productivity and food security, this study builds on the Sustainable Livelihoods Framework (SLF) as shown Figure 5.1 below. The Sustainable Livelihoods Framework focuses on the various assets (natural, human, social, physical, and financial) that farmers use to sustain their livelihoods. It offers a structured approach to analysing how these assets influence farmers' strategies and responses to challenges such as land degradation (Jendoubi et al., 2020; Lin & He, 2021; Ehteshammajd et al., 2023; Nasrnia & Ashktorab, 2021). In the context of semiarid regions of South Africa, the SLF highlights how land degradation depletes natural capital, such as soil fertility and water resources, which are critical for agricultural productivity (Jendoubi et al., 2020).

The framework also underscores the interconnectedness of various livelihood assets and how the deterioration of one asset, like natural capital, can lead to a cascade of negative effects on other assets, ultimately compromising food security (Masuka, 2020). Through using the SLF, this study analyses how land degradation impacts the different assets that smallholder farmers rely on, thereby providing an overview of the vulnerability and resilience of rural households in the Greater Sekhukhune District Municipality. In addition to the above theories, the study integrated the Theory of Planned Behaviour (TPB) with socio-economic factors to have a comprehensive understanding of farmers' decisions regarding land degradation.

While other studies have used various theoretical frameworks to explain the adoption of new technologies in the agricultural sector, especially when they are straightforward to implement and offer clear economic benefits (Fadeyi et al. 2022), however, they often fail to account for the full complexity of farmers' decision-making processes (Bagheri et al., 2016;). Particularly in the context of mitigating land degradation, where traditional cost-benefit analyses may overlook critical environmental and social factors. As a result, farmers might not adopt certain mitigation strategies despite positive economic indicators, or they might choose to implement these strategies even when the economic benefits are uncertain (Wauters et al., 2010).

To address these complexities and better understand smallholder farmers' adaptation choices, it is critical to employ the Theory of Planned Behavior (TPB). Socio-economic factors such as age, gender, income, education, and farm size have a significant influence in farmers attitude, subjective norm, and perceived behavioural control (Bagheri, & Teymour, 2022; El Bilali et al., 2021; Faisal et al.,2020).



**Figure 5.1: Theoretical framework**

The empirical results are consistent with the five livelihood capitals outlined in the Sustainable Livelihoods Framework (SLA).

**Natural capital:** The documented forms of land degradation, including water erosion and gully formation (36.8%), compaction (28.1%), and topsoil loss (26.6%), directly reduce agricultural productivity (API) and heighten household food-insecurity risk. The depletion of soil quality and structure undermines the productive base upon which rural livelihoods depend.

**Human capital:** Education exerts a significant negative association with food insecurity (OLR  $\beta = -0.551$ ,  $p = 0.014$ ), indicating that more educated household heads are better equipped to manage resources and adopt sustainable land-management (SLM) practices. This highlights the role of knowledge, skills, and awareness in strengthening adaptive capacity.

**Social capital:** Although only marginally significant ( $\beta = 0.331$ ,  $p = 0.077$ ; see Chapter 4), participation in land-care projects enhances social learning and peer-to-peer diffusion of conservation knowledge. These collective actions foster behavioural change and increase community resilience.

**Physical capital:** Waterlogging and inadequate drainage infrastructure continue to constrain agricultural productivity (MLR  $\beta = 0.241$ ,  $p < 0.01$ ), underscoring the need for investment in physical assets such as irrigation and water-control systems to sustain yields under variable climatic conditions.

Financial capital: Higher household income significantly reduces food insecurity (OLR  $\beta = -0.156$ ,  $p = 0.043$ ), while secure land tenure and ownership ( $\beta = -0.919$ ,  $p = 0.018$ ) incentivise long-term conservation investments. Financial stability thus underpins both short-term coping and long-term adaptation.

Taken together, the SLA framework elucidates why households with stronger human, social, and financial capital are more likely to adopt sustainable land-management practices and buffer environmental and economic shocks, whereas the depletion of natural capital through degradation amplifies food-access constraints and livelihood vulnerability.

### 5.3 Data analysis

#### 5.3.1 Determination of household food security

Household food insecurity access was measured using items from the Household Food Insecurity Access Scale (HFIAS) of FAO-FANTA (Coates et al., 2007), which remains widely applied and validated in recent empirical studies (e.g., Demie & Gessese, 2023; Charamba et al., 2023; Krishnamoorthy et al., 2022). The HFIAS is a continuous measure of the degree of food insecurity (access) in the household in the past 30 days. Despite the limitations of all measures, the HFIAS has been found to be understandable and applicable across varying contexts (Delbiso, 2024; Langer, 2024). Additionally, it has been identified as uniquely able to detect aspects of food insecurity involving decreased access to a sufficient quantity or quality of food (Lee, 2021).

According to Lee, (2019), the HFIAS reflects the three universal domains of household food insecurity that is anxiety about household food insecurity, insufficient quality and insufficient quantity of food supplies. This framework has been reaffirmed by recent studies, which note that the scale effectively measures the experiential dimension of food insecurity through households' self-reported perceptions of access, availability, and adequacy of food (Lee, 2021; Delbiso, 2024; Langer et al., 2024; Kabalo, 2019). Importantly, this indicator captures the household's perception about their diet regardless of its nutritional composition. It is supported the idea that households' experiences of food insecurity cause predictable reactions and responses which will be captured and quantified through a survey then summarised into a score.

Following Mango et al., (2014), the HFIAS is computed as follows:

$$\text{HFIAS} = \sum_{i=1}^n X_i F_i \quad 16$$

where "HFIAS" is the score, " $X_i$ " is the food insecurity occurrence observation and " $F_i$ " is the frequency of occurrence. The "HFIAS" is a continuous access measure of the household's food insecurity over a

period of 30 days. The HFIAS method is based on the idea that the experience of food insecurity (access) causes predictable reactions and responses that can be captured and quantified through a survey and summarised in a scale. The HFIAS prevalence indicator categorises households into four levels of household food insecurity (access): food-secure and mildly, moderately and severely food-insecure. As such, and informed by Coates et al. (2007), the HFIAS was categorised into “food secure (0-7)”, “mildly food insecure (8-13)”, “moderately food insecure (14-20)” or “severely food insecure (21-27)”. Households were categorised as increasingly food insecure as these responded affirmatively to more severe conditions and/or had experienced these conditions more frequently.

According to Coates et al., (2007:19), the operational definitions, as used in the current study are as follows:

- *“Food-secure:* A household was labelled ‘food-secure’ when the members ‘rarely’, in the past four weeks, worried about not having enough food.
- *Mildly food-insecure:* The members of the household worried about not having enough food sometimes or often, and/or were unable to eat preferred foods, and/or ate a more monotonous diet than desired, and/or ate some foods considered undesirable but only rarely.
- *Moderately food-insecure:* The household members sacrificed quality more frequently by eating a monotonous diet or undesirable foods sometimes or often, and/or had started to cut back on quantity by reducing the size of meals or number of meals, rarely or sometimes.
- *Severely food-insecure:* The individuals in the household had to cut back on meal-size or number of meals often, and/or experienced any of the three most severe conditions (running out of food, going to bed hungry, or going a whole day and night without eating)”.

#### **Definitions used for HFIAS categories (30-day recall)**

**1 = Food secure (score 0–7):** rare worry about food; no regular compromise on quality/quantity.

**2 = Mildly food insecure (8–13):** worry about food and/or reduced dietary preference/quality.

**3 = Moderately food insecure (14–20):** frequent quality compromise and some quantity reduction.

**4 = Severely food insecure (21–27):** meal size/number often reduced; may run out of food, go to bed hungry, or not eat for a whole day.

#### **5.3.2 Propensity Score Matching: Estimating the impact of land degradation on food security**

The Propensity Score Matching (PSM) method was utilised to ascertain the impact of land degradation on food security in the study area. This method estimates the average treatment effect on the treated (*ATT*) by comparing households who experienced land degradation (treated group) to those that did not

(control group), while controlling the observable covariates. This study adopted and modified the following approach by Ngarava et al. (2018). For a household  $j$ , (where  $j = 1, 2, 3, \dots, J$  and  $J$  represents the population of households), and have two potential outcomes.  $FS_j(1)$  = representing the food security outcome if the household experienced land degradation.  $FS_j(0)$  = representing the food security outcome if the household did not experience land degradation. This represents the difference between the outcomes in experiencing land degradation:

$$\tau_i = FS_j(1) - FS_j(0) \quad 17$$

Where FS = outcome variables related to food security

The impact  $\tau_i$  is unobservable, since a household has experienced land degradation or has not, but never both. The average population effect is estimated through the average treatment effect of the treated (ATT):

$$\tau_{ATT} = E[FS(1)|LD = 1] - E[FS(0)|LD = 1] \quad 18$$

The method subtracts the unobserved effect of experiencing land degradation  $E[APFS(0)|LD = 0]$  had they been observed  $E[FS(0)|LD = 1]$ :

The impact under investigation is in the right-hand side of equation (19), with  $E[APFS(0)|LD = 1] - E[APFS(0)|LD = 0]$  representing selection bias.

The true impact,  $\tau_{ATT}$ , is achieved when:

$$\Pr(X) = \Pr(LD = 1|X) \quad 20$$

Irrespective of experiencing the impact of land degradation, households with similar propensity scores shared similar unobservable characteristics through the balancing assumption  $D \perp X | \Pr(X)$ . Experiencing the impact of land degradation is as good as random, after controlling household characteristics as implied by the conditional independence assumption in  $FS(0), FS(1) \perp LD | X, \forall X$ . Probability of experiencing impact of land degradation has enough overlap in the characteristics with households who did not experience impacts, for each X vector, finding adequate matches ensured through the common support assumption in  $0 < [\Pr(X) = \Pr(LD = 1|X)] < 1$ .

The resulting PSM, through a probit regression estimator for ATT is generalised as:

$$\tau_{ATT}^{PSM} = E_{\Pr(X)|LD=1}\{E[FS(1)|LD = 1, P(X)] - E[FS(0)|LD = 0, \Pr(X)]\} \quad 21$$

### 5.3.3 Drivers of Food Insecurity

The key drivers of household food insecurity were assessed using an Ordinal Logistic Regression (OLR) model which is an extension of the binomial logistic regression model called binary logistic regression

model (Ullah et al.,2022). This model is appropriate when the dependent variable is ordinal, meaning that the categories follow a natural order in this case: food secure, mildly food insecure, moderately food insecure, and severely food insecure (Williams, 2023; Gemechu & Elifas, 2025). The OLR model captures how socio-economic and demographic factors influence the probability that a household in the sample will fall into a more severe level of food insecurity, relative to less severe categories. Unlike the multinomial model, the OLR model assumes proportional odds that the relationship between each pair of outcome groups is the same. This assumption allows for a more parsimonious model and interpretable coefficients. The proportional odds assumption was tested using the Brant test, and the results confirmed that the OLR model is appropriate for this analysis. Following (Ayele., 2020; Tuholske et al.,2018; Garratt, & Armstrong, 2024; Liu, et al.,2023). Ordinal logistic regression model is defined as follows:

$$P_{ji} = \log \left( \frac{P(Y_i \leq j)}{P(Y_i > j)} \right) = \theta_j - \beta^T X_i \text{ for } j = 1, 2, \dots, J - 1 \quad 22$$

Where:  $Y_i$ : represent the categorical outcome variable for household  $i$ , is representing food insecurity status.  $P(Y \leq j)$ : is the cumulative probability that a household is in category  $j$  or lower  $j$  or lower.  $P(Y > j)$  : is the probability that a household is category higher than  $j$  and  $\theta_j =$  is the threshold estimated by the model which sperate the ordered response categories.  $\beta =$  vector of regression coefficients corresponding to the predictor variable.  $X =$  vector of independent variables such as income, household size, education...

The log -odds ratio is that on the left-hand side quantifies the odds of being in category  $j$  or below as opposed to being in the higher category. The model estimates  $j-1$  equations where  $j$  is the number of categories each sharing the same slope coefficient  $\beta$  coefficient for all explanatory variables. The key assumption is that the effect of predictors is consistent across thresholds i.e., the relationship between food secure households vs. others, food secure or mildly insecure vs. others, and so on, is governed by the same set of coefficients.

### 5.3.3.1 Coefficients Estimation and Goodness of fit test

The logistic regression model uses maximum likelihood estimation (MLE) to estimate the unknown parameters that are included in the model (Ayele, 2020). Therefore, in this study this assumption was tested using the Brant test. The test compares the estimated coefficients across outcome levels to check for violation. The test did not find significant evidence ( $p > 0.05$ ) that the proportional odds assumption is violated. Therefore, the OLR model is appropriate, and its results are statistically reliable under this assumption.

The coefficient  $\beta_k$  associated with a predictor variable  $X_k$  in the model represents the change in the log-odds of being in a higher category of food insecurity (i.e., more severe) for a one-unit increase in  $X_k$  holding all other variables constant. However, because this model is inherently non-linear, the coefficients do not directly convey the magnitude of change in probabilities. That is, one cannot simply interpret them as “one unit change  $X_k$  in increases the probability of outcome Y by Z%. To overcome this limitation a marginal effect was computed. The marginal effects represent the change in the probability of being in each specific category of food insecurity, given a unit change in an explanatory variable, holding other variables constant. And it is computed as follows.

$$\frac{\partial P(Y = j)}{\partial X_i} = P(Y = j) \left( \beta_i - \sum_{k=1}^{j-1} P(Y = \kappa) \beta_i - \beta \right) = P_j (\beta_i - \beta) \quad 23$$

Where  $P_j$  = is the predicted probability in category  $j$

$\beta_i$  is the coefficient of the explanatory variable  $X_i$

$\beta$  = is the average effect across all outcome categories.

The marginal effects measure the expected change in the probability of a household to fall into a particular household food insecurity level in relation to a unit change in an explanatory variable (Greene & Hensher, 2010). The signs of the marginal effects and respective coefficients could also be different because marginal effects depend on the sign and magnitude of all other coefficients. Table 15 below shows that variables that were used in the PSM and OLR models.

#### 5.4. Nexus of Land degradation and Food Security: Structural equation modelling (SEM)

This study employed Structural Equation Modelling (SEM) to assess relationship between land degradation and food security, incorporating both direct and indirect effects mediated by agricultural productivity as assessed in chapter 4. The model also controls for key socioeconomic variables, including age, gender, education, and employment status (Endawkie et al., 2025). The structural model posits that land degradation negatively affects agricultural productivity, this in turn, influences household food security, which is assessed above on an ordinal scale ranging from food secure to severely food insecure. Following and modifying the approach of Zwane et al., (2024), SEM was computed as follows:

$$\begin{cases} AP = \gamma_1 LD + \gamma_2 Age + \gamma_3 Gender + \gamma_4 Employment + \gamma_5 Educ + \zeta_1 \\ FS = \beta_1 AP + \beta_2 LD + \zeta_2 \end{cases} \quad 24$$

Where AP is Agricultural Productivity (mediator), FS is household food security (outcome),

**Table 15: Variables used in the PSM and OLR models**

Variable	Explanation	Type of Measurement	Expected Sign
<b>Treatment variable</b>			
Land Degradation ( <i>LD</i> )	Experienced impacts of land degradation	Binary: 1 = yes, 0 = no	+
<b>Outcome variables</b>			
Agricultural Productivity ( <i>AP</i> )	Agricultural productivity impact	Binary: 1 = experienced impact, 0 = no impact	+
Food Security ( <i>FS</i> )	Food security status (HFIAS score)	Ordinal: 1 = food secure, 2 = mildly food insecure, 3 = moderately food insecure, 4 = severely food insecure	-
<b>Independent variables</b>			
Age	Age of household head	Ordinal: 0 = less than 60, 1 = 60 or older	+/-
Gender	Gender of household head	Binary: 1 = male, 0 = female	+
MaritalStat	Marital status	Binary: 1 = married, 0 = not married	+
HHSize	Household size	Binary: 0 = less than 5 members, 1 = 5 or more members	+/-
EducLevel	Education level	Binary: 0 = less than grade 9, 1 = grade 9 or higher	+/-
EmplStatus	Employment status	Binary: 1 = employed, 0 = not employed	+/-
HHDInc	Total household income	Binary: 0 = less than R2000, 1 = R2000 or more	-
FarmSize	Farm size (hectares)	Binary: 0 = less than 3, 1 = 3 or more	+/-
LandOwn	Land ownership	Binary: 1 = individual ownership, 0 = no ownership	+/-
ProdType	Type of production	Binary: 1 = mixed farming, 0 = otherwise	+/-
LivOwn	Livestock ownership	Binary: 1 = yes, 0 = no	+/-
AdopterLD	Adoption of land degradation practices	Binary: 1 = yes, 0 = no	-
AccInfo	Access to information	Binary: 1 = yes, 0 = no	+/-

Source: Author compilation

LD is land degradation (binary treatment variable: 1 = experienced, 0 = not experienced), Age, gender etc are control variables,  $\gamma_i$  and  $\beta_i$  are parameters to be estimated and lastly  $\zeta_1$  and  $\zeta_2$  are error terms.

**Table 16: Variables used in SEM model**

<b>Variable</b>	<b>Type</b>	<b>Role in SEM</b>
Land Degradation (LD)	Binary (0/1)	Exogenous predictor
Agricultural Productivity (AP)	Continuous or latent variable	Mediator
Food Security (FS)	Ordinal (1-4)	Outcome (latent or observed)
Age	Ordinal	Exogenous control
Gender	Binary	Exogenous control
Education	Ordinal	Exogenous control
Employment	Binary	Exogenous control

Source: Author compilation

## **5.5. Results And Discussion**

### **5.5.1 Descriptive statistics**

The key socio-economic characteristics of the respondents in the study area are presented in Table 17. The analysis reveals a diverse food security landscape among respondents, with the majority classified as food secure (39.0%), followed by those deemed mildly food secure (25.4%) and moderately food insecure (35.6%). Notably, there are no individuals in the sample classified as chronically food insecure. This distribution highlights a complex situation in which a significant portion of the population enjoys food security, while a substantial group faces varying levels of food insecurity.

#### **5.5.1.1 Gender of the respondent**

An examination of the data reveals gender disparities in food security status. Among male respondents, food security categories are relatively balanced, with a slightly higher proportion of food-secure individuals (47.0%) compared to those who are mildly (47.7%) or moderately food insecure (38.5%). However, the situation among female respondents is quite different. A higher percentage of females are classified as moderately food insecure (61.5%) compared to those who are mildly food secure (52.3%) or food secure (53.0%). This discrepancy suggests that females may be disproportionately vulnerable to moderate food insecurity, possibly due to the impacts of land degradation. These findings emphasise the

need to address gender-specific vulnerabilities and implement targeted interventions to reduce the gender disparities observed in food security outcomes, particularly in the context of land degradation.

**Table 17: Descriptive statistics for farmer characteristics vs. status of food security**

Variable	Status of Food security							
	Food secure		Mildly food secure		Moderately food insecure		Chronic food insecure	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
	100	39.0	65	25.4	91	35.6	0	0.0
<b>Gender of respondent</b>								
Male	47	47.0	31	47.7	35	38.5	0	0.0
Female	53	53.0	34	52.3	56	61.5	0	0.0
<b>Age of respondent</b>								
Less than 60 years	74	46.6	56	27.7	64	31.5	0	0.0
>60 years	26	41.9	9	14.5	27	43.6	0	0.0
<b>Marital status of respondent</b>								
Married	53	34.6	35	22.9	65	42.5	0	0.0
Not married	47	53.0	30	24.0	47	23.0	0	0.0
<b>Education level of the respondent</b>								
None	17	40.5	8	19.0	17	40.5	0	0.0
Primary	33	43.4	13	17.1	30	39.5	0	0.0
Secondary	39	38.6	32	31.7	30	29.7	0	0.0
Tertiary	11	29.7	12	32.4	14	37.9	0	0.0
<b>Employment status of the respondent</b>								
Employed	27	36.5	18	24.3	29	39.2	0	0.0
Unemployed	38	42.7	28	31.5	23	25.8	0	0.0
Actively Searching	12	35.3	6	17.7	16	47.0	0	0.0

**5.5.1.2 Age of the respondent**

The analysis shows a nuanced relationship between age and food security status. A higher proportion of respondents under 60 years old are food secure (46.6%) compared to those aged 60 and above (41.9%), indicating a slight advantage in food security for the younger group. However, moderate food insecurity is significantly more prevalent among older respondents, with 43.6% of those over 60 experiencing moderate food insecurity, compared to 31.5% of those under 60. Possible contributing factors include

fixed incomes, higher healthcare costs, and limited social support networks, all of which may make older individuals more vulnerable to food insecurity.

#### **5.5.1.3 Marital status of the respondent**

A correlation between marital status and food security status is evident in the data. Among married individuals, 42.5% are classified as moderately food insecure, while most unmarried individuals are mildly food secure (53.0%). The breakdown of food security categories among married respondents shows 34.6% as food secure, 22.9% as mildly food secure, and 42.5% as moderately food insecure. This suggests that marital status can influence food security, but factors such as household size, income levels, and social support networks likely play significant roles in determining food security status.

#### **5.5.1.4 Level of education of the respondent**

The data analysis reveals a notable trend regarding education level and food security status. Among respondents with no formal education, 40.5% are food secure, with an equal percentage classified as moderately food insecure, and a smaller proportion (19%) as mildly food secure. As education levels increase, the proportion of food secure individuals decreases, which is contrary to conventional expectations. For instance, 43.4% of those with primary education are food secure, followed by 38.6% with secondary education, and 29.7% with tertiary education. Interestingly, the percentage of moderately food insecure respondents rises with higher education levels, reaching 37.9% among those with tertiary education. This unexpected pattern suggests that factors beyond education, such as socio-economic variables, sampling biases, or differing perceptions of food security, may influence food security outcomes.

#### **5.5.1.5 Employment status of the respondent**

The relationship between employment status and food security shows distinct patterns. Among employed respondents, 36.5% are food secure, 24.3% are mildly food secure, and 39.2% are moderately food insecure. In contrast, unemployed respondents have a higher proportion of food-secure individuals (42.7%) and fewer moderately food insecure individuals (25.8%). Notably, among those actively searching for employment, only 35.3% are food secure, while 47.0% are moderately food insecure, the highest percentage of food insecurity among all groups. This suggests a positive correlation between employment and food security, with employed individuals being more likely to be food secure. However, those in transitional periods between jobs or unemployed appear to face greater challenges, highlighting the significant impact of employment status on food security.

### **5.5.2 Relationship Between Land Degradation Experience and Household Food Security Status**

Disparities in food security between households experiencing land degradation and those unaffected are evident in the data presented in Table 18. Among households facing land degradation, 46.6% are food secure, compared to only 31.2% of those not affected by land degradation, highlighting a significant difference in food security levels.

**Table 18: Household food security**

Parameter	Food security			
	Food secure	Mildly food insecure	Moderately food insecure	Total
Household experienced land degradation (%)	61 (46.5%)	31 (23.7%)	39 (29.8%)	<b>100%</b>
Household did not experience land degradation (%)	39 (31.2%)	34 (27.2%)	52 (41.6%)	<b>100%</b>
<b>Total</b>	<b>100</b> <b>(39.1%)</b>	<b>65</b> <b>(25.4%)</b>	<b>91</b> <b>(35.5%)</b>	<b>100%</b>

Source: survey data, 2022

The severity of food insecurity is notably higher among households experiencing land degradation, with 23.7% classified as mildly food insecure and 29.8% as moderately food insecure. In comparison, 27.2% and 41.6%, respectively, of households not experiencing land degradation fall into these categories. These findings suggest a clear association between land degradation and an increased likelihood of moderate food insecurity, underscoring the need for targeted interventions to address the root causes of land degradation and mitigate its negative impact on food security.

**5.6 Impact of land degradation on food security: PSM approach**

As shown above, experiencing land degradation had significant impact on the agricultural productivity and food security status at the 1% and 10% levels, respectively. The results of the propensity score matching indicate a positive treatment effect of ( $TT = 0.254$ ) of land degradation on food security. This suggests that households experiencing land degradation are on average 25.5% more likely to be food insecure than those who did not experience it. However, the marginal statistical significance ( $p\text{-value} = 0.053$ ) implies that further investigation is warranted. This impact can be attributed to various factors, particularly the strong dependence of farmers on land resources for their livelihoods (Kirui, 2016; Nachtergaele et al., 2010). In the study area, farmers face challenges such as gullies (36.8%), soil compaction (28.1%), and topsoil loss (26.6%), which directly affect agricultural activities and contribute to increased food insecurity. These findings emphasise the urgent need to combat land degradation to

protect agricultural productivity, which is vital for food production and supply, while also addressing its potential impacts on food security, especially for vulnerable populations.

Interestingly, the high prevalence of food insecurity among some households not affected by land degradation suggests that other underlying factors may be driving food insecurity in the study area.

## **5.7 Drivers of food insecurity: Ordinal Logistic Regression**

An ordinal logistic regression (OLR) model was used to assess drivers of food insecurity as measured by the Household Food Insecurity Access Scale (HFIAS). The results of this analysis are presented in Table 19.

### **5.7.1 Age of the household head**

The results show a significant positive relationship between the age of the household head and the likelihood of experiencing food insecurity at 5% level ( $\beta=0.384$ ,  $p = 0.026$ ). In an ordinal logistic regression, a positive coefficient means that as age increases, households are more likely to fall into more severe food insecurity categories. This suggests that older household heads face higher food insecurity risks, possibly due to reduced physical capacity, greater dependency burdens, or limited adaptability to modern farming techniques. While some studies (Basher, 2010; Moroda et al., 2018) highlight the advantages of experience and capital among older farmers, others (Mazenda et al., 2021) argue that younger heads are often better positioned due to smaller households and fewer financial pressures.

### **5.7.2 Education level of the household head**

The analysis indicates a significant negative relationship between education level and food insecurity ( $\beta=-0.551$ ,  $p = 0.014$ ). This means that households led by more educated individuals are less likely to experience severe food insecurity. Education may enhance decision-making, improve access to information, and enable diversification of income sources, all of which contribute to better food security outcomes. However, the relationship remains complex and may be influenced by broader socio-economic and contextual factors, thus requiring further exploration to fully understand the dynamics at play.

**Table 19: Drivers of food insecurity: Ordinal Logistic Regression**

<b>Variable</b>	<b>Coefficient (<math>\beta</math>)</b>	<b>Std. Error</b>	<b>z-value</b>	<b>p-value</b>	<b>Significance</b>
Age	0.384	0.173	2.23	0.026	**
Gender	0.162	0.439	0.37	0.711	
Marital Status	0.447	0.336	1.33	0.183	
Household Size (HHS)	-0.644	0.446	-1.44	0.149	
Education Level	-0.551	0.224	-2.46	0.014	**
Employment Status	-0.054	0.191	-0.28	0.777	
Household Income	-0.156	0.077	-2.02	0.043	**
Land Ownership	-0.919	0.389	-2.36	0.018	**
Farm Size	-0.042	0.158	-0.26	0.791	
Production Type	0.119	0.305	0.39	0.697	
Own Livestock	0.459	0.457	1.00	0.316	
Access to Information	-0.233	0.453	-0.51	0.607	
Land Degradation	-1.097	0.476	-2.30	0.021	**
Adoption of LD Practices	-20.250	0.582	-34.78	0.000	***
<b>Threshold</b>	21.484	2.394	8.97	0.000	***
<b>Mean dependent var</b>	1.965				
<b>R<sup>2</sup></b>	0.288				
<b>Chi-square</b>	11150.921				
<b>Akaike crit. (aic)</b>	1782.665				
*** $p < .01$ , ** $p < .05$ , * $p < .1$ , $p > 0.1$ (Not Significant)					

Source: survey data, 2022

### 5.7.3 Household income

Household income shows a statistically significant negative coefficient in the OLR model ( $\beta = -0.156$ ,  $p = 0.043$ ), indicating that higher income is associated with lower odds of being in more severe food insecurity categories. This implies that wealthier households are more likely to be food secure, likely due to greater purchasing power and better access to food. These findings are consistent with previous

research in Ethiopia, Ghana, and South Africa, where increased income was similarly found to improve household food security (Motbainor et al., 2016).

#### **5.7.4 Land ownership**

The model reveals a statistically significant negative association between land ownership and food insecurity ( $\beta = -0.919$ ,  $p = 0.018$ ), indicating that individual land ownership reduces the odds of experiencing more severe food insecurity. Specifically, households with secure land tenure are less likely to fall into the mildly food insecure category. This relationship likely reflects that farmers with secure land rights are more incentivized to invest in agricultural activities and adopt sustainable land management practices to enhance productivity and food security. Secure tenure is critical for encouraging responsible land stewardship and long-term agricultural development. This finding is supported by prior research highlighting the role of secure land rights in promoting investments in sustainable practices such as soil conservation and agroforestry (Allen et al., 2020).

#### **5.7.5 Exposure to land degradation**

The analysis reveals a statistically significant negative coefficient ( $\beta = -1.097$ ,  $p = 0.021$ ), indicating that greater exposure to land degradation reduces the odds of being in a more food-secure category. In practical terms, households experiencing more severe land degradation are significantly more likely to fall into higher levels of food insecurity. This result is consistent with prior findings by Hurni et al. (2010), who documented the detrimental effects of land degradation on agricultural productivity and rural livelihoods. Furthermore, the United Nations Convention to Combat Desertification (2022) highlights that land degradation reduces productive capacity, forces households to divert resources to combat land loss, and ultimately intensifies poverty and food insecurity. By undermining both production and access dimensions of food security, land degradation poses a critical threat to vulnerable rural households.

#### **5.7.6 Adoption of land degradation practices**

The results show a significant negative relationship between the adoption of sustainable land management practices and household food insecurity, with statistical significance at the 1% level ( $p$ -value = 0.000). Specifically, each marginal increase in the adoption of these practices reduces the likelihood of food insecurity by 20 times. The results show a highly significant negative association between the adoption of sustainable land management practices and household food insecurity ( $\beta = -20.250$ ,  $p < 0.001$ ). This coefficient indicates that households adopting such practices are substantially less likely to fall into more severe categories of food insecurity. The adoption of sustainable land management (SLM) practices appears to act as a strong buffer against food insecurity, likely by

enhancing soil fertility, improving water retention, and promoting long-term agricultural productivity. This finding is consistent with previous studies such as Nkomoki et al. (2018), who argue that farmers adopting sustainable land management practices are generally more food secure. To effectively reduce degradation and enhance food security, it is crucial to optimize the use of all resources available to households natural, human, physical, social, and financial as these contribute significantly to improving livelihoods and food security (Makate et al., 2016).

### 5.7.8 Modelling the impact of land degradation on food security: SEM Approach

This study further assessed the pathway through which land degradation influences household food security, incorporating both direct and indirect effects. The results are presented in Table 20.

**Table 20: Results: SEM Approach**

Path	Coefficient	Std. Error	z-value	p-value	Interpretation of path directionality
AP ← LD	-0.75	0.10	-7.5	<0.001	Land degradation strongly reduces agricultural productivity.
AP ← Age	-0.12	0.05	-2.4	0.016	Modest but significant inverse relationship; older age is associated with slightly lower agricultural productivity.
AP ← Gender (male=1)	0.20	0.08	2.5	0.012	Males report higher agricultural productivity.
AP ← Education	0.25	0.07	3.57	<0.001	Higher levels of education are significantly associated with improved agricultural productivity.
AP ← Employment	0.18	0.06	3.0	0.003	Employment is linked to higher agricultural productivity.
FS ← AP	-0.60	0.12	-5.0	<0.001	Lower agricultural productivity moderately increases the risk of food insecurity.
FS ← LD	0.40	0.15	2.67	0.008	Unexpected moderate positive effect of LD on food security, which may indicate the effect of social grant services and food aid programs.

Source: Author compilation

The results of the study confirm that land degradation has both a direct and indirect impact on household food security in the semi-arid region. Land degradation significantly reduces agricultural productivity ( $\gamma_1 = -0.75$ ,  $p < 0.001$ ), which in turn increases the risk of food insecurity ( $\beta_1 = -0.60$ ,  $p < 0.001$ ). Interestingly, land degradation also shows a moderate positive direct association with food security ( $\beta_2 = 0.40$ ,  $p = 0.008$ ). This unexpected relationship may be attributed to the adoption of land management practices and the presence of social grant services, particularly for older household heads, which may help improve food security despite declining productivity. As a result, while land degradation negatively impacts productivity, government support mechanisms may simultaneously improve household food access, producing the observed positive direct association. These findings highlight the urgent need for an integrated intervention that mitigate land degradation and enhances the effectiveness of social grant services. This also require improvement of other socioeconomic development efforts, particularly education and employment, to help bolster household resilience in semi-arid environments.

#### **5.7.8.1 Degradation, productivity and food access**

The strong association between degradation types (water erosion, waterlogging, vegetation loss) and API, and the PSM/SEM evidence that degradation worsens food access, is consistent with SA studies linking soil loss and rangeland decline to reduced smallholder output and household hunger, particularly in Limpopo and Eastern Cape contexts, where biophysical constraints are compounded by limited support services. These studies similarly emphasise erosion control and vegetative rehabilitation as first-order priorities for food security.

#### **5.7.8.2 Gender and practice adoption**

The higher likelihood of female-headed households adopting mulching and conservation tillage mirrors SA findings that women often lead subsistence plot management and soil stewardship. Programmes that recognise women's central role in residue management and soil cover show stronger adoption and persistence of low-cost SLM practices.

#### **5.7.8.4 Tenure/income/extension**

The protective effects of income and individual land ownership against food insecurity echo SA evidence that secure tenure and liquidity enable investment in conservation and input use. At the same time, our counter-intuitive association between "access to information" and degradation risk suggests that information without quality extension and enabling resources can be ineffective also noted in SA evaluations of extension performance.

## **5.8 Conclusions**

This study highlights the severe and pervasive impacts of land degradation on agricultural productivity and food security in the GSDM, Limpopo Province. The findings reveal that a significant portion of smallholder farmers in the region are directly affected by land degradation, primarily caused by soil erosion, compaction, and topsoil loss. These processes are further exacerbated by unsustainable farming practices, climate variability, and socio-economic challenges, leading to reduced agricultural yields and heightened food insecurity.

The analysis also underscores the importance of socio-economic factors, such as land ownership, access to information, and gender, which significantly influence farmers' ability to manage land degradation. The study reveals that those with access to information and land ownership are more likely to engage in sustainable land management practices, which mitigate the adverse effects of degradation. However, despite these findings, the prevalence of food insecurity persists, highlighting the complexity of addressing this issue and the interrelated factors influencing both agricultural productivity and food security.

Considering these challenges, land degradation is not only an environmental issue but also a socio-economic one that requires integrated solutions. Immediate action is needed to address the root causes of degradation and its impacts on food security, especially in vulnerable communities that rely heavily on agriculture for their livelihoods.

## **5.9 Limitations of the study**

While this study provides valuable empirical evidence into the relationship between land degradation, agricultural productivity and household food security among smallholder farmers in the Sekhukhune District Municipality, certain methodological and contextual limitations must be acknowledged. Firstly, it is the use of a non-probability convenience sampling technique which was necessitated by the absence of a reliable sampling frame for smallholder farmers in the district, a challenge that is common in rural research in many developing countries (Luke, 2025; Agarwal & Devra, 2024). Although this approach enabled access to active farming households in dispersed and remote settlements, it may have introduced sampling bias and limits the external validity of the findings (Bryman, 2016). The results should therefore be interpreted as context-specific rather than statistically generalisable to all smallholder farmers in South Africa.

Secondly, the study utilised a cross-sectional design, capturing data at a single point in time. While cross-sectional surveys are useful for establishing associations between variables in resource-constrained settings (Creswell, 2014), they limit the ability to infer causality or analyse dynamic feedback effects that evolve over time (Kumar, 2018). Although Propensity Score Matching (PSM) and

Structural Equation Modelling (SEM) were used to strengthen causal inference, these techniques cannot fully substitute for longitudinal data (Kline, 2023). Future studies would benefit from panel data to explore long-term changes in land conditions, productivity trends and adaptation trajectories.

Thirdly, some variables, particularly land degradation severity and household food security measured using the Household Food Insecurity Access Scale (HFIAS), were based on self-reported responses. While widely accepted in livelihood and vulnerability research such indicators may be subject to recall bias or social desirability bias. To mitigate these risks, triangulation with observable field indicators and internal consistency checks were incorporated, but measurement error cannot be entirely ruled out.

The study primarily focused on socio-economic determinants of land degradation and did not incorporate biophysical assessments such as soil nutrient analysis, land cover change from remote sensing, or hydrological assessments. Integrating such assessments in future research would provide a more holistic understanding of the degradation processes affecting smallholder systems in semi-arid regions like Sekhukhune, where climate variability and land pressure intersect with poverty and marginalisation. Despite these limitations, provides a basis for future interdisciplinary research and policy engagement aimed at building resilience among smallholder farmers.

### **5.10 Recommendations**

To effectively combat land degradation and improve food security, several key interventions are recommended:

- There is an urgent need to scale up awareness programs and training sessions on sustainable farming practices. Smallholder farmers should be educated on soil conservation techniques, such as crop rotation, conservation tillage, and agroforestry, which can help restore soil fertility and prevent erosion. Governments and NGOs should collaborate to provide technical support and access to appropriate technologies.
- The study highlights the importance of information access in mitigating land degradation. Expanding agricultural extension services and ensuring that farmers receive accurate, localized, and actionable information about land management can significantly improve their ability to adopt sustainable practices. Mobile technology, community-based training, and farmer field schools should be utilised to enhance information dissemination.
- The gender disparities in food security outcomes suggest the need for gender-sensitive policies. Women, who are disproportionately affected by food insecurity, must be included in decision-making processes related to land management and agricultural practices. Empowering women through education, access to resources, and leadership opportunities will strengthen community resilience to land degradation.

- Strengthening land tenure security, particularly for smallholder farmers, is crucial for incentivising long-term investment in sustainable land management. Policies that provide secure land rights can encourage farmers to adopt practices that improve land productivity and prevent further degradation. This could include formalising land titles for communal areas and providing support for land tenure reforms.
- Policymakers should prioritise land degradation and food security in national and regional development strategies. This includes the formulation of policies that integrate environmental sustainability with agricultural development. Governments should also allocate sufficient resources for land restoration programs, including tree planting, watershed management, and soil fertility improvement projects.
- Local communities, including traditional authorities, should play a central role in managing land resources. Collaborative efforts between local governments, farmers, and traditional leaders can foster collective action to address land degradation. Community-based natural resource management programs should be scaled up to integrate traditional knowledge with modern scientific approaches to land restoration.
- Financial assistance, such as subsidies for sustainable farming inputs (e.g., fertilisers, seeds, and equipment), could be provided to farmers, especially those in vulnerable communities. Additionally, incentives for adopting land restoration practices, such as carbon credits or market-based schemes, could enhance farmer participation.
- Finally, continuous monitoring and research on land degradation, agricultural productivity, and food security are essential for understanding the evolving challenges and assessing the effectiveness of interventions. Research should focus on developing climate-resilient crops, improving water management, and identifying region-specific solutions to land degradation.

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## **CHAPTER 6: GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS**

### **6.1 Introduction**

The following section presents a comprehensive overview of the summary, conclusions, and recommendations pertaining to the profound impact of land degradation on agricultural productivity and food security. This critical analysis encapsulates the core findings and implications drawn from an in-depth exploration of the intricate relationship between land degradation and the vital domains of agricultural productivity and food security. The summary provides a succinct synthesis of the key insights garnered throughout the study, while the conclusions distil perspectives and implications derived from the empirical data and analytical assessments. Ultimately, the recommendations put forth concrete, actionable strategies and initiatives that aim to address the multifaceted challenges posed by land degradation and, in doing so, enhance agricultural productivity and bolster food security for vulnerable populations in South Africa.

### **6.2 Synthesis of the study**

The importance of land in agricultural production is indisputable, emphasized by classical political economists and esteemed researchers. Land is not only the primary source of food but also offers invaluable ecosystem services, aligning with Sustainable Development Goals (SDGs) particularly those related to zero hunger, climate action and life on land. Unfortunately, land is increasingly under threat due to a range of interlinked factors, including rapid land conversion for urban and agricultural expansion, climate change, and population growth. This poses a significant challenge to sustainable development and has severe consequences to long term resilience of both natural systems and human livelihoods. Despite acknowledging the problem, there's a knowledge gap regarding the full impact of land degradation on agriculture and socio-economic development. Bridging this gap, this study investigated the complex relationship between land degradation, agricultural productivity, and household food security in the Sekhukhune District Municipality in Limpopo province of South Africa. Through mixed methods including descriptive statistics, correlation analysis, probit and regression models, propensity score matching (PSM), ordinal logistic regression, and structural equation modelling (SEM), the study examined the prevalence, drivers, and impacts of various forms of land degradation such as water erosion, soil compaction, and topsoil loss on farming households.

Key findings revealed that over half of the households (51.2%) experienced land degradation, primarily driven by water erosion and soil compaction. Land degradation significantly reduced agricultural productivity, with 91.6% of affected households reporting negative impacts on crop yields. This productivity loss was strongly associated with increased food insecurity; households experiencing land degradation were 25.5% more likely to face food insecurity than those unaffected.

Socioeconomic factors, including age, gender, land ownership, education, employment, and access to information, significantly influenced both the experience of land degradation and food security outcomes. The SEM analysis confirmed that land degradation indirectly undermines food security by severely reducing agricultural productivity, while direct effects of land degradation on food security were moderated by adaptive behaviours such as the adoption of sustainable land management practices and social support systems. The study calls for urgent integrated interventions that aims to address environmental degradation while simultaneously strengthening household capacities through education, employment, and extension services.

### **6.3 Conclusions of the study**

The literature reveals a troubling nexus between land degradation and global agricultural productivity. In the South African context, this nexus is particularly evident in communal areas where inequalities in land use and tenure systems deepen the vulnerability of these landscapes and accelerate degradation. However, increasing awareness of the severe and far-reaching impacts of land degradation to food security, biodiversity, climate resilience, and socio-economic well-being has spurred intensified global efforts. These include initiatives such as the United Nations Convention to Combat Desertification (UNCCD) and the integration of land-related targets within the Sustainable Development Goals (SDGs). The UNCCD's 2018–2030 Strategic Framework, which promotes the goal of achieving Land Degradation Neutrality (LDN), reflects a shared global commitment to reversing degradation, enhancing livelihoods, and mitigating the impacts of drought.

South Africa is an active participant in several Multilateral Environmental Agreements (MEAs) and has aligned its national environmental strategies accordingly. Its engagement with the UNCCD through the National Action Programme (NAP) signals a clear intent to address land degradation and drought while supporting sustainable development at both national and international levels. So far, despite the substantial investments made by the South African government and international donors, land degradation continues to pose a serious threat to sustainable agriculture and food security, particularly in semi-arid rural areas such as the Sekhukhune District Municipality.

Empirical findings from this study demonstrate that degradation processes most notably water erosion, soil compaction, and topsoil loss have significantly reduced agricultural productivity in the region. This decline, in turn, exacerbates household food insecurity. While some households have managed to mitigate these impacts through sustainable land management practices and social support systems, the overall effect remains deeply detrimental. Socio-economic conditions, including poverty, land tenure insecurity, and limited access to resources, are critical in shaping vulnerability to both land degradation and food insecurity.

## **6.4 Recommendations of the study**

Addressing land degradation among smallholder farmers in South Africa requires a comprehensive and context-responsive approach that recognises the historical legacies of unequal land access, weak rural institutions, and persistent poverty in former homeland areas. The findings of this study demonstrate that land degradation is both an environmental and socio-economic problem, driven by insecure land tenure, limited capital, poor access to extension services, and climate variability. Therefore, policy responses should not only promote environmental rehabilitation but also address structural rural development challenges such as inequality, unemployment, and low agricultural productivity. This calls for a holistic and integrated policy framework that aligns national strategies with district-level implementation.

To enhance sustainable land use and resource rehabilitation, the study recommends strengthening the adoption of Sustainable Land Management (SLM) practices through practical, farmer-driven support mechanisms. To effectively implement SLM requires institutionalisation of locally appropriate conservation practices supported by collaborative learning platforms, including farmer field schools, demonstration sites, and peer-to-peer farmer networks, which help build local knowledge and improve adoption. Furthermore, targeted advocacy and awareness campaigns, implemented through community workshops, local radio programmes, and agricultural cooperatives, can encourage behavioural change and sustained farmer participation.

A major policy implication of the study is the need to revitalise and strategically integrate the Land Care Development Programmes as a vehicle for landscape rehabilitation and rural development. Land Care projects should be embedded within municipal Integrated Development Plans (IDPs) to ensure budget allocation, local accountability, and long-term sustainability. This will enhance cross-sector collaboration between municipalities, traditional authorities, and the Department of Agriculture, Land Reform and Rural Development (DALRRD), ensuring that land rehabilitation initiatives are not fragmented. Additionally, integrating land restoration priorities into IDPs provides opportunities to link land management efforts with infrastructure development, access roads, water harvesting systems, and market access key enablers of rural economic development in South Africa.

The study further recommends strengthening agricultural extension services as a critical institutional mechanism for supporting adaptation and resilience among smallholder farmers. The current extension system is constrained by limited personnel, outdated technical skills, and weak farmer outreach. Therefore, extension reforms led by DALRRD should prioritise recruiting additional officers in under-serviced districts, enhancing their technical expertise in climate-smart agriculture and SLM, and improving operational logistics to reach remote villages. Partnerships with universities, NGOs, and research institutes should be expanded to support continuous professional development for extension

officers and facilitate innovations in digital advisory services and mobile-based farmer support platforms.

The study emphasises the importance of social inclusion and equity in land restoration and agricultural development. Women and youth, who are often excluded from formal agricultural support systems despite their active role in household farming, they should be deliberately targeted in SLM programmes through customised training, access to resources, and leadership roles in community-based land management structures. Gender-responsive and youth-inclusive strategies are essential to ensure long-term adoption of land rehabilitation practices and enhance local ownership of development initiatives. Moreover, efforts to combat land degradation must be accompanied by improved access to rural finance, cooperative enterprise development, and market linkages to enhance the economic incentives for sustainable land management.

### **6.5 Areas for further study**

The areas for further study are discussed within the context of the study, as well as based on the emerging issues emanating from previous research on land degradation and its associated impacts. These are briefly discussed under the following themes below:

- *Long-term impact assessment*: there is a need to conduct longitudinal studies to assess the long-term impact of land degradation on agricultural productivity and food security to provide insights into trends and patterns over time.
- *Climate change resilience*: studies need to investigate strategies and technologies that can enhance the resilience of agricultural systems to climate change within the context of land degradation. This would involve exploring climate-smart agriculture practices and their effectiveness in mitigating the adverse effects of both land degradation and climate variability.
- *Economic valuation*: further research is needed to quantify the economic costs of land degradation in South Africa, including both direct and indirect costs. This would help policymakers prioritize interventions and allocate resources more effectively.
- *Gender and youth inclusion*: studies that explore the gender and generational dimensions of land degradation and its impact on agricultural productivity are crucial in terms of understanding how women and youth are affected differently and develop strategies to empower them in sustainable land management practices.
- *Policy implementation*: there is a need for studies that analyse the effectiveness of existing policies and governance structures in addressing land degradation. These studies should further identify barriers to policy implementation and propose solutions to improve the enforcement of sustainable land management practices.

- *Community-based initiatives*: there is also a need to study the role of community-based initiatives and local knowledge in combating land degradation towards assessing the effectiveness of community-driven approaches in sustainable land management.
- *Capacity building*: studies that investigate the effectiveness of capacity-building programs for smallholder farmers in adopting sustainable land management practices are imperative towards identifying best practices and strategies for scaling up these programs.

**APPENDIX A: RESEARCH QUESTIONNAIRE - ENGLISH**

**IMPACT OF LAND DEGRADATION ON  
AGRICULTURAL PRODUCTIVITY AND HOUSEHOLD  
FOOD SECURITY: EVIDENCE FROM SMALLHOLDER  
FARMERS IN A SEMI-ARID REGION OF SOUTH  
AFRICA**

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*Researcher:*

*NWABISA BUDAZA (PHD. STUDENT) UNIVERSITY OF KWAZULU-NATAL*

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*Supervisor:*

*PROF MAXWELL MUDHARA UNIVERSITY OF KWAZULU-NATAL*

*Co-Supervisors:*

*DR. J. MWENGE KAHINDA COUNCIL FOR SCIENTIFIC AND INDUSTRIAL  
RESEARCH*

*DR. C. MUSVOTO COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH*

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**Note:**

The information captured in this questionnaire is certainly confidential, your answers will only be used for research purposes by the student at the University of KwaZulu-Natal. Please understand that you are not being forced to participate in this study, you have a choice to participate or not to. However, we would appreciate it if you do share your thoughts and experiences with us. If you choose not to take part in answering these questions, you will not be affected in any way. If you agree to participate, you may stop me at any time and tell me that you do not want to go on with the interview. If you do this there will also be no penalties and you will not be prejudiced in any way.

Enumerators

Code

.....

Gender of the  
respondent

.....

Questionnaire  
No.

.....

Date of the  
interview

.....

Village name

.....

**PART I: HUMAN CAPITAL**

**1. The age range of household head**

- <20
- 20-30
- 30-40
- 40-50
- 50-60
- >60

**2. Household Composition**

Total household size	
Adult males	
Adult females	
Children (<15 years)	
Economic Active	
No of Dependents	

**3. Education of a household**

Levels of education

- None
- Primary
- Secondary
- Tertiary
- Informal

**4. Households Assets**

Working Assets	
Tractor	
Irrigation equipment	
Borehole	
Planter – ox-drawn	
Plough	
<i>Others (Specify)</i>	

**5. Marital status** (*Tick appropriately*)

- Single  Married  Widowed  Separated

**6. Employment status**

- Self-employed  Unemployed  Actively Searching  Retired  Disabled & unemployable

**PART II: NATURAL CAPITAL**

**Land -Use**

1. How many hectares of farmland do you own? \_\_\_\_\_ ha

2. How long have you been farming? \_\_\_\_\_ years

3. What is the type of land ownership? *(Tick appropriately)*

Individual  Communal  Rental  State-owned/allocation

4. How is the slope of your farmland? *(Tick appropriately)*

Plain  Medium  Steep  Very steep

5. Which agricultural production do you practice?

Livestock Production	
Crop Production	
Mixed Production	
Poultry Production	
Fish Farming	
Bee Keeping	
<i>Others (Specify)</i>	

6. Which crops do you grow? indicate the average yield for each crop *(Tick appropriate)*

Season	Crops	Yield (Kg or bag)
Winter	Cabbage	
	Morongo	
	Spinach	
	Carrot	
	Beetroot	

	<i>Others (Specify)</i>	
Summer crops	Sorghum	
	Soybeans	
	Maize	
	Groundnut	
	Sunflower	
	Potatoes	
	Others (Specify)	
Winter and summer crops	Tomatoes	
	<i>Others (Specify)</i>	

### Livestock Production

1. Do you own livestock? Yes  No

2. If 'YES', how many heads of the following livestock do you have?

Livestock	No.	Livestock	No.
Oxen and bulls	_____	Sheep	_____
Cows	_____	Goat	_____
Calves	_____	Poultry	_____
<i>Others (Specify)</i>	_____	<i>Others (Specify)</i>	_____

5. On what basis is the use of grazing land?

Private  Shared arrangement  Open-access

6. What is the share of the farm income in your household total income?

Up to 25%	
26 - 50%	
51 – 75	
76 – 100	
<i>Others (Specify)</i>	

### Water Resources

1. Below indicate the type of water source, uses, constraints, and changes in the last 10 years

*(Tick appropriate)*

Water Sources	Use/available during which Months?	Used for D- Drinking, I- Irrigation,	Need access rights or payment	Constraints P-Price D- Distance	Changes <i>(Specify)</i>
River					
Dam/Rese					
Tap					
Borehole					
<i>Others (Specify)</i>					

### PART III: LIVELIHOOD ACTIVITIES

1. Indicate household sources of income *(Tick appropriate)*

Livelihood Strategy	Economic activity	Average Income
<b>On-farm</b>	Crop production	
	Wages	
	livestock sales	
	Fisheries	

	Wood selling	
	Sales of Processed Food	
	<i>Others (specify)</i>	
<b>Off-farm income</b>	Remittance	
	Government social grant	
	Pension	
	Self-employed	
	Employment	
	<i>Others (specify)</i>	

2. What is the range of your total household income per month? *(Tick appropriate)*

<R500	R600- R1000	R1100- R1500	R1600- R2000	R2100- R3000	R3100- 3500	R3600- 4000	R4100- 5000
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**PART IV: IMPACTS OF LAND DEGRADATION IN THE HOUSEHOLD**

1. What types of land degradation does your farm or garden experience? and to what extent?

	Light	Moderate	Strong	Extremely strong	Not at all
Water erosion (including gullies)	1	2	3	4	5
Wind erosion	1	2	3	4	5
Loss of topsoil	1	2	3	4	5
Waterlogging	1	2	3	4	5
Compaction	1	2	3	4	5
Encroachment by alien invasive species	1	2	3	4	5
Vegetation degradation	1	2	3	4	5
Salinity					

*Others (specify)*

2. What specific impact of land degradation do you have on your farm?

Loss of seedling	
Reduce soil nutrients and organic matter	
Reduce root depth and water retention	
Reduce farm output	
Reduced farm size	
Migration due to reduced farm size	
Loss of vegetation cover	
Loss of palatable species for livestock	
Reduced grazing land	
Encroachment by alien invasive species	
<i>Others (specify)</i>	

*If your farm output decreased, what was your average production per annum previously? And what is it now? (Indicate now and then)*

<b>Average farm output</b>	<b>Then</b>	<b>Now</b>
<5 tons	<input type="text"/>	<input type="text"/>
5 -10 tons	<input type="text"/>	<input type="text"/>
11-15 tons	<input type="text"/>	<input type="text"/>
16-20 tons	<input type="text"/>	<input type="text"/>
21-25 tons	<input type="text"/>	<input type="text"/>
26-30 tons	<input type="text"/>	<input type="text"/>
31-35 tons	<input type="text"/>	<input type="text"/>
36-40 tons	<input type="text"/>	<input type="text"/>
41-45 tons	<input type="text"/>	<input type="text"/>
46 -50 tons	<input type="text"/>	<input type="text"/>
Others (specify)	<input type="text"/>	<input type="text"/>

*If it reduced farm size, how big was your farm before? And how big is it now? (Indicate now and then)*

<b>Farm Size</b>	<b>Then</b>	<b>Now</b>
<5 ha	<input type="text"/>	<input type="text"/>
5 -10ha	<input type="text"/>	<input type="text"/>
11-15 ha	<input type="text"/>	<input type="text"/>
16-20 ha	<input type="text"/>	<input type="text"/>
21-25 ha	<input type="text"/>	<input type="text"/>
26-30 ha	<input type="text"/>	<input type="text"/>
31-35 ha	<input type="text"/>	<input type="text"/>
36-40 ha	<input type="text"/>	<input type="text"/>
41-45 ha	<input type="text"/>	<input type="text"/>

46 -50 ha	<input type="text"/>	<input type="text"/>
Others (specify)	<input type="text"/>	<input type="text"/>

3. What specific impacts does land degradation have in your household? *(Tick appropriate)*

Reduction in income <i>(indicate estimated amount before and after)</i>	<input type="checkbox"/>	<input type="checkbox"/>
Food shortage	<input type="checkbox"/>	<input type="checkbox"/>
A smaller number of products to sell	<input type="checkbox"/>	<input type="checkbox"/>
More time spent on farm activities'	<input type="checkbox"/>	<input type="checkbox"/>
Spending more money buying livestock feed due to poor grazing land <i>(indicate an average increase in spending)</i>	<input type="checkbox"/>	<input type="checkbox"/>
<i>Others (specify)</i>	<input type="checkbox"/>	<input type="checkbox"/>

a) If you are experiencing food shortages, how does your household cope with this adverse situation?

Coping strategy	Yes	No	The reason if there is any
Reduce daily food intake			
Collect wild food			
Look for daily work			
Collect fuelwood for sale			
Sell assets: livestock and others			
Borrow food from others			

Borrow money			
Bartering			
Purchase of food on credit			
Others (specify)			

4. Have you ever tried to reduce/ prevent land degradation? 1=Yes, 2=No

If Yes, below indicates the method you have used (*Tick appropriate*)

	Agree	Disagree	Not sure
Practice mulching	1	2	3
Crop rotation	1	2	3
Use of organic manure	1	2	3
Use fertilizer	1	2	3
Conservation tillage	1	2	3
Crop diversification	1	2	3
Use crop residues	1	2	3
Afforestation	1	2	3
Construction of windbreakers	1	2	3

*Others (specify)*

5. To what extent do the following methods/ techniques reduce the degree of land degradation on your farm?

	Very high	High	Moderate	Low	Not effective
Practice mulching	1	2	3	4	5

Crop rotation	1	2	3	4	5
Use of organic manure	1	2	3	4	5
Use fertilizer	1	2	3	4	5
Conservation tillage	1	2	3	4	5
Crop diversification	1	2	3	4	5
Use crop residues	1	2	3	4	5
Afforestation	1	2	3	4	5
Construction of .....	1	2	3	4	5
Others (specify)					

6. If you haven't tried to reduce/prevent land degradation, what are the reasons?

No challenge	
Lack of technical skills or knowledge of land rehabilitation strategies	
Lack of capital or resources to control land degradation	
Inadequate access to information	
Others (specify)	

7. Have you participated in land care projects? Yes  No

8. What are your sources of information for land care/ soil conservation?

Community meetings/ Traditional leaders	
Co-operative groups/fellow farmers	
Extension officers	

<i>Others (Specify)</i>	
-------------------------	--

**PART VI: VULNERABILITY ASSESSMENTS**

1. What crises has the household faced in the past five to ten years?

<b>Crises</b>	<b>When</b>
Drought	
Food insecurity	
Crop failure	
Livestock losses	
Indebtedness	
Migration	
Others (specify)	

2. Which months are the most difficult in access to food, grazing, fodder, and water?

<b>Shortage/limited access</b>	<b>Month(s)</b>
Food	
Fodder	
Water	
<i>Others (specify)</i>	

3. What have been the main changes in the landscape over the last 10 years? (*specify*)

a. Changes in landscape

.....

.....

.....  
.....  
4. What have been the main changes in the socio-economic conditions?

a. Changes in socio-economic conditions

.....  
.....  
.....

b. Indicate challenges in the area and you would like them to be improved

.....  
.....  
.....

**PART VII: FOOD SECURITY**

**Household Food Insecurity Access Scale (HFIAS)** *(Tick appropriate)*

Sources of information	Rank		
1 In the past four weeks, did you worry that your household would not have enough	<input type="checkbox"/> Yes		<input type="checkbox"/> No
2 How often did this happen?	<input type="checkbox"/> Rarely	<input type="checkbox"/> Sometimes	<input type="checkbox"/> Often
3 In the past four weeks, were you or any household member not able to eat the kinds	<input type="checkbox"/> Yes		<input type="checkbox"/> No

4	How often does this happen?	Rarely	Sometimes	Often
5	In the past four weeks, did you or any household member have to eat a limited	Yes		No
6	How often did this happen?	Rarely	Sometimes	Often
7	In the past four weeks, did you or any household member have to eat some foods	Yes		No
8	How often does this happen?	Rarely	Sometimes	Often
9	In the past four weeks, did you or any household member have to eat a smaller	Yes		No
10	How often does this happen?	Rarely	Sometimes	often
11	In the past four weeks, did you or any household member have to eat fewer meals	Yes		No
12	How often does this happen	Rarely	Sometimes	Often
13	In the past four weeks, was there ever no food to eat of any kind in your household	Yes		No
14	If yes how often do you experience that?	Rarely	Sometimes	Often
15	In the past four weeks, did you or any household member go to sleep at night	Yes		No
16	How often does that happen	Rarely	Sometimes	Often
17	In the past four weeks, did you or any household member go a whole day and night	Yes		No
18	How often does this happen?	Rarely	Sometimes	Often

**Consumption Coping Strategy Index (CSI)** *(Tick appropriate)*

1	In the past 30 days, if there have been times when you did not have enough food or money to buy food, how often has your household had to:	Every day	3-6 /week	Once in a while	Hardly at All? <1 */week	Never 0*/week	Severity Ranking	Score

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 household members to eat elsewhere?							
g	Send household members to beg?							
h	Limit portion size at mealtimes?							
i	Restrict consumption of adults 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 entire days without eating?							

## **APPENDIX B: CONSENT FORM**

### **SECURING MULTIPLE ECOSYSTEM BENEFITS THROUGH SLM IN THE PRODUCTIVE BUT DEGRADED LANDSCAPES OF SOUTH AFRICA**

Dear Participant,

My name is Nwabisa Budaza (220107900). I am a PhD candidate studying at the University of KwaZulu-Natal Pietermaritzburg Campus. The title of my research is: IMPACT OF LAND DEGRADATION ON AGRICULTURAL PRODUCTIVITY AND HOUSEHOLD FOOD SECURITY: EVIDENCE FROM SMALLHOLDER FARMERS IN A SEMI-ARID REGION OF SOUTH AFRICA. The aim of the study is to assess the impacts of this environmental condition to farming households. I am interested in interviewing you to share your experiences and observations on the subject matter.

Please note that:

- The information that you provide will be used for scholarly research only.
- Your participation is entirely voluntary. You have a choice to participate, not to participate or stop participating in the research. You will not be penalized for taking such an action.
- Your views in this interview will be presented anonymously. Neither your name nor identity will be disclosed in any form in the study.
- The interview will take about (15 to 30min).

- The record as well as other items associated with the interview will be held in a password-protected file accessible only to myself and my supervisors. After a period of 5 years, in line with the rules of the university, it will be disposed by shredding and burning.
- If you agree to participate, please sign the declaration attached to this statement (a separate sheet will be provided for signatures)

I can be contacted at: School of Social Sciences, University of KwaZulu-Natal, Pietermaritzburg Campus, Scottsville, Pietermaritzburg. / Howard College Campus, Durban. Email: [REDACTED]  
 Cell: 0 [REDACTED]

My supervisor is Prof Maxwell Mudhara who is located at the Pietermaritzburg Campus of the University of KwaZulu-Natal.

The Humanities and Social Sciences Research Ethics Committee contact details are as follows: Ms Phumelele Ximba, University of KwaZulu-Natal, Research Office, Email: [ximbap@ukzn.ac.za](mailto:ximbap@ukzn.ac.za), Phone number +27312603587.

Thank you for your contribution to this research.

DECLARATION

I..... *(full names of participant)*  
 hereby confirm that I understand the contents of this document and the nature of the research project, and I consent to participating in the research project.

I understand that I am at liberty to withdraw from the project at any time, should I so desire. I understand the intention of the research. I hereby agree to participate.

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

SIGNATURE OF PARTICIPANT

DATE

.....

**APPENDIX C: RESEARCH ETHICS APPROVAL LETTER**

06 November 2017

Dear: **Dr Jean-Marc Mwenge Kahinda**

Approval of Protocol: **Securing multiple ecosystems benefit through sustainable land management in the productive but degraded landscapes of South Africa.**

This is to confirm that your Protocol reviewed by the CSIR REC has been approved. The reference number of this research project is **Ref: 227/2017**.

This approval is granted under the condition that:

1. The researcher remains within the procedures and protocols indicated in the proposal, as well as the additions made to the procedures and protocols as indicated in the responses submitted to the questions of the REC, particularly in terms of any undertakings made and guarantees given.
2. The researcher notes that **any deviations to the approved project/protocol must be submitted to the REC for approval before implementation.**
3. The researcher remains within the parameters of any applicable national legislation, institutional guidelines and scientific standards relevant to the specific field of research.
4. This approval is **valid for one calendar year from the date of this letter.**
5. The researcher submit bi-annual progress reports to the REC
6. The researcher immediately alert the REC of any adverse events that have occurred during the course of the study, as well as the actions that were taken to immediately respond to these events.
7. The researcher alert the REC of any new or unexpected ethical issues that emerged during the course of the study, and how these ethical issues were addressed. If unsure how to respond to these unexpected or new ethical issues as they emerge, the researcher should immediately consult with the REC for advice.
8. The researcher submit a short report to the REC on completion of the research in which it is indicated (i) that the research has been completed; (ii) if any new or unexpected ethical issues emerged during the course of the study; and if so, (iii) how these ethical issues were addressed.

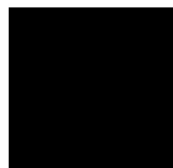
We wish you all of the best with your research project.

Kind regards



Dr Shenuka Singh

(CSIR REC Chair)



Ms Brenda Mapunya

(CSIR REC Secretariat)

***NDM English Language  
Scientific Editing  
Services***

I, **N. MAKUVAZA** hereby confirm that I have proof read and edited the Thesis of Doctor of Philosophy (Food Security)

Titled

**Impact of Land Degradation on Agricultural Productivity and Food Security of Smallholder Farming Households in Semi-Arid**

**A Case of The Greater Sekhukhune District Municipality, Limpopo Province, South Africa**

By

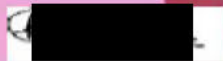
**NWABISA BUDAZA**

The Windows 'Tracking' System was used to reflect my comments and suggested corrections are given for the author to action.

During the process of proof reading and editing, the following changes were recommended: punctuation, grammatical and sentence construction and how to improve on coherence and cohesion of the document. In addition, consistency in use of abbreviations, uniformity in referencing style (intext and reference list) were given by the editor. Although greatest care was taken in editing this document, the final responsibility for the product rests with the author.

03/12/2023

Date



**Dr. N Makuvaza**

*Language and Writing and Editing Consultant*