Land reforms

LAND REFORMS:

The Impact of Land Registration on Agricultural Productivity in Kenya

DISSERTATION

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Lay Summary

This PhD dissertation has three empirical papers that investigate the impact of land tenure on sustainable agricultural productivity. The thesis aims to find out if land registration translates to tenure security which motivates farmers to increase agricultural productivity. More specifically it investigates 1) the psychological factors that influence farmers' decision-making on adopting climate resilience farming 2) the impact of land registration on cropping intensity and 3) the impact of land registration on farmers' decision-making on short-and long-term on-farm investments.

Chapter 1: Introduces the study background. It identifies a research gap whereby past studies have been inconclusive. The inconsistency can be attributed to methodologies which have used cost-benefit models paying little attention to the farmers' psychological factors. It is argued that such methodologies are unreliable, especially in Sub-Saharan African (SSA) countries where subsistence farming is dominant. This study uses behavioural and spatial econometrics to address the research gap.

Chapter 2 is a scoping study that carries baseline analysis identifying psychological factors that influence farmers' decision-making in the adoption of Climate Resilience Agriculture (CRA). The study is motivated by psychological and economics literature that indicates that regardless of the farming system, the decision to adopt farming practices is based on farmers' behaviour, hence, understanding socio-psychological factors that motivate farmers is critical in enhancing the uptake and sustainability of the practice. Using an extended TPB framework, the study finds that farmers' intention to adopt climate resilience agriculture is high but it is limited by perceived efficacy and capacity. The study finds that farmers' intention was highly influenced by perceived behavioural control (PBC); the perception that CRA adoption is under the farmers' volitional control. Other factors included farmers' age category, access to information, financial resources, and provision of professional guidance.

Chapter 3 contributes to the existing literature by examining the impact of land registration on cropping intensity using remote sensed data. Cropping intensity is used as a proxy for agricultural productivity. This study is motivated by the existing inconclusiveness of existing studies on the relationship between land tenure security and agricultural productivity. Literature suggests that the inconsistency can be attributed to a methodological approach that often consists of crop-yield models. Unlike past studies that have used cost-benefit models, the study uses a novel methodology by combining spatial econometrics and agronomic models to evaluate variations in cropping intensity on registered and unregistered farms in the study area. Normalized Difference Vegetation Index (NDVI) data covering 7 years is used as its dependent variable to measure cropping intensity in addition to farm and climatic characteristics used as

explanatory variables. Using Geographically Weighted Regression (GWR) analysis, the study affirms that land registration has a positive impact on cropping intensity and this relationship is particularly pronounced in arid and semi-arid areas (ASALs).

Chapter 4 evaluates the impact of land registration on short and long-term on-farm investments. The study contributes to the existing literature by focusing on land registration to assess whether it translates to tenure security which motivates farmers to uptake sustainable on-farm investments. Using an extended TPB framework the study carries out a cross-sectional assessment to establish the impact of land registration, and farm and farm characteristics on farmers' decision-making to uptake short- and long-term investments. The findings indicate that land registration is crucial for farmers to uptake long-term, sustainable investments. It returned the highest magnitude. Conclusively, the research upholds that land registration creates the security of tenure which motivates farmers to uptake sustainable agricultural investments in Kenya. The fifth chapter of the dissertation entails a conclusion and policy recommendations based on the results presented in each chapter.

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Abstract

Declining agricultural productivity in Sub-Saharan Africa (SSA) increases the population's vulnerability to food insecurity and poverty. The trend can be linked to climate change and the reduction in agricultural land. Sustainable utilization of land is therefore critical to meet the demand deficit. Historically, agricultural productivity has been a driver behind land reforms in Kenya. Despite this, implementation is still lagging. Past studies in SSA and Kenya have been inconclusive on the relationship between land registration and agricultural productivity. The inconsistency may be attributed to the methodologies used such as the Ricardian approach which implicitly incorporates adaptive behaviour in its analysis. Failure to account for farmers' psychological behaviour, endogeneity, unobservable heterogeneity, and spatial components further results in biased estimates and misleading conclusions. Cost-benefit models do not adequately capture the nuance in regions dominated by small-scale and subsistence farming such as Kenya. As such, the study incorporates different methodologies namely, socio-psychological models and agronomic models to add a critical layer of information for policymaking efficacy.

Using Tharaka Nithi County in Kenya as a case study, the research aims to establish if land registration creates tenure security for farmers and thus promotes agricultural productivity. To accomplish the main research aim, the study uses the theory of planned behaviour (TPB) and geographically weighted regression (GWR) techniques that have not been used for analysis in Kenya. Primary data was collected due to the unavailability of secondary data for TPB constructs. Data was derived from a sample (n=446) of farmers across 90% of the sub-locations in Tharaka Nithi County. Data on land registration status was acquired from the Ministry of Lands and digitized. In total, three separate analyses are conducted and then presented as three papers.

The study starts with a scoping study that explores the psychological factors that influence farmers' intention to adopt climate resilience farming using the theory of planned behaviour (TPB). This is based on the assumption that farmers perceptions are key to the decision-making on on-farm investments. Hence there is a need to obtain deeper insights into psychological factors that influence farmers' decision-making. It is therefore a baseline analysis for identifying farmer characteristics and the factors that influence them in decision-making to adopt climate resilience farming. An ordered logit regression was run. The analysis shows that the majority of farmers have a positive intention to adopt climate resilience farming. Attitude, perceived behaviour control, Professional guidance, resources and age(51-64yrs) are key socio-psychological factors that were found to impact farmers' decision-making to adopt climate resilience farming in Kenya.

Secondly, the study seeks to evaluate the linkage between farming intensification and land registration using a novel methodology. It applies an agronomic approach using the Normalized Difference Vegetation Index (NDVI) as its dependent variable to measure cropping intensity which is a proxy to crop productivity. The NDVI dataset used in the analysis covered 7 years and was acquired from an online database, Copernicus Global Land Service. Ordinary Least Squares (OLS) and Geographically Weighted Regression (GWR) techniques are applied for assessment at global and local levels. The explanatory variables used are land registration together with farm and climatic characteristics. NDVI was found a robust tool in identifying cropping intensity and vital for conducting assessments in the absence of reliable data such as where subsistence farming is dominant. Land registration significantly correlates to cropping intensity and the relationship is particularly significant in arid and semi-arid lands (ASALs).

The study further examines the impact of land registration on farmers' decision-making in short-and-long-term on-farm investments using the TPB framework. Alongside the traditional TPB constructs, additional constructs included resources, barriers/drivers and utility. Land registration is used as an additional variable together with farm and farmer characteristics. Farmers' intention to undertake sustainable on-farm investments is high but they perceive some limitations based on their efficiency and capacity. Provision of professional advice and access to resources were significantly correlated to farmers' intention on both short- and long-term investment. Land registration was found to have the largest magnitude of change on farmers' intention to uptake sustainable (long-term) investments. This can be attributed to land tenure security associated with land registration in Kenya. The TPB constructs, attitude and perceived barriers/drivers that impacted long-term investments are also linked to tenure security due to the creation of an assurance effect for farmers.

The study recommends fast-tracking land registration and prioritizing arid and semi-arid areas to promote sustainable agriculture. Land registration was found to have an assurance effect that motivates farmers to uptake long-term investments. It was perceived to create land tenure security that influences farmers' behaviour on locus of control, personality traits and economic preference. In line with this, the study recommends digitizing land registration data in the country and improving public access to data for further research. Noting that the majority of the farmers intended to uptake long-term investments, government initiatives should also focus on capacity building, subsidizing farming inputs to lower costs of farm improvements, and providing professional advice on sustainable agriculture at the local level. Implementation of the above policies will impact the farmers' behaviour and boost the adoption of sustainable agriculture in the country. The research findings can be replicated

in other parts of the country and SSA countries experiencing land tenure insecurity.

Keywords: Food insecurity, land registration, climate change, land tenure security, assurance effect, sustainable agriculture, psychological factors, farmers' behaviour

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List of Abbreviations

AIC	Akaike Information Criterion
ASALs	Arid and Semi-Arid Lands
GDP	Gross Domestic Product
GIS	Geographic Information System
GoK	Government of Kenya
GNDVI	Green Normalized Difference Vegetation Index
GWR	Geographically Weighted Regression
LAI	Leaf Area Index
LISA	Local Indicators of Spatial Association
LWR	Locally Weighted Regression
MoALF	Ministry of Agriculture, Livestock & Fisheries
MODIS	Moderate Resolution Imaging Spectroradiometer
NDVI	Normalized Difference Vegetation Index
NLC	National Land Commission
NDVI	Normalized Difference Vegetation Index
OLS	Ordinary Least Squares
SPOT	Satellite Infrared I 'Observation de la Terre Vegetation
SSA	Sub Saharan Africa
SUID	Soil Unit Identifier
VHI	Vegetation Health Index
VIF	Variance Inflation Factor
VIIRS	Visible Infrared Imaging Radiometer Suite
TPB	Theory of Perceived Behaviour
TRA	Theory of Reasoned Action
PCA	Principal Component Analysis

1.0 General Introduction

1.1 Context

Food insecurity is a global concern particularly in Sub-Saharan Africa (SSA), an area often cited as the most vulnerable region (Kipkulei et al., 2022; FAO 2017). Global and local policy efforts and development agendas such as the Sustainable Development Goals (SDGs), and the Malabo Declaration on Agriculture emphasize the need to increase agricultural productivity to meet SSA's food security gap and alleviate poverty (OECD-FAO, 2016). Increasing sustainable agricultural productivity is crucial given that approximately 80% of the rural population in SSA rely on agriculture for their livelihoods and rural poverty accounts for 90% of total poverty in the region (Byamugisha 2014). However, the extent to which the deficit can be met represents one of the key challenges and uncertainties facing the region (Giller et al., 2021)

Historically, productivity growth in the region was achieved by the expansion of agricultural land but this lacks feasibility due to population pressure, competing land uses and climate change amongst other factors (AU, 2019; Brink & Eva, 2009; van Wijk et al., 2019; Chamberlin et al., 2014). As such, sustainable intensification on existing farmland is called for to meet the production deficit (Wu et al., 2018; Gray et al., 2014). An emerging challenge to sustainable intensification is on farmers involvement and their role. Concerningly, literature shows that farmers' inclusion and participation in sustainable intensification in SSA remains the least globally (Zerssa et al., 2021; Zeweld et al., 2019; Mwangi & Kariuki 2015; Van der Bliek et al., 2014). There is need for further insight into farmers' perceptual and cognitive processes that influence farmers' behaviour to uptake sustainable agricultural investments in SSA. (Thompson Bethan 2021; Ngungu et al., 2018; Niles et al., 2016).

Grounded in neoclassical theories, this study identifies a gap in the relationship between land tenure security with regard to farmer psychology and agricultural productivity in SSA. Land tenure security is a critical component in agricultural productivity in SSA as optimal utilization of land is influenced by the prevailing pattern of land ownership that influences its control and usage (Yamano & Deininger, 2005). Neoclassical theories argue that land tenure security is a key factor in agricultural productivity (Swynerton, 1954; Atwood, 1990; Deininger & Feder, 2009). They posit it promotes agricultural investments by creating an assurance effect for farmers through protecting them from dispossession, conflicts and increasing confidence they will recoup their on-farm agricultural investments (Mbudzya et al., 2022; Ayano, 2018; Ng'ang'a et al., 2017; Prosterman et al., 2009; FAO 2022).

Several countries in SSA have embarked on land reforms aimed at creating security of tenure, however inequality in land ownership and landlessness are still at unacceptable levels (Byamugisha, 2016). About 90% of rural SSA lacks tenure

security leaving farmers vulnerable to conflicts, land grabbing and eviction (Byamugisha 2014). Typically, land tenure security in SSA is typically acquired through land registration (Lawry 2014). Existing literature remains inconclusive on the linkage between land registration and agricultural productivity due to studies that negate its impact. (Jacoby & Minten 2007; Abdulai & Ochieng, 2017; Abdulai & Owusu, 2014; Bromley, 2009; Bruce & Migot-Adholla, 1994; Payne et al., 2009). Hence, using original data from a cross-sectional field survey, this study seeks to provide evidence-based insights on whether land registration creates land tenure security that influences farmers' psychology in adopting sustainable agriculture. Hence this study seeks to contribute a critical data layer by addressing the nuance of farmers' decision-making in the face of different land tenure systems beyond traditional cost-benefit calculations and yield models by utilizing a novel research path combining behaviour theory and spatial econometric techniquesThe study aims to provide an empirical reference for policymakers in addressing land tenure security and sustainable agriculture in SSA

1.2 Analytical Goal

Building on neoclassical theories that postulate land tenure security is a prerequisite for agricultural productivity this study hypothesizes that; land registration creates land tenure security which motivates farmers to increase sustainable agricultural productivity (Deininger 2005). The study is motivated by several theoretical underpinnings. First, there exists inconclusive evidence on the relationship between land tenure security, particularly land registration and agricultural productivity in SSA (Bromley 2009; Peters 2009; Lund 2000; Lawry et al., 2014). Past studies on the impact of land tenure security and its impact on agricultural productivity have utilized cost-benefit and yield models. Such methodologies fail to encompass the risk and uncertainty of insecure land tenure that influences farmers' emotional and psychological processes (Qian, 2022). This study aims to provide further insight into this relationship using a different research path that utilizes spatial econometrics and behaviour theory techniques.

Secondly; past studies have primarily focused on how economic resources, demographic factors, and biophysical factors, affect the adoption of sustainable agriculture however little attention has been paid to farmer psychology in SSA (Barasa et al., 2021; Balew et al., 2014; Deininger et al., 2011; Kaptymer et al.,2019). Additionally, farmers' decision-making in a predominant subsistence farming system such as found in SSA is often driven by factors beyond product or profit maximization that traditional cost benefit approaches cannot adequately capture Thus this study seeks to provide insight into the socio-psychological factors that influence farmers in adopting sustainable agriculture. Insight into farmers perceptual and cognitive processes is crucial in tailoring more effective policies promoting sustainable agriculture (Thompson Bethan 2021; Ngungu et al., 2018; Niles et al., 2016).

Thirdly, this study was motivated by literature that theorizes farmers' behaviour and decision making is influenced by the way they perceive the security of land tenure (Broegaard, 2005; Qian et al 2022). In SSA, land tenure security is typically delivered through registering land. Land registration in Kenya focuses on individual titling of land under the communal tenure system as it is perceived to provide secure land rights (Dale, 1997). It entails the legal sanctioning of traditional land claims which are already recognized informally by the local community. The claims are made legal by measuring the boundaries of each claim, recording it in a formal state-administered land records system, and providing a state guarantee by issuing deed or title certificates to the claim that appears in the land records system (Hanstad, 1998). Land registration is expected to secure farmers' land rights as well as an instrument of national land policy to support economic development (Alban & Willem, 2020; Smuckers, 2002).

Kenya has embarked on several land reforms to create secure land tenure and increase agricultural productivity; however, few strategies explicitly focus on land tenure security to boost agricultural productivity (GOK, 2009). The Constitution (2010) and Vision 2030 highlight land registration as key to agricultural productivity, and the social, economic and political progress of the country (GOK, 2010). The country is in the process of implementing the National Land Policy (2009), Community Act (2016) Land Registration Act (2012). However, implementation is lagging with 64% percent of land still under insecure tenure systems (Kieyah & Nyagah, 2010).

This study, therefore, aims to provide a critical layer of information on land policy and agricultural productivity in the country. The study's main research question is:

- What is the impact of land registration on agricultural productivity in Kenya?

The following sub-questions are addressed;

1. What are the psychological factors that influence farmers' intentions to adopt climate resilience farming?
2. What is the impact of land registration on crop intensification in Kenya?
3. What is the impact of land registration on farmers' decision-making on the uptake of short and long-term on-farm investments?

The sub-questions form three publishable papers presented in Chapters 2, 3 and 4

1.3 Literature Review

1.3.1 Relationship between agricultural productivity and land tenure security

Past studies have indicated that land registration creates land tenure security and increases agricultural productivity by motivating farmers to uptake on-farm investments, improving factor mobility, creating access to agricultural credit, reduction in land conflicts, and creating a competitive land market (Macmillan, 2000; Tenaw et al., 2009; De Janvry et al., 2001; Yamano & Deininger 2005; Atwood,

1990; Place, 2009; Akram, et al, 2019; Ayano, 2018). Some of the studies that affirm the theory include, Brasselle (2002) who found that land registration introduced assurance, reliability, and collateralization effect that promotes farm investment; Holden et al (2009) found that land certification in Tigray (Ethiopia) increased land security, investment in trees, better management of soil conservation structures, and enhancement of land productivity; and Alston et al (1996) study in Brazil found that secure titles enhance property values and promotes farm specific investment (Brasselle et al., 2002; Holden et al., 2009; Holden et al., 2007; Alston et al., 1996). Other studies establish that redefining property rights through titling increases migration out of rural areas and increases agricultural productivity (De Janvry et al., 2015; Prosterman et al., 2009). Impact studies have confirmed that the massive land certification program in Ethiopia and the countrywide registration program in Rwanda has been associated with significant increases in agricultural investment (Deininger et al., 2005; Ali et al., 2011; Deininger et al., 2003).

In contrast, other studies note that land registration has no significant impact on agricultural productivity unless it translates to tenure security and opportunities that are associated with it (Okoth-Ogendo, 1976; Bruce & Migot-Adholla, 1994). For example, Fortin (2005), found that land registration has created insecurity rather than security for women-headed households in SSA countries where inheritance is based upon patrilineal lineage, as it exacerbates gender inequality. Bromley (2009), also found that land formalization will do little good if it is not backed up by an effective legal system and authority structure for enforcement of the rights implied by the registration. Pickney and Kimuyu (1994) found no significant relationship between land registration and agricultural productivity when they compared coffee productivity in Kenya where land was registered and in Tanzania where land was government owned. Place and Otsuka (2002) also found no significant of land registration on agricultural productivity in Uganda (Place & Otsuka, 2002). Thus, it's not certain that land registration impacts productivity unless it is perceived to create tenure security (Place & Otsuka, 2001; Okoth-Ogendo, 1976; Platteau, 1996; Bromley, 2009, Atwood, 1990).

Studies in Kenya cite land registration as one of the policies that positively impact agricultural productivity while others have found it insignificant (Alila & Atieno, 2006;). Studies by Kabubo-Mariara (2007) and Miceli and Kieyah, (2003) found land registration had a positive impact on on-farm investment and productivity (Kabubo-Mariara, 2007; Miceli & Kieyah, 2003). On the contrary, Migot-Adholla (1994), Pinckney and Kimuyu (1994) and Wilson (1971) found land registration insignificant to agricultural productivity (Migot-Adholla, 1994; Pinckney & Kimuyu, 1994; Wilson, 1971). These divergent views create a problem in that the studies are inconclusive. According to Place (2009), the divergence may be due to the methodology adopted in the studies or the land tenure security as perceived by the farmers. The studies failed to establish if farmers perceived land registration to

create security of tenure or not. Also, the methodologies used such as crop yield models or the Ricardian approach implicitly incorporate adaptive behaviour in their analysis (Di Falco et al., 2012). This may result in biased estimates and misleading conclusions due to the failure to account for both endogeneity and unobserved heterogeneity (Timmins, 2006). The approach also does not factor in spatial components which dictate the farm and climatic characteristics, and determine farm productivity. This study seeks to fill the gap by using novel methodologies that factor in farmers' heterogeneity and spatial components.

1.3.2 Land tenure security as perceived by farmers

The perceptions of land tenure security by the farmers have been cited as a major factor that directly affects farmers' land-related decision-making behaviour. Perceived land tenure security comprises psychological factors (also known as "feeling" and "thinking") that influence farmers' decision-making in agricultural investments (Qian, et al 2022). Land tenure security is expected to reduce or eliminate farmers' uncertainty and in so doing, directly affect farmers' decision-making behaviour (Broegaard, 2005, Van Gelder, 2010). According to Qian (2022), such psychological factors have important implications for future research and policymaking. This study incorporates social and psychological factors that influence farmers' decision-making in the uptake of agricultural investment relating it to perceived land tenure security.

Perceived tenure security lacks a consistent way of measurement since it is an individual perception of the sense of security and emotional fears farmers have regarding their property rights (Broegaard, 2005). Additionally, investment in land involves both emotional and psychological factors due to the cultural, historical and symbolic meanings that influence the farmers' decision-making (Chigbu and Klaus, 2013).

Thus, the taxonomy of farmers' psychology which includes personality characteristics, locus of control or economic preference is important in policy making (Van Gelder, 2007). Understanding the psychology of the farmers is therefore important given that farmers' perceptions may serve as a bottleneck in decision-making. Deeper insights into perceived land tenure security and psychological determinants are key in decision-making. According to Qian (2022), such perceptions may generate corresponding feelings such as worry, fear and insecurity which past studies on land tenure security have overlooked. Hence, aspects of perceived land tenure security which is affected by psychological factors of the farmers are still unknown (Qian, et al 2022). This study uses the theory of planned behaviour model aimed at exploring the farmers' psychological factors that would influence their decision-making in investing in sustainable agriculture.

1.3.3 Chronology of land policy reforms in Kenya

Kenya has over a half-decade of history of land reforms dating back to the colonial era that involves land registration. The white highlands were the first to be registered to protect the interest of the white colonizers. Land policies during the colonial period emphasized individual land ownership. These included first, the Devonshire White Paper (1923) which Asians called for the reservation of land for their use like the white highlands. Secondly, the Report on Land Commission (1933) emphasized delineating all the land along tribal lines while the third and fourth policies the Swynerton Plan (1954) and the East African Loyal Commission (1953-1955) emphasized individual ownership to improve land productivity. Report of the Mission on Land Consolidation and Registration 1965-1966, emphasized consolidating fragmented farms into an economic parcel to increase efficient use of labour by obviating the need to walk to scattered plots.

After independence, the Kenya government entrenched the inherited land policies by enacting laws that emphasized individual land registration, among them the Land Adjudication Act, Registration of Lands Act, Registration of Titles Act, Land Titles Act, Government Land Act, and Trust Land Act among others. Due to the many laws governing land by then, there was poor management of land in the country resulting in land grabbing and land conflicts. The government in its effort to resolve the land issue in the country appointed two commissions, one was the Njonjo Commission (1999) named after its chairman and was mandated to study the existing Land Laws in pursuance of harmonizing them. The second was the Ndung'u Commission (2004) also named after its chairman and which was tasked with investigating illegal/irregular allocation of public land to identify those who had acquired public land illegally/irregularly and developing a mechanism of making the culprits accountable (Kieyah & Mbae, 2010; Manji, 2012).

The recommendations of the two reports were never implemented by the government that was then in power (Bassett, 2017). However, following the publishing of the National Land Policy (2009) and the promulgation of the Constitution (2010), some of the recommendations raised especially in the Njonjo report have now been implemented especially on harmonizing the laws. The laws that have been enactment include the Land Act (2012) and Land Registration Act (2012) which harmonized the existing land laws, and second the National Land Commission Act (2012) which provided guidelines for the implementation body. The above policies assert that securing land rights contributes to social and economic development and guarantees tenure security.

1.4 Relevance and Research Gap

Due to population growth, urbanization and climate change, scarce land and resources are leading to major food insecurity and mostly in SSA. Kenya is one of the countries experiencing low agricultural productivity with over 5.4 million

under severe food insecurity (Bhavnani et al., 2023). The main question is how the agricultural systems can meet the needs of the growing population sustainably. Existing literature indicates that current agricultural systems have the potential to increase productivity but require policy transformations (Alban & Willem, 2020; Giller et al., 2021; FAO, 2017). Some of the strategies recommended include the adoption of climate resilience agriculture (CRA), conservation agriculture, and agro-forestry (World_Bank 2021; Ochieng et al., 2016). Other studies have recommended land reforms as a key component in promoting sustainable agricultural productivity (Deininger, 2005). However, SSA countries have been slow in adopting agricultural and land reforms (Zeweld, et al. 2019; Mwangi & Kariuki 2015; Byamugisha, 2014).

This demonstrates the need for further research to ensure policy coherence and synergy. This research recognizes the key role that farmers' perceptions and behaviour play and aims to find out the behavioural factors that would create an enabling environment to increase agricultural productivity (Goedde et al., 2019, Mizik, 2021; von Ketteler 2018). Most of the SSA countries have embarked on land registration as a means to create land tenure security. Studies have however been inconclusive and this can be attributed to methods used that are limited in accounting for farmers' social and psychological heterogeneity and spatial components (Qian, 2022; Place, 2009; Khan, 2011). This study seeks to fill this gap using novel methodological approaches. The study uses spatial econometrics and behavioural models that capture the dynamics of heterogenous regions such as Kenya and farmer dynamics beyond cost-benefit models (Knowler & Bradshaw 2007; Liu et al., 2013). This is driven by the knowledge that Kenya and SSA at large are characterized by subsistence farming and smallholder farming systems (Brown, et al. 2017, FAO, 2023; Mbithi & Mutiso 1974). Hence, data is often unreliable or missing. Moreover, farmers in such a system are more likely to be driven by factors outside profit maximization which yield models may fail to adequately capture.

The aim is to establish if land registration creates land tenure security that influences the farmers to adopt sustainable agricultural practices. The analysis is based on three objectives as follows; (i) to examine the psychological factors that influence farmers' intention to adopt climate resilience agriculture; (ii) to evaluate how land registration impacted crop intensification; (iii) to assess the impact of land registration on farmers' decision-making in short and long-term on-farm investments. The study seeks to provide empirical evidence for policymakers. Although land tenure security is identified in various policies such as the Constitution and Kenya's Vision 2030 as a strategy to increase agricultural productivity, tenure insecurity persists in the country. The study is key in the provision of deeper insights into the relationship between farmers' behaviour, land registration and agricultural productivity. There are no existing studies in Kenya to our knowledge that have used TPB and spatial econometrics in assessing the impact

of land registration on agricultural productivity, and the study will go a long way in adding to the knowledge gap.

1.5 Methodological Approach

The thesis consists of three empirical chapters 2-4 that form its core. Chapter 2 addresses the first research objective which is to assess the psychological factors that influence farmers to adopt climate resilience agriculture. It is a scooping study and baseline analysis for the thesis that utilizes a behavioural theory approach specifically the extended TPB framework to establish socio-psychological factors that influence farmers' intentions in agricultural investments. The TPB framework in Chapter 2 models farmer characteristics and includes a novel construct (actual behavioural control) which strengthens the model. Chapter 3 addresses the second research objective, to evaluate the impact of land registration on cropping intensity. It hypothesizes that land registration incentivizes farmers to undertake cropping intensity. This chapter employs an agronomic approach and spatial econometric techniques which is novel and facilitates a move beyond global models to account for spatial heterogeneity of geographically varying factors. Chapter 4 addresses the third research objective which is to evaluate the impact of land registration on short-and-long-term on-farm investments. It also adopts a behavioural theory approach using an extended TPB framework to evaluate the impact of land registration and socio-psychological factors on farmers' intention to make on-farm investments. The TPB model includes additional constructs for the usefulness of the investment practices and the barriers to their uptake. The chapter hypothesizes that land registration is perceived by the farmers to provide security of tenure, which motivates them to undertake sustainable investments. The study provides additional and new information for policymakers and extension agents to enhance the adoption of sustainable agriculture.

Below is a summary of the conceptual framework, materials and methods used while more detailed descriptions of the methodology are presented in each chapter.

1.5.1 Conceptual framework

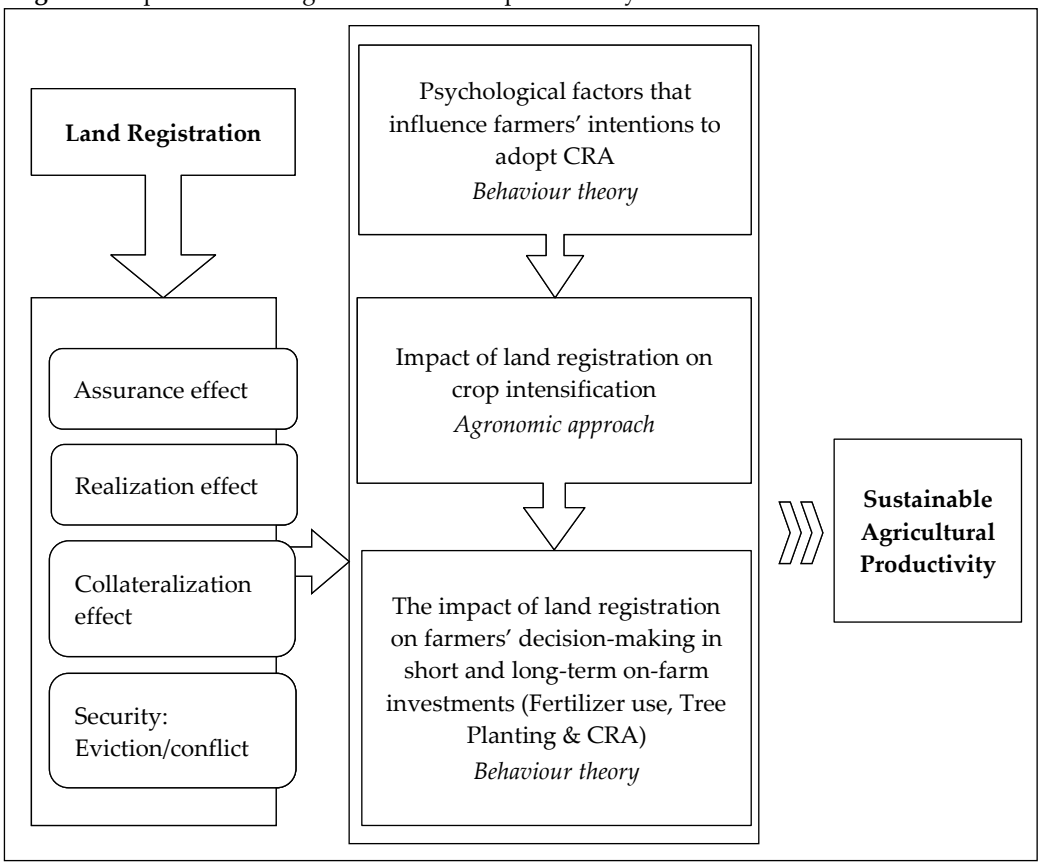
According to Ahmad et al (1999), growth in agriculture that is sustainable and appropriate is only possible if all the factors of production are accessible to all strata of the farming community, hence access to land, land redistribution and increased inputs are key to growth in sustainable agriculture. This is grounded on neoclassical theories that aver that land registration is a precondition for land productivity (Deininger,2005). It is assumed that firstly; land registration creates secure land rights that create incentives for the land owners and investors to undertake long-term related investments that would increase productivity. Secondly, it promotes the usage of land as collateral to borrow credit from the banking system, the funds acquired are used to purchase agricultural inputs especially machinery and intermediate inputs such as seeds, pesticides, fertilizers and others. Such inputs

improve the quality and quantity of the output which boosts the land tenure security that exists when farmers have enforceable rights to their land, are protected from dispossession or conflicts and are psychologically contented that they will reap the benefits of their investment (Prosterman et al., 2009; FAO 2022).

Thirdly, land registration creates secure land rights that reduce the risks and transaction costs in the market, thus increasing the allocative efficiency where the best productive users have access to land. This encourages the investors to acquire/lease large agricultural land to enjoy economies of scale. The competitive land market also raises land values benefiting the land owners willing to lease or sell their land (Deininger, 2004; Besley, 1995). Fourthly, the study assumes that secure land rights minimize land conflicts caused by undefined boundaries or "intruders" in communally-owned land. The absence of conflicts encourages investors to invest in sustainable long-term on-farm investments such as land terracing, planting of trees, irrigation systems, and infrastructure among others (Place, 2009). Insecure land tenure on the other hand encourages investment in seasonal crops that may not be environmentally sustainable but can be harvested easily to lower the risk

The perceptions of farmers on land tenure security created by land registration are cited as a major factor that directly affects farmers' land-related decision-making behaviour. Land registration is theorized to create land tenure security through an assurance effect, that eliminates uncertainty and risk factors, directly motivating the farmers' uptake of sustainable investments that increase agricultural productivity (Broegaard, 2005, Van Gelder, 2010)

Figure 1: Impact of land Registration on Land productivity



Source: Author Conceptualization

1.5.2 Data

The study scope is limited to one County in Kenya due to constraints in accessing data on land registration. Land registration data is only available in hardcopy which is acquired from the Ministry of Lands and then digitized. There are no government records on unregistered land boundaries and as such, data is acquired from the 2019 Landsat acquired image (USGS, 2022). Roads and natural boundaries such as fences, rivers, or trees were used for farm boundaries.

Data on TPB constructs, farm and farmer characteristics

In analyzing farmers' behavioural factors that influence their decision-making, chapters 2 and 4 of the study used raw data from a cross-sectional survey for the TPB constructs. Chapter 2 which is a scoping study uses TPB constructs for analysis, and Chapter 4 which is a comparative analysis of short and long-term investments uses an extended TPB model that incorporates land registration status. To obtain acceptable county representation, the survey framework was based on sub-

locations (the smallest administrative unit in Kenya), where farm sampling was carried out. Systematic random sampling and snowballing techniques were used during data collection to minimize biases. Systematic sampling was applied in the densely populated sub-locations where data collection would be done on every fifth farmer. Snowballing was used in sparsely populated areas, whereby the farmer would advise on the location of the next farmer. A total of 446 farms were sampled. Data was collected from 90% of the sub-locations while the remaining 10% of the sub-locations were inaccessible due to poor terrain and inaccessible infrastructure. The data was collected on an ordered pre-defined 5-point Likert-type scale based on the extent to which the farmers agreed (strongly disagreed (1), disagree (2), neither (3), agreed (4), and strongly agree (5) with the proposed statements to make it easier for analysis using TPB methodology.(Appendix D)

Data on NDVI, and climatic and land characteristics

To evaluate crop intensification on registered and unregistered farms, in Chapter 3, climatic and land characteristics which included average annual temperature and rainfall, soil types, and altitudes (elevation) were generated from national satellite spatial datasets under the World Resources Institute site (Kenya Metrological Department, 2022; WRI, 2007). For soil quality, SUID was used which refers to soil units, each defined by a combination of soil properties like drainage, bulk, texture, and class (Global Yield Gap Atlas, 2022)[1]. NDVI images dataset was acquired from Copernicus Global Land Service. The NDVI data used for analysis was for 7 years (2014-2020). The data is derived from the VITO NV site which runs on behalf of the European Commission Joint Research Centre (JRC, 2022). It is collected using a sentinel-3 sensor which provides quality surface-level vegetation data generated by synergistic and co-situated optical instrument measurements similar to those from the Vegetation instrument on SPOT, and with full earth coverage in one to two days.

1.5.3 Methodology

Theory of Planned Behaviour

A TPB framework was used in chapters 2 and 4. TPB is an appropriate framework based on behaviour theory as it allows for the inclusion of additional predictors which can enhance a model's accuracy (Ajzen 1991). Chapter 2 is a scoping study that addresses research objective 1 to examine farmers' intention to adopt CRA. It aims at understanding farmers' characteristics and psychological factors that influence their decision-making on on-farm investments. The dependent variable is 'intention' which is an ordinal variable based on past studies that assert measuring the dependent variable requires an ordered 5-point Likert scale (Malhotra & Birks, 2007; Wauters et al., 2010). The application of the theory goes beyond traditional

[1] SUID: Soil Unit Identifier. Defined by a combination of soil properties like drainage, bulk, texture, and class (Global Yield Gap Atlas, 2022)

cost-benefit calculations by considering community-level behaviours ("social norms"), attitudes (perceived importance of a benefit) and capabilities, which are usually missed out in traditional analyses.

The additional TPB variable in Chapter 2 is actual behaviour control, that is, the resources that may affect a farmer's behaviour such as lack of money, local politics, and family commitments. Other additional variables used are farm and farmer characteristics (gender, land size, marital status, age, and education level). Chapter 4 goes further in gaining insight into farmers' psychological perspectives given comparative situations. It addresses objective 3 which examines the impacts of land registration on farmers' intention to uptake short and long-term on-farm investments. The additional TPB constructs used in Chapter 4 include utility (USE); the level to which farmers find the practice being assessed advantageous and useful and, perceived barriers/drivers; factors farmers perceive affect their behaviour such as lack of money, local politics, land registration and family commitments. Other additional variables for farm and farmer characteristics included farm size, gender, marital status, age group, education level and lastly land registration status which aims to give insights into farmers' perceived land tenure security.

Several empirical methodologies are employed in both Chapters 2 and 4. First, all the TPB variables are validated and confirmed using principal component analysis (PCA). An ordered logistic regression model is then used to examine the influence of the TPB and additional variables on farmers' intention. Ordered logistic regression analysis is used to predict the probability of occurrence of an event when the dependent variable can take more than two categories of response (Timprasert et al. 2014; Daxini et al. 2018). Past studies posit that there are challenges in interpreting the results from ordinal logistic regression and in comparing across samples and models, due to the problem of unobserved heterogeneity (Kneafsey & Regan, 2020). Hence, average marginal effects (AME) analysis is applied to describe the magnitude of change in explanatory variables used in the ordered logit regression. AME is robust to unobserved heterogeneity (Kneafsey & Regan, 2020).

Spatial Econometrics

Chapter 3 entails the second objective of evaluating cropping intensity in registered and unregistered farms in the study area. Cropping intensity is used in this study as a proxy for crop productivity (Tao et al., 2022; Li et al., 2019). The paper uses agronomic models with the Normalized Difference Vegetation Index (NDVI) as its dependent variable to measure cropping intensity. The NDVI dataset used for analysis covers 7 years (2014-2020) acquired from Copernicus Global Land Service. Thematic variables are mapped for initial data exploration of the spatial variation and distribution in Tharaka Nithi. The study then uses the exploratory regression tool in ArcGIS 10.4 to choose a regression model by eliminating collinearity and endogeneity. NDVI is used as the dependent variable while land registration is used as an explanatory variable together with farm and climatic characteristics,

temperature, rainfall, elevation and soil quality. The study then selects variables that made intuitive sense based on AIC, R^2, p-values and VIF values (Philippe et al., 2019; ESRI, 2018)

Ordinary Least Squares (OLS) and Geographically Weighted Regression (GWR) analysis are applied to assess the relationship between cropping intensity and land registration. OLS is limited as it is a global model. The assumption of a spatial uniformity of the explanatory variables' effect on the dependent variable fails to account for geographic variations (Brunsdon et al. 1996). Local regression models like GWR are therefore more precise in that they account for spatial heterogeneity (Fotheringham, et al., 2003). Unlike OLS, GWR incorporates spatial heterogeneity by generating parameter estimates for each location of interest (Oshan et al., 2020).

The study runs LISA Statistics tests (Moran's Tests & Gettis-Ord GI* Statistic) to identify and measure the spatial autocorrelation degree and to define localized density (ESRI, 2023; Rowe & Arribas Bel, 2022; Fotheringham, 2009; Anselin, 1995). GWR allows the exploration of the explanatory parameters' relationship to the dependent variable accounting for this spatial heterogeneity. The GWR model identifies details not identified in a global model (OLS) by accounting for spatial non-stationarity and revealing the varying degrees of the parameters' influence (Oshan et al., 2020; ESRI 2018).

1.6 Case Study Context

1.6.1 Kenya's Agricultural Context

The agriculture sector is vital to the country's development. It contributes 33% of the country's GDP, and 27% of GDP indirectly, while contributing 65% of exports (World Bank, 2021). The sector is highly correlated to the growth of the national economy, with 40% of the population directly employed in agriculture of which 70% is rural population (FAO, 2023). The majority of the farmers are smallholders with farms measuring 0.2-3 ha, accounting for 78% of total agricultural production. Subsistence farming is also predominant with approximately 75% of the production consumed at the household level (GDC, 2017).

Past studies have noted that the majority of the farmers are poor, and therefore increase in productivity is associated with poverty reduction in the country. However, due to climate change, and heavy reliance on rain-fed cultivation, the yield has been declining particularly maize production (World Bank, 2021). According to Wiggins (2018), Kenya has experienced a decline in agricultural productivity on direct contribution from 40% in 1963 to approximately 20% in 2022. The production decline has been attributed to the high cost of farming inputs, lack of financial resources, poor fertilizer/seeds variety, lack of knowledge on adaptation methods, low access to extension officers, erratic weather patterns, lack of infrastructure and poor market access (CBK, 2023). Climate change and extreme weather variabilities are significant challenges to productivity given the high

reliance on rain-fed farming despite 80% of the country being ASALs (Birch, 2018). Approximately 41 thousand hectares of agricultural land are under irrigation in Kenya, which is less than 0.2 of the total agricultural land (KNOEMA, 2022). Thus, policies that would strengthen the agricultural sector would alleviate overall poverty.

1.6.2 Tharaka Nithi County Context

The County lies to the South of the equator between latitudes 000 07' and 000 A26' South and between longitudes 370 19' and 370 46' East. It has an area of approximately 2,660 km². Administratively the county is divided into 5 sub-counties, Tharaka North, Tharaka South, Chuka, Igambang'ombe and Maara. They are subdivided into 53 locations and 134 sub-locations. The main physical feature of the County is the Mt. Kenya forest in Maara, Chuka and Igambang'ombe. Total forested land is approximately 770 km², (GOK 2014). The topography is characterized by hilly terrain and lowlands with several streams and rivers that drain into the Indian Ocean through the Tana River (GOK 2018).

The county falls under two main agroecological zones. The highlands (upper zone) are located in the west, whereas the semi-arid regions (lower zone) are located in the northeast and Southern tip of the County. The upper zone has reliable rainfall, averaging 2,000mm, and temperatures ranging 14°C-30°C, with mixed, rain-fed farming being practised in the area. The lower zone has an average of 500mm annual rainfall and temperatures between 22°C-36°C with agro-pastoralism as the main activity (GOK, 2018; MoALF, 2018). Tharaka Nithi County experiences a bi-modal rainfall pattern marked by long rains from March to May followed by short rains from October to December (Shisanya et al., 2011; Wawire, 2021).

Population density is largely influenced by the climate and ecology whereby areas with good climatic conditions and fertile soils generally have dense populations. The county has a population of approximately 3,900,000 and a population density of 153 persons per km² with a growth rate of 3.0%. Overall, 35% of the total population lives in absolute poverty and 40% suffer from food insecurity. The County has a 77% rural population. This is reflective of Kenya which has a 71% rural population. 80% of Tharaka Nithi's County population relies on agriculture for food, income and livelihood (GOK, 2018). This reaffirms the importance of agriculture in the County.

Farming in the county occupies 54% of the total area and is predominantly small-scale and subsistence (O'Neill, 2023; KNOEMA, 2022). The average farm holding is 2.9 ha. Most farmers practice mixed farming which is a combination of crop farming, and goat and cattle herding. In the semi-arid region, the dominant staple crops are sorghum, millet, cowpeas and green grams, while in the wetter midlands (900mm+), the main staple crop grown is maize and subsistence dairy farming. Below 900mm, farmers rely mostly on goats, sheep, cattle, and poultry. Cash crops include tea, coffee and tobacco (MoALF, 2017; GOK 2018). The major challenges to

agricultural production in the county include high weather variability and climate change. Since crop farming is mainly rain-fed, it is therefore characterized by frequent crop failures especially in semi-arid regions (MoALF, 2017). Farming activities are largely based on human labour, (GOK 2021).

1.7 Structure of Thesis

This thesis is divided into 5 chapters. The research questions form three publishable papers. While care has been taken to avoid repetition, there is some overlap in the description of the case study context and data. The thesis is structured as follows:

Chapter 2: Psychological Factors that Influence Farmers' Intention to Adopt Climate Resilience Agriculture.

The chapter is a scoping study aimed at understanding psychological factors that influence farmers' decision-making in the adoption of climate resilience agriculture. The chapter uses an extended TPB framework to identify critical elements that impact farmers' decision-making on adopting CRA. The chapter includes a literature review, theoretical framework for the study, detailed materials and methods section, results, discussion on the statistical findings, policy recommendations and further areas of research recommended. Results indicate that attitude, perceived behaviour control, professional guidance, resources and age (51-64 yrs) are key socio-psychological predictors of farmers' decision-making on the adoption of CRA in Kenya. The chapter concludes that policies geared at capacity building of farmers at local levels and targeting the age groups would increase farmers' adoption of CRA in Kenya.

Chapter 3: Evaluating Cropping Intensity in Registered versus Unregistered Farms

The chapter evaluates the level of crop intensification in registered and unregistered farms using an agronomic approach. Significant variations in cropping intensity based on land registration status would indicate that land registration creates land tenure security that motivates farmers to intensify farming. The study runs a GWR analysis to account for spatial heterogeneity. The chapter also factors in farm and climatic characteristics in statistical analysis. The chapter presents both descriptive and statistical results as well as policy recommendations and future areas of research from the findings. Overall, the results demonstrate that land registration has a statistically significant correlation to cropping intensity which is a proxy for agricultural production. This relationship is more significantly pronounced in ASALs. Land registration status is conclusively found to have a higher impact on cropping intensity variations in the County than climatic characteristics. The chapter concludes that policies on fast-tracking land registration should target ASALs as priority areas.

Chapter 4: Impact of Land Registration on Short-and-Long-Term On-farm Investments

The chapter goes further in gaining insight into farmers' psychological perspectives given comparative situations while verifying the findings in Chapter 3. It addresses the third research question on the impact of land registration on short- and long-term investments using an extended TPB framework. In addition to the TPB constructs, the study uses additional variables namely farm and farmer characteristics and land registration status. It has a detailed literature review, theoretical framework and materials and methods section. The chapter presents the results from the analysis, and policy implications and recommends further areas of research. In sum, the chapter finds that while the provision of professional advice and access to resources were significantly correlated to farmers' intention on both short- and long-term investments, land registration has the largest magnitude of change on farmers' intention to uptake long-term investments. This can be attributed to the farmers' perceived land tenure security associated with land registration in Kenya.

Chapter 5: Conclusion

This chapter summarizes the thesis' main findings and conclusions and policy implications from all the chapters. The section also details study limitations and potential areas of further research. The findings of this research are important for the future design of policies that could help increase agricultural productivity. The main conclusion is that land registration has a positive impact on farmers' psychology in agricultural on-farm investments in Kenya. This can be related to the farmers' perception that land registration creates tenure security and motivates them to adopt sustainable on-farm investments. Therefore, fast-tracking of land registration with priority to ASALs should be prioritized. Additional policy measures should include, capacity building to improve farmers' livelihood status, subsidizing farming inputs, improved access to agricultural advisors and farmer-based learning models. The policy measures should be tailored at the local level to increase efficacy.

2.0 Psychological Factors that Influence Farmers' Intention to Adopt Climate Resilience Agriculture

Abstract

Agriculture is the economic mainstay in most African countries, contributing 20-30% of their gross domestic product (GDP). In Kenya, agriculture contributes about 24% of the GDP and employs over 70% of the rural population. Due to reliance on subsistence and rain-fed agriculture in Kenya, there is low productivity and the adoption of climate resilience agriculture (CRA) would promote productivity. However, despite initiatives in promoting CRA strategies from international and local institutions, there is a low adoption rate. This study examines the psychological factors influencing farmers' intention to adopt CRA practices in the country. It assumes that apart from resources, farmers' psychological factors have important implications on the uptake of agricultural investments. The study uses the theory of planned behaviour (TPB) where social and psychological factors are presumed to influence the intention to adopt various CRA strategies. A field survey was conducted due to the unavailability of secondary data. Structured questionnaires were administered to sample farmers in Tharaka Nithi County in Kenya. Farmers perceived that adopting CRA would increase agricultural productivity. Significant predictors that influenced intention included perceived behaviour control (PBC), age (51-64yrs), professional guidance, resources and attitude. Conclusively, farmers have a positive intention to adopt CRA, but they are limited by low professional guidance and resources. The study recommends policy strategies subsidising farming inputs and providing professional guidance at the local level. Such strategies are expected to lead to a snowballing effect on agricultural productivity that can meet national and local goals.

Keywords; climate change, psychological factors, sustainable agriculture, Theory of planned behaviour

3.0 Evaluating Cropping Intensity in Registered versus Unregistered Farms

Abstract

Due to climate change, conventional farming has placed considerable stress on agricultural land leading to food insecurity and low agricultural productivity. Sustainable farming intensification is required to meet the deficit and demands of a rapidly increasing population. This study seeks to provide insight into the linkage between farming intensification and land tenure security. Existing literature on this relationship is inconsistent and largely based on crop yield models. As such, this study seeks to extend the literature using a novel methodology. The study hypothesizes that land registration in the country creates land tenure security which motivates farmers to adopt farming intensification increasing agricultural productivity.

Using Tharaka Nithi County in Kenya as a case study, this study employs an agronomic approach using the Normalized Difference Vegetation Index (NDVI) as its dependent variable to measure cropping intensity which is a proxy to crop productivity. Geographically Weighted Regression and Ordinary Least Squares analysis are applied for assessment at global and local levels. The model incorporates land registration as an explanatory variable together with farm and climatic characteristics; elevation, rainfall and temperature.

NDVI was found a robust tool in identifying cropping intensity and vital for conducting assessments in the absence of reliable data such as where subsistence farming is practised. The study found land registration positively impacts cropping intensity and the relationship is particularly significant in arid and semi-arid lands (ASALs). Thus, this study recommends fast-tracking land registration and prioritizing ASALs to incentivize farmers to adopt farming intensification for increasing agricultural productivity. The findings can be replicated in other parts of Kenya and Sub-Saharan Africa (SSA) countries experiencing land tenure insecurity. Further research based on agronomic models is recommended to enrich the literature on agricultural intensification.

Keywords: cropping intensity, land registration, Normalized Difference Vegetation Index (NDVI), Geographically Weighted Regression (GWR)

4.0 Impact of Land Registration on Short and Long-Term on-farm Agricultural Investments

Abstract

Farmers' uptake of sustainable agricultural production is lagging across Africa. Poverty and policy limitations are some of the factors identified as impediments to the adoption of sustainable agricultural practices in Sub-Sahara Africa (SSA). Further insight into factors influencing farmers' decision-making in SSA is required for pragmatic policy formulation to increase farmers' adoption of sustainable agriculture.

Using Tharaka Nithi County in Kenya as a case study, this paper evaluates how land registration impacts farmers' decision-making in agricultural investments. The study employs an extended theory of planned behaviour (TPB) model and incorporates barriers/drivers and utility as additional constructs. Farm and farmer characteristics variables incorporated include age, marital status, education, gender, farm size, and land registration status. A bespoke survey was used due to the unavailability of secondary data on TPB constructs.

The study conclusively finds that farmers' intention to undertake on-farm investments is high but they perceive some limitations based on efficacy and capacity. Notably, land registration impacted had the highest magnitude of impact on farmers' decision-making in long-term investments. Professional advice and resources were found to impact both short- and long-term investment decisions. The study, therefore, recommends fast-tracking land registration to promote sustainable agricultural practices. Secondly, government initiatives should focus on capacity building to improve farmers' livelihood status and lower the costs of farm improvements. Lastly, professional advice from agricultural advisors on sustainable farming should be provided at local levels. This study adds to the discourse on the magnitude to which land policy impacts sustainable agriculture.

5.0 General Conclusion

5.1 Introduction

This study examines the impact of land registration on agricultural productivity using evidence from Kenya. It explores if land registration creates security of tenure that influences farmers' psychology in sustainable farming practices. The research was motivated by several reasons that include; low agricultural productivity in SSA; population pressure; climate change; low farmer uptake of sustainable agriculture in SSA despite increasing initiatives; and lagging land reforms in SSA. Theoretically, the research is motivated by inconclusive evidence from existing literature on the linkage between land registration and agricultural productivity; predominance of subsistence farming in SSA which adds nuance to farmer decision-making beyond profit maximization; and reduces data reliability for traditional cost-benefit models Therefore, grounded in neoclassical theories, the study sought to fill a knowledge gap by utilizing a novel research path in agricultural productivity in SSA. The study uses behavioural models and spatial econometrics techniques to add a critical layer to production models that crop yield and cost-benefit models cannot adequately capture. The study uses remote-sensed data in GWR analysis and original data in extended TPB models. The findings are key in providing evidence-based results that support agricultural and land policy reforms in the country as well as identifying areas for further research.

To answer the research question, three studies were formulated to investigate (i) psychological factors that influence farmers' intentions to adopt climate resilience agriculture; (ii) the impact of land registration on cropping intensity and; (iii) the impact of land registration on farmers' decision-making in short and long-term on-farm investments.

The rest of the chapter is structured as follows, Section 5.2 articulates the main research findings per chapter, identifying the academic contribution and areas of further research; Section 5.3 discusses the study contribution, 5.4 discusses policy implications based on the findings and finally, section 5.5 discusses the study limitations, section 5.6 recommends areas of further research and section 5.7 concludes the overall study.

5.2 Study Summary

The findings are presented in the form of statements from each of the three research questions. Findings are briefly summarised, identifying the policy implications, academic contribution and areas of further research.

Statement 1: Psychological factors that influence farmers' intentions to adopt climate resilience farming

Chapter 2 addresses research objective 1 using an extended TPB model to examine farmers' intention to adopt CRA. This is a scoping study that establishes farmers' psychological factors that influence the adoption of CRA in Kenya and SSA at large. The study evaluates the influence of TPB constructs and additional farm & farmer characteristics on farmers' intention to adopt CRA. An analytical contribution of this study is the use of the additional TPB variable actual behaviour control (ABC), that is, the resources that may affect a farmer's behaviour such as lack of money, local politics, and family commitments. Other additional variables used were farm and farmer characteristics (gender, land size, marital status, age, and education level). The study gave deeper insights into the farmers' psychological factors that influence them in decision-making to adopt agricultural investments.

Principal Component Analysis (PCA) was carried out as a standard methodology in TPB analysis to re-express multivariate data into relatively few components that capture the maximum variation and underlying patterns From the PCA analysis, six components are retained for predicting the new explanatory variables that are factored into the ordinal logistic regression. They include attitude, perceived behaviour control (PBC), subjective norms, resources, professional advice, and perceived barriers/drivers.

A descriptive analysis indicates that 89 %. of the farmers had positive intention to adopt CRA accounting for approximately. Ordered logit regression analysis shows that out of the six PCA components, only four are statistically significant to farmers' intention. They include attitude, PBC, resources and professional advice. Average Marginal Effects (AME) Analysis was run based on past studies that indicate it is a robust measure of heterogeneity that improves the interpretation of ordered logit regression results (Kneafsey & Regan, 2020). The analysis indicated the PBC resulted in the highest magnitude of change in farmers' intention; followed by the perception that CRA adoption is under the farmers' volitional control, and by age (51-64yrs), resources and professional guidance respectively.

Analytically, the study contributes to the existing literature by the use of original data collected in a field survey. Secondly, the use of additional constructs, ABC and farm & farmer characteristics is novel and improves the overall accuracy of the TPB model used. Thirdly, the results indicate the suitability of the TPB framework for the study context and demonstrate that socio-psychological variables can provide insight into farmers' decision-making process on adopting CRA. Lastly, the study adds TPB constructs that can be used for further studies. For instance, the findings show the provision of professional advice as a key

additional predictor of farmers' intention and this can be explored in future studies.

The study recommends policies aimed at increasing agricultural productivity should focus on creating an assurance effect to the farmers (that it is within their volition control), and farmers' capacity building. through the provision of subsidies on agricultural inputs, and providing professional advice at local levels. This is in line with existing agricultural and land reform policies in the country.

Further research that would enrich the findings should establish the actual behaviour after the agricultural subsidies and professional guidance are provided as past studies have shown that intention does not always translate to actual behaviour.

Statement 2: Impact of land registration on crop intensification

Chapter 3 addresses research objective 2, using Geographically Weighted Regression (GWR) analysis, which evaluates the impact of land registration on cropping intensity. Cropping intensity is used in this study as a proxy for crop productivity. The paper utilizes an agronomic approach using the Normalized Difference Vegetation Index (NDVI) for 7 years (2014-2020) as its dependent variable. The land registration, farm and climatic characteristics are used as explanatory variables in the regression model.

Initial exploratory analysis on heterogeneity and correlations indicated that climatic characteristics were correlated and thus the best-fit model chosen incorporated elevation and land registration. The parameter estimates demonstrated that land registration has a larger range of impact on NDVI variation than elevation, especially in the arid and semi-arid zone (Lower Zone) than in the upper zone (Highlands). In the Lower zone, NDVI is higher in registered sections, indicating the relationship between NDVI and registration is highly significant. Overall, registration status has a significant impact on the variation of NDVI in registered areas than unregistered areas in regions in the Lower zone. This suggests NDVI is higher in registered land in comparison to unregistered land. A hot-spot analysis on GWR residuals to evaluate density distribution at a localized level also confirms the findings. Unregistered land and especially in the semi-arid zone had cold spots significant at 99% confidence and hotspots significant at 99% confidence were mainly in registered land.

The chapter contributes to academic knowledge and research in several ways. First, the use of remotely sensed data captures data that is often unavailable or unreliable especially where subsistence farming is predominant. Secondly, the data is readily available and cost-effective, hence suitable for research on large-scale such as county level. The findings are in line with existing government policies that recommend land registration as an intervention to promote

agricultural productivity in the country. The study recommends fast-tracking land registration, especially in ASALs to motivate farmers to practice cropping intensification to increase agricultural productivity. Further research using agronomic models is recommended in other parts of the country as well as SSA countries experiencing insecure land tenure and low agricultural productivity.

Statement 3: The impact of land registration on farmers' decision-making in short and long-term on-farm investments

Chapter 4 addresses research objective 3 using the Theory of Planned Behaviour (TPB) to evaluate farmers' intention to uptake short or long-term on-farm investments. The paper aims to reassess the findings of paper 2 using farmers' psychological lens. The use of fertilizer is classified as a short-term investment, while climate resilience agriculture (CRA) and planting of trees are classified as long-term investments. The study uses an extended TPB approach with intention as the dependent variable. Explanatory variables include TPB constructs and additional TPB construct utility (USE), land registration status, and farm and farmer characteristics. Using Principal Components Analysis (PCA), seven explanatory variables were derived, namely attitude, perceived behaviour control (PBC), subjective norm, barriers/drivers, usefulness, professional advice, and resources. The regression model included the 7 principal components together with land registration status, farm and farmer characteristics.

A descriptive analysis of intention showed that the majority of the farmers had positive intention to uptake. both short and long-term on-farm investments (71% fertilizer use, 89% adopt CRA, 92% planting trees). All TPB constructs were positively statistically significant on farmers' intention to invest in long-term investments but only ATT, SN, barriers and drivers were statistically insignificant on short-term investments. On farm and farmer characteristics, education level is statistically significant to farmers' intention on short-term investments while land registration and age have a significant correlation to intention to adopt long-term investments.

Average Marginal Effects (AME) describing the magnitude of change in explanatory variables indicated that education level, followed by PBC has the highest impact on farmers' intention to adopt short-term investments with 8% and 6% on the use of fertilizer respectively. On the other hand, land registration has the highest magnitude on long-term investments at 9% and 12% change for CRA and Trees respectively, followed by PBC and professional guidance at 5% for both CRA and Trees. The findings are in line with the studies that hypothesize that land registration creates tenure security which motivates farmers to uptake long-term investments but has no impact on short-term investments.

The results provide insight into farmers' decision-making on sustainable on-farm sustainable investments. Land registration created land tenure security that

creates an assurance effect on the farmers, which influenced them to adopt long-term investments. On the other hand, unregistered land was found to create insecure land tenure exposing farmers' vulnerability to land conflicts and acquisitions which influenced them to adopt short-term on-farm investments. This has been demonstrated by chapters 3 and 4 where crop intensity was higher in registered land and farmers' intention to adopt long-term investments had a higher magnitude in registered land respectively This study has proved the hypothesis demonstrating that land registration creates tenure security that correlates to farmers' intention to uptake long-term investments.

Policies that seek to promote sustainable agricultural investments in the country should advocate for land registration as it creates security of tenure motivating farmers to uptake sustainable on-farm investments. The research also found professional advice from agricultural advisors as key to sustainable farming but should be tailored to local levels due to low education levels among other factors. Further studies are recommended in other counties in the country to validate the findings. Such findings would build a strong case to fast-track land registration. Further research is also needed to assess the actualization of farmers' behaviour vs intention concerning land registration and sustainable agricultural practice, to analyze policy efficacy and impact on farmers' behaviour. Due to the lack of secondary data, there is a need for a data collection centre to build a reliable database platform for use by farmers, researchers and the public in future.

5.2.1 Synthesis of the main results

This section discusses key findings from the three empirical studies (Chapter 2, Chapter 3 and Chapter 4) in the context of the wider literature.

- ***Farmers' social and psychological attributes are key in decision-making to adopt agricultural investments***

Chapter 2 gives insights of farmers' psychological factors that influence them in decision-making to adopt climate resilience farming. The key finding indicates that perceived behaviour control (PBC), which entails the farmers' assurance effect that their on-farm investments are within their control to reap the benefits without uncertainties. Attitude and age-group 54-61 were second and third respectively. Attitude is associated with the farmers' negative or positive evaluation of agricultural investments depending on the output that they expect. In the age group, 54-61 are retired people whose means of livelihood is farming, making it their only choice. Chapter 4 affirms the findings in chapter 2, whereby land registration was found to have the highest magnitude in influencing farmers to adopt sustainable investments. This is attributed to the land tenure security associated with land registration that creates an assurance effect to the farmers.

important to note that the majority of the sampled farmers had a positive intention to uptake both short and long-term on-farm investments (71% fertilizer use, 89% adopt CRF, 92% planting trees). This high intention can be attributed to the high reliance on rain-fed agriculture, subsistence farming, and the high significance of agriculture on farmers' livelihood where over 80% of the rural population rely on the sector for food, income and livelihood (GoK, 2018). The County is also adversely impacted by extreme weather variabilities and climate change increasing the risk of crop failure, especially in the drier sections (MoALF, 2017). As such, the majority of farmers have positive intention to undertake sustainable agriculture to increase yield. There have also been several initiatives in the country targeting agriculture, Tharaka Nithi county is identified as one of the at-risk Counties for climate change and has a running CRA Program 2015-2030 (Newell, et al. 2019, World Bank 2015). This direct policy intervention may translate to farmers' positive intentions to adopt climate resilience farming and tree planting.

- ***TPB is a suitable framework in the study context***

The findings are in support with previous studies that confirm TPB is an appropriate framework for assessing farmers' behaviours and attitudes (Micha et al., 2015; Borges & Oude Lansink, 2016; Lalani et al., 2016; Zeweld et al., 2017; Jiang et al., 2018). The TPB framework is suitable, especially in areas which predominantly practice subsistence farming such as the study area to give further insight outside of profit-maximization incentives. Unlike cost-benefit models, the TPB examines the complexities of a farmer's attitudes and behaviours which are not driven solely by profit (Goforth, 2015).

Additionally, the findings support existing literature that theorizes that socio-psychological issues must be considered when assessing farmers' decision-making (Borges et al., 2014; Zeweld et al., 2017). In chapters 2 & 4 attitude and perceived behaviour control were more significant predictors to intention than subjective norms. This is similar to previous studies that have found subjective norm (pressure from others) to be the weakest predictor of intention in voluntary contexts. The results show farmers perceive undertaking farm improvements to be under their volitional control and view the improvements to be of benefit to them. This further validates the finding that farmers are willing to undertake farm improvements but often lack the efficacy and capacity to do so.

The TPB framework allows for the inclusion of additional predictors beyond the constructs of the theory, as noted in previous studies to provide comprehensive insight (Wauters et al., 2010; Garforth, 2010). In Chapter 2, the study included 'utility' which measured the factors that may affect a farmer's behaviour such as lack of money, local politics, and family commitments. The study also included farm and farmer characteristics such as gender, land size, marital status, age, and

education level. The additional TPB constructs in Chapter 4 include utility (USE); the level to which farmers find the practice being assessed advantageous and useful and, perceived barriers/drivers; factors farmers perceive affect their behaviour such as lack of money, local politics, land registration and family commitments. Chapter 4 also incorporates land registration status amongst other farm and farmer characteristics. The additional predictors improved the TPB model's capacity to explain underlying mechanisms that influence farmers' decision-making processes. Thus, the framework is versatile to a wide range of studies.

- ***NDVI was a fitting proxy for cropping intensity***

NDVI is the most widely used vegetation index in remote sensing as it is effective in assessing plant growth and yield through an entire crop season. NDVI has also been found suitable for assessing large tracts of land such as the County with spatial-temporal variations. It is cost-effective in obtaining large-scale temporal data whereby field surveys would be time-consuming, expensive and sometimes unreliable. For instance, Chapters 2 & 4 highlight a key limitation in acquiring field survey data due to inaccessible terrain in the county. Multiple studies have found NDVI to have a high correlation with crop health and yield (Pettorelli et al., 2007; Wittemyer et al., 2007; Piekarski & Zwoliński, 2014; Andersen et al., 2004). Studies have also found NDVI as key in determining crop yield variations (Anghileri et al., 2022; Kourouma et al., 2021; Janin et al., 2009; Zhang et al.,2016). The paper additionally tested other vegetation variables such as dry matter production, forest cover and leaf area index which were found to have a high correlation to NDVI further attesting to its suitability. The use of spatial data was also found robust in measuring agricultural productivity in predominantly subsistence farming where crop yield data is often missing or unreliable. The majority of the farmers in the study area are subsistence farmers, 80% of maize produced is consumed at the household level and doesn't reach the markets (GDC, 2017; Kipkulei et al., 2022). As such the use of remotely sensed data was found reliable as NDVI is capable of tracking plant growth and yield over a cropping season.

- ***Land registration creates tenure security which positively impacts crop productivity***

There has been inconsistency in the existing literature on the relationship between land registration and agricultural productivity particularly in SSA. The study sought to fill this gap and evaluate the impact of land registration on agricultural productivity using several empirical methodologies. Overall, the thesis conclusively finds a positively significant correlation between land registration and agricultural productivity. Chapter 3 demonstrated that the land

registration parameter has a significant correlation to NDVI from both OLS & GWR analysis. NDVI is generally higher in registered areas of the county than in unregistered areas with a large variance in arid and semi-arid areas. The GWR analysis further proved that the land registration parameter (coefficients range: -0.024672 to 0.167589) had a larger magnitude of effect on NDVI than climatic characteristics (coefficients range: 0.00013-0.001384). The findings in Chapter 4 verified the results. Land registration was found to have the highest magnitude on the farmers' likelihood to uptake long-term agricultural investments but insignificant on short-term investments. The TPB constructs attitude and barriers/drivers that impacted long-term investments are also linked to tenure security due to the creation of an assurance effect on farmers' investments. Inferring from this, farmers' perception of tenure security impacts their decision-making on agricultural investment. This is in line with existing literature which indicates that land tenure security increases farmers' probability of investing in long-term on-farm improvements but has no impact on short-term investments (Akram et al., 2019; Chand & Yala, 2009; Fenske, 2011; Obunde et al., 2004; Place & Hazell, 1993). Hence, land registration is translated to land tenure security in Kenya.

- ***GWR analysis is a robust methodology for evaluating the impact of land tenure security on agricultural productivity***

The GWR model explores details not identified in a global model (OLS) by accounting for spatial non-stationarity and revealing the varying degrees of the parameters' influence (Oshan et al., 2020; ESRI 2018). The study found climatic characteristics (elevation, rainfall, temperature) and farm characteristics (registration status, soil quality) variables as having high collinearity and endogeneity. Semi-arid regions (lower zones) are characterized by low elevation, high temperature, and low rainfall while the highlands (upper zones) have high elevation, high rainfall, and low temperatures. The best-fit model included elevation and registration. Study findings established that NDVI is higher in areas with high elevation however changes in impact on NDVI were less detectable in the highlands than in semi-arid regions. This can be associated with favourable climatic conditions in high-elevation areas that contribute to higher vegetation density without necessarily high input from the farmer. Thus, farmers' inputs are a key factor that influences change in NDVI in semi-arid regions. GWR methodology is reliable in this study since it incorporates spatial heterogeneity and as such, similar models can be replicated in other studies

- ***Land registration had a higher impact on agricultural productivity in semi-arid areas.***

Assessing the vulnerability of ASALs to low agricultural production is crucial in the face of climate change and extreme weather variabilities. In addressing the research question on how land registration impacts cropping intensity, chapter 3 illustrates the vulnerability of the semi-arid zone in the study area. The OLS results indicated a general declining trend with NDVI being lowest in the semi-arid zone and highest in the Upper zone, proximal to Mt. Kenya. From the GWR results, a positive relationship between NDVI and climatic characteristics is observed in the County's semi-arid zone. The GWR local R^2 map illustrates NDVI is lowest in unregistered land, to the far-east and the southern tip. This corresponds to the semi-arid zone/lower zone of the county.

Observed NDVI was highest in high-elevation areas (proximal to Mt Kenya) in registered land and lowest in low-elevation areas with unregistered status. This indicates that farmers in semi-arid areas intensify farming when they perceive land tenure security as they have the reassurance that they will be able to recoup any investment. Semi-arid areas have a higher risk of land conflict due to scarcity of resources and as such farmers are reluctant to intensify farming in the absence of tenure security. The finding is in line with previous studies that postulate land tenure security incentivizes farmers to increase agricultural productivity. Notably, variation of NDVI is more easily detected in the semi-arid regions than in the highlands. This is because a variation in the highlands is not easily reflected as favourable climatic conditions are conducive for all types of vegetation unlike in semi-arid regions.

- ***While land tenure security is an important motivator in increasing sustainable agricultural productivity, it is not sufficient on its own***

Although land registration created an assurance effect for farmers, it is not adequate on its own. Professional advice was found to influence farmers' intention to adopt sustainable agricultural practices. In Chapter 2, if farmers received guidance from government land experts and agricultural advisors, their likelihood to adopt CRA increased by 4%, while in Chapter 4 professional guidance from agricultural advisors and discussion groups increased the likelihood to uptake both short-term investments and long-term investments by 2%. Secondly, the availability of resources influenced farmers' intention to uptake farm investments. Chapters 2 and 4 highlights that access to information and financial resources increased farmers' likelihood to uptake sustainable agricultural practices by 4%, and 3% respectively. Other factors included age, with the base age category (54-61 years) having the highest magnitude of change at 6% on farmers' intention. This is attributed to the average age of farmers in Kenya and SSA (60 years) which falls within this category (Birch, 2018). Existing

literature has shown that the majority of retirees move to rural areas and start farming (GoK 2018). Other factors that were found to influence agricultural investments included climatic factors, local politics, and low farm public investments.

5.3 Research Contribution

Studies on the relationship between land registration and on-farm productivity have been inconclusive, particularly in SSA. This is critical since arable land is limited, yet the majority of the population, over 60% especially of the rural poor in sub-Saharan countries depend on agriculture for their livelihood (Bluffstone & Kohlin, 2011). In Kenya, several policies such as Vision 2030 and Agricultural Policy 2021 have recommended land registration as a strategy to increase agricultural productivity (MoALF, 2021)The country is equally in the process of implementing the National Land Policy, Land Registration Act of 2012, Land Act of 2012, National Spatial Plan of 2015-2045, and Community Land Act of 2016 anchored in the 2010 Constitution that identifies land registration as a prerequisite to securing land rights (Wily, 2011). Though these policies and legal frameworks are in place, implementation is still slow.

This study has established that land registration creates the security of land tenure which positively impacts agricultural productivity in Kenya. This has been demonstrated through study findings that show farmers' intention to uptake long-term investments is significantly correlated to registration status. Further analysis has found significant variance in crop intensification in registered land as compared to unregistered land, especially in arid and semi-arid areas. The findings fill the gap of divergent views from past studies. Place (2009) argues that the divergence may be due to the methodology adopted in the studies. While past studies have adopted cost-benefit models, this study has explored the use of spatial econometrics and socio-psychological approaches (Geographically weighted Regression and Theory of Planned Behaviour) that are reliable and robust frameworks for this and similar studies.

The study recommends further studies using spatial econometrics and socio-psychological approaches, especially in SSA countries with insecure land tenure and where subsistence farming is predominant and yield data may not be reliable.

5.3.1 Methodological contributions

- ***Original data***

Due to the unavailability of secondary data, a cross-section survey was carried out in Kenya-Tharaka Nithi County. The field survey entailed the administration of questionnaires to the farmers based on random sampling and snowballing methodologies. The raw data was collected on farmers' household characteristics, land tenure characteristics, household crop yield, farmers' access to information,

credit and remittances, and TPB constructs. This adds vital knowledge to the literature, the data can also be used for further studies.

- ***Theory of Planned Behaviour***

Chapters 2 and 4 used an extended Theory of Planned Behaviour (TPB) framework to assess the psychological factors that influence farmers' intention to uptake sustainable agricultural investments. First, the study extends the existing literature by adding two significant constructs to the TPB framework namely professional advice and resources. The constructs were found statistically significant in the study and hence can be used for similar studies. Secondly, past studies on agricultural productivity have focused on cost-benefit models that do not adequately assess the complexities of farmers' psychological motivators/impediments that go beyond profit maximization, especially in predominantly smallholder and subsistence farming systems (Cullen et al., 2020). The use of extended TPB methodology gives a detailed assessment of psychological and socio-economic factors affecting farmers' decision-making on agricultural investments. This enables the provision of a more comprehensive outlook on farmer behaviour and decision-making process. It also provides a rational approach for policy-makers in designing policies that promote sustainable agriculture. Finally, past studies posit that secure land rights incentivize farmers to undertake long-term related investments that would increase productivity. The studies in SSA that have used TPB methodology in agricultural research have however neglected farmers' decision-making process based on the different land tenure systems (Brown et al., 2017; Kreft et al., 2020; Kaptymer et al., 2019). Thus, the study included land registration status, farm and farmer characteristics variables that improved the TPB model's explanatory power in evaluating farmers' decision-making on sustainable agriculture.

- ***Geographically Weighted Regression***

Chapter 3 uses spatial econometrics which is a novel methodology to evaluate the impact of land registration on agricultural intensification. Spatial econometrics adds a critical layer to production models that crop yield models cannot capture, such as spatial-temporal variations (Anghileri et al., 2022; Kourouma et al., 2021; Khan, 2011; Janin et al., 2009). To account for spatial autocorrelation that is common in spatial data, spatial econometrics deals with spatial interaction (spatial autocorrelation) and spatial structure (spatial heterogeneity) in regression models for cross-sectional data (Anselin, 2003). Geographically Weighted Regression (GWR) methodology was used for the study with Normalised Difference Value Index (NDVI) as the dependent variable. The GWR model gives finer details not identified in a global model (OLS) by accounting for spatial non-stationarity and revealing the varying

degrees of the parameters' influence on NDVI (Oshan et al., 2020; ESRI 2018). The extraction of 7 years of NDVI data was done from online databases Copernicus Global land service and the average NDVI was analysed in ArcGIS. The methodology identified the relationship between land registration and cropping intensification in the county using the 7 years of data. The methodology is reliable and such studies can be replicated in other areas, use of spatial data in research is also timely because it is available and cost-effective compared with field surveys.

5.3.2 Substantive contributions

This study is grounded on neoclassical theories that posit that land tenure security is a prerequisite for agricultural productivity (Obeng-Odoom, 2012; Atkins, 1988). The study hypothesized land registration creates secure land tenure that motivates farmers to invest in sustainable agricultural productivity. To test the hypothesis, three study objectives were formulated.

The first objective presented in Chapter 2 was a baseline analysis aimed at identifying the socio-psychological factors that influence farmers' intention to adopt climate resilience agriculture. The study conclusively finds five factors that impact farmers' decision-making in adopting climate resilience agriculture. The probability of adopting climate resilience agriculture increases if a farmer falls within the base age category (51-64yrs); if they perceive adopting the practice to be within their ease (PBC); if they have access to information and financial resources; if professional advice is provided by government land experts and agricultural advisors and if they perceive the practice will result in desirable outcomes for them (attitude).

The second objective outlined in Chapter 3 aimed to examine the impact of land registration on crop intensity which was used as a proxy for agricultural productivity in registered and unregistered farms. This objective sought to add to the existing discourse whereby some studies argue that land registration has no impact on agricultural productivity unless it translates to tenure security (Okoth-Ogendo, 1976; Migot Adholla, 1994; Fortin, 2005; Bromley 2009; Pinckney & Kimiyu 1994; Place & Otsuka 2002) while others posit that land registration increases farmers investment in on-farm productivity (Ali et al.,2011; De Janvry et al., 2015; Prosterman et al., 2009; Tenaw et al., 2009; Deininger & Feder, 2009; Akram, et al, 2019; Ayano, 2018). The chapter hypothesized higher levels of crop intensification would be found in registered farms. The study found land registration to be positively correlated to cropping intensity. Land registration was found to have a greater impact on cropping intensity in the ASAL region. Additionally, the analysis demonstrated that land registration had a greater impact on variation in cropping intensity than farm and climatic characteristics. In sum, the study finds that land registration has a positively significant relationship with agricultural production, especially in ASALs.

Chapter 4 aims to verify the findings in Chapters 2 and 3 by establishing the impact of land registration on farmers' decision-making in investing in short- or long-term on-farm investments. This is attributed to the assurance effect created by land registration on the farmers that impact their psychological attributes. The chapter hypothesized that land registration translates to tenure security that influences farmers' psychology to invest in sustainable agricultural productivity namely climate resilience agriculture and tree planting. The study found five cross-cutting factors that impact farmers' decision-making on investing in sustainable agriculture. Land registration had the highest impact on farmers' decision-making. Other cross-cutting factors such as the perception that investing in the practices is within their volitional control (PBC), the practices would result in positive outcomes (attitude) and the practices would be useful to them (utility) are also linked to tenure security. Land tenure security creates an assurance effect that farmers will recoup and benefit from their investments. In addition to land registration, other factors that impacted farmers' decision-making on long-term investments were the provision of professional guidance from agricultural advisors and discussion groups and the availability of resources.

The study builds on the neoclassical theories by verifying that land tenure security motivates farmers to adopt sustainable agricultural practices. The use of spatial econometrics and socio-psychological approaches have shown a novel way of analysing agriculture productivity where subsistence farming is practised. The findings uphold that land tenure security influences farmers to adopt sustainable farming through intensification and long-term on-farm investments. This is in agreement with past studies that indicate that tenure security is important for behavioural incentives yet it has received the least explicit attention in the literature (Murken & Gornott, 2022; Holden & Ghebru, 2016). The study also gives a comparative assessment of psychological and socio-economic factors affecting farmers' decision-making in sustainable agriculture. This enables the provision of a rational approach for policy-makers in designing policies that promote sustainable agriculture by incorporating farmers' psychology into consideration.

- ***Generalizability***

The research findings can be replicated in other parts of Kenya and SSA countries experiencing land tenure insecurity and low agricultural productivity. First, the study area has two climatic zones, the highlands (upper zone) and arid areas (lower Zones) which makes it suitable for countries with either both or any climatic zone. Secondly, food security is a global concern and international studies aim to identify strategies that can increase agricultural productivity

(FAO, 2017). The study affirms that land registration creates tenure security and motivates farmers to adopt sustainable agricultural practices that increase agricultural productivity in Kenya. Lastly, the methodologies used are applicable in all similar studies since it departs from the regular cost-benefit analysis which is not reliable in subsistence farming where input and output data are not dependable. However due to the size of the study (one county out of 47 counties in the country), further studies are recommended to validate the findings.

5.4 Policy Implications

Globally, the study underpins Sustainable Development Goals (SDG) and Paris Agreement targets among others that advocate the need to accelerate land tenure security to mitigate climate change effects, increase sustainable development, and preserve nature (Garnett et al., 2018; Holland & Diop, 2022). International organizations such as FAO, World Bank, and the United Nations have actively been involved in the campaigns and implementation of land tenure security policies because they would alleviate poverty, especially in SSA (World Bank, 2021)

In SSA, land tenure systems were communal or state-owned, but due to population growth, food insecurity and climate change, African countries have adopted new policies and laws aimed at increasing land tenure security through land regularization. The study points towards various policy recommendations as governments across Africa seek to boost agricultural productivity. Past studies are inconclusive on the impact of land registration on land productivity, some indicate that it promotes agricultural productivity, and others have found that it leads to conflicts that reduce productivity (Cotula et al., 2004). The study affirms that land registration creates tenure security which is key in promoting sustainable agricultural productivity. The findings offer different dimensions for policymakers to tailor more efficient solutions.

The study discusses various policy implications and their different levels of targeting (National & County/local) for efficacy. First, it recommends fast-tracking of land registration with priority in the arid and semi-arid areas. Secondly, digitization of land data for future research. That should include public access to such data for research. Given that resources and professional guidance were influential to farmers' intention to invest in sustainable practices, government initiatives should focus on promoting farmers' capacity building through training and economic empowerment. Incentives can be built based on discussion groups and subsidized inputs at local levels.

The findings will enhance the country's policy frameworks on land tenure security and sustainable agriculture. This is engulfed in the country's key policies among them; the 2010 constitution and Vision 2030 which emphasize climate change adaptation and promoting land reforms. Other policies include Climate Smart Agriculture Strategy, National Adaptation Plan 2015-2030, Special

Presidential Programme on the national tree growing restoration campaign (seeks to promote sustainable agriculture by increasing national tree cover to 30% by 2032), National Spatial Plan 2005-2045, National Land Policy 2009 among other policies. The research outcomes provide an evidence-informed finding that supports the implementation of policies aimed at strengthening land tenure security and promoting agricultural productivity. In light of the study, policies that seek to promote sustainable agricultural investments in the country should advocate addressing land registration as a priority to other hindrances.

5.5 Limitations

This study has some limitations that should be considered when interpreting the results and the policy recommendations. The use of behavioural factors and geostatistical analysis aimed at using novel methodologies that would give in-depth data for subsistence farming where yield data for cost-benefit analysis are not reliable. Such analysis however has some limitations as explained below.

5.5.1 Theory of Planned Behaviour (TPB)

Rational choice models, such as the TPB, implicitly assume that individuals make rational decisions by carefully calculating the costs and benefits of different courses of action and selecting the options that maximise their expected overall benefits (Yazdanpanah & Forouzani, 2015, Gardner & Abraham, 2008). This may not be the case in our study where the majority practise subsistence farming whereby cost-benefit assessments may not be feasible. Their choice may also be influenced by past behaviour, such as habits which are not included in the TPB framework though past studies have shown that it impacts farmers' decision-making processes in agriculture (Nuthall & Old, 2018).

Secondly, the TPB does not consider contextual factors that may impact behaviour. It assumes that behaviour is solely based on an individual's intention to perform it, but it ignores environmental, social, and cultural factors (Fishbein & Ajzen, 2010). For example, access to resources like water and food can affect the likelihood of an individual carrying out a particular behaviour. Thus, further studies should include such factors in the extended TPB model to improve its consistency.

Third, the TPB method does not test for implementation of the intention. The study does not determine how the intention to adopt a behaviour differs from actual adoption. Past studies indicate that there may be significant differences between intended and actual behaviour (Borges et al., 2016; Daxini et al., 2018; Niles et al., 2016; Rezaei, 2018). This study, therefore, recommends further studies on intention versus implementation of the same and especially in the same area after the implementation of the recommended policies.

Lastly, the use of primary data for TPB constructs. Behavioural methodology limits the use of secondary data because behaviours are not static. The

methodology therefore limits the area of study because field surveys have to be conducted within the research time bound which is costly. For our study, a county was used as a case study due to limited time and the high cost.

5.5.2 Geographically Weighted Regression (GWR)

First, agronomic models use remotely sensed data with limited crop-specific information. NDVI is a commonly used index to monitor vegetation health and productivity. However, NDVI may not be effective in differentiating between crops with similar growth patterns (Sagar et al., 2016). Secondly, NDVI data is available on a large scale which is not very appropriate for analysis on small-scale farms. In our study, the best available data was Copernicus Global Land Service data at 300mX300m cell size. This limits the analysis at the farm level where small-scale farming is practiced.

5.5.3 General limitations

Due diligence is required in generalizing the findings since Kenya and specifically Tharaka Nithi County may not be similar to other counties or countries. Farmers' intentions and agricultural practices may be affected by other factors such as cultural, environmental and economic factors that are not applicable in other areas and which are not accounted for in the study.

5.6 Further research

Based on the methodologies used in this research, further studies are recommended to support the existing theories and develop new theories that would validate the impact of security of tenure on agricultural productivity. Future studies should focus on,

- Evaluation of the actualization of farmers' behaviour vs intention regarding land registration and sustainable agricultural practice. The study has conclusively found that land registration creates security of tenure and motivates farmers to increase agricultural investments. Further studies would establish the actualisation of the same when registration is done.
- In Kenya, a study on the impact of the policy and legal initiatives on farmers' behaviour is crucial. Tree planting has been a strictly regulated sector in the country. In 2010, the government passed legislation to ensure 10% of agricultural land is forested. However, implementation by the farmers has slacked. In Chapter 4, subjective norm (pressure from others) was significantly correlated to tree planting but AME results revealed it had no significant effect. Past studies have found SN to significantly impact mandatory policies. Thus, further research would reveal farmers' psychological factors causing the low uptake.
- Further studies are also recommended to establish the rate of conflicts in registered lands on both highlands and ASALs farms. This is based on

past studies that have indicated that land registration intensifies conflict (Peters, 2009; Lund, 2000). The study would assess the impact of conflicts on agricultural productivity.

- The study has found that the base age group (51-64) had a positive impact on on-farm investments. Further studies are recommended to establish socio and psychological factors that drive each age group to adopt sustainable agriculture.
- Further studies are recommended to establish the impact of parks and conservation areas on land tenure security. In Chapter 3, the thesis highlights an anomaly that was attributed to the study area's complex interactions with Meru National Park as its buffer zone exacerbating land tenure insecurity (KWS 2006; West et al., 2006; Nyamweya, 2014).
- Lastly, further studies are recommended to assess the impact of land tenure security on agricultural productivity in Kenya and SSA using agronomic models. Few studies have used agronomic models in this area, if many more are done, they can better capture the crop diversity that exists in mixed farming systems which the study was not able to identify.

5.7 Main Conclusion

The dissertation builds on existing literature that explores the impact of land tenure security on agricultural productivity. The study examines the impact of land registration on farmers' intention to uptake sustainable agricultural investments. Findings demonstrate that land registration creates secure land tenure in Kenya which motivates farmers to invest in sustainable agriculture. This is demonstrated by the high intention of farmers to uptake agricultural intensification and long-term on-farm investments. Thus, land registration is expected to protect the interest of farmers as well as be an instrument of national land policy to support economic development. Fast-tracking of land registration is therefore recommended, prioritizing ASALs to promote sustainable agriculture.

Secondly, the methodologies used in this thesis are recommended for further studies to assess factors that promote agricultural productivity and land policy implementation in other areas. Unlike the methodologies that rely on crop yield, the agronomic and socio-psychological models were found reliable where crop yield data is unavailable or unreliable such as in areas where subsistence farming is predominant. TPB is a useful framework for evaluating the factors that impact farmers' intention to uptake sustainable agricultural practices. The agronomic models' framework is robust and cost-effective, particularly for regions with predominant subsistence, and small-scale farming where yield data is unreliable or unavailable. The agronomic model is also replicable in areas with high spatial-

temporal variations such as SSA due to the use of techniques such as GWR which account for spatial heterogeneity.

Third, farmers indicated that they were limited in accessing information and resources to adopt sustainable agriculture. Government initiatives should therefore focus on capacity building to improve farmers' livelihood status through, the provision of professional advice, promote learning models such as farmers discussion groups, subsidizing farming inputs and lowering costs of farm improvements. Policy formulation and information dissemination should be tailored towards local levels through government experts, agricultural advisors and farmer-led learning models such as discussion groups.

Lastly, the extent of the study area was limited by the acquisition of data, on registered and unregistered farms where the author had to purchase hard-copy maps and digitize them. The collection of primary data was also costly and time-bound. This limited the extent of the study to one county. In line with this, the study recommends digitizing land ownership data in the country and establishing a data Centre that can provide public access for research.

The research findings are relevant to other parts of Kenya and SSA countries experiencing land tenure insecurity and low agricultural productivity. The methodologies used are replicable as they account for heterogeneity and spatial variation. Further studies are recommended to enrich the study findings.

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Appendix A

Appendix A1: Interpreting Kaiser-Meyer-Olkin Tests Results

KMO Value	**Explanation**
0.00 to 0.49	unacceptable
0.50 to 0.59	miserable
0.60 to 0.69	mediocre
0.70 to 0.79	middling
0.80 to 0.89	meritorious
0.90 to 1.00	marvelous

Appendix A2: Principal Component Analysis (Loadings>0.30)

	Component1	**Component2**	**Component3**	**Component4**	**Component5**	**Component6**
VARIABLE	Attitude	Subjective Norm	Barriers/ Drivers	Perceived Behaviour Control	Professional guidance	Resources
I am confident in my ability to do so PBC[24]1				0.43		
It is under my control to do so PBC2				0.56		
It depends entirely on me PBC3				0.55		
It is easy to do so PBC4				0.36		
Increases productivity ATT[25]1	0.43					

[24] PBC_Perceived Behaviour Control
[25]ATT_Attitude

Produces better quality crop ATT2						
Increases profits ATT3	0.40					
Reduces input costs ATT4	0.33					
Saves time ATT5	0.35					
Improves soil fertility ATT6	0.40					
Helps to protect environment ATT7	0.37					
Is expensive ATT8						0.58
Likelihood to follow family SN[26]1						
Likelihood to follow agricultural advisor SN2					0.57	
Likelihood to follow discussion group SN3		0.42				
Likelihood to follow government land experts SN4					0.58	
Likelihood to follow local		0.44				

[26] SN_Subjective Norm

leaders Politicians SN5						
Likelihood to follow media SN6		0.47				
Likelihood to follow legal professional SN7		0.34				
Likelihood to follow other SN8		0.41				
How lack of money has affected ABC[27]1						0.61
How access to information has affected ABC2						0.37
How local politics has affected ABC3			0.39			
How family has affected ABC4			0.52			
How low farm output has affected ABC5			0.36			

Appendix A3: Average Marginal Effects

		Delta-method				
	dy/dx	**Std. Err.**	**z**	**P>z**	**[95% Conf.**	**Interval]**
Attitude						
_predict						
1	-0.00175	0.000997	-1.76	0.078	-0.00371	0.000199

[27] ABC_Actual Behaviour Control

2	-0.00417	0.001865	-2.24	0.025	-0.00783	-0.00052
3	-0.00599	0.002546	-2.35	0.019	-0.01098	-0.001
4	-0.01448	0.005592	-2.59	0.01	-0.02544	-0.00352
5	0.026396	0.009761	2.7	0.007	0.007265	0.045528
Subjective norm						
_predict						
1	-0.00079	0.000772	-1.02	0.307	-0.0023	0.000723
2	-0.00188	0.001707	-1.1	0.271	-0.00522	0.001468
3	-0.0027	0.002422	-1.11	0.266	-0.00744	0.002051
4	-0.00651	0.005674	-1.15	0.251	-0.01763	0.00461
5	0.011872	0.010315	1.15	0.25	-0.00835	0.03209
Barriers and Drivers						
_predict						
1	-0.00013	0.000775	-0.17	0.865	-0.00165	0.001388
2	-0.00031	0.001842	-0.17	0.865	-0.00392	0.003297
3	-0.00045	0.00264	-0.17	0.865	-0.00562	0.004726
4	-0.00109	0.006377	-0.17	0.865	-0.01358	0.011413
5	0.00198	0.011627	0.17	0.865	-0.02081	0.024769
Perceived Behaviour Control						
_predict						
1	-0.0041	0.001932	-2.12	0.034	-0.00789	-0.00031
2	-0.00976	0.002806	-3.48	0.001	-0.01526	-0.00426
3	-0.01402	0.0035	-4	0	-0.02088	-0.00715
4	-0.03385	0.008258	-4.1	0	-0.05004	-0.01767
5	0.061728	0.011635	5.31	0	0.038925	0.084532
Professional guidance						
_predict						
1	-0.00235	0.00131	-1.79	0.073	-0.00492	0.000221
2	-0.00558	0.002158	-2.59	0.01	-0.00981	-0.00135
3	-0.00802	0.002914	-2.75	0.006	-0.01373	-0.00231
4	-0.01937	0.007117	-2.72	0.006	-0.03332	-0.00542
5	0.035317	0.011674	3.03	0.002	0.012437	0.058196
Resources						
_predict						
1	-0.00235	0.001349	-1.74	0.082	-0.00499	0.000297
2	-0.00558	0.002474	-2.26	0.024	-0.01043	-0.00074
3	-0.00802	0.003465	-2.31	0.021	-0.01481	-0.00123
4	-0.01937	0.007713	-2.51	0.012	-0.03449	-0.00425

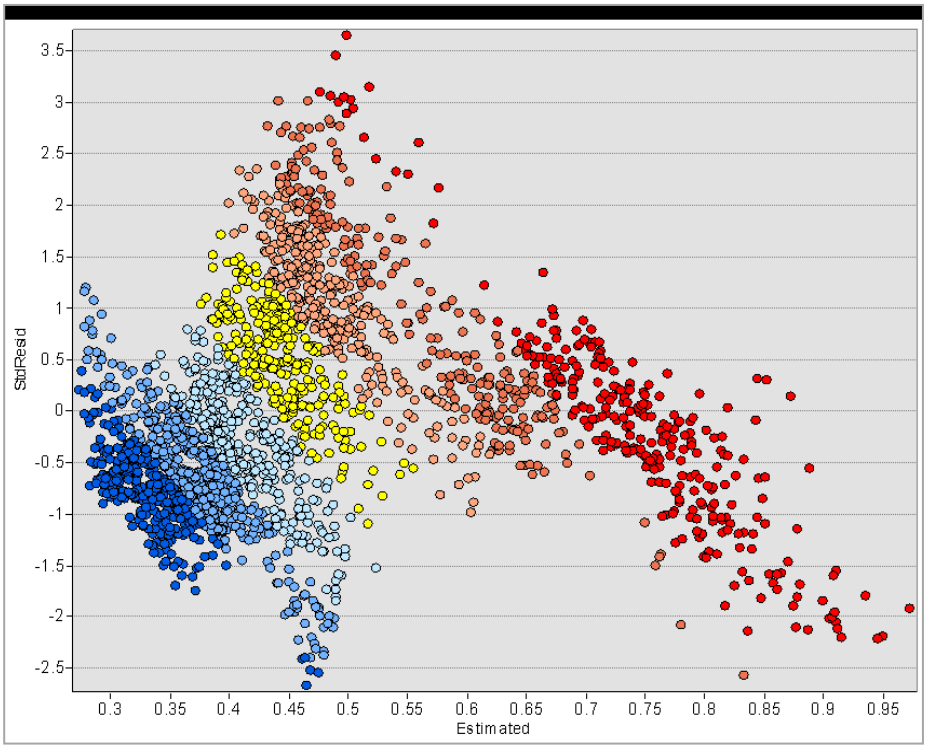
5	0.035318	0.013368	2.64	0.008	0.009118	0.061519
Education (secondary)						
_predict						
1	-0.00247	0.002451	-1.01	0.313	-0.00728	0.002331
2	-0.00588	0.005472	-1.08	0.282	-0.01661	0.004841
3	-0.00845	0.00779	-1.08	0.278	-0.02372	0.006817
4	-0.02041	0.018451	-1.11	0.269	-0.05657	0.015753
5	0.037217	0.033372	1.12	0.265	-0.02819	0.102625
farm size						
_predict						
1	0.000217	0.000429	0.51	0.613	-0.00062	0.001058
2	0.000516	0.001006	0.51	0.608	-0.00145	0.002487
3	0.000742	0.001448	0.51	0.609	-0.0021	0.00358
4	0.001791	0.003471	0.52	0.606	-0.00501	0.008594
5	-0.00327	0.006321	-0.52	0.605	-0.01565	0.009122
age						
_predict						
1	-0.00403	0.002884	-1.4	0.162	-0.00968	0.001619
2	-0.00959	0.005908	-1.62	0.104	-0.02117	0.001986
3	-0.01378	0.008265	-1.67	0.095	-0.02998	0.002421
4	-0.03328	0.019292	-1.73	0.085	-0.07109	0.004532
5	0.060685	0.034373	1.77	0.077	-0.00668	0.128054
Gender						
_predict						
1	-0.00146	0.004675	-0.31	0.755	-0.01062	0.007702
2	-0.00348	0.010991	-0.32	0.752	-0.02502	0.018066
3	-0.00499	0.01577	-0.32	0.752	-0.0359	0.025917
4	-0.01206	0.038076	-0.32	0.751	-0.08669	0.062568
5	0.02199	0.069377	0.32	0.751	-0.11399	0.157966
Marital status						
_predict						
1	-0.00409	0.004288	-0.95	0.341	-0.01249	0.004318
2	-0.00972	0.009418	-1.03	0.302	-0.02818	0.008737
3	-0.01396	0.013369	-1.04	0.296	-0.04016	0.012239
4	-0.03373	0.031431	-1.07	0.283	-0.09533	0.027878
5	0.061497	0.057258	1.07	0.283	-0.05073	0.173721

Appendix B

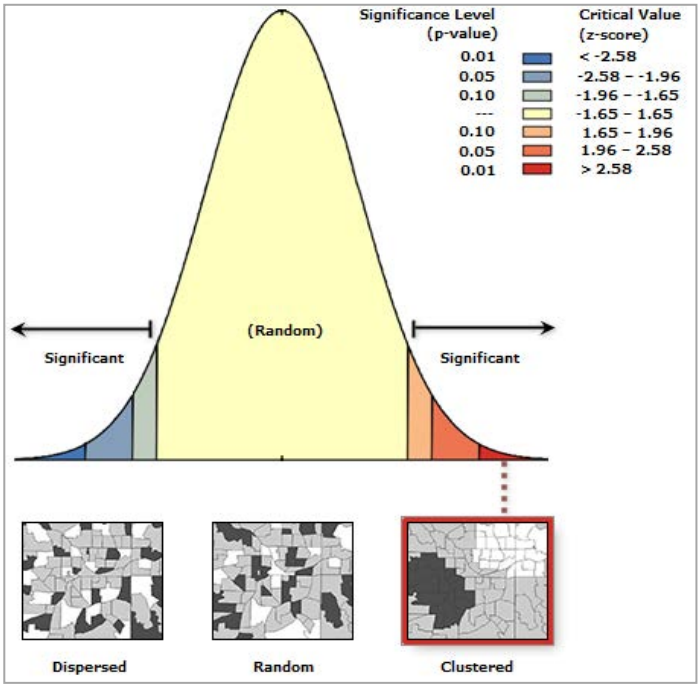
Appendix B1; Goodness of fit model criteria

Adjusted R-squared	> 0.5
p-value regression coefficients	< 0.05
p-value JB statistic	> 0.1
p-value Moran's I test	> 0.1
VIF	7.5
AICc	Model with the lowest is the best fit

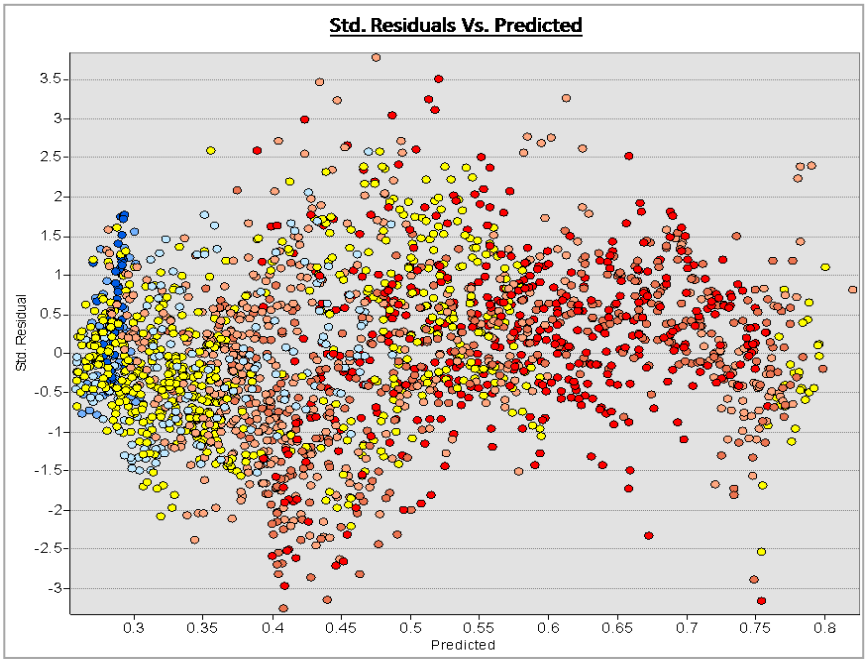
Appendix B2; OLS Std Residuals Plot



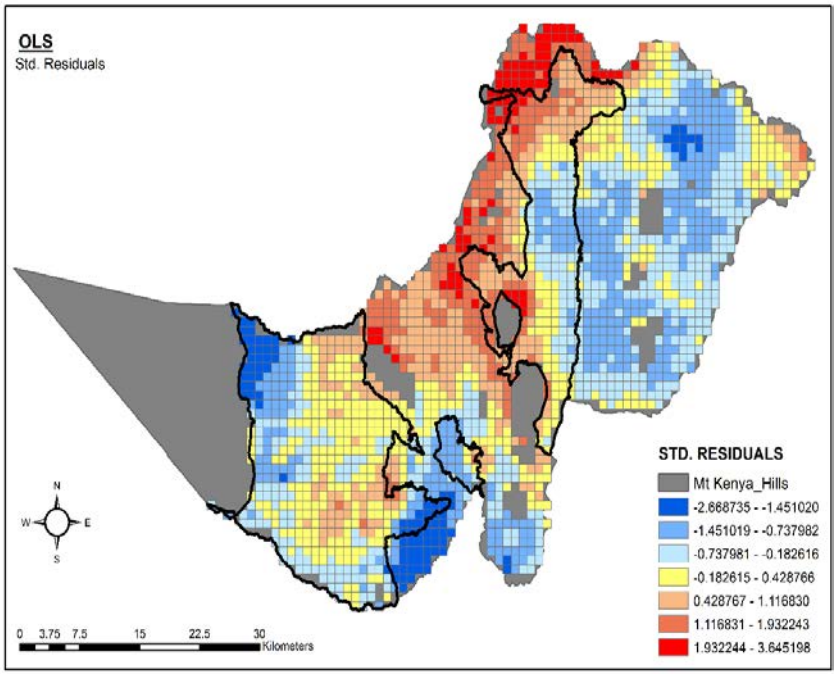
Appendix B3; Global Moran I



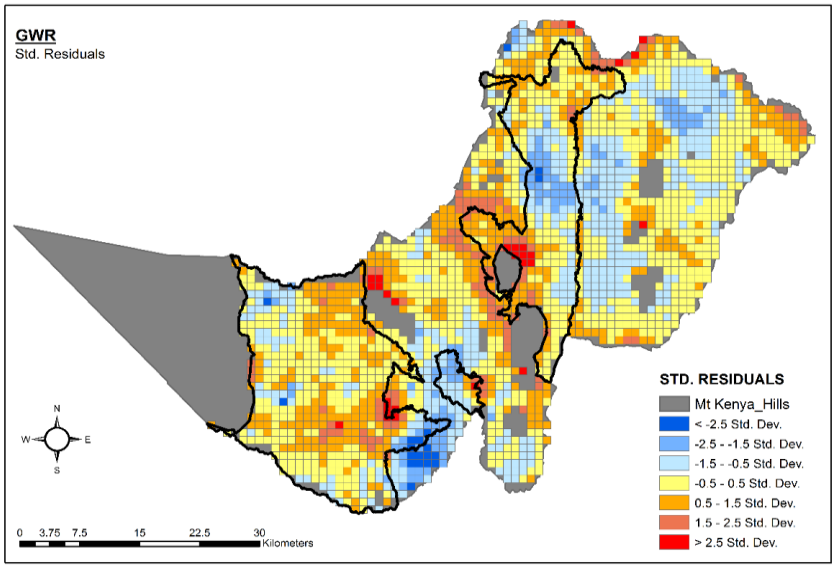
Appendix B4: GWR Std. Residuals Vs Predicted



Appendix B5: OLS Residuals Map



Appendix B6; GWR Residuals Map



Appendix C

Appendix C1

Questionnaire

Latent variable **(based on ordinal responses-5 Likert Scale)**	
Attitude **ATT**	Q: In your opinion *fertilizers/climate resilience farming/trees*……. ATT 1: Increases productivity ATT 2: Produces better quality crop ATT 3: Increases profits ATT 4: Reduces input costs ATT 5: Saves time ATT 6: Improves soil fertility ATT 7: Helps to protect the environment ATT 8: Is expensive
Subjective Norm **SN**	Q. How likely are you to follow advice from the following people/sources regarding *fertilizers, climate resilience farming, and trees* on your farm? SN 1: Your family SN 2: Agricultural advisor SN 3: Local Politicians SN 4: Discussion groups SN 5: government land experts SN 6: media SN 7: legal professional SN 8: other farmers
Perceived Behaviour Control **PBC**	Q. When it comes to *fertilizers/climate resilience farming/ trees*..... PBC 1: I am confident in my ability to do so PBC 2: It is under my control to do so PBC 3: It depends entirely on me and not on factors enabling or preventing me from doing so PBC 4: It is easy to do so
Barriers and drivers **AFF**	Q. How have the following affected *fertilizers/climate resilience farming/ trees* on your land……. AFF 1: Lack of money AFF 2: Access to information AFF 3: Local Politics Affected AFF 4: Family commitments AFF 6: Land registration status AFF 7: Low farm output
Utility **USE**	Q. In your opinion *planting trees/use of fertilizer/adoption of climate resilience farming* is…… USE 1: A good idea USE 2: Useful USE 3: Reliable USE 4: Important

Intention I	Q. When it comes to *use of fertilizers/adoption of climate resilience farming/ planting trees* in the near future……. 1. I intend to do so 2. It is likely that I will do so 3. I would consider doing so
Farm & farmer characteristics	
Gender	Male_1, Female_2
Age group	• <35=1, 35-50=2, 51-64=3 (base category), >65=4 • Base category=1, Not in base category =0
Marital status	• Married=1(Base category), Single=2, Widowed =3, Divorced=4 • Base category married=1, Not in base category =0
Education level	• None=1, Primary =2, Secondary=3 (base category), Tertiary =4 • Base category=1, Not in base category =0
Land registration	Unregistered_0 Registered_1

Appendix C2 KMO Interpretation

KMO Value	Explanation
0.00 to 0.49	unacceptable
0.50 to 0.59	miserable
0.60 to 0.69	mediocre
0.70 to 0.79	middling
0.80 to 0.89	meritorious
0.90 to 1.00	marvellous

Appendix C3 *KMO summary*

	Short-term investment	**Long-term investment**	
	Fertiliser	**Climate Resilience Agriculture**	**Trees**
VARIABLE	**KMO**	**KMO**	**KMO**
PBC[28] 1	0.9032	0.8755	0.8184
PBC 2	0.8907	0.8516	0.8394
PBC 3	0.9074	0.8413	0.8416
PBC 4	0.9190	0.9133	0.9087
ATT[29] 1	0.9018	0.8274	0.8380
ATT 2	0.9030	0.8238	0.8441
ATT 3	0.8888	0.8727	0.8572
ATT 4	0.8781	0.8795	0.9104
ATT 5	0.9162	0.8611	0.8932

[28] PBC_ Perceived Behaviour Control

[29] ATT_Attitude

ATT 6	0.9066	0.8551	0.8659
ATT 7	0.8874	0.8646	0.8248
ATT 8	0.8327	0.7845	0.9020
Use 1	0.9179	0.8526	0.7931
Use 2	0.8901	0.8312	0.8125
Use 3	0.9132	0.8065	0.8411
Use 4	0.8946	0.7870	0.8828
SN [30]1	0.8099	0.8242	0.9020
SN 2	0.8059	0.7432	0.8073
SN 3	0.8915	0.8674	0.8754
SN 4	0.7624	0.7474	0.7769
SN 5	0.8676	0.8663	0.8746
SN 6	0.8482	0.8336	0.8140
SN 7	0.8631	0.8306	0.8120
SN 8	0.8150	0.8536	0.9030
AFF[31] 1	0.7814	0.7599	0.7796
AFF 2	0.8288	0.8656	0.8509
AFF 3	0.8815	0.9066	0.9070
AFF 4	0.8344	0.7892	0.8883
AFF 5	0.8585	0.8757	0.8831
AFF 6	0.9219	0.8648	0.8751
Overall	**0.8796**	**0.8427**	**0.8591**

Appendix C4: Fertilizer Principal Components

		Comp[32]1	**Comp2**	**Comp3**	**Comp4**	**Comp5**	**Comp6**	**Comp 7**
Variable		**PBC**	**Attitude**	**USE**	**SN**	**Barriers/drivers**	**professional advice**	**resources**
I am confident in my ability to do so	PBC[33] 1	0.4675						
It is under my control to do so	PBC 2	0.4711						
Depends entirely	PBC 3	0.4745						

[30] SN_Subjective Norm
[31] AFF_Barriers and drivers
[32] Comp_Component
[33] PBC_ Perceived Behaviour Control

on me and not external factors								
It is easy to do so	PBC 4	0.366						
Increases productivity	ATT 1							
Produces better quality crop	ATT 2							
Increases profits	ATT [34]3		0.4621					
Reduces input costs	ATT 4							
Saves time	ATT 5		0.3241					
Improves soil fertility	ATT 6		0.4044					
Helps to protect the environment	ATT 7		0.4402					
Is expensive	ATT 8							0.6087
A good idea	USE 1			0.5014				
Useful	USE 2			0.4946				
Reliable	USE 3							
Important	USE 4			0.4803				
Your family	SN [35] 1							

[34] ATT_Attitude

[35] SN_Subjective Norm

Agricultural advisor	SN 2						0.6071	
Local Politicians	SN 3				0.4146			
Discussion groups	SN 4						0.6532	
government land experts	SN 5				0.4223			
media	SN 6				0.4474			
legal professional	SN 7				0.424			
other farmers	SN 8				0.376			
Lack of money	AFF[36] 1							0.5579
Access to information	AF F 2							0.4225
Local Politics Affected	AF F 3					0.3952		
Family commitments	AF F 4					0.4762		
Land registration status	AF F 5					0.41		
Low farm output	AF F 6							

Appendix C5: CRF Principal Components

		Comp1	**Comp2**	**Comp3**	**Comp4**	**Comp5**	**Comp6**	**Comp7**
Variable		**ATT**	**SN**	**Barriers/drivers**	**USE**	**PBC**	**Professional advice**	**Resources**

[36] AFF_Barriers and Drivers

I am confident in my ability to do so	PBC[37] 1					0.4146		
It is under my control to do so	PBC 2					0.5552		
Depends entirely on me and not external factors	PBC 3					0.5456		
It is easy to do so	PBC 4					0.3809		
Increases productivity	ATT[38] 1	0.4193						
Produces better quality crop	ATT 2	0.3026						
Increases profits	ATT 3	0.3957						
Reduces input costs	ATT 4	0.3144						
Saves time	ATT 5	0.341						
Improves soil fertility	ATT 6	0.4055						
Helps to protect the environment	ATT 7	0.3765						
Is expensive	ATT 8							0.6044

[37] PBC_Perceived Behaviour Control
[38] ATT_Attitude

A good idea	USE 1				0.4489			
Useful	USE 2				0.472			
Reliable	USE 3				0.4937			
Important	USE 4				0.5428			
Your family	SN[39] 1							
Agricultural advisor	SN 2						0.5743	
Local Politicians	SN 3		0.4194					
Discussion groups	SN 4						0.5848	
government land experts	SN 5		0.4441					
media	SN 6		0.4658					
legal professional	SN 7		0.3193					
other farmers	SN 8		0.4203					
Lack of money	AFF[40] 1							0.4744
Access to information	AFF 2							0.38
Local Politics Affected	AFF 3			0.3704				
Family commitments	AFF 4			0.4786				
Land registration status	AFF 5			0.4101				

[39] SN_Subjective Norm

[40] AFF_Barriers and Drivers

Low farm output	AFF 6			0.3712				

Appendix C6

Trees Principal Components

Variable		**Comp1**	**Comp2**	**Comp3**	**Comp4**	**Comp5**	**Comp6**	**Comp7**
		Barriers/Drivers	**ATT**	**SN**	**PBC**	**Professional Advice**	**USE**	**Resources**
I am confident in my ability to do so	PBC[41] 1				0.4805			
It is under my control to do so	PBC 2				0.5112			
Depends entirely on me and not external factors	PBC 3				0.4842			
It is easy to do so	PBC 4				0.4135			
Increases productivity	ATT[42] 1		0.5032					
Produces better quality crop	ATT 2		0.5119					
Increases profits	ATT 3						0.3168	
Reduces input costs	ATT 4							
Saves time	ATT 5		0.3282					
Improves soil fertility	ATT 6		0.3868					
Helps to protect the environment	ATT 7							
Is expensive	ATT 8							0.4325
A good idea	USE 1					0.3055		
Useful	USE 2							

[41] PBC_Perceived Behavioural Control

[42] ATT_Attitude

Reliable	USE 3						0.5874	
Important	USE 4						0.4165	
Your family	SN[43] 1							
Agricultural advisor	SN 2					0.4876		
Local Politicians	SN 3			0.3813				
Discussion groups	SN 4					0.5203		
government land experts	SN 5			0.456				
media	SN 6			0.4612				
legal professional	SN 7			0.4304				
other farmers	SN 8			0.3698				
Lack of money	AFF[44] 1							0.5543
Access to information	AFF 2							0.4194
Local Politics Affected	AFF 3	0.3672						
Family commitments	AFF 4	0.4009						
Land registration status	AFF 5	0.4375						
Low farm output	AFF 6	0.4323						

Appendix C7

Ordered Logistic Regression Results-Fertilizer application

Ordered logistic regression Number of obs = 427
LR chi2(12) = 191.46
Prob > chi2 = 0.0000
Log likelihood = -262.02586 Pseudo R2 = 0.2676

fert_intent	**Coefficient**	**Std. err.**	**z**	**P>z**	**[95% conf. interval]**

[43] SN_Subjective Norm
[44] AFF_Barriers and Drivers

Perceived Behavioural Control	0.564913	0.094744	5.96	0.00	0.379219
Attitude	0.088904	0.091877	0.97	0.33	-0.09117
Use	0.278632	0.086469	3.22	0.00	0.109157
Subjective Norm	0.002451	0.081032	0.03	0.98	-0.15637
barriers/drivers	-0.01399	0.083105	-0.17	0.87	-0.17687
Professional advice	0.175586	0.101065	1.74	0.08	-0.0225
Resources	0.271512	0.102407	2.65	0.01	0.070799
Education Level	0.657234	0.265566	2.47	0.01	0.136733
Land registration	0.194524	0.282728	0.69	0.49	-0.35961
Farm size	-0.04532	0.054075	-0.84	0.40	-0.15131
ageroup3	-0.3886	0.277235	-1.4	0.16	-0.93197
sex	0.003232	0.507645	0.01	1.00	-0.99173
Marital Status	0.044914	0.204891	0.22	0.83	-0.35666

Appendix C8

Ordered Logistic Regression Results-Climate Resilience Farming

Ordered logistic regression	Number of obs = 418
	LR chi2(12) = 160.77
	Prob > chi2 = 0.0000
Log likelihood = -286.5411	Pseudo R2 = 0. 2191

Climate Resilience Agriculture Intent	**Coefficient**	**Std. Err.**	**z**	**P>z**	**[95% conf. interval]**
Attitude	0.1475906	0.076014	1.94	0.05	-0.00139
Subjective Norm	0.0527135	0.07983	0.66	0.51	-0.10375
Perceived Behavioural Control	0.393141	0.090535	4.34	0.00	0.215695
barriers/drivers	0.0753047	0.087367	0.86	0.39	-0.09593
Use	0.3447712	0.087415	3.94	0.00	0.17344
Professional advice	0.1671955	0.090136	1.85	0.06	-0.00947
Resources	0.1973918	0.098527	2	0.05	0.004282
Education (Secondary)	0.2773541	0.256365	1.08	0.28	-0.22511
Land Registration	0.681256	0.269638	2.53	0.01	0.152776
Farm size	-0.0219468	0.049107	-0.45	0.66	-0.11819
Age group (51-64 Years)	0.4781875	0.263609	1.81	0.07	-0.03848
Sex	0.2107337	0.486298	0.43	0.67	-0.74239
Marital status	-0.3130243	0.213569	-1.47	0.14	-0.73161

Appendix C9

Ordered Logistic Regression Results-Trees Intent

Ordered logistic regression	Number of obs = 417
	LR chi2(13) = 156.56
	Prob > chi2 = 0.0000
Log likelihood = -268.30852	Pseudo R2 = 0.2259

Trees_intent	Coefficient	Std. err.	z	P>z	[95% conf. interval]
Barriers/drivers	-0.016	0.084	-0.190	0.848	-0.181
Attitude	0.143	0.083	1.730	0.085	-0.019
Subjective Norm	0.183	0.084	2.190	0.028	0.019
Perceived Behavioural Control	0.373	0.089	4.200	0.000	0.199
Professional advice	0.267	0.088	3.050	0.002	0.095
Use	0.225	0.090	2.500	0.012	0.049
Resources	0.262	0.099	2.650	0.008	0.068
Education	-0.413	0.265	-1.560	0.119	-0.932
Land registration	0.935	0.288	3.250	0.001	0.371
Farm size	-0.016	0.048	-0.340	0.735	-0.111
Age(51-64yrs)	0.114	0.267	0.430	0.668	-0.408
Sex	-0.356	0.519	-0.690	0.492	-1.372
Marital Status	0.060	0.224	0.270	0.790	-0.379

Appendix C10

Average Marginal Effects: Short-term On-farm Investments (Fertilizer Application)

	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
Perceived Behavioural Control	-0.00269	-0.00842***	-0.01666***	-0.03809***	0.06587***
Attitude	-0.00042	-0.00132	-0.00262	-0.00599	0.01035
Use	-0.00132	-0.00414***	-0.00818***	-0.01871***	0.03236***
Subjective Norm	-0.00001	-0.00003	0.00005	-0.00012	0.00020
Barriers/drivers	0.00006	0.00020	0.00040	0.00091	-0.00157
Professional advice	-0.00084	-0.00263	-0.00521*	-0.01191*	0.02060*
Resource	-0.00130	-0.00406**	-0.00803**	-0.01835***	0.03173***
Education	-0.00313	-0.00980**	-0.01938**	-0.04431**	0.07662**
Land registration	0.00092	0.00288	0.00570	0.01304	-0.02254
Farm size	0.00022	0.00068	0.00134	0.00307	-0.00530
Age (51-64yrs)	0.00185	0.00578	0.01143	0.02615	-0.04521
Sex	0.00000	-0.00001	-0.00001	-0.00003	0.00005
Marital status	0.00040	0.00125	0.00246	0.00563	-0.00974

Appendix C11

Average marginal effects: Long-term Investments (CRF Intent)

	Strongly Disagree	Disagree	Neither	Agree	Strongly agree
Attitude	-0.00132	-0.00297*	-0.0042*	-0.01052*	0.019018**
Subjective Norm	-0.00047	-0.00106	-0.0015	-0.00376	0.006792

Barriers/Drivers	-0.00068	-0.00152	-0.00214	-0.00537	0.009703
Use	-0.00309**	-0.00695***	-0.00981***	-0.02458***	0.044425***
Perceived Behavioural Control	-0.00353**	-0.00792***	-0.01118***	-0.02803***	0.050657***
Professional advice	-0.0015	-0.00337*	-0.00476*	-0.01192*	0.021544*
Resources	-0.00177	-0.00398*	-0.00562*	-0.01407**	0.025435**
Education	-0.00249	-0.00559	-0.00789	-0.01977	0.035738
Land registration	-0.00611*	-0.01372**	-0.01938**	-0.04857***	0.087782***
Farm size	0.000197	0.000442	0.000624	0.001565	-0.00283
Age (51-64 yrs)	-0.00429	-0.00963	-0.0136*	-0.03409*	0.061616*
Sex	-0.00189	-0.00425	-0.00599	-0.01502	0.027154
Marital status	0.002807	0.006306	0.008904	0.022317	-0.04033

Appendix C12

Average Marginal Effects: Long-term Investments (Trees)

	Strongly Disagree	**Disagree**	**Neither**	**Agree**	**Strongly agree**
Attitude	-0.0012486	-0.0021229*	-0.0045872**	-0.01626**	0.024222**
Perceived Behavioural Control	0.0025697*	- 0.0043691**	- 0.0094407***	- 0.03347***	0.04985***
Subjective Norm	-0.0000196	-0.0000334	-0.0000721	-0.00026	0.000381
Barriers/drivers	-0.0009474	-0.0016108	-0.0034806	-0.01234	0.018379 *
Professional Advice	-0.0021675	- 0.0036853**	-0.0079632**	-0.02823**	0.042048**
Resources	-0.0016975	-0.0028862*	-0.0062365**	-0.02211**	0.032931**
USE	-0.0016718	- 0.0028424**	-0.0061419**	-0.02177**	0.032431**
Education	0.0029643	0.00504	0.0108904	0.03861	-0.0575
Land registration	-0.0063131	- 0.0107339**	- 0.0231936***	- 0.08223***	0.122469***
Farm size	0.0001378	0.0002343	0.0005063	0.001795	-0.00267
Age(51-64yrs)	-0.0008339	-0.0014179	-0.0030638	-0.01086	0.016178
Sex	0.0024081	0.0040944	0.0088471	0.031366	-0.04672
Marital Status	-0.0004186	-0.0007117	-0.0015379	-0.00545	0.00812

Appendix D

SURVEY ON FARMS ON "IMPACT OF LAND REGISTRATION ON AGRICULTURAL PRODUCTIVITY"

SECTION 1: INTRODUCTION STATEMENT (TO BE READ TO THE RESPONDENT)

Greetings! My name is …… I am carrying out a PhD study on "Impacts of land Registration on Agricultural Productivity" in Tharaka Nithi County. A total of 500 households have been randomly selected to participate in the survey. Your household is one of those selected in this area. I will be asking questions on status of registration of your land, type of crops that you grow, source of labor, household access to extension services, etc. The information obtained from the survey will be used for this study, and will be treated anonymous and remain strictly confidential. Your name will not appear in any data that is made publicly available. However, we would like to write down your contact information in case some issues in the questionnaire are unclear and we need to follow up with you later for more information or clarification. I therefore would like to ask you some questions as a responsible member of this household. These questions will take a short time to complete and therefore I will appreciate your patience. Thanks

SECTION 2: HOUSEHOLD IDENTIFICATION

1.01 HOUSEHOLD ID NUMBER …… 1.02. HOUSEHOLD CELL PHONE……

1.02 SUB COUNTY ……....

1.03 LOCATION ……

1.04 SUB LOCATION …….

1.05 REGISTRATION ZONE …….

1.06 GPS COORDINATE

Elevation (M): |___|___|___|___| Latitude (N) |___|___|. |___|___|___|___|___| Longitude (E) |___|___|___|.|___|___|___|___|___|

1.07 Respondent Name ……..……Tel. No…….. ID …….

1.08 Respondent Relationship to head of household ……(1: Head of household, 2: Husband, 3: Wife, 4: Son, 5: Grandchild, 6: Parent, 7: Siblings, 8: other

Member (specify)……..

1.09 What Christian denomination does the household head belong to …… (1: Catholic, 2: Protestant, 3: Atheism 4. Other (Specify)

2.0 HOUSEHOLD CHARACTERISTICS

Member ID	Name	2.1 **Relationship to Household Head** 1 HH 2 Spouse 3 Child 4 Sibling 5. Other (specify)	2.2 **Gender** 1 Male 2 Female	2.3 **Age (Date of Birth)**	2.4 **Marital status** 1 Married 2 Single 3 Divorced 4 Windowed	2.5 **Education level** 1 None 2 Primary 3 Secondary 4 Tertiary	2.6 **Literacy level** 1 Cannot read/ write 2 Cannot write 3 Read only 4 Read & write
1							
2							

SECTION 3.0: LAND TENURE CHARACTERISTICS

3.1 What is the size of your land?..... (Acres)

3.2 What is the total number of acres farmed by you in 2018? During 1. Short rains…… (Acres) 2. Long rains …… (Acres)

3.3 Land Characteristics

Farm ID No.	Location of land parcel from homestead	3.3.1 **Mode of acquisition of land** 1 Inherited 2 Purchased 3 Allocated by government 4 Leased from owner	3.3.2 **Area of land (Acres)**	3.3.3 **Soil Type** 1 Clay 2 Sandy 3 Black cotton 4 Red loamy 5 Other-specify	3.3.4 **Terrain of farm** 1 Flat 2 undulating 3 Gentle slopes 4 Steep Slopes 5 Hilly	3.3.5 **Fertility of soil** 1 Highly fertile 2 Moderately fertile 3 Infertile	3.3.6 **Major source of Water for farming** (See Annex)	3.3.7 **Type of farming** (see Annex)	3.3.8 **Who makes majority of the decision on the use of the land?** 1 Husband 2 Wife 3 others (specify)

		5 Other (specify)							
	KMs	Code above	Acres	Code above	Code above	Code above	Code 1	Code 2	Code above
1									
2									

3.4 Land Tenure and succession

Farm ID	Do you own this land or have you leased it? Owned=1 Leased=2	If leased for how long?		If you are the owner, do you have a legal document to show that you own the land? Yes=1 No=2	What document do you have? Title=1 Lease=2 Allotment no/letter =3 Other (Specify)	When did you acquire the ownership document?	Whose name appears on the documents? 1 Husband 2 wife/wives 3. Husband and wife 4 Other (Specify)	Who would inherit the land in the absence of household head? 1 husband 2 wife(s) 3 Sons 4 Daughters 5 Sons and daughters 6 Others, specify
	Code	Date leased (Year)	End of lease (Year)	Code above	Code above	Year	Code above	Code above
1								

SECTION 4: CROP PRODUCTION AND YIELD

4.1 List two main seasonal crops that you farmed in 2018 (Code 3), during 1. Short rains……..…….. 2. Long rains ……..……

4.1.1 Production cost for seasonal crops for 2018 (long season)

Activity	**Labor**						**Machinery**		
	Male		**Female**		**Cost per day**		**Type Code 4**	**No. of days**	**Cost per day**
	No.	**Days**	**No.**	**Days**	**Males**	**Female**			
Land preparation									
Planting									
Application of chemicals (fertilizers, and Manure)									
Weeding and application of herbicides									
Harvesting and threshing									
Application of pesticides									
Post-harvest activities									
Other, specify									
Cost in acquisition of Agricultural inputs									
	Amount (from farm and purchased)				**Cost (Kshs)**				
Seeds									
Agricultural chemicals (fertilizers, and Manure									
Herbicides									
Irrigation									
Pesticides									

Storage		
Other, Specify		

4.1.2 Yield from seasonal crops of last year (2018)

Season	Crop Code	Total Output	Amount consumed by the family	Amount consumed by livestock	Amount left for seed next season	Amount sold	Selling price	Who did you sell the crop to?
		kg	kg	Kg		kg	Kshs	Code 5
Long rains	1							
	2							
Short rains	1							
	2							

4.2 Production cost and income from Perennial crops

4.2.1 Do you grow trees or permanent crops (Yes=1, No=2) ----------

4.2.2 Why did you plant trees? List 3 reasons starting with most important (Code 6) 1 ----------2----------3----------

4.2.3 Name three main perennial crops that you grow 1 ----------2----------3----------

4.2.4 If none, why don't you grow trees or permanent crops? (List up to 3 reasons-Code below) 1 ----------2----------3----------

Code

1. Shortage of land
2. Shortage of money for investment
3. Lack of secure Land tenure
4. Less profitable than seasonal crops

5. Shortage of labor
6. Other (Specify)

4.3 Production data on perennial crops

Farm ID	Crop Type code 3	What is the share of the farm planted with trees	what is the size of land planted with perennial crops	Planting date for the majority of the trees/crops	Beginning harvesting date	Total Output		Source of water for this farm	Type of irrigation if any	What is the total value if you were to sell trees/crop today	Did you make any charcoal from trees in the last year? 1 Yes 2 No If yes, indicate the quantity and price sold	
						Unit 1 Kg 2 No	Quantity					
		%	No.	Year	Year			Code 1			Qty (sack)	Cost per sack
1												
2												

SECTION 5: ACCESS TO INFORMATION, CREDIT AND REMITTANCES

5.1 Access to information

	Do you have access to information on crop farming on the following sectors? 1 Yes 2 No	Source (s): Please list the main sources of information you receive for various sectors. (Tick up to 3 sources in order of importance, with source 1 being most important)	Were you able to use this informati on? 1 Yes 2 No	If yes, how did you use this information? Tick up to 3 uses	If no, why were you not able to use this information?

		Source 1	Source 2	Source 3					
Information type		Code 7	Code 7	Code 7		Code 8	Code 8	Code 8	Code 9
1. Forecast of extreme events (e.g. drought, flood)									
2. Forecast for the start of the rains (seasonal forecast)									
3. Information on climate change									
4. Information on crop production and management									
5. Information on tree management and agroforestry									
6. Information on marketing of crop									
7. Information on processing and adding value									

5.2 Access to Credit

	Did your household attempt to borrow loan for the last 12 months? Yes=1, No =2	Whom did the household attempt to borrow from (see list on the left on the table)	Why did HH want to borrow money from (that source)	Was the member successful in obtaining the loan from the source? Yes=1 No=.2	If yes, what did the household use as a collateral? 1-Land 2-Car 3-Employment slip 4. other, specify…..	If no, why was the member not successful to borrow from that Source? 1 Inadequate collateral 2 Bad credit history 3 Have outstanding loan 4 History of default with lender 5 No reason given	What was the amount that you received from (Source) in the past 12 months		How was the credit used
Lending source			Code 10	Code	Code	Code	Cash	Kind	Code 10
Savings and credit association									
Informal lender									
Bank									
Village-level savings association									
Cooperative									
Friends or relatives									
Traders									
Shopkeepers									

Landlords								
Other (Specify)								

5.4 Remittances

Please tell us the remittances received by the household for the last one year.

Source of remittances/Use	Food		Education		Agricultural production and inputs		Medical expenses		Others (Specify)	
	No. of remittances per year	Average amount per remittance (Kshs)	No. of remittances per year	Average amount per remittance (Kshs)	No. of remittances per year	Average amount per remittance (Kshs)	No. of remittances per year	Average amount per remittance (Kshs)	No. of remittances per year	Average amount per remittance (Kshs)
Household Head										
Spouse										
Son(s)										
Daughter(S)										
Son in law(S)										
Daughter in law (S)										
Parents of HH										
Parents of Spouse										
Sister/brother of HH										
Other (Specify)										

SECTION 6: PERCEPTIONS ON LAND SECURITY AND REGISTRATION

6.1 Is your land registered? Yes/No. What are the main challenges in land registration process?

a)……..

b)……..

6.2 Land disputes

Farm ID	Have you experienced land dispute in the past? Yes=1, No=2	The main causes of the disputes?	Was the dispute settled? Yes=1. No=2	How was it settled?	When did you experience a lot of disputes on land? 1=Before adjudication 2=During adjudication process 3=After adjudication process
	Code	Code 11	Code	Code 12	Code
1					
2					

6.3 Land Investment

Farm ID	When did you acquire the land	Was the land registered before or after you acquired it? 1-Before, 2-After	If registered after purchase, indicate the year of registration	what are the advantages of having a registered land (List up to 3 advantages in order of importance, with advantage 1 being most important			what are the challenges of unregistered land (List up to 3 advantages in order of importanc	How has the land registration influenced your investment on the farm		What is approximate value of your land per acre? 1-Kshs…… 2.Do not know (No land market)	How frequent are the farms sold/leased in the area 1-No sales/leases 2-Rare (1 in a year) 3-fairly frequent (1
				Advantage 1	Advantage 2	Advantage 3		Registered	Unregistered		

		3. Not registered					e, with advantage 1 being most important			3-Other (specify)… .	in 6 months) 4-Frequent (1 or more in a month)	
	Year	Code		Code 13 below	Code 13 below	Code 13 below	Code 14 below	Code 15	Code 15	Code above	sold	leased
1												

6.4 Fear of losing the land: Can you leave your farm fallow for more than a year without worrying that you may lose it? Yes/No……..

a) If yes, why aren't you afraid of losing it?

I have a title deed or any other legal ownership document (Specify)……..
The land customarily owned-inherited and family members know their boundaries
No past experience in land related conflicts
No past experience of encroachment or alienation
Other (Specify)……..

(b) If No, why are you afraid of losing the farm?

I do not have any legal ownership documents for the land
I have experienced land conflicts in the past from……..
There are family disputes on the land
I am poor in comparison to some members of the community
I am from minority ethnic group
I am a woman
I am young
Other (Specify)…….

c) To whom do you fear you can lose the land to?

Perceived likelihood of losing the land	**Very likely**	**Likely**	**Neutral**	**Unlikely**	**Very Unlikely**
family and extended family, clan members	1	2	3	4	5
Investors (Elites)	1	2	3	4	5

Neighbors	1	2	3	4	5
Local authority	1	2	3	4	5
Government	1	2	3	4	5
Others, Specify……					

d) If you are afraid of losing the land to a relative, why would that happen? (Multiple answers allowed)
Because I am a woman (Single/window)
Land succession has not been done (registered under late parent/grandparents)
There are family disputes on the land
There is inadequate farmland in the family
Because I am young
Land not registered
e) Do you have the right to exclusively or jointly bequeath your land?

i. Yes by my own/individually
ii. Yes, jointly with my spouse
iii. Yes with others. Specify……...
iv. No

6.5 Migrants and indigenous farmers

Are you an indigenous member of the community or you migrated to the area?
Indigenous (where my fathers and great fathers lived)
Migrated to the area (less than 10 years)
Migrated to the area (between 10-20 years ago)
Migrated to the area (Over 20 years ago)

6.6 Plans for future farming

I would like to hear from you the farming plans you have in the next five (5) years. Indicate the best statement that describes your plans on the list below
Continue farming with no significant change

Continue farming but with increased diversification
Increase intensity of agricultural production
Decrease intensity of agricultural production

6.7 Attitudes towards Farming and the Environment

I am now going to read you a list of statements about farming. I would like you to tell me how strongly you agree or disagree with each one of them?

	Strongly Disagree	**Disagree**	**Neither**	**Agree**	**Strongly Agree**
A farmer must focus on production to survive and be successful	1	2	3	4	5
I aim to manage the farm business to maximise profit	1	2	3	4	5
It is important for me to find new information to help me to run my farm in general	1	2	3	4	5
It is important for me to be respected by other farmers	1	2	3	4	5
Successful farming is the result of careful planning	1	2	3	4	5
Farmers have a strong role to play in protecting the environment	1	2	3	4	5
It is important for me to maintain traditional ways of farming	1	2	3	4	5
Successful farmers take financial risks	1	2	3	4	5
I think it is a good idea to change my farming practices if it helps to protect the environment	1	2	3	4	5
It is important for me to have the best livestock/crops/pastures	1	2	3	4	5
It is important for me to adapt and use new farming technologies	1	2	3	4	5
The use of fertilizers/manure can have a negative impact on water quality	1	2	3	4	5
I am cautious about adopting new ideas and farm practices	1	2	3	4	5
Moderate yields, modest improvements and old equipment suit me fine	1	2	3	4	5

Before I apply different farming practices, they first need to be proven on other farms	1	2	3	4	5

6.8 Use of fertilizer/manure, planting trees, Climate resilience Agriculture

1. Use of fertilizer/manure

Please tell me if you agree or disagree with each of the following statements?

When it comes to use of fertilizer/manure on my land.....

	Strongly Disagree	**Disagree**	**Neither**	**Agree**	**Strongly Agree**
I am confident in my ability to do so	1	2	3	4	5
It is under my control to do so	1	2	3	4	5
It depends entirely on me and not on factors enabling or preventing me from doing so	1	2	3	4	5
It is easy to do so	1	2	3	4	5

In your opinion, use of fertilizer/manure

	Strongly Disagree	**Disagree**	**Neither**	**Agree**	**Strongly Agree**
Increases productivity	1	2	3	4	5
Produces better quality crop/grass	1	2	3	4	5
Increases profits	1	2	3	4	5
Reduces input costs	1	2	3	4	5
Saves time…….	1	2	3	4	5
Improves soil fertility……	1	2	3	4	5
Helps to protect environment……	1	2	3	4	5
Is expensive……	1	2	3	4	5

Please tell me if you agree or disagree with each of the following statements?

In your opinion past use of fertiliser/manure has shown its……...

	Strongly Disagree	**Disagree**	**Neither**	**Agree**	**Strongly Agree**

A good idea	1	2	3	4	5
Useful…	1	2	3	4	5
Reliable .	1	2	3	4	5
Important……....	1	2	3	4	5

How likely are you to follow advice from the following people/sources regarding use of fertilize/manurer on your farm?

	Very unlikely	**Unlikely**	**Neither**	**Likely**	**Very Likely**
Your family	1	2	3	4	5
Agricultural advisor	1	2	3	4	5
Discussion group	1	2	3	4	5
Government land experts	1	2	3	4	5
Local leaders (Politicians)	1	2	3	4	5
Media (Press and magazines, TV, Radio)	1	2	3	4	5
Legal professional	1	2	3	4	5
Other (please state_____)	1	2	3	4	5

How have the following affected use of fertilizer/manure on your land

	Strongly Disagree	**Disagree**	**Neither**	**Agree**	**Strongly Agree**
Lack of money	1	2	3	4	5
Access to information	1	2	3	4	5
Local politics	1	2	3	4	5
Family	1	2	3	4	5
Land registration status (Registered/unregistered)	1	2	3	4	5
Low farm output	1	2	3	4	5

If I want to use fertilizer/manure on my farm, I have…

	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
A clear understanding of how to do so	1	2	3	4	5
Access to enough information/sources to do so	1	2	3	4	5
Enough time to do so	1	2	3	4	5
Enough financial resources to do so	1	2	3	4	5
Conditions in my household enable me to do so	1	2	3	4	5

When it comes to using fertilizer/manure in near future

	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
I intend to do so	1	2	3	4	5
It is likely that I will do so	1	2	3	4	5
I would consider doing so	1	2	3	4	5

2. Planting trees

Please tell me if you agree or disagree with each of the following statements?

When it comes to planting trees on my land.....

	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
I am confident in my ability to do so	1	2	3	4	5
It is under my control to do so	1	2	3	4	5
It depends entirely on me and not on factors enabling or preventing me from doing so	1	2	3	4	5
It is easy to do so	1	2	3	4	5

	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
Increases productivity	1	2	3	4	5

Produces better quality crop/grass	1	2	3	4	5
Increases profits	1	2	3	4	5
Reduces input costs	1	2	3	4	5
Saves time…….	1	2	3	4	5
Improves soil fertility……	1	2	3	4	5
Helps to protect environment……	1	2	3	4	5
Is expensive……	1	2	3	4	5

In your opinion, planting trees

Please tell me if you agree or disagree with each of the following statements?
In your opinion planting trees is……..

	Strongly Disagree	**Disagree**	**Neither**	**Agree**	**Strongly Agree**
A good idea	1	2	3	4	5
Useful…	1	2	3	4	5
Reliable .	1	2	3	4	5
Important……...	1	2	3	4	5

How likely are you to follow advice from the following people/sources regarding planting trees on your farm?

	Very unlikely	**Unlikely**	**Neither**	**Likely**	**Very Likely**
Your family	1	2	3	4	5
Agricultural advisor	1	2	3	4	5
Discussion group	1	2	3	4	5
Government land experts…….	1	2	3	4	5
Local leaders (Politicians)	1	2	3	4	5
Media (Press and magazines, TV, Radio)	1	2	3	4	5
Legal professional…….	1	2	3	4	5
Other (please state_____)	1	2	3	4	5

How have the following affected planting trees on your land

	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
Lack of money	1	2	3	4	5
Access to information	1	2	3	4	5
Local politics	1	2	3	4	5
Family	1	2	3	4	5
Land registration status (Registered/unregistered)	1	2	3	4	5
Low farm output	1	2	3	4	5

If I want to plant trees on my farm, I have…

	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
A clear understanding of how to do so	1	2	3	4	5
Access to enough information/sources to do so	1	2	3	4	5
Enough time to do so	1	2	3	4	5
Enough financial resources to do so	1	2	3	4	5
Conditions in my household enable me to do so	1	2	3	4	5

When it comes to planting trees in near future

	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
I intend to do so	1	2	3	4	5
It is likely that I will do so	1	2	3	4	5
I would consider doing so	1	2	3	4	5

3. Climate Resilience Agriculture (CRA)

Please tell me if you agree or disagree with each of the following statements?

When it comes to CRA on my land.....

	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree

I am confident in my ability to do so	1	2	3	4	5
It is under my control to do so	1	2	3	4	5
It depends entirely on me and not on factors enabling or preventing me from doing so	1	2	3	4	5
It is easy to do so	1	2	3	4	5

In your opinion, CRA…..

	Strongly Disagree	**Disagree**	**Neither**	**Agree**	**Strongly Agree**
Increases productivity	1	2	3	4	5
Produces better quality crop/grass	1	2	3	4	5
Increases profits	1	2	3	4	5
Reduces input costs	1	2	3	4	5
Saves time…….	1	2	3	4	5
Improves soil fertility……	1	2	3	4	5
Helps to protect environment……	1	2	3	4	5
Is expensive……	1	2	3	4	5

Please tell me if you agree or disagree with each of the following statements?
In your opinion past CRA is ……...

	Strongly Disagree	**Disagree**	**Neither**	**Agree**	**Strongly Agree**
A good idea	1	2	3	4	5
Useful…	1	2	3	4	5
Reliable .	1	2	3	4	5
Important……...	1	2	3	4	5

How likely are you to follow advice from the following people/sources regarding CRA on your farm?

	Very unlikely	**Unlikely**	**Neither**	**Likely**	**Very Likely**
Your family	1	2	3	4	5

Agricultural advisor	1	2	3	4	5
Discussion group	1	2	3	4	5
Government land experts…….	1	2	3	4	5
Local leaders (Politicians)	1	2	3	4	5
Media (Press and magazines, TV, Radio)	1	2	3	4	5
Legal professional…….	1	2	3	4	5
Other (please state_____)	1	2	3	4	5

How have the following affected CRA on your land

	Strongly Disagree	**Disagree**	**Neither**	**Agree**	**Strongly Agree**
Lack of money	1	2	3	4	5
Access to information	1	2	3	4	5
Local politics	1	2	3	4	5
Family	1	2	3	4	5
Land registration status Registered/unregistered)	1	2	3	4	5
Low farm output	1	2	3	4	5

If I want CRA on my farm, I have…

	Strongly Disagree	**Disagree**	**Neither**	**Agree**	**Strongly Agree**
A clear understanding of how to do so	1	2	3	4	5
Access to enough information/sources to do so	1	2	3	4	5
Enough time to do so	1	2	3	4	5
Enough financial resources to do so	1	2	3	4	5
Conditions in my household enable me to do so	1	2	3	4	5

When it comes to CRA in near future

	Strongly Disagree	**Disagree**	**Neither**	**Agree**	**Strongly Agree**
I intend to do so	1	2	3	4	5

It is likely that I will do so	1	2	3	4	5
I would consider doing so	1	2	3	4	5

ANNEX 1: CODES

CODE 1: Source of water
1 Rainfed
2 water harvesting
3 private well/borehole

CODE 2: Type of farming
1 Mixed farming (Crops and livestock)
2 Crops Farming (food crops and cash Crops)
3 Food crops Farming (food crops only)
4 Cash crops farming (Cash crops only)
5 Livestock rearing

CODE 3 : Crop type

1 Avocado	14 Mango
2 Banana	15 Melon
3 Beans	16 Millet
4 Cabbage	17 Papaya
5 Carrot	18 Potato
6 Cassava	19 Pumpkin
7 Cowpeas	20 Sorghum
8 Eucalyptus trees	21 Tea
9 Fodder	22 Tobacco
10 Green grams	23 yam
11 Grevilia trees	24 Other (Specify)
12 Lemon	

Code 4: Tools/Machinery used

1 Hoe
2 Spade
3 Plough and yoke for animals
4 Reaper/Sickle
5 Manual sprayers
6 Rake
7 Wheelbarrow
8 Tractor
9 Thresher
10 Generator/Diesel pump

CODE 5: Whom did you sell the crop to?

1 Other local farmer
2 Local market
3 Middleman/trader
4 Cooperative
5 Relative

CODE 6: Why own trees?

1 Source of income from selling firewood, charcoal etc
2 Source of income by selling materials for building
3 For own use firewood
4 For own use as construction materials
5 Soil conservation
6 Shade
7 income security in case of crop failure
8 more profitable than annual crops
9 Used for preparing medicine
10 Used as fence
11 used as boundary
12 other (Specify)

CODE 7 Sources of ǀInformation

1 –Government Extension Workers	2 – NGOs
3- Community Meetings	4 -Farmer Organizations
5- -Research Stations/Researchers	6 - Religious Groups
7- Media	8 -Family Members
9 –Neighbors/friends	10-Schools/Teachers
11 -Traditional forecasters/indigenous knowledge	

CODE 8: How did you use the information? 1 - Change in Crop type 2 - Change in Crop variety 3 - Change in land size cultivated 4 - Change in fertilizer/pesticides 5 Use of manure/compost/mulch 6 - Change in field location 7 - Change in timing of activities 8 - Soil and water conservation activities implemented 9 - Started irrigating 10 – Used water management 11 - planting trees 12 - change in livestock type 13– change in livestock breed 14 change in feed management	**CODE 9: Why were you not able to use the information?** 1 Found the advice in the past to be unsuitable or unhelpful 2 Not interested in changing production practice 3 cannot access credit to make changes 4 Do not want to purchase inputs 5 Advice was received too late in the season to make a difference 6 Conflicts with other sources of information that I trust more 7 Suggests changes that I am not comfortable with 8 did not provide enough information 9 No market for crops they suggest 10 not enough labor to make suggested changes 11 Not enough information, too many question 12 Changes are too risky
Code 10: why borrow/what was the credit used for? 1 Purchase of agricultural equipment's (tractor, thresher, etc) 2 Purchase of agricultural land 3 To pay for agricultural labor 4 To purchase farm inputs (seeds, fertilizers, pesticides 5 Other, specify……..	**Code 11: The main causes of land disputes** 1 Boundary dispute with Neighbor (determining the extent of the land) 2 Boundary disputes with Relative (such as brothers, sisters, uncles etc) 3 Boundary disputes with neighboring community 4 Boundary disputes with administration on public purpose land (Roads, Electricity lines, riparian reserves. Etc) 5 Land ownership disputes with neighbor (other person claiming ownership of the same land) 6 Land ownership disputes with community (reserved for community use) 7 Land ownership disputes with government (Land for public use purpose)

Code 12: How was the dispute settled? 1 Between the disputing individuals 2 By the Elders 3 By the church members 4 By the community/County administration 5 By the government police administration 6 By court 7 Through adjudication/Registration 8 By the lands board	**Code 13: Advantages of Registration** 1 security 2 Minimize land conflict 3 Can acquire credit using it as a collateral 4 can be inherited by children 5 encourages permanent investment 6 Can sell land 7 Can lease land 8 Others (specify)
Code 14: Challenges of Unregistered Land 1 Eviction 2 Boundary conflicts 3 Ownership conflicts 4 family wrangles 5 expropriation by government 6 others, (specify)	**Code15: Impact of land registration on investment** 1 Planting permanent trees 2 increased use of fertilizers 3 Increased use of manure 4 Made terraces 5 Acquired loan to buy farm machinery and other inputs 6 Started irrigation 7 Adapted new crops 8 Increased leasing of land 9 Others (specify)

Summary

The PhD dissertation explores the impact of land tenure security on sustainable agricultural productivity. Agricultural productivity has been declining in SSA and remains low in comparison to the rest of the world. Moreover, the region is often cited as the most vulnerable to adverse effects of climate change resulting in a significant 34% decrease in agricultural production. Given that the agricultural sector contributes an average of 15% of GDP to SSA countries; a decline poses a substantial threat to the overall economy. The fact that over 50% of the population and at least 80% of the rural population relies on agriculture directly and indirectly for their livelihoods and income makes the scenario even more critical. Promoting sustainable agricultural productivity is paramount for building resilience across the continent, particularly in light of the high reliance on agriculture, poverty and food insecurity. While sustainable agriculture has been a focal point in development agendas, farmers' uptake or rather participation in initiatives remains notably low. Hence, further research using an interdisciplinary approach is required to create scientific references for increased policy efficiency and efficacy.

Historically, land tenure security has been a key pillar for promoting social justice and economic well-being reforms in SSA. Research points towards tenure security being a key incentive for farmers to invest in sustainable agricultural production. However, approximately 90% of rural land in SSA remains under communal tenure which is often considered as lacking secure land rights. To rectify this, land registration programmes have been implemented across the region. Typically, land tenure security in SSA is created through the conversion of communal land to freehold titling through land registration. Studies in Ethiopia and Rwanda have demonstrated that land certification programmes translate to significant increases in agricultural investment.

This intersection between agriculture and land reforms opens up questions on the extent and impact of their linkage. It opens up possibilities for decision-makers and stakeholders to leverage land reforms and collaborate towards meeting SDG goal 2 among other global policies to end hunger and increase agricultural productivity on a global scale. However, despite the abundance of research on this interlinkage, there remains inconsistency in the literature on whether land registration increases agricultural productivity. The existing studies are yet to reach a conclusive agreement on how and which land reforms effectively support sustainable agriculture, creating a knowledge gap. Particularly in systems that are dominated by small-scale and subsistence farmers understanding this interlinkage is essential. This dissertation aims to bridge this gap by assessing the impact of land registration on agricultural productivity.

The main idea of this dissertation's approach is to provide empirical evidence beyond crop yield models and profit maximization models to improve the accuracy and replicability of the study findings in areas that are dominated by subsistence farming. Previous studies have also shown that even though initiatives educating farmers on climate resilience agriculture have indicated increased adoption, they have been found unlikely to raise farmers' willingness to adopt sustainable practices. To enhance the effectiveness of policy design for sustainable agriculture, it is crucial to delve into the behavioural drivers and barriers that shape farmers' decision-making.

By providing a comprehensive approach, this dissertation fills a crucial knowledge gap by evaluating if land registration creates security of tenure which motivates farmers to adopt sustainable investments that increase agricultural productivity. The following sub-questions are addressed;

1) What are the psychological factors that influence farmers' intentions to adopt climate resilience farming?
2) What is the impact of land registration on crop intensification in Kenya?
3) What is the impact of land registration on farmers' decision-making on the uptake of short and long-term on-farm investments?

To address the research questions, the study used a case study of Tharaka Nithi County in Kenya. Tharaka Nithi County reflects diverse agricultural systems and tenure systems found in SSA; this includes but is not limited to subsistence, semi-commercial and commercial farming systems, large-scale and small-scale systems, semi-arid and arid land (ASALs) agro-ecological zones, private and communal land tenure, registered and unregistered farmland. The county has two main ecological zones namely the highlands (Upper zone), and the Semi-arid zone (Lower Zone). It experiences a bimodal rainfall pattern with long rains falling from March to May (MAM), and short rains from October to December (OND). Agriculture in the county is predominantly small-scale and subsistence and reliant on rain. Small-scale farming has an average landholding of 2.9 hectares, while the average landholding for large-scale farmers is 6.7 hectares. Additionally, Tharaka Nithi County has similarities in population characteristics as to the country and SSA in general. The County has a 77% rural population with 80% of this population relying on agriculture for food, income, and livelihood. This is reflective of Kenya and SSA's average population which have roughly 71% and 69% rural populations respectively.

The dissertation uses primary data collected from Tharaka Nithi County in Kenya, and remotely sensed data, due to the unavailability of data. A structured questionnaire was administered to a sample of 446 farmers to collect cross-sectional data. To obtain acceptable county representation, farmer sampling was based on sub-locations which are the smallest administrative units. Systematic

random sampling and snowballing techniques were used during data collection to minimize biases. Systematic sampling was applied in the densely populated sub-locations where data collection would be done on every fifth farmer. Snowballing was used in sparsely populated areas, whereby the farmer would advise on the location of the next farmer. Data on land registration status was acquired from the Ministry of Lands and digitized while landmarks were used to identify land ownership on unregistered land. Remote sensed data for the Normalized Difference Vegetation Index (NDVI) dataset used in analysis covered 7 years and was acquired from an online database, Copernicus Global Land Service. Climate conditions were generated from national satellite spatial datasets under the World Resources Institute site.

The dissertation is composed of an introductory chapter, three main chapters and a concluding chapter. The chapters are summarized as follows:

Chapter 1 introduces the study background of the main issues of interest: agricultural productivity and land registration. The chapter gives a brief context and explores the study's analytical goal. A review of the literature on the relationship between sustainable agricultural productivity and land registration in SSA is presented. The section then gives a detailed chronological review of land reforms in Kenya. Based on the literature, a relevance and research gap is identified and explained.

The study is relevant due to food insecurity and low agricultural productivity in SSA which can be attributed to rapid population growth, urbanization and climate change, diminishing arable land and resources. There are also frequent land conflicts that have been associated with land use competition due to population explosion. Kenya is one of the countries experiencing low agricultural productivity with over 5.4 million under severe food insecurity. Despite policy intervention, SSA countries have been slow in adopting agricultural and land reforms. Existing studies have recommended land reforms as a key component in promoting sustainable agricultural productivity but they are inconclusive. The study identifies a research gap based on the inconsistency in findings on this relationship and this can be attributed to methods used that are limited in accounting for heterogeneity and spatial components.

This study seeks to fill the gap using a different methodological approach. The study uses spatial econometrics and behavioural models that capture the dynamics of heterogenous regions such as Kenya and farmer dynamics beyond cost-benefit models. This is driven by the knowledge that Kenya and SSA at large are characterized by subsistence farming and smallholder farming systems. The dissertation's conceptual framework is grounded in neoclassical theories that posit land registration creates incentives to invest, promotes access to credit, promotes land market and minimizes land conflict. An overview of the materials and methods used in the three empirical chapters is given but the detailed

methodology is discussed individually in the subsequent relevant chapters. The chapter further details the study's context and scope by giving a background on Kenya's agricultural context and Tharaka Nithi County context. The chapter lastly summarizes the structure of the study.

Chapter 2 is a scoping study aimed at identifying psychological factors that influence farmers' decision-making in the adoption of climate resilience agriculture (CRA). The chapter includes a literature review, theoretical framework for the study, detailed materials and methods section, results, discussion of the statistical findings, policy recommendations and recommends further areas of research.

The study uses an extended TPB framework to examine farmers' intention to adopt CRA. The framework evaluates the influence of TPB constructs (attitude, perceived behavioural control, and subjective norm) and additional variables (Actual Behaviour Control, farm, and farmer characteristics) on farmers' intentions. Attitude entails the degree to which a person evaluates the behaviour in question favourably or unfavourably. Subjective norms enquire about perceived social pressure to perform or not to perform the behaviour. Perceived behaviour control measures the perceived ease or difficulty of performing the behaviour. The additional TPB construct is actual behaviour control refers to the resources that may affect a farmer's behaviour such as lack of money, local politics, and family commitments. Other additional variables used are farm and farmer characteristics (gender, land size, marital status, age, and education level).

A descriptive analysis shows that the majority of the farmers had positive intention to adopt CRA. Farmers' intention was highly significant on PBC; the perception that CRA adoption is under the farmers' volitional control, followed by age (51-64yrs), then resources and professional guidance respectively. The findings contribute to the existing literature in two ways. First, the results indicate the suitability of the TPB framework for the study context and demonstrate that socio-psychological variables can provide insight into farmers' decision-making process on adopting CRA. Secondly, it extends studies that have recommended the TPB framework because it allows for the inclusion of additional variables. Notably, the findings show the provision of professional advice as a key additional predictor of farmers' intention in agricultural productivity in Kenya. The variable can be explored in future studies.

Findings indicate that policies aimed at increasing agricultural productivity should focus farmers' assurance effect where the farmers perceive that they will reap their output without uncertainties, and on government intervention to build farmers' capacity. This includes the provision of subsidies on agricultural inputs, and providing professional advice at local levels through government experts, agricultural advisors and farmer discussion groups. This is in line with existing agricultural and land reform policies in the country. Past studies have shown that

there is a difference between intended and actual behaviour as such this study recommends further studies to establish the actual behaviour after the agricultural subsidies and professional guidance are provided.

Chapter 3 evaluates crop intensification in registered and unregistered farms using an agronomic approach. The chapter includes a literature review, theoretical framework for the study, detailed materials and methods section, results, discussion of the findings, policy recommendations and further areas of research. Cropping intensity is used in this study as a proxy for crop productivity. The paper uses Normalized Difference Vegetation Index (NDVI) as the dependent variable and also a proxy for cropping intensity. The NDVI dataset used for analysis covers 7 years (2014-2020) acquired from Copernicus Global Land Service. The use of remote-sensed data from online databases is a cost-effective and time-efficient alternative to field surveys. Additionally, this approach addresses data limitations in regions with predominant subsistence farming systems, where crop yield models may be hindered by data unavailability and unreliability. Climatic and farm characteristics; rainfall, temperature, elevation, and soil quality are used as explanatory variables. The study employs Ordinary Least Squares (OLS) and Geographically Weighted Regression (GWR) analysis. NDVI is used as the dependent variable while Land registration is used as an explanatory variable together with farm and climatic characteristics, temperature, rainfall, elevation and soil quality. The GWR technique accounts for spatial heterogeneity, enhancing the accuracy and replicability of the study findings. A hot-spot analysis on GWR residuals to evaluate density distribution at a localized level affirms the findings. Unregistered land and especially in the semi-arid zone had cold spots significant at 99% confidence and hotspots significant at 99% confidence were mainly in registered land. An indication that GWR results were reliable.

The paper conclusively finds that land registration has a positively significant impact on cropping intensity particularly in arid and semi-arid lands (ASALs). Interestingly, land registration impact on cropping intensity is greater than climatic and farm characteristics. Practical implications for policymakers and researchers are fast-tracking land registration with priority given to ASALs, and creating and improving open-access land management information systems for public use. Further research is recommended using agronomic models and spatial econometrics to expand understanding of factors that can further increase sustainable agricultural productivity

Chapter 4; is a comparative study that verifies the findings in chapter 2 and 3 by addressing the research question on the impact of land registration on short- and long-term investments using an extended TPB framework. In addition to the TPB constructs, the study uses additional farm and farmer characteristics including land registration. The chapter has a detailed literature review, theoretical

framework and materials and methods section. The chapter then discusses the results from the statistical analysis, and policy implications and recommends further areas of research. In the logistic regression, intention is used as the dependent variable. Explanatory variables include TPB constructs and additional variables include, utility (USE), land registration status, and farm and farmer characteristics. The analysis is based on fertilizer use, adoption of CRA, and planting trees. The use of fertilizer is classified as a short-term investment, while climate resilience agriculture (CRA) and planting of trees are classified as long-term investments.

Average Marginal Effects analysis indicated that land registration had the highest magnitude on long-term investments the findings are in line with Chapter 3 which found that land registration had a positive impact on crop intensity. The results also provide insight into farmers' decision-making on on-farm investments by proving the hypothesis that land registration creates tenure security that increases farmers' willingness to uptake sustainable investments. Policies that seek to promote sustainable agricultural investments in the country should therefore advocate for land registration as it creates security of tenure motivating farmers to uptake sustainable on-farm investments. Additionally, the study found that professional advice from agricultural advisors on sustainable farming should be tailored to local levels by providing extension agricultural officers and farmer-led learning centres such as discussion groups.

The chapter recommends further studies in other counties in the country to ascertain the findings. Such findings would build a strong case to fast-track land registration. Further research is also recommended to assess the actualization of farmers' behaviour vs intention concerning land registration and sustainable agricultural practice, to analyze policy efficacy and impact on farmers' behaviour. Due to the lack of secondary data, there is a need for a data collection centre to build a reliable database platform for use by farmers, researchers and the public in future.

Chapter 5 summarizes the main results, draws conclusions and discusses the limitations, implications and further areas of research;

1) ***What are the psychological factors that influence farmers' intentions to adopt climate resilience farming (CRA)?***

The findings found that farmers' decision-making to adopt CRA has several psychological determinants. Farmers' intention is positively influenced by the perception that CRA adoption is under their volitional control, being in the base age category (51-64yrs), availability of resources and provision of professional guidance. For these results to translate into increased willingness to adopt sustainable agricultural practices it is important to tailor policies at the local level that would create assurance effect to the farmers, provide agricultural officers, government experts and farmer-led learning

models. It is equally important to build the capacity of farmers and the rural community to enable access to financial resources.

2) ***What is the impact of land registration on crop intensification in Kenya?***

The study conclusively finds that land registration has a positive significant relationship to cropping intensity particularly in ASALs. The study also finds that land registration has a higher positive correlation to cropping intensity than farm and climatic characteristics. Since these findings are from one county, further research is needed using a similar methodological approach in other counties and SSA at large.

3) ***What is the impact of land registration on farmers' decision-making to invest in short and long-term on-farm investments?***

The study found that land registration has the highest magnitude of positive impact on farmers' intention to undertake long-term on-farm investments using farmers' psychological factors. Additionally, some of the positively significant TPB constructs such as attitude and barriers/drivers are linked to tenure security. In sum, land registration incentivises farmers to adopt sustainable agriculture farming that would increase agricultural productivity.

The main objective of this research is to find out if land registration creates security of tenure which motivates farmers to uptake sustainable agricultural production. Overall, the findings validate the study hypothesis and recommend fast tracking of land registration in the country. The study however recognises that land registration in isolation is unlikely to yield strong impacts on farmers' adoption of sustainable agricultural production, it should be coupled with complementary interventions such as the provision of professional advice, capacity building to improve farmers' livelihood status and lowering costs of farm improvements.

The policy implications derived from this study are summarized as follows;

1) Fast-tracking of land registration with priority in ASALs. Policies that seek to promote sustainable agricultural investments in the country should advocate for addressing land registration as a priority to other hindrances.
2) Creation of a digital land management information system. Digitization of land data for future research and public access is vital to fully implement Vision 2030 flagship projects on land tenure that point towards creating a GIS-based national land information system and modernizing land registries and land adjudication programs.
3) Given that resources and professional guidance were influential to farmers' intention to invest in sustainable practices, government initiatives should focus on promoting farmers' capacity building through

training and economic empowerment. Incentives can be built based on discussion groups and subsidized inputs at local levels.

4) The study also recommends tailoring policies towards the local level to increase efficacy and efficiency. This can be achieved through the provision of government experts, agricultural advisors and farmer discussion groups.

Further studies are recommended focusing on;

1) Evaluation of the actualization of farmers' behaviour vs intention regarding land registration and sustainable agricultural practice. The study has conclusively found that land registration creates security of tenure and motivates farmers to increase agricultural investments.
2) In Kenya, a study on the impact of the policy and legal initiatives on farmers' behaviour is crucial. Tree planting has been a strictly regulated sector in the country. In 2010, the government passed legislation to ensure 10% of agricultural land is forested. However, implementation by the farmers has slacked. In Chapter 4, subjective norm (pressure from others) was significantly correlated to tree planting but AME results revealed it had no significant effect. Past studies have found SN to significantly impact mandatory policies. Thus, further research would reveal farmers' psychological factors causing the low uptake.
3) Further studies are also recommended to establish the rate of conflicts in registered lands on both highlands and ASALs farms and the impact of conflicts on agricultural productivity.
4) The study has found that the base age group (51-64) had a positive impact on on-farm investments. Further studies are recommended to establish socio and psychological factors that drive each age group to adopt sustainable agriculture.
5) Further studies are recommended to establish the impact of parks and conservation areas on land tenure security. In Chapter 3, the thesis highlights an anomaly that was attributed to the study area's complex interactions with Meru National Park as its buffer zone exacerbating land tenure insecurity
6) Lastly, further studies are recommended to assess the impact of land tenure security on agricultural productivity in Kenya and SSA using agronomic models. Few studies have used agronomic models in this area, if more is done, they can capture the crop diversity that exists in mixed farming systems.

Impact/ Valorization Addendum

This addendum describes the relevance of this thesis for policy implications. The thesis comes at an important time when Sub-Saharan Africa is being cited as the most vulnerable to climate change adverse impacts and food insecurity calling for urgent action. For instance, according to the 2023 IPC report, food insecurity in Kenya has increased to 43% over the last year and is expected to increase further, affecting 5.4 million residents as the country misses its fifth consecutive rainy season. It particularly affects the ASAL regions which comprise 80% of the country's landmass. This study, therefore, fits right into existing global and local policy efforts and development agendas to meet food security needs and increase livelihood resilience by providing an empirical reference for decision-makers and stakeholders.

Globally, the study is in line with several key policies. First, the Sustainable Development Goals (SDGs) goals 2, 12, and 15 support climate-resilient agriculture to increase agricultural productivity, especially for 75% of the World's poor living in rural areas. Secondly, the EU and FAO's main agenda emphasizes the need to increase agricultural productivity to meet the food security gap and alleviate poverty in SSA, the study contributes to how to achieve that. Thirdly, the Malabo Declaration developed by the African Union (AU) aims to accelerate Agricultural growth and transformation in Africa through a commitment of at least 10% of the annual GDP to agriculture and rural development. This study addresses the question of "how to make it happen", focusing on land reforms that can accelerate sustainable agricultural productivity. Those are just a few of the policies directed to promote agricultural productivity.

Land tenure security is a critical component in promoting sustainable agricultural productivity as optimal utilization of land in SSA is influenced by the prevailing pattern of land ownership that influences its control and usage. Even though several countries in SSA have embarked on land reforms aimed at creating security of tenure, inequality in land ownership and landlessness are still at unacceptable levels with approximately 90% of land under communal tenure which often lacks secure land rights heightening its vulnerability to conflicts, land grabbing and eviction. This study is at the intersection of these two sectors, "agriculture and land policy", and seeks to provide insight into the impact of land registration on agricultural productivity.

First, land tenure insecurity is theorized to cause farmers' reluctance to invest sustainably on their farms due to a lack of assurance that they will recoup benefits in the case of conflict or eviction. Additionally, there is a major concern about the continual decrease in arable land due to population pressure, urbanization and industrialization. In the past, growth in agricultural productivity in SSA was achieved by the expansion of agricultural land which currently lacks viability.

Thus, land reforms that would lead to sustainable intensification of existing land are crucial to promoting sustainable agricultural productivity.

A major contribution of this study is the addition of original data collected due to the unavailability of secondary data for the TPB model. The study conducted a cross-sectional survey in Kenya-Tharaka Nithi County. The field survey entailed the administration of questionnaires to the farmers based on systematic random sampling and snowballing methodologies. The data adds vital knowledge to the literature and can be used for further studies.

Secondly, the study also contributes an interdisciplinary research path to evaluate the impact of land tenure security on agricultural productivity in Sub-Saharan Africa (SSA) using novel methodologies. The study employs behaviour theory, agronomic models, and logistic and spatial econometrics that are based on theoretical foundations, unlike past studies that have majorly employed profit maximisation theories. The study comprises three main chapters that investigate, one, the psychological factors that influence farmers' intention to adopt climate resilience farming; two, the evaluation of agricultural intensification on registered and unregistered farms; and lastly impacts of land registration on farmers' intention to invest in sustainable agricultural investments.

Thirdly, the consistency in the three papers is worth noting that the socio-psychology of the farmers plays a major role in decision-making on agricultural investments. Land registration promotes agricultural productivity due to the perceived assurance effect it creates for the farmers which motivates them to invest. Chapter 2 findings indicate unravels the socio-psychological factors influencing farmers' decision-making to adopt climate resilience agriculture (CRA). The findings provide the baseline analysis of the farmers' attributes that are key to policymakers. Paper 4 found that land registration had the highest magnitude in influencing farmers' decision-making. This is in line with paper three which found that cropping intensity was higher in the registered areas compared to unregistered farms. The findings provide an empirical reference for policymakers to address land tenure security to boost agricultural productivity as it would influence the farmers' decision-making to invest.

The findings are summarized as follows;

Chapter 2, was a scoping study on the impact of farmers' socio-psychological factors in adopting CRA. The study employs the theory of planned behaviour and found attitude, professional guidance, resources, perceived behaviour control, and age (51-64 years) as key socio-psychological predictors of farmers' decision-making to adopt CRA in Kenya. The chapter concludes that policies geared at creating assurance effect to the farmers, capacity building at local levels and targeting the age groups would increase farmers' adoption of CRA.

Chapter 3 evaluates the level of crop intensification in registered and unregistered farms using an agronomic model. Significant variations in cropping intensity based on land registration status would demonstrate that land registration creates security of tenure that motivates farmers to intensify farming. Using remotely sensed data where the Normalised Difference Vegetation Index (NDVI) is the dependent variable, Geographically Weighted Regression (GWR) methodology is used to factor in spatial heterogeneity. Additional factors used in the analysis included farm and climatic characteristics and land registration status. Findings demonstrated that land registration has a statistically significant correlation to cropping intensity. Notably, it had the highest magnitude in the impact in comparison to farm and climatic characteristics. This relationship is more significantly pronounced in ASALs. The chapter concludes that the use of GWR methodology was appropriate since spatial econometrics captures the dynamics of heterogenous regions which is beyond cost-benefit models. Land registration was found to be a key component in promoting sustainable agricultural productivity. The study recommended fast-tracking of land registration in the country targeting ASALs as priority areas. Such a move is expected to create tenure security and motivate farmers to embrace agricultural intensification.

Chapter 4, explored the impact of land registration on short- and long-term investments. The study is based on the assumption that the significance of long-term investment reflects sustainable agricultural investment. For example, farmers will only invest in irrigation, or planting of trees if they feel secure and are assured to reap their benefits in the long term. The study used primary data collected through field surveys. An extended TPB model and logistic regression methodology are used to capture behavioural dynamics instead of crop yield models. This is driven by the knowledge that Kenya and SSA at large are characterized by subsistence farming and smallholder farming systems whereby yield data is unreliable or missing. Findings revealed that professional advice and access to resources were significantly correlated to farmers' intention to adopt both short- and long-term investments and land registration was significant for long-term investment. Land registration had the largest magnitude of change on farmers' intention to uptake long-term investments, an indication that land tenure impacts highly farmers' intention to invest in sustainable agriculture. The study recommends implementation of the land registration in the country to strengthen land tenure for farmers. In so doing, farmers will be incentivized to adopt sustainable long-term investments that will promote agricultural productivity. The study also recommends further behavioural research in the field that would guide the policymakers on socio-psychological attributes that influence the farmers.

To reach the scientific community, policymakers, and the public, the research has been shared extensively, chapters 2, 3, and 4 were presented in the UNU_MERIT (Maastricht), during the annual internal conferences, and the whole study was presented at the University of Galway (Ireland), Department of Social and Public Policy, during a Natural Resource Modelling Seminar. Comments from the researchers were incorporated to enrich the study. This culminated in a presentation made as a guest lecturer at the University of Galway on 'agricultural development in Kenya'. The research has also been used widely in teaching and guiding undergraduate students on the research process. The three chapters have been submitted to the journals for publishing, "Evaluating Cropping Intensity in Registered versus Unregistered Farms in Kenya-Tharaka Nithi County" is under review by the Journal of Remote Sensing Applications Society and Environment. The second paper "Psychological Factors that influence farmers' Intentions to Adopt Climate Resilience Agriculture: Evidence from Tharaka Nithi County in Kenya" is under review by the Journal of Sustainable Futures. The third paper "Impact of land registration on short- and long-term investments" is under review by the Journal of Land Use Policy. The study has enlightened me in the research process and am disseminating the knowledge in teaching.

In conclusion, land registration has a positive impact on agricultural productivity in Kenya, an indication that it creates tenure security which motivates farmers to adopt sustainable on-farm investments. The findings are replicable in other SSA countries with insecure land tenure. The study provides an empirical reference for policymakers in developing the future design of agricultural policies to include the security of tenure because of its socio-psychological attributes that influence the farmers to adopt sustainable agricultural practices. Therefore, fast-tracking of land registration with priority to ASALs is recommended. This should go hand in hand with other policy measures such as capacity building to improve farmers' livelihood status, subsidizing farming inputs and improved access to agricultural advisors which are crucial in expanding the farmers' capability to adopt sustainable agricultural practices. These policy measures should be tailored at the local level to increase efficacy

Curriculum Vitae

Casty Gatakaa Mbae Njoroge was born on 6th March 1970 in Meru District in Kenya. She holds a bachelor's degree in Land Economics from the University of Nairobi (Kenya), a Masters in Geoinformation Science and Earth Observation specializing in Land administration and Geographical Information Systems (GIS) from the International Institute for Aerospace Survey and Earth Sciences (ITC-Netherlands) and a Masters in Urban and Regional Planning from the University of Nairobi. She was awarded Best Student Class of Masters in Urban and Regional Planning in 2005.

Casty served as a Valuation Officer under the Ministry of Lands (Government of Kenya -GoK) for 11 years after completing her undergraduate degree. Her main duties encompassed carrying out land valuation and formulation of guidelines on land administration. After attaining a Master's degree, she worked for 5 years as a Physical Planner under the Urban and Regional planning department (GoK). Her duties included land use planning, approval of local residential plans, and formulation of land use policies. In 2010, she was seconded to a government research institution Kenya Institute of Public Policy (KIPPRA), as a researcher on the governance and land reforms sector where she worked for 4 years.

While at KIPPRA, She published 3 policy discussion papers namely; "Ndung'u Report on Land Grabbing in Kenya: Legal and Economic Analysis", "The Achilles ' Heel of Police Reforms in Kenya", and "Is There a Real Estate Market Boom or Bubble in Urban Kenya: A Case Study of Residential Real Estate in Nairobi Metropolitan Region".

In 2014, Casty was deployed as a lecturer in a government university, the 'Technical University of Kenya' where she is currently teaching in Spatial Planning and Land administration. She is also involved in consultancy works and particularly in the preparation of Resettlement Action Plans (RAPs) for land acquisitions, and land policy analysis.

Casty is married to Dr Njoroge and has 3 children. She is currently living in Nairobi, the Capital City. She is a Christian, brought up in a rural village and a big lovely family.

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