CLIMATE CHANGE PERCEPTION, CROP DIVERSIFICATION AND LAND USE CHANGE AMONG SMALL-SCALE FARMERS IN THE MIDLANDS REGION OF KWAZULU-NATAL, SOUTH AFRICA: BEHAVIOURAL AND MICROECONOMIC ANALYSES

By

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ABSTRACT

The future of small-scale agriculture in South Africa is facing the challenges of high population growth, land degradation, and agro-biodiversity loss. In the Midlands region of KwaZulu-Natal (KZN), the challenges are exacerbated by climate change (CC). Agricultural land use change (ALUC) is among farm-level options to exploit the synergy between local adaptation and global mitigation of CC, whilst restoring degraded lands and agro-biodiversity reservoirs. The literature contends that the pathways to climate-resilient sustainable land use start with the farming sector's vulnerability to CC, and translate into behavioural change through farmers' perceptions about the climate risk. Two major steps characterize behavioural response to changing distributions of weather patterns. Behavioural responses to CC begin with reducing the vulnerability to climatic variability (e.g. by using tactical adjustments such as crop diversification), followed by forward-looking integration of adaptation and mitigation into farm planning (e.g. through ALUC).

The purpose of this study was to provide a systematic and detailed understanding of climate-driven ALUC in the setting of small-scale farming in South Africa. Taking the Midlands region of KZN as an illustrative case, this study aimed (i) to explore some meso-level aspects of climate-related agricultural vulnerability; (ii) to investigate the perceptions of small-scale farmers about CC and their socio-psychological, institutional and cultural determinants; (iii) to analyse the farmland use systems and assess the microeconomic determinants of seasonal crop diversification; and (iv) to assess the attitudes of small-scale farmers towards land use and the constraints governing ALUC decision-making.

To assess the meso-level vulnerability of farming sector to CC in the Midlands region of KZN, an indicator approach was adopted. Various aspects of exposure, sensitivity and adaptive capacity of the farming sector were explored using a systematic review of available empirical evidence. The review suggested that the farming sector is exposed to a warming and wetting climate. The reviewed evidence also suggested that the farming

sector is highly sensitive to CC due to high population densities, high rates of small-scale farming, low irrigation rates and susceptibility to land degradation. Nevertheless, diversified crop portfolios remain a major aspect of resilience among small-scale farmers. The reviewed evidence further indicated that farmers' adaptive capacity is confounded by inadequate access to infrastructure, rural exodus, skills shortages, poor health status, and low level of social capital.

The remaining objectives were empirically investigated based on primary data from a household survey of 152 small-scale farmers in the uMshwati local municipality. With regard to the second objective, a principle component analysis (PCA) of eight variables of perceived seasonal climatic abnormality yielded two dominant perceptual shapes. CCP_1 score captured the extent to which an individual farmer perceives the winter season as cooling and the summer season as warming and drying. CCP_2 score captured the extent to which an individual farmer perceives the winter season as warming and wetting, and summer season as drying. The results of a Double-Hurdle (DH) model showed that the probability of perceiving abnormal trends in the local seasonal climate increases with holistic affect, egalitarian worldviews, age, female-headedness and hilly and wetter agro-ecological regions, and decreases with education. The model results also showed that the CCP_1 score increases with holistic affect and other factors related to personal experience such as age and distance to the river, signifying experience-based learning. The results further showed that CCP_2 score increases with cognitive ability (knowledge) and related socio-demographic factors such as education, extension and trust, indicating analytic processing of climate information.

With regard to the third objective, a two-stage cluster analysis of land use data unveiled a diversified farmland use matrix characterised by a maize-beans inter-cropping system coexisting with of mixed crop-livestock, sugarcane and timber mono-cropping systems. After accounting for potential endogeneity biases, the results of a logit transformation model showed positive effects of labour and landholding on the intensity of multiple-cropping among poorer and richer households, suggesting that responding to technological constraints is an important driver of seasonal crop diversification.

Furthermore, the results showed that the intensity of multiple-cropping among richer households decreases with education due to faster shadow wage rise at higher farm assets position. Among poorer households, the intensity of crop diversification decreases with off-farm occupation and increases with distance to water sources, suggesting that mitigating income and production risks are key motivations for crop diversification.

Regarding the fourth objective, the results of a Mixed-multinomial Logit model that accounts for potential endogeneity biases showed that the decisions about ALUC from seasonal crops towards forestry or sugarcane cultivation are rationally derived and driven by clear but heterogeneous preferences and trade-offs between crop productivity, food security, and labour requirements. These motivations override income generation and ecological sustainability incentives, the common policy foci in South Africa. The model results also indicated that the utility of planting sugarcane increases with size of landholding, suggesting economies of size. The preference for forest plantation decreases with household size, a Chayanov-like afforestation pattern. Furthermore, the results indicated that the preference for ALUC increases with the proportion of ALUC in the community/ward (suggesting peer group influence) and hilly and wetter agro-ecological conditions (due to higher land conversion cost and acute soil erosion).

The empirical findings of this study pointed to the need for designing a region-specific CC communication strategy that involves affected farmers and locally trusted agricultural extensions agents, and aligns the information content to local beliefs, values and norms. The findings also inferred that reduced agro-biodiversity loss and enhanced resilience in the face of the increasing climatic variability through crop diversification could be major co-benefits of the ongoing land reform, and explicit strategies should focus on regions with widespread poverty and dryland farming. For supporting ALUC towards farmland afforestation, the findings advocated the promotion of timber-based agroforestry systems as an effective strategy to align public goals with private incentives. The findings further advocated incentive-based afforestation schemes (such as payment for ecosystem services) designed on a per-capita or equivalent-consumption basis and targeting farms located in regions with steeper slopes and higher climate variability.

DECLARATION 1 – PLAGIARISM

I, Patrick Hitayezu, declare that:

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

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

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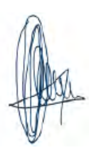

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Prof. Edilegnaw Wale Zegeye (Supervisor)

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Prof. Gerald Ortmann (Co-supervisor)

DECLARATION 2 – PUBLICATIONS

The following articles, published or under review, form part of the research presented in this thesis.

Publication 1 – Chapter 2 of the thesis:

Hitayezu, P., E. Wale, G.F. Ortmann. (2014). Some aspects of agricultural vulnerability to climate change in the KwaZulu-Natal Midlands, South Africa: A systematic review. *Journal of Human Ecology*, 48(3): 347-356.

Publication 2 – Chapter 3 of the thesis:

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Publication 3 – Chapter 4 of the thesis:

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Publication 4 – Chapter 5 of the thesis:

Hitayezu, P., E. Wale, G.F. Ortmann. Assessing agricultural land-use change in the Midlands region of KwaZulu-Natal, South Africa: Application of mixed multinomial logit. *Environment, Development and Sustainability* (In Press).

The data collection, analyses, and discussion of empirical results for all the above-listed articles were conducted in their entirety by Patrick Hitayezu with technical advice from Prof. E.W. Zegeye and Prof G.F. Ortmann. All figures, tables, and graphs were produced by the same, unless otherwise referenced in the respective publications.

DECLARATION 3 – CONFERENCE PRESENTATIONS

Papers have been presented at the following conferences:

Conference paper 1 – Chapters 3 of the thesis:
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Conference paper 3 – Chapter 5 of the thesis:
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- the 53rd Conference of the Agricultural Economics Association of South Africa (AEASA), 28 September – 01 October, 2014, Mpekweni Beach Resort, Eastern Cape, South Africa;
- the 9th Congress of the African Farm Management Association (AFMA), 16 - 20 November, 2014, Cape Town, South Africa; and
- the 29th Triennial Conference of the International Association of Agricultural Economists (IAAE), 8 - 14 August, 2015, Milan, Italy.

DEDICATION

To my beloved Father, Mother, Brothers and Sisters.

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LIST OF ACRONYMS

ACCESS	:	Applied Centre for Climate and Earth Systems Science
AERC	:	African Economic Research Consortium
AEZ	:	Agro-Ecological Zoning
AFOLU	:	Agriculture, Forestry and other Land Uses
ALUC	:	Agricultural Land Use Change
AR5	:	Fifth Assessment Report of the Intergovernmental Panel on Climate Change
BDR	:	Behavioural Decision Research
BLP	:	Berry-Levinsohn-Pakes Approach
BPT	:	Biophysical Threshold
CBD	:	Convention on Biological Diversity
CC	:	Climate Change
CDI	:	Crop Diversification Index
CDM	:	Clean Development Mechanism
CER	:	Certified Emission Reduction
CL	:	Conditional Logit
CO_2		Carbon Dioxide
CO_2eq	:	Carbon Dioxide Equivalent
COP	:	Conference of the Parties
CSM	:	Climate Systems Model
CV	:	Coefficient of Variation
DAFF	:	Department of Agriculture, Forestry and Fisheries
DCE	:	Discrete Choice Experiments
DFID	:	British Department for International Development
DH	:	Double-Hurdle
EBA	:	Ecosystem-based Adaptation
EGS	:	Ecosystem Goods and Services
EV	:	Expected Utility
GCM	:	General Circulation Model

GDP	:	Gross Domestic Product
GHG	:	Greenhouse Gas
GLM	:	Generalized Linear Model
IIA	:	Independence of Irrelevant Alternatives
IID	:	Independent and Identically Distributed
IMR	:	Inverse Mills Ratio
IPCC	:	Intergovernmental Panel on Climate Change
IV	:	Instrumental Variables
KMO	:	Kaiser-Meyer-Olkin Criteria
KZN	:	KwaZulu-Natal
LUFs	:	Land Use Functions
MMNL	:	Mixed-Multinomial Logit
MNL	:	Multinomial Logit
MVP	:	Marginal Value Product
NL	:	Nested Logit
PC	:	Principal Component
PCA	:	Principal Component Analysis
PES	:	Payment for Ecosystem Services
PPF	:	Production Possibility Frontier
PRA	:	Participatory Rural Appraisal
QMLE	:	Quasi-maximum Likelihood Estimators
RCPs	:	Representative Concentration Pathways
REDD	:	Reducing Emissions from Deforestation and forest Degradation
REDD+	:	Reducing Emissions from Deforestation and Forest Degradation, with Sustainable Management of Forests, Conservation of Forest Carbon Stocks and Enhancement of Forest Carbon Stocks.
RMSE	:	Root Mean Squared Error
RP	:	Revealed Preference
SASA	:	The South African Sugarcane Association
SP	:	Stated Preference
SSA	:	Sub-Saharan Africa
UK	:	United Kingdom

UKZN	:	University of KwaZulu-Natal
UNFCCC	:	United Nation Framework Convention on Climate Change
USD	:	United States Dollars
ZAR	:	South African Rand

CHAPTER 1 . INTRODUCTION

1.1. Background

Unlike many countries in the sub-Sahara Africa (SSA) region, South Africa is a highly transformed economy. Over the last decades, the role of the primary agricultural sector has been shrinking as the economy grew. By 2013, primary agricultural production had a relatively low macroeconomic value, contributing about 3% of Gross Domestic Product (GDP), 7% of formal employment, and 6.5% of exports (Tibane and Vermeulen, 2014). However, agricultural production remains a key livelihood strategy for over 200 000 market-orientated smallholders and 2.5 million subsistence-orientated farmers (Hall and Aliber, 2010). Based on the 2011 census, Statistics South Africa (2011) reports that 24.9% of the small-scale farmers (mainly engaged in grain crops, vegetable, poultry and livestock production) are located in the province of KwaZulu-Natal (KZN). The livelihoods of small-scale farmers in KZN also rely on unmanaged agricultural and forest ecosystem goods and services (EGS) such as traditional vegetables that do not require formal cultivation, deadwood, and medicinal plants (De Wet et al., 2012; Odhav et al., 2007).

The productivity of Small-scale farms in KZN, however, remains relatively low. Studies suggest that, on average, maize production ranges from 750 kg (conventional and Bt varieties) to 1.9 metric tonnes ha^{-1} (genetically modified varieties) (Gouse et al., 2009; Regier et al., 2012). These figures are far below the regional agro-ecological potential of nearly 10 to 11 metric tonnes ha^{-1} (Abraha and Savage, 2006; Estes et al., 2013). The poor performance of small-scale farmers has been attributed to the lack of institutional support, as well as frictions in market access that distort price incentives and discourage commercialization (e.g. high transaction costs, poor infrastructure, and weak bargaining power) (Ortmann and King, 2010; van Schalkwyk et al., 2012).

The future of small-scale farming systems in South Africa is facing even more local and global challenges. The country's population is expected to grow from 49 million in 2009 to nearly 82 million by 2035 (Goldblatt, 2010). In the rural areas where small-scale farming is expected to remain the backbone of food security, agricultural production must more than double to feed the growing population, using the same or smaller natural resource base (Goldblatt, 2010).

Yet, since 1994, land cover in KZN has been undergoing anthropogenic conversion and modification at a rate of 1.35% (or 127,909ha) per annum, with severe consequences on natural EGS and biodiversity (Jewitt, 2012). The spatial expansion of small-scale farming within and outside communal land areas in the post-apartheid era has been associated with depletion of forest and fallow lands, increased risk of soil, water and vegetation degradation, and severe losses of agro-biodiversity. This is mainly due to socio-economic factors such as uncontrolled grazing, over-reliance on forest products, intensive cultivation, adoption of monoculture, loss of interest in indigenous crops, increased adoption of exotic and invasive/alien species, and farmland abandonment (Hoffman, 2014; Khumalo et al., 2012; Mahlase and Fakir, 2001; Palmer and Bennett, 2013; Puttick et al., 2014; Wigley et al., 2010). Thus, agricultural land use change (ALUC) in small-scale farming areas has considerably affected the potential of the land to produce EGS critical for the sustenance of rural livelihoods in the future.

The threat to the potential productivity of land is compounded by climate change (CC), i.e. an irreversible, permanent phenomenon of new trends superimposed on natural climate variability (Callaway, 2004; Schulze, 2000). Generally, South Africa's average annual temperature has increased by 0.5°C (or 2%) and its mean annual rainfall has decreased by 40mm (or 6%) over 1997–2006 compared to the 1970–1979 period (Blignaut et al., 2009). Climate change has also been marked with schemes of spatial expansion of intensive and extensive droughts and heavy rainfall eastwards, towards the summer rainfall areas (Crétat et al., 2012; Richard et al., 2001). In the future, most general circulation models (GCMs) project increases in temperature of 2.9 - 3.9°C and 3.9 - 9.6°C by 2050 and 2100, respectively, juxtaposed with reductions of 2 - 8% and 4 - 8% in precipitation by 2050 and 2100, respectively (Benhin, 2008). Towards the end of the century, whilst the western coastal areas and their adjacent interiors could experience drying trends (with increased inter-annual rainfall variability), wetting trends are projected over most eastern interior parts (Lumsden et al., 2009).

The climatic changes could negatively affect agricultural performance directly (through changes in crop suitability) or indirectly (through increased risk of land degradation). In many parts of KZN, for example, agro-ecological zoning (AEZ) studies for maize production have shown that the increase in temperature could reduce the duration of maize growth cycle (due to early occurrence of senescence) (Abraha and Savage, 2006; Estes et al., 2013).

Increase in air temperature beyond +2^{0}C could become a limiting factor to the extent that any yield gains caused by increased CO_2 concentration in the atmosphere cannot compensate for the yield loss caused by a reduced growing season, even under a +20% rainfall scenario (Abraha and Savage, 2006; Estes et al., 2013). This could create maize production losses of up to 11% (Estes et al., 2013). A +1^{0}C increase in temperatures and a +1mm increase in monthly precipitation during the summer farming seasons in KZN could result into farm income changes of, respectively, -1684 United States Dollars (USD) ha^{-1} and -142USD ha^{-1} (Benhin, 2008).

In an indirect manner, research shows that increased rainfall variability, coupled with steeper slopes, could accentuate the risk of land degradation and decrease the net primary productivity of land, particularly during hotter months (Meadows and Hoffman, 2003; Wessels et al., 2007). Future climatic changes could also cause major species extinction, redistribution, and biodiversity reduction, further challenging the sustained provision of EGS. Therefore, the climate- and ALUC-driven biodiversity loss could hamper ecosystem-based adaptation (EBA), defined as the reduction of vulnerability using natural ecosystem services as safety nets (Jewitt, 2012).

Incidentally, ALUC in small-scale farming areas also contributes to global warming. A recent inventory of greenhouse gas (GHG) emission from South Africa suggests that net emissions of the agriculture, forestry and other land uses (AFOLU) sector have increased from 19,974Gg CO_2eq in 2000 to 33,717Gg CO_2eq in 2010, mainly due to a decrease in the forest land CO_2 sink (Republic of South Africa, 2013). The report attributes the decline in above- and below-ground CO_2 sink to land conversion, wood harvesting, and fuelwood consumption in small-scale farming areas, coupled with major disturbances such as fires.

As various assessment reports of the Intergovernmental Panel on Climate Change (IPCC) recommend, reducing the environmental and economic risks associated with CC requires major responsive actions that exploit the synergy between local adaptation and global mitigation to substantially reduce GHGs emissions, increase the prospects for efficient adaptation in the longer term, and contribute to climate-resilient pathways to sustainable development (Stocker et al., 2013). In the AFOLU sector, some mitigation strategies (i.e. strategies to enhance CO_2 sequestration) such as land afforestation, reforestation, and avoided deforestation may have potentials to address climate-driven changes in suitable agro-climatic conditions, restore biodiversity reservoirs, and provide other EGS important for EBA (Locatelli et al., 2010; Ravindranath, 2007).

In the KZN province, for example, AEZ studies suggest that CC could cause major spatial expansions of climatically optimum growth areas for tree crops production towards the areas where small-scale agriculture is concentrated (Schulze and Kunz, 2010a, 1995). In such areas, major climate-driven land use conversion to tree plantations could be expected, given that the gains in optimum growing conditions for trees and the reduction in grain crops suitability could occur simultaneously (Warburton and Schulze, 2008). Indeed, reducing emissions from deforestation and forest degradation (REDD+) is viewed as a way in which South Africa could achieve its emission reduction goal (i.e. 34% deviation below the 'business as usual' emissions growth trajectory by 2020) (Rahlao et al., 2012). Moreover, timber out-growing secures access to technologies, credits, and markets that would not be available to small-scale farmers under any other circumstances (Cairns, 2000; Sartorius and Kirsten, 2002).

Climate-driven ALUC, however, is a complex process involving environmental, behavioural, and socio-economic factors. Neoclassical economists argue that, in the short-run, farmers who can hardly learn about CC continue to cope with the normal climatic variability by doing tactical adjustments in variable inputs (Callaway, 2004). In the long-run, autonomous learning and adaptation processes are governed by series of transitory losses in farm productivity or profitability that create awareness about CC (Kelly et al., 2005). As CC is autonomously learnt and reliable CC information is obtained from external sources, farmers consider changing the use of (quasi) fixed inputs such as land (Callaway, 2004).

However, the adepts of behavioural decisions research (BDR) contend that confining the understanding of individual learning process to the rationality of profit maximization would be an oversimplification of a complex reality. They argue that complex socio-psychological, cultural, and institutional processes (van der Linden, 2014a; Weber, 2010) that take place within specific vulnerability contexts (Brody et al., 2008; Saleh-Safi et al., 2012) determine peoples' judgment and decision-making about climate risk. Risk perceptions mediate the transition from climate-related vulnerability towards resilience, via behavioural change (Weber, 1997).

Given positive perceptions about CC, the firth assessment report (AR5) of the IPCC contends that two major steps characterize behavioural responses to CC (Stocker et al., 2013). Responding to future CC begins with reducing vulnerability and exposure to present climate variability, followed by forward-looking integration of adaptation and mitigation into planning at all levels of decision-making (Stocker et al., 2013). Indeed, in many developing regions where rain-fed agricultural production is expected to remain vital for food security, exposure to erratic climates and incidences of extreme weather has been a common experience among farmers, even where average rainfall is reasonably good (Gowing, 2003). Therefore, researchers in the field of CC commonly argue that the ability of farming communities to cope with the extant constraints must first be understood and enhanced in order to design effective agricultural policy strategies for future household resilience (Cooper et al., 2008; Vermeulen et al., 2012). From an economic perspective, coping with the "normal" climatic variability on farms involves tactical adjustments in variable inputs (Callaway, 2004).

However, even with reliable information about CC and its agro-ecological impacts, strategic decisions about changing fixed input use (e.g. land use change) are inherently normative (Callaway, 2004). The landscape literature evidences that ALUC decision-making is derived from and driven by farmer's attitudes (i.e. the product of outcome belief and subjective outcome evaluation) (Zubair and Garforth, 2006). With such considerations, behavioural decisions researchers argue that whether or not the risks posed by CC and ALUC can be avoided or contained will ultimately depend on the outcome of individual behaviour and decision-making (van der Linden, 2014a). The insights of BDR are, therefore, indispensable in the CC policy discourse in South Africa.

1.2. Problem statement

In South Africa, a CC detection study by Warburton et al. (2005) revealed two major hotspots of warming, *viz*. the Midlands region of KZN and some areas in the Western Cape province. Given that KZN is home to a larger proportion of small-scale farmers in South Africa, the Midlands region should be a priority to CC policymakers and an exemplary case for empirically investigating CC-related vulnerability, adaptation and mitigation in South Africa. To date, however, research on farmers' experiences with CC and their adaptive land use management in this region remain limited in various respects.

1.2.1. Profiling micro-level agricultural vulnerability to climate change in the Midlands region of KwaZulu-Natal

Vulnerability assessment is an important tool to gauge the appropriateness of any adaptation strategy (Smit and Wandel, 2006). Mapping climate-related vulnerability is a useful tool to help spatial planning of adaptation and educating vulnerable communities (Preston et al., 2011). Recently, a macro-level vulnerability assessment by Gbetibouo et al. (2010) reported that, unlike in provinces such as Western Cape and Gauteng, the farming sector in the KZN, Eastern Cape, and Limpopo provinces has higher scores of vulnerability. The farming sector in the KZN province, in particular, scored higher sensitivity due to higher population density coupled with a larger share of small-scale farmers, overreliance on rain-fed agriculture, and acute levels of land degradation. Gbetibouo et al. (2010) further showed that the provincial adaptive capacity was confounded by lower literacy rates, higher HIV prevalence, and inadequate access to infrastructure.

Notwithstanding the importance of Gbetibouo et al.'s (2010) insights for informing the regional policy focus, it is a common argument that such macro-level assessments of vulnerability can mask substantial variability in micro and meso-level exposures, sensitivities and adaptive capacities (Thornton et al. 2006). In a certain region, there might be considerable heterogeneity in local climate, farming systems, and adaptive capacity. For example, as Reidsma et al. (2010) observed in Europe, although a larger diversity in farm types at regional levels was a key indicator of resilience, certain farm types remained vulnerable, mainly due to the way they are managed. This view underscores the importance of understanding the vulnerability at lower scales of decision-making.

Meso- and micro-level assessments of agricultural vulnerability have been conducted in various parts of the developing world such as Mozambique (Hahn et al., 2009), Ethiopia (Deressa et al., 2008), Mexico (Luers et al., 2003), India (Pandey and Jha, 2012) and Nepal (Urothody and Larsen, 2010). In South Africa, attempts to profile the vulnerability of farming systems at smaller spatial scales include studies conducted in Limpopo (Shewmake, 2008) and in Northern Cape (Jordaan et al., 2013). Paradoxically, eleven years after Warburton et al. (2005) evidenced high level of exposure to CC in the KZN’s Midlands, no micro-level study has been undertaken to profile the sensitivity of the regional farming sector and its adaptive capacity. The lack of empirical evidence creates an important gap in the understanding of the major sources of resilience, a key input in the design of CC response strategies.

1.2.2. Perceptions about climate change among small-scale farmers in South Africa

Economists view adaptation to CC as a two-step decision-making process. Unlike the standard simulation approaches to agricultural impact assessment that assume accurate detection of and/or expectations about CC, economic models consider perception as a pre-condition for technological and economic adaptation (Deressa et al., 2011; Maddison, 2007; Weber, 1997). Awareness and self-reported knowledge of CC are key precursors to personal behavioural change and support of CC mitigation and adaptation policies (Leiserowitz, 2006; Poortinga et al., 2011; van der Linden, 2014a).

Raising public awareness of the real threat posed by CC has been a common pledge in many countries' CC response policies (United Nations Environment Programme, 2006). The CC communication policy, however, faces a set of two interrelated challenges: uncertainty and scepticism (Whitmarsh, 2011). Unlike other natural hazards, the slow and gradual nature of CC makes it difficult to be discerned from the natural variability of local climate (Hansen et al., 2012; Hulme et al., 1999). The inherent uncertainty in the CC discourse is not only recognized among the scientific community that use state-of-the-art apparatus and models, but also across various segments of the general public who learn about CC in different ways (Poortinga et al., 2011; Whitmarsh, 2011). In many cases, tendencies by policymakers to downplay the uncertainty (in order to justify their actions) and overlook the differences in public opinions have resulted in policy inertia, passive resistance, and even active opposition from those concerned by new regulations (United Nations Environment Programme, 2006). Therefore, effective CC communication requires a good understanding of public opinions and a recognition of individual variation in learning processes (Whitmarsh, 2011).

In the SSA region, recent empirical studies have shown that small-scale farmers hardly recognize the new trends super-imposed on normal climatic variability. In a study covering ten African countries, Maddison (2007) reported that, despite the lack of evidence that temperature and rainfall had changed in countries such as Kenya, Niger, Senegal, Egypt and South Africa, farmers in these countries stated that their local climates were becoming hotter and dryer. Bryan et al. (2009) reported that misdetection of CC is more widespread among South African farmers than among Ethiopian farmers.

In South Africa, studies conducted by Bryan et al. (2009) and Gbetibouo (2009) reported that a high proportion of farmers in the Limpopo River Basin reportedly noticed a decrease in rainfall, whilst meteorological analysis suggested no significant changes in rainfall over the period of 1960-2003. In this region, Shewmake (2008) found a weak correlation between self-reported floods and droughts and actual meteorological records. In the Camdeboo Local Municipality of the Eastern Cape province, where rainfall records show a significant increase since 1990, Muller and Shackleton (2013) reported that only 48% of communal land farmers perceived CC, the majority of whom rather reported a decreasing trend in rainfall. A similar study conducted among small-scale farmers in the Thaba Nchu district of the Free State province by Gandure et al. (2013) corroborated the findings of Muller and Shackleton (2013). The study found that whilst the perceived high rainfall variability and increasing temperature corresponds to the 1962-2009 meteorological data, perceptions of increased rainfall intensity and drying trends were largely inaccurate. Similar findings were reported from other parts of SSA region such as Uganda (Osbahr et al., 2011), Zimbabwe (Moyo et al., 2012), Botswana and Malawi (Simelton et al., 2013).

The limited success of CC communication policy underscores the need for investigating the causes of misperceptions among small-scale farmers in South Africa. The existing empirical literature, however, simplistically argues that the misperception could be due to the complexity of biophysical processes that can be hardly discerned by most farmers. The classical example is that most farmers could incorrectly perceive long-term rainfall changes due to the impact of increased temperature in the form of higher evapotranspiration and increased demand on available water, faster development of water stress during dry spells, etc. (Moyo et al., 2012; Osbahr et al., 2011; Simelton et al., 2013). Hence, the existing studies commonly argue that the reason behind the incorrect perception could be attributed to the fact that most farmers recall production (i.e. the impact) rather than the climate itself (Gandure et al., 2013; Gbetibouo, 2009; Muller and Shackleton, 2014).

The BDR offers a unique perspective for empirically understanding the processes of learning about CC. The behavioural approach unravels the importance of socio-psychological, institutional and cultural processes underlying individual perceptual formation (Dessai et al., 2004; Leiserowitz, 2006; Marx et al., 2007; van der Linden, 2014a; Weber, 2010, 2006). The adepts of the behavioural approach contend that there are two pathways of perceiving climate risk. Perception about CC accrues from (i) experiential processing and affects, and/or from

(ii) analytical processing of climate data (Marx et al., 2007; Weber, 2006). The differential learning processes explain the differences in perceptions about CC and the variation in ensuing responses (van der Linden, 2014a; Weber, 2010).

This approach, however, remains an underexplored perspective in the empirical literature on CC. Klöckner (2011) notes that even in the IPCC reports, there is virtually no mention of insights of BDR. The underrepresentation of BDR in the discourse of perceptions about CC is even more pronounced in empirical literature in SSA. Virtually all the existing behavioural studies of climate risk perception have been conducted in the developed countries such as the UK (Poortinga et al., 2011; van der Linden, 2014a; Whitmarsh, 2011) and the US (Leiserowitz, 2006; Weber, 2006). Among the UK public, for example, Poortinga et al. (2011) and Whitmarsh (2011) reported that scepticism about CC among the UK public is not a result of knowledge deficit but an outcome of low pro-environmental values and conservative political values. van der Linden (2015) showed that the knowledge about CC only influence societal (i.e. holistic) risk perception, whilst personal experience and egoism only influence personal risk perception. In the US, Leiserowitz (2006) reported that affect and imagery were the most important determinants of CC risk perception among people.

In Africa, a recent review by Juana et al. (2013) shows no evidence of the insights of BDR in the discourse of perceptions about CC in SSA. It is worth noting, however, that a handful of empirical studies (e.g. Bryan et al., 2009; Gbetibouo, 2009; Maddison, 2007) have attempted to investigate the factors influencing perceptions about CC in South Africa. Notwithstanding the importance of their insights, the empirical studies have overlooked the importance of socio-psychological, institutional and cultural processes underlying individual perceptual formation. Therefore, critical information for the design of CC communication strategies in South Africa is still lacking.

1.2.3. Seasonal crop diversification among small-scale farmers in South Africa

Crop diversification is an important aspect of resilience of farming systems facing environmental as well as economic challenges. In the biophysical sphere, the diversity in farm types at regional scale provides biological means of controlling the incidence of pest outbreaks and the transmission of pathogens (Behera et al., 2007; Lin, 2011; Njeru, 2013; Reidsma and Ewert, 2008). At farm level, crop diversification reduces the sensitivity of production to climatic variability (Gilbert and Holbrook, 2011). In the socio-economic sphere, crop diversification imparts the advantages of economies of scope in farming systems and improves their scale efficiency (Rahman, 2009). It is also a practical way to promote agro-biodiversity (Bezabih and Sarr, 2012; Cavatassi et al., 2012; Di Falco et al., 2010; van Dusen and Taylor, 2005) and dietary diversity important for livelihoods diversification and household food security (Di Falco et al., 2010; Njeru, 2013).

The advantages of crop diversification are more vivid for largely income-poor regions (Kaulich, 2012) facing the challenges of lower and variable rainfall (Bezabih and Sarr, 2012; Di Falco et al., 2010; Gilbert and Holbrook, 2011) and inadequate access to the market among small-scale farmers (van Dusen and Taylor, 2005) such as South Africa. The majority of South African small-scale farmers remain poor and can hardly access the markets for their produce and key inputs such as land, labour, credit and insurance (Obi et al., 2012). Moreover, they are concentrated in the eastern parts of the country where intensive spells of highly variable rainfall are expanding (Crétat et al., 2012). Under such circumstances, the conceptual literature suggests that crop diversification would allow farmers to satisfy their demand for household consumption entirely from own production (van Dusen and Taylor, 2005) while mitigating the negative effect of rainfall variability (Gilbert and Holbrook, 2011). This view is supported by empirical evidence from the KwaZulu-Natal (KZN) province, showing that crop diversification is the most common response to the major risks perceived by small-scale farmers such as uncertain climate, uncertain product prices, inadequate market information, and low bargaining power (Kisaka-Lwayo and Obi, 2012).

The promotion of crop diversification, however, remains a policy dilemma (Budhi, 2010). In many parts of the world, the necessity of specialization according to comparative advantage for economic development (i.e. farmers concentrate on crops they can produce and market best) continues to be an integral part of policy advice (Budhi, 2010). However, economists argue that the benefits of specialization are often misconceived. They show that, in many cases, the proponents of specialization perceive comparative advantages in a static rather than dynamic perspective (Rodrik, 2007). Yet, empirical evidence indicates a U-shaped relationship between specialization and GDP per capita, and shows that the turning point at which the diversification trend switches to specialization is at quite high levels of per capita income (Kaulich, 2012).

Therefore, for regions with high concentration of poor farmers, the crucial question is not whether diversification should be promoted or not, but whether crop diversification should be governed by market forces or could be achieved through explicit agricultural policy incentives (Kaulich, 2012). Two major aspects of welfare economics justify the need for explicit policy incentives: (i) the extension information required to understand the performance of certain crops is a public good in nature because it is hardly excludable (Birkhaeuser et al., 1991), and (ii) agro-biodiversity provides some public goods (Baumgärtner and Quaas, 2010). The positive externalities, if not taken into account, can create sub-optimal diversification patterns, leading to inefficiencies in the utilization of land resources.

Unlike most countries in the sub-Saharan Africa region, South Africa's agricultural policy does not explicitly recognize crop diversification (Gemmill, 2002). The white paper on agriculture emphasizes that the country's comparative advantages should be reflected in both large-scale and small-scale agricultural production systems (Republic of South Africa, 1995), and the only strategy for promoting efficient farmland use under this policy is the removal of agricultural subsidies (Gemmill, 2002). Policymakers believe that, in the long run, removing government intervention in the working of local and export markets will creates incentives for increased efficiency in farmland management (Gemmill, 2002).

The absence of specific policies relating to crop diversification in South Africa, therefore, deters the multiple cropping practices among small-scale farmers. Indeed, the rate of climate-driven crop diversification among farmers in South Africa is the lowest in the SSA region (Maddison, 2007). This deterrence bogs down the country's sustainable rural development efforts in different ways. Economic studies show that lower diversity of cropping portfolios among the small-scale farmers in South Africa exacerbates their technical inefficiencies (Mkhabela, 2005). Empirical studies also show that the lack of crop diversification lowers the resilience of small-scale farmers facing high rainfall variability (Gilbert and Holbrook, 2011). Other studies show that lower crop diversity among South African small-scale farmers is often associated with food insecurity (Mavengahama et al., 2013) and the lack of explicit support and incentives for crop diversification in South Africa contributes to significant loss of agro-biodiversity, reducing farmers' options for livelihoods diversification in the future (Chitakira and Torquebiau, 2010).

This situation underscores the importance of understanding the confounding factors to inform potential policy interventions. The conceptual literature suggests that crop diversification is influenced by microeconomic factors such as land and labour endowments (Benin et al., 2004; Bezabih and Sarr, 2012; Di Falco et al., 2010), market integration (van Dusen and Taylor, 2005), and off-farm occupation (Mishra et al., 2004). The preference for crop diversification also depends on the extent of production risk (Bezabih and Sarr, 2012; Di Falco et al., 2010) and the degree of risk aversion (Baumgärtner and Quaas, 2010; Bezabih and Sarr, 2012). Socio-cultural factors such as gender norms and social capital also dictate the preference for crop diversification (Cavatassi et al., 2012; Doss and Morris, 2000).

Understanding the determinants of crop diversification has been the primary objective of several empirical studies. Case studies have been conducted in developed countries such as Canada (Bradshaw et al., 2004), and developing countries such as Mexico (van Dusen and Taylor, 2005), India (Mishra et al., 2004), Nigeria (Ibrahim et al., 2009), Ethiopia (Bezabih and Sarr, 2012; Cavatassi et al., 2012), and Mozambique (Turner, 2014). In South Africa, however, research in this domain remains scanty. In KwaZulu-Natal, whilst Chitakira and Torquebiau (2010) and Mkhabela (2005) focused on the patterns and technical efficiency of crop diversification, respectively, they did not investigate the factors influencing crop diversification. Therefore, potential policy interventions to promote crop diversification in South Africa remain unclear.

1.2.4. Farmland afforestation among small-scale farmers in South Africa

Although crop diversification is an economically important tactical response to seasonal climatic conditions, building long-term resilience requires specific actions that concurrently address GHG emissions and the gradual anthropogenic and climate-driven changes in agro-ecological conditions (Bradley et al., 2012; Dale, 1997; Olesen and Bindi, 2002; Viglizzo et al., 1997). Farmland afforestation is considered a hallmark of sustainable, climate-smart, and multifunctional agriculture (Food and Agriculture Organization of the United Nations, 2013). Farmland afforestation provides arrays of private and public benefits. These include the restoration of soil fertility in degraded farmland, on-farm conservation of tree species traditionally important for livelihoods (food, fuel wood, medicine, construction materials, etc.), the promotion of entrepreneurship and off-farm opportunities, the mitigation of global warming through carbon sequestration, the contribution to clean water provision, the control of insect pests and diseases, and the reduction of air pollution (Alix-Garcia and Wolff, 2014; Leakey, 2010; Stein et al., 2009).

However, the design of appropriate incentive mechanisms for increasing on-farm tree cultivation is a major policy challenge. At farm-level, where important land use decisions are taken, farmers face a trade-off between long-term land conservation and/or carbon sequestration and short-term land productivity (Goklany, 1999; Zelek and Shively, 2003). In addition, economists argue that environmental externalities of afforestation enterprises increase the gap between private and social benefits for land uses, creating inefficiencies in land allocations (Alix-Garcia and Wolff, 2014; Sobool, 2004). Given that individual farmers' decisions are driven by private benefits, under-representation of private goals in the design of sustainable land use policies could result in sub-optimal farmland afforestation patterns. Policy incentives are, therefore, appropriate to address the market failure in private land afforestation, and the success of land use policies critically depends on individual land use decision-making process.

In South Africa, agricultural policy strategies intending to integrate environmental planning into the ongoing land reform process have mainly taken two forms. The direct interventions for conservation (e.g. the LandCare programme) mainly focus on the rehabilitation of degraded public lands (Republic of South Africa, 1998). Private land afforestation is indirectly supported through strategies that seek to extend industrial tree cultivation to small-scale farming areas. Such strategies have taken two major forms: the creation of out-grower schemes as a corporate social responsibility of major timber companies (e.g. Sappi Project Grow and Mondi Forestry Partners), and the change in companies' asset structure to comply to the black economic empowerment (BEE) policy (Karumbidza, 2005).

However, research evidence suggests that the strategies of land use policy have scored limited success. Analysis of ALUC over the last decades shows that, although tree cover has considerably increased in commercial farming areas, the expansion of small-scale farming within and outside communal land areas has resulted into depletions of woody plant cover (Giannecchini et al., 2007; Puttick et al., 2014; Wessels et al., 2011; Wigley et al., 2010). Research conducted in the KZN by Pillay (2010), Wigley et al. (2010) and others (e.g. Hottman and O'Connor, 1999) reported that forestry cover in small-scale farming areas has generally declined, whilst other agricultural land uses such as subsistence crops production have substantially increased.

The limited success of land use policy underscores the importance of understanding small-scale farmers' incentives as well as the constraints they face for ALUC (Brey et al., 2007). The literature shows that farmland conversion to forestland is an outcome of various socio-economic and environmental factors. Despite the factors associated with economic benefits (i.e. profit maximization) (Sobool, 2004), the utility of farmland afforestation is governed by behavioural factors such as attitudes towards land use (Irshad et al., 2011; Martínez-García et al., 2013; Poppenborg and Koellner, 2013; Purushothaman et al., 2013; Zubair and Garforth, 2006). The utility of farmland afforestation could be also determined by household-level socio-demographic and cultural factors such as gender (Villamor et al., 2014), age (Perz et al., 2006; Walker et al., 2002), skills (Parks, 1995; Walker et al., 2002) and consumption levels (Angelsen, 1999; Klemick, 2011; Perz et al., 2006). Farmland afforestation could be also defined by economic factors such as technology, production risk, risk aversion, required fixed costs, and land value (Erenstein et al., 2006; Just and Zilberman, 1983; Kajisa and Payongayong, 2013; Schatzki, 2003; Walker, 2014), and agro-ecological factors such as precipitation and topography (Fu et al., 2000; López and Sierra, 2010), as well as social influences (Deffuant et al., 2002; Foster and Rosenzweig, 2010; Libby and Sharp, 2003; Wuepper et al., 2014).

However, the empirical literature on ALUC in South Africa is still dominated by spatially-explicit, non-economic models (Giannecchini et al., 2007; Puttick et al., 2014; Wessels et al., 2011). Notwithstanding the importance the insights of spatially-explicit land use change analyses, economists argue that their choice of economic variables to explain the human behaviour in that leads to the spatial processes is "ad hoc" because it overlooks individual farmer's attitudes and characteristics that underlie most economic theories (Irwin and Geoghegan, 2001). Therefore, some important insights indispensable for the land use policy debate in South Africa are still missing.

1.3. Research objectives

Advocating ALUC as a viable strategy for the future of small-scale farming in South Africa requires a systematic understanding of key underlying processes of adaptive land use management. With this consideration, the purpose of this study is to provide a systematic and detailed understanding of climate-driven ALUC in the setting of small-scale farming in South Africa. The general objective is to assess farmers' vulnerability to CC and the determinants of their climate risk perceptions and adaptive land use management.

Taking the KZN midlands as an illustrative case, this study pursues the following specific objectives:

(i) to explore some meso-level aspects of climate-related agricultural vulnerability;
(ii) to investigate the perceptions of small-scale farmers about CC and their socio-psychological, institutional and cultural determinants;
(iii) to analyse the current farmland use systems and assess the microeconomic determinants of seasonal crop diversification; and
(iv) to assess the attitudes of small-scale farmers towards land use and constraints governing ALUC decision-making.

1.4. Policy relevance

Although farmers are expected to respond to the ongoing environmental changes, it does not mean that they are able to perform all the adaptive land use management tasks autonomously. There is need for stimulation by policymakers, who should create an environment in which adaptation and mitigation can thrive. This study contributes to the design of appropriate policy strategies in three major ways.

South Africa has ratified the United Nation Framework Convention of Climate Change (UNFCCC) and has entered into acceptance of the Kyoto protocol in 2002. Through the national CC response white paper, the government has made strong commitments to integrate CC mitigation and adaptation into national development policies (Republic of South Africa, 2011). Amongst the strategic priorities, the policy paper recognizes the need for developing education, training and public awareness programmes to facilitate access to climate information through agricultural extension and promote understanding and informed participation in the fight against CC at all levels. The evidence-based information on the understanding of CC among small-scale farmers and the constraints they face in acquiring appropriate knowledge provided under the present research are two crucial ingredients for the design of effective CC communication strategies.

The national CC response white paper also aims at orienting the country's efforts towards building and sustaining socio-economic resilience to CC and joining the global mitigation efforts. The policy recognizes that the rural poor, particularly small-scale farmers, constitute the most affected stratum of South African society, and underscores the relevant guidelines of adaptation in agriculture and forestry sectors. Even though crop diversification is not explicit in the South African agricultural policy, the country is a signatory of the multilateral treaty of Convention on Biological Diversity (CBD). Therefore, in line with the CC response policy guidelines, the agricultural policy of South Africa pledges to secure a conducive environment for conservation of biodiversity. The evidence-based information on the nature and constraints to multiple-cropping among small-scale farmers is indispensable for the design of appropriate strategies for reducing the vulnerability to climatic extremes and the restoration and preservation of agro-biodiversity.

As a developing country, South Africa is not required to reduce its GHG emissions under the Kyoto protocol, and the country is not integrated into the UNFCCC's REDD+ programme (Rahlao et al., 2012). However, the country maintains the obligations to promote practices and processes that control or reduce anthropogenic GHG emission and foster adaptive capacity through technological development and research (Warburton and Schulze, 2010, 2008). Such obligations are incorporated into the country's CC response policy. The policy advocates the integration of forestry into rural development planning in order to leverage synergies between adaptation and mitigation and build climate resilience. Moreover, the country's agricultural policy pledges to promote sustainable use of agricultural land resources and integrate environmental planning into land reform processes. The promotion of afforestation to enhance carbon sequestration, support the resilience of small-scale farmers, and restore degraded lands remains at the intersection of both policy debates. To inform the design for the CC and agricultural land use policy strategies, this study provides key insights into the criteria for ALUC that are prioritized by farmers. This information is unequivocal for aligning government's goals with farmers' priorities. Moreover, the evidence-based information on structural constraints to ALUC is an important ingredient for spatial planning.

1.5. Overview of the methodology

To achieve the specific objectives, this study proposes innovative approaches. With regard to the first objective, most CC impact assessment studies based on the vulnerability-led approach use econometric (e.g. the vulnerability as expected poverty) (Deressa et al., 2008) or indicator approaches (Gbetibouo et al., 2010; Hahn et al., 2009; Luers et al., 2003; Pandey and Jha, 2012; Urothody and Larsen, 2010). Unlike previous studies that often rely on quantitative or quantified qualitative data, this study uses a systematic review approach to analyse the meso-level vulnerability of agriculture in the Midlands region of KZN. Systematic reviews and research syntheses combine the findings from multiple (seemingly unrelated) studies to increase the robustness of the their evidence, reduce uncertainty created by contrasting evidences, and generate a holistic evidence greater than sum of its parts (Bronson and Davis, 2011).

The other objectives of this study are achieved based on survey data collected in the KZN midlands. With regard to the second objective, this study proposes a two-step estimation procedure for modelling perceptions about CC. Previous empirical studies used either binary outcome regression models (Bryan et al., 2009; Gbetibouo, 2009; Maddison, 2007) or linear regression models, based on a single index of perceptual strength (Leiserowitz, 2006; van der Linden, 2015). Using a single index of perception about CC, however, does not allow discerning the factors determining different shapes of perceptions. Moreover, a few attempts to estimate both the probability and intensity of perception have run binary and linear regression models separately (e.g. Poortinga et al., 2011), failing to control for potential self-selection bias. Against this methodological backdrop, the present study uses the PCA technique to construct two fairly contrasting indices of perceptual strength (appraised based on meteorological records) and analyse their socio-psychological, institutional and cultural determinants using Double Hurdle (DH) estimation technique.

With regard to the third objective, this study first presents a simplified version Cavatassi et al.'s (2012) land allocation model of a multi-crop household economy. The study then uses the two-stage cluster analysis technique to explore various household-level farmland use systems in the region. Subsequently, the study computes a Herfindhal Index of seasonal crop diversification in order to provide a precise measure of relative composition of seasonal crops within the operated farmland area. The influences of technological, socio-demographic, and agro-climatic factors on the crop diversification index (CDI) are estimated using a logit transformation model (Papke and Wooldridge, 1996). A two-stage estimation technique is used to account for potential endogeneity of off-farm occupation in the model, whilst the potential endogeneity of the wealth-effect is controlled for by estimating one model for the entire sample and another two models for households below and above the income median.

Regarding the fourth specific objective, this study joins the growing literature that applies the Mixed-Multinomial Logit (MMNL) model to the investigation of ALUC (e.g. Brey et al., 2007; de Valck et al., 2014; Goibov et al., 2012). Unlike previous studies that mainly use discrete choice experiments (DCE) of the stated preference (SP) technique, the present study adopts a method that uses a combination of revealed preference (RP) and SP data in order to produce more robust estimates and better identification of attributes, and reduce the potential endogeneity and other biases (Whitehead et al., 2008). An attempt is also made to correct for potential endogeneity in spatial variables using the Berry-Levinsohn-Pakes (BLP) approach (Berry et al., 1995).

1.6. Thesis structure

The remainder of this thesis is organized into five chapters, based on the specific objectives outlined in Section 1.3. The subsequent chapter is a systematic review that provides an eclectic discourse about the aspects of agricultural vulnerability to CC in the KZN midlands. The review chapter is followed by three empirical chapters, the analyses of which are based on climate data and household survey data collected in the study area. Chapter 3 gives a structural presentation of the dominant shapes of perceptions about CC among small-scale farmers in the KZN midlands region, and investigates the socio-psychological, institutional and cultural factors underlying the perceptual formation. Chapter 4 examines the household-level farmland use systems among small-scale farmers in KZN, and investigates the microeconomic determinants of seasonal crop diversification. Chapter 5 examines farmers' attitudes towards LUFs and the constraints governing ALUC decision-making among small-scale farmers in the KZN midlands. The last chapter recapitulates the purpose of the study, concludes the major findings, and provides recommendations for policy strategies and further research.

CHAPTER 2 . SOME ASPECTS OF AGRICULTURAL VULNERABILITY TO CLIMATE CHANGE IN THE KWAZULU-NATAL MIDLANDS, SOUTH AFRICA: A SYSTEMATIC REVIEW[1]

2.1. Introduction

Based on the first specific objective of this study, the purpose of this chapter is to explore some aspects of agricultural vulnerability to CC in the midlands region of KZN. Drawing upon the indicator approach, a systematic review approach is used to provide an eclectic discourse about the extents of regional exposure, agricultural systems' sensitivity, and adaptive capacity. The chapter is sub-divided into five sections. Section 2.2 describes briefly the KZN midlands' agro-ecology. Section 2.3 overviews the concept and measurement of vulnerability. Section 2.4 presents the conceptual structuring of the review. Sections 2.5, 2.6, and 2.7 discuss the existing research evidence portraying the extent of exposures to CC, agricultural systems' sensitivity and adaptive capacity of the farming sector, respectively. Section 2.8 summarizes the major aspects of agricultural vulnerability documented in the chapter. The conclusions and policy implications drawn from the review are contained in the last chapter of the thesis.

2.2. Brief description of the KZN Midlands' agro-ecology based on historical conditions

The midlands region of the KZN province is an inland area stretching between the low-lying coastal strip of the Indian Ocean and the high altitudes of the Drakensberg escarpment (see Figure 2.1). The region comprises 876,049 hectares of land (Mkhabela and Materechera, 2003), cutting across the Districts of Umgungundlovu (mainly in the Local Municipalities of uMshwathi, Msunduzi, Mkhambathini, and Richmond), iLembe (mainly in the Ndwedwe and Maphumulo Local Municipalities), and Umzinyathi (mainly in the Msinga and Umvoti Local Municipalities).

The region is one of the country's three principal agro-ecological regions (*viz*. the summer Highveld plateau in the Free State, the winter rainfall region of the Western Cape, and the Highveld and Midlands regions of KZN) (Benhin, 2006). Based on the Koppen climate

[1] This chapter gave rise to the following paper published as: Hitayezu, P., E. Wale, G.F. Ortmann. (2014). Some aspects of agricultural vulnerability to climate change in the KwaZulu-Natal Midlands, South Africa: A systematic review. *Journal of Human Ecology*, 48(3): 347-356.

classification (Peel et al. 2007), the region is located in the subtropical oceanic climate zone, marked by cooler and drier winters and mild summers. Based on historical conditions, the region cuts across many agro-climatic zones[2] (Bezuidenhout and Gers, 2002).

These climatic configurations, coupled with other criteria such as soils and geology, provide suitable or optimal growth conditions for major annual crops such as maize (Abraha and Savage, 2006), perennial crops such as sugarcane (Schulze and Kunz, 2010b), and commercial forestry (Schulze and Kunz, 2010a; Warburton and Schulze, 2008) as well as subtropical fruits such as avocado and granadilla (Allemann and Young, 2006; Schulze and Kunz, 1995).

Figure 2.1. Geographical regions of the KwaZulu-Natal province, South Africa
Source: adapted from http://www.roomsforafrica.com/

[2] A map of some homogenous agro-climatic zones of KZN is provided in appendix B1.

Dryland sugarcane production dominates the landscape in the region. It is found throughout the region, except for the extreme northern and southern portions (Lawes et al. 2004). Under historical climatic conditions, the mean sugarcane yield per harvest cycle ranges from 70 metric tonnes ha^{-1} in the interior of the region to 110 metric tonnes ha^{-1} towards the north-eastern and south-eastern parts (Schulze and Kunz, 2010b)[3].

The region is classified as one of the major strategic forestry zones for South Africa (Meadows, 1999; Smith, 2005). Commercial forestry is the dominant land use in the wetter slopes of the Karkloof mountain range and the Blinkwater mountain in the north-western quadrants (Lawes et al. 2004). Commercial forestry in the region is dominated by short-rotation eucalypt pulpwood trees (du Toit, 2006). Historically, although most of the interior parts of the midlands region are climatically unsuitable (deemed too dry), the northern and south-western parts have a potential for annualized increments ranging from 14 to 20 metric tonnes ha^{-1} (Schulze and Kunz, 2010a; Warburton and Schulze, 2008).

Rain-fed maize cultivation is the major land use in the low-lying, communal land farming systems prevailing in the northern and interior parts of the region (Lawes et al. 2004). Based on historical climate, potential mean maize grain yield in the midlands region ranges from 8 to 12.5 metric tonnes ha^{-1} (Abraha and Savage, 2006). The KZN Midlands is also the most important milk producing region in the province. Large scale production from the Mooi River, Howick, Boston, Bulwer, Underberg and Ixopo areas is dominated by grazing farms, with irrigated ryegrass and dryland kikuyu (Mkhabela and Mndeme, 2010).

2.3. The concept of vulnerability and approaches to vulnerability assessment

Recent developments in CC impact assessment have been marked by a shifting attention from impact-led approaches to costing and vulnerability-led approaches (Hassan, 2010; Smit and Wandel, 2006; Stage, 2010). Although the impact-led (or Ricardian) approach remains instrumental for "hypothetically" estimating the extent to which human systems can moderate or offset the damage or take advantage of the opportunities of a certain CC stimuli, it overlooks the process of adaptation decision-making. Whilst the costing approach unpacks

[3] van den Berg and Singels (2013) show that actual cane production in both large-scale and small-scale growing areas have hardly attained this potential yield, cane yield in small-scale growing areas remaining generally far lower.

the portfolio of distinct/discrete adaptation options to appraise their desirability, i.e. adoption process, it disregards one important factor in development intervention, namely "appropriateness". The thrust of the vulnerability-led approach is geared towards identifying the systems that are more susceptible, thus have more demand for planned adaption strategies. The IPCC defines vulnerability as "the degree to which a bio-physical or socio-economic system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes" (Schneider et al. 2007, p. 783). Therefore, vulnerability is viewed as an aggregate term comprising exposure, sensitivity and adaptive capacity (Adger, 2006).

The literature approaches vulnerability assessment mainly from two perspectives: the vulnerability variable assessments and the indicator approach. On the one hand, the vulnerability variable assessment consists of measuring and assessing the changes in selected variables of a system attributed to sets of specific stressors, based on a number of metrics (Luers et al., 2003). Notwithstanding the importance of this method, its metrics cannot sufficiently capture all the dimensions of vulnerability. The indicator approach, on the other hand, measures vulnerability by combining a set of proxy indicators with different relative weights (Gbetibouo et al., 2010). The weighting is based on subjective or statistical methods.

2.4. Conceptual structuring of the review

To document the aspects of agricultural vulnerability to CC in the KZN midlands, this chapter adopts the indicator approach. Following Gbetibouo et al. (2010), the indicators chosen for the review are summarized in Table 2.1. The extent of exposure is indicated by detected and projected climatic trends. For the sensitivity of agricultural systems, population density indicates the number of people who could be at climate risk, whilst share of small-scale farmers generally portrays the associated socio-economic vulnerability in the form of small farm sizes, low capitalization and technology adoption rates, and multiplicity of livelihood stressors. Irrigation represents the resilience of small-scale farming systems. Crop diversification indicates the advantages of variance in the effects of rainfall and temperature on heterogeneous cropping patterns (Bradshaw et al., 2004; Reidsma et al., 2010; Reidsma and Ewert, 2008). Land degradation indicates the quality of land, i.e. its productivity and sustainability under CC conditions.

Table 2.1. Selected indicators for the assessment of livelihood vulnerability to CC

Exposure	*Sensitivity*	*Adaptive capacity*
• Detected CC • GCM projections	• Rural population density • Share of small-scale farmers • Irrigation • Crop diversification • Land degradation	• Access to physical capital • Access to financial capital • Access to human capital • Access to social capital

Source: Based on Gbetibouo et al.'s (2010b) typology.

To portray the regional adaptive capacity, physical capital indicates the relative access to markets in times of climatic crisis. Financial assets represent economic diversification that reduces the susceptibility to CC. Access to human capital indicates the relative availability and quality of labour to mitigate the effects of CC. Social capital portrays the relative access to social networks to overcome the challenges associated with remoteness and isolation such as access to information, credit, and collective action.

To apply the indicator approach to the investigation of agricultural vulnerability in the study area, this chapter adopts a systematic review of the available empirical literature. The method consists of identifying and synthesizing peer-reviewed research evidence relevant to a certain research problem (Bronson and Davis, 2011). Searches were conducted using the UKZN online database. For general literature, the Google Scholar® search engine was also used. However, in some cases, the search resorted to grey literature, i.e. research works that cannot be found through the conventional channels such as publishers and scholarly literature databases. The search led to an inventory of over 60 peer-reviewed journal articles and reports/unpublished theses. A concept-centric approach was used to classify and synthesize the collected literature. Based on the proposed indicator framework, the studies were grouped, summarized and analysed in accordance with the three aspects of vulnerability to CC.

2.5. Regional exposure to climatic change

2.5.1. Detection of CC in the midlands region of KZN

The existing literature shows that the local climate has exhibited clear signs of warming and wetting trends. For example, a comparative analysis of the 1950 - 1970 vs 1980 – 2000 periods' temperatures and runoffs by Warburton et al. (2005) unveiled two clear clusters of warming, *viz.* the midlands and south coast regions of KZN, and some areas in the Western Cape province. Based on the Mann-Kendall non-parametric test and split-sample analyses, the study revealed that historical records of clusters of stations in the KZN midlands exhibit increasing trends in annual means of daily minimum temperatures and summer means of daily maximum temperatures, increasing and decreasing number of days per year of below the 10^{th} percentile of winter daily minimum and summer daily maximum temperatures, as well as decreasing and increasing trends in the number of frost occurrences and heat units per season.

In the midlands region, the hydrological modelling of Warburton et al. (2005) further showed an increasing trend in accumulated annual total of rainfall-driven daily river flows, and higher ratios of later (1980 – 1999) to earlier (1950 – 1969) highest annual accumulated runoffs in ten years.

2.5.2. CC model projections

Other CC researchers have primarily focused on climate projection under different scenarios. For example, based on a set of high-resolution scenarios created through the process of downscaling, Engelbrecht et al. (2011) derived regional climate response to the larger scale atmospheric dynamics. Based on the CSIRO's Conformal-Cubic Atmospheric Model ensemble under the A2 emission scenario, this study projected temperature increase ranging from 2^0C to 3^0C, coupled with -10% drying and pockets of 10% wetting trends over the KZN province for the period 2071- 2100 relative to 1961-1990. For the KZN midlands region, based on the regional climate scenarios derived from AR4 GCMs, Lumsden et al. (2009) showed evident patterns of 10% to 20% increase in precipitation towards the last quarter of the 21^{st} century.

2.6. Sensitivity of regional farming systems

2.6.1. Rural population density and the share of small-scale farmers

Based on the 2011 census data shown in Table 2.2, the midlands region of KZN is inhabited by approximately 1.3 million people. Msunduzi, an urban local municipality, accounts for the majority of regional population (45%) and has the highest population density in the region (976 people per km^2). In general, the patterns of rural population density are marked by low-density municipalities in the southwestern parts of the region (e.g. Richmond with 41 people per km^2), and high-density rural municipalities in the north-eastern quadrant (Ndwedwe and Maphumulo with more than 100 people per km^2). Rural population density in the interior and western parts of the region ranges from 59 (uMshwathi) to 71 people per km^2(Mkhambathini and Msinga).

Table 2.2. Population distribution across eight Local Municipalities in the KZN Midlands (2011)

Local Municipality	Population	Percentage of regional population	Area (km^2)	Density (people/km^2)
uMshwathi	106 374	7.7	1 818	59
Msunduzi	618 536	45.0	634	976
Mkhambathini	63 142	4.6	891	71
Richmond	65 793	4.7	1 256	53
Ndwedwe	140 820	10.2	1 093	129
Maphumulo	96 724	7.0	896	108
Msinga	177 577	12.9	2 501	71
Umvoti	103 093	7.5	2 516	41
Total	1 372 059	100	11 605	119

Source: Based on the 2011 census data (Statistics South Africa, 2013).

Therefore, the levels of climate-related human vulnerability are not equally distributed in the region. The number of people at climate risk increases northeasterly. If no major responsive policy actions are taken, a large cross-section of inhabitants in the northern and eastern parts of the region could face significant risks associated with climatic changes.

Estimates suggest that nearly 80% of the KZN midlands' population are small-scale, dryland farmers. About 86% of them cultivate maize on less than 2 hectares of communal land, mainly for household consumption (Mkhabela and Materechera, 2003). For this region, Abraha and Savage (2006) showed that maize grain yield response to a scenario of '2 X CO_2 + 2^0C' and +10% rainfall could range from +6% (for early planting) to +10% (for late planting). However, their simulation suggested that any increase in temperature beyond +2^0C (corresponding a 50-day reduction in the average growing season length compared to the baseline) could lower the grain yield to a level of 7% below baseline yield, even under a +20% rainfall scenario. Therefore, small-scale farmers' vulnerability to food insecurity is acutely pronounced in this region.

Only few farmers practice market-oriented farming such as sugarcane and forest production. Research has shown that these land uses could be resilient under future projected climatic changes. With regard to sugarcane production, Schulze and Kunz (2010) and Warburton and Schulze (2008), based on ECHAM5/MPI-OM GCM, projected major gains in climatically optimum growth areas for dryland sugarcane and eucalyptus in some interior and western parts of the region by the intermediate (2046-2065) and distant futures (2081-2100). However, the sugarcane and timber productivities among small-scale growers remain very low compared to the regional potential yields and the yields recorded in commercial farming areas. van den Berg and Singels (2013) reported that, whilst potential yield of sugarcane in the Midlands region ranges from 130 tonnes ha^{-1} (1988 and 2007 records) to 62 tonnes ha^{-1} (1993 record), cane yield in large-scale and small-scale farming areas ranged from 110 tonnes ha^{-1} (1988 record) to 46 tonnes ha^{-1} (1993 record), and from 87 tonnes ha^{-1} (2000) to 35 tonnes ha^{-1} (1994 record).

2.6.2. Irrigation

Despite the fact that the majority of the region's inhabitants are dryland farmers, the northern part of the region hosts one of the largest small-scale irrigation schemes in the province. The Tugela-Ferry irrigation scheme along the Thukela river covers an area of approximately 840 hectares of high-potential soils, and currently over 540 hectares are under cultivation by nearly 1000 producers (Cousins, 2013). On average, a household has 0.27 hectare of farmland under irrigation (Muchara et al., 2014). Based on ten regionally downscaled future climate projections, an assessment of the CC impacts on the hydrology of the Thukela River by Graham et al. (2011) showed a predominant signal for an increase in river runoff, particularly towards the end of the 21st century.

However, following the irrigation management transfer from government agencies to water users, access to water by scheme members has been challenged by issues of siltation, cracks, leaks and dysfunctional holding dams resulting from inadequate maintenance and repair work since the 1960s (Cousins, 2013). Muchara et al. (2014) reported that 63% of farmers in the scheme lack any formal training in irrigation water management, and more than 17% do not currently participate in irrigation water management at all. Inadequate access to irrigation water increases household's working time budget (Reid and Vogel, 2006), with adverse impact on small-scale farmers' welfare and food security (Sinyolo et al. 2014a, 2014b). If the weak or dysfunctional institutional governance of irrigation water is not addressed, therefore, it could prevent small-scale farmers from taking advantage of projected increases in river runoff.

2.6.3. Crop diversification

To the vast majority of small-scale farmers lacking access to irrigation water, crop diversification offers a simple form of agricultural risk mitigation. Empirical studies show that household cropping portfolios in the region are highly diversified. In the Mkhambathini Local Municipality, for example, Kisaka-Lwayo and Obi (2012) reported a Herfindahl Index of crop diversification[4] ranging between 0.23 (among non-organic farmers) and 0.89 (among partially certified organic farmers). The diversification comprises a mixture of annual crops such as taro, potatoes, green beans, maize, chillies and peas, with semi-perennials such as sugarcane and bananas. Similar crop diversification patterns were reported in the small-scale farming systems of the Tugela-Ferry irrigation scheme in the Msinga District (Mkhabela, 2005). Mixed crop-livestock production is also a common aspect of farming systems in the region (Mkhabela and Materechera, 2003).

Therefore, land use constitutes an important aspect of resilience in small-scale farming systems in the midlands region. Indeed, Mkhabela (2005) found that technical efficiency of vegetable-based farming systems increased with intensity of crop diversity (from combinations of two to six crops).

2.6.4. Land degradation

Estimates suggest that around 35% of the region's land surface is arable, and 20% is considered to harbour soils of high agricultural potential (Mkhabela and Materechera, 2003). However, land degradation is a major concern for ecological sustainability in South Africa, particularly for small-scale farming systems operating on communal lands. An index combining water, soil and vegetation degradation compiled by Hoffman and Ashwell (2001) indicated that, generally, the KZN midlands have light to moderate land degradation indexes, although the north-eastern parts of the region (where small-scale, subsistence farming is concentrated) show severe degradation scores. Wessels et al. (2007) further showed that the rate of degradation in the region has been moderately increasing.

[4] As shown in Section 4.2, the Herfindhal Index of crop diversification take values between zero (representing complete diversification) to one (reflecting complete specialization) (Bradshaw et al. 2004)

The acute land degradation in communal land areas is partly a legacy of the segregationist apartheid regime that relocated subsistence farming to 'homeland' areas, often characterised by steeper slopes (Meadows and Hoffman, 2003; Palmer and Bennett, 2013). However, Wessels et al. (2007) showed that climate change is the most important confounding factor. They showed that areas with higher rainfall variability also experienced high variability in net primary vegetation production, particularly in and around communal land areas. In the future, based on the downscaling of the Climate Systems Model (CSM) and the Genesis model, Meadows and Hoffman (2003) showed that the projected wetter summers in the KZN midlands region could indicate a high risk of land degradation in the former homelands due to steeper slopes, uncontrolled grazing, and intensive cultivation, particularly during hotter periods.

Research done in this region suggests that ALUC accentuates land degradation. With regard to soil degradation, an environmental impact assessment conducted by Haynes et al. (2003) has shown that shifting from native grasslands to maize, sugarcane and timber production have differential effects on soil organic matter content and on the size and composition of earthworm communities. They showed that, compared to native grasslands, cultivation of maize and sugarcane under conventional tillage results in a loss of organic matter and microbial biomass, while shifting to timber production results into higher microbial biomass and quotient. A comparison between dryland and irrigated sugarcane show that the most prominent soil chemical properties contributing to soil degradation under sugarcane cultivation were increased acidity in dryland areas and increased salinity and sodicity levels in irrigated areas (Van Antwerpen and Meyer, 1996). A comparison of the midlands and south coast regions of KZN shows that soil degradation caused by sugarcane cultivation was less pronounced in the midlands, owing to higher clay protection of organic matter (Dominy et al., 2002)

2.7. The adaptive capacity of socio-economic systems

2.7.1. Access to physical capital

The British Department for International Development (DFID, 1999a, 1999b) asserts that physical capital consists of access to public infrastructure as well as private producer goods. The KZN midlands region has good road networks and access to the provincial (R33) as well as national highways (N3) linking its municipalities to major economic centres such as

Pietermaritzburg and Durban. However, small-scale farmers in communal land areas have little access to such facilities. A recent study by Dinkelman (2011) showed that, on average, farmers in communal lands of KZN travel 37km to the nearest tarred road. In the Swayimana and Umzumbe districts, for example, Hendriks and Lyne (2003) showed that small-scale farmers walk on average 35km to reach the nearest tarred road, and less than 8% owned a vehicle. Hendriks and Lyne (2003) also showed that only 12% of households had access to electricity, and farmers had to travel more than 9km to reach the nearest public telephone. As Matungul et al. (2001) contend, this lack of access to public and private infrastructure severely constrains their ability to participate in the market economy. Consequently, without external intervention, the ability of the midlands' farmers to absorb and recover from climate-related shocks and stresses remains constrained.

2.7.2. Access to financial assets

With an acute lack of access to infrastructure, smallholder agriculture is not commercialized in the study region. For example, in the Muden area, Reid and Vogel (2006) found that households' annual farm income averages 1,265 South African Rand (ZAR) (currently equivalent to USD111), compared to off-farm incomes of ZAR7,400 or USD654 per year. However, they also showed that social grants of about ZAR650 (equivalent to USD57) per month constitute a considerable proportion of household incomes. Similar findings were reported in a recent study conducted by Sinyolo et al. (2014b) among small-scale farmers around the Tugela Ferry irrigation scheme, showing that annual farm income ranges from ZAR312 or USD27 (non-irrigators) to ZAR15,341 or USD1,357 (irrigators), compared to an off-farm income range of ZAR42,332 or USD3,746 (non-irrigators) to ZAR36,333 or USD3,215 (irrigators).

A study conducted by Graham and Darroch (2001) showed that lower liquidity and income prospects, coupled with land tenure insecurity, and lack of technical and managerial capabilities have constrained their access to agricultural credit. They found that less than 10% of farmers participated in agricultural credit markets as borrowers. In addition to the lack of credit access, Hendriks and Lyne (2003) found that saving rates in this area are negligible, as household expenditures almost equate incomes. Among groups of land reform beneficiaries, Shinns and Lyne (2004) showed that most of the household financial assets are kept in the form of livestock due to its relatively high liquidity. The lack of access to credit and over-reliance on transfers from government heightens the levels of farmers' vulnerability to CC.

2.7.3. Access to human capital

The relatively low levels of incomes in the regional agricultural economy coupled with the geographical proximity of major urban centres in the area are a source of an increasing trend in outward migration. Although households tend to have more than six members (Matungul et al., 2001; Sharaunga et al., 2013), many economically active men leave communal land areas to work in major urban centres, leaving women, children and the elderly to work the land (Denis and Ntsimane, 2006; Hoffman and Ashwell, 2001). For example, a survey by Hendriks and Lyne (2003) conducted in two communities of Swayimana and Uzumbe districts revealed that between 65% and 77% of households had migrant members.

Consequently, estimates have suggested that nearly 90% of farm workers in this region are women, elderly and uneducated (Reid and Vogel, 2006). In the Tugela-Ferry irrigation scheme, for example, the farm household surveys by Sinyolo et al. (2014b) and Muchara et al. (2014) revealed that the majority of farm household heads are ageing (>56 years) and uneducated (<3 years of formal education) women. Early farm household surveys conducted in the KZN midlands had reported similar figures (Matungul et al., 2001). Yet, in this region the HIV prevalence among women is 37%, and more than 80% of TB patients (constituting nearly 1% of the population) are HIV co-infected (Gandhi et al. 2010).

The poverty of agricultural extension services in this region is also noteworthy. In the Msinga District, Sinyolo et al. (2014b) reported rates of participation in extension programs ranging from 35% (of non-irrigators) to 70% (of irrigators). In the Impendle and Swayimana Districts, Matungul et al. (2001) found that, on average, a farm household had received only one extension visit or training per year.

The rural exodus and lack of household capabilities, coupled with the lack of access to finance and dysfunctional or high transaction costs related to land markets, often lead to underutilization of land. This situation creates acute allocative inefficiencies and equity issues, whereby those who have capabilities to use land resources more economically and those willing to lease or sell their land plots are hindered (Crookes and Lyne 2003). Consequently, poverty in the KZN midlands tends to be associated with household demographics. Shinns and Lyne (2005), for example, found that households with the lowest per capita income and wealth tended to be female-headed and larger in terms of membership. They further showed that asset-rich households had more skills (in terms of high school matriculation), whilst income-rich households had lower dependency ratios.

2.7.4. Access to social capital

Amongst small-scale farmers in South Africa, studies have shown that social capital is more cognitive than structural, i.e. founded more on trust, traditions, norms and values rather than on tangible local organizations and networks (Jordaan and Grové, 2013). In the Muden area, for example, Reid and Vogel (2006) showed that despite the existence of social structures around agriculture (such as block and water management schemes), inter-household cooperation in terms of farm production and property right enforcement is at low levels. They argue that the ineffectiveness of social capital structures is due to the lack of interest in farming by most economically active sections of the populace. With higher levels of transaction costs faced by small-scale farmers in agricultural marketing, the lack of cooperation is found to be a significant challenge to agricultural marketing and hence farm income generation (Matungul et al., 2001).

2.8. Summary

Based on the indicator approach, the chapter used a systematic review method to document the extent of agricultural vulnerability to CC in the midlands region of KZN. With regard to exposure, the review suggests that the region is a hotspot of CC, and most climate model projections have shown warming and wetting trends towards the end of the 21^{st}century. The sensitivity of farming systems is high due to high population density, large share of small-scale farmers, low rate of irrigation, and susceptibility to land degradation. However, the highly diversified cropping portfolios in the region remain the major sources of resilience. The adaptive capacity is compromised by lack of access to public infrastructure, lower liquidity and income prospects, rural exodus, skills shortage, and limited inter-household cooperation.

The acute levels of exposure signifies the need of understanding the perceptions of local farmers about CC, whilst the resilience in the form of land use change underscores the importance of investigating the attitudes and constraints to agricultural land use change. These pertinent empirical investigations needed to inform the regional CC response policy are presented in the subsequent chapters.

CHAPTER 3 . ANALYSIS OF SOCIAL-PSYCHOLOGICAL FACTORS SHAPING SMALL-SCALE FARMERS' PERCEPTIONS ABOUT CLIMATE CHANGE IN THE MIDLANDS REGION OF KWAZULU-NATAL, SOUTH AFRICA: A DOUBLE-HURDLE APPROACH[5]

3.1. Introduction

This empirical chapter addresses the second objective of this study by unpacking the dominant shapes and determinants of perceptions about CC among small-scale farmers in the midlands region of KZN. The chapter presents an innovative empirical methodology for investigating the perceptions and reports the estimation results. The subsequent section (3.2) overviews the literature on the determinants of climate risk perception based on the insights of the behavioural decision research. The methodological section (3.3) outlines the empirical strategy used to investigate the dominant shapes of perceptions about CC among small-scale farmers and to estimate the influence of socio-psychological, institutional and cultural factors on such perceptions. Section 3.4 reports and discusses the empirical results of the investigations. It presents a brief description of the socio-economic characteristics of interviewed farmers and graphical descriptions of local climate patterns. The section also describes the dominant shapes of perceptions and discusses their determinants. Section 3.5 gives a brief summary of the chapter. The conclusions and policy implications drawn from the empirical results are contained in the last chapter of the thesis.

3.2. Determinants of climate risk perception: some insights of the behavioural decision research

Analysis of the perceptual aspect of vulnerability to CC and adaptation is based on the climate risk management process proposed by Jones (2001). As shown in Figure 3.1, the biophysical threshold (BPT) is the frontier between coping range (*i.e.* the range of climate variability that is normally/historically experienced by the majority of natural or human systems and within which conditions vary from beneficial to tolerable) and the vulnerability range. When the variability of the distribution of a climate variable trespasses the BPT (*i.e.* the present stage), the farming system is drawn into vulnerability, necessitating adaptive measures. Adaptation is viewed as future changes in BPT resulting from adaptive actions.

[5] This chapter gave rise to the following manuscript: Hitayezu, P., E. Wale, G.F. Ortmann. Assessing farmers' perceptions about climate change in KwaZulu-Natal, South Africa: Application of Double-Hurdle model. *Journal of Environmental Psychology* (reviewed, revised, and resubmitted).

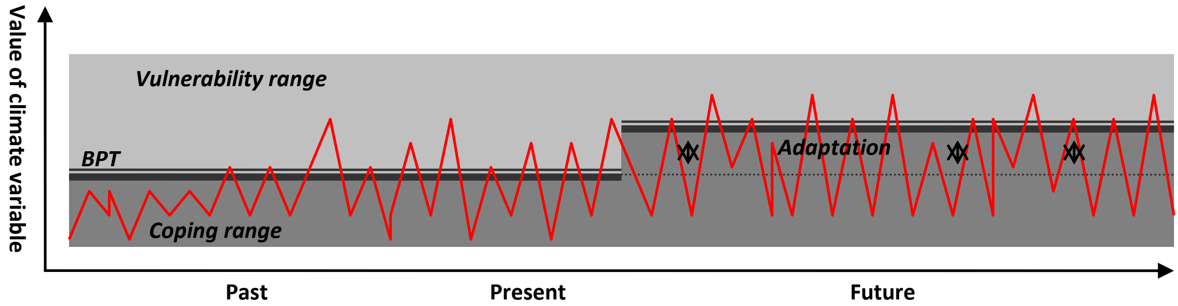

Figure 3.1. Schematic diagram of the relationship between biophysical threshold, climate variable distribution, coping range, vulnerability range, and adaptation
Source: adapted from Jones (2001) and Willows and Connell (2003).

Although this framework constitutes the basis for adaptive management, behavioural decision research[6] views the assessment of thresholds and vulnerability across farming systems for the purpose of adaptation analysis as an expert-centred approach defining harmful CC "externally" *i.e.* based on experts' criteria (Dessai et al., 2004). This strand of research proposes an alternative approach consisting of defining dangerous CC "internally". The approach focuses on socio-psychological, institutional and cultural processes influencing perceptions about "dangerous or abnormal" climate as a precondition for adaptation.

The crux of the behavioural approach (Figure 3.2) is that, depending on the way they are learnt, similar trends in climate can lead to different perceptions and eventually different responses. On the one hand, learning CC from repeated personal experiences with weather outcomes involves "fast" and "automatic" associative and affective processes, whereas learning with information from statistical descriptions of weather outcomes and their likelihoods requires analytic processing and cognitive efforts (Marx et al., 2007; Weber, 2010). Experience-based learning comprises information availability and affective heuristics used to identify the positive and negative connotations and symbolic meanings associated with climatic hazards, whereas the analytic process of description-based perceptions involves cognitive efforts as well as individual values and worldviews, trust, and the amount of information available (Leiserowitz, 2006; Weber, 2010).

[6] The behavioural decision research is a intensively multidisciplinary approach that employs the concepts and models from economics, cognitive and social psychology and other related disciplines in testing normative theories of judgment and choice (Payne et al., 1992).

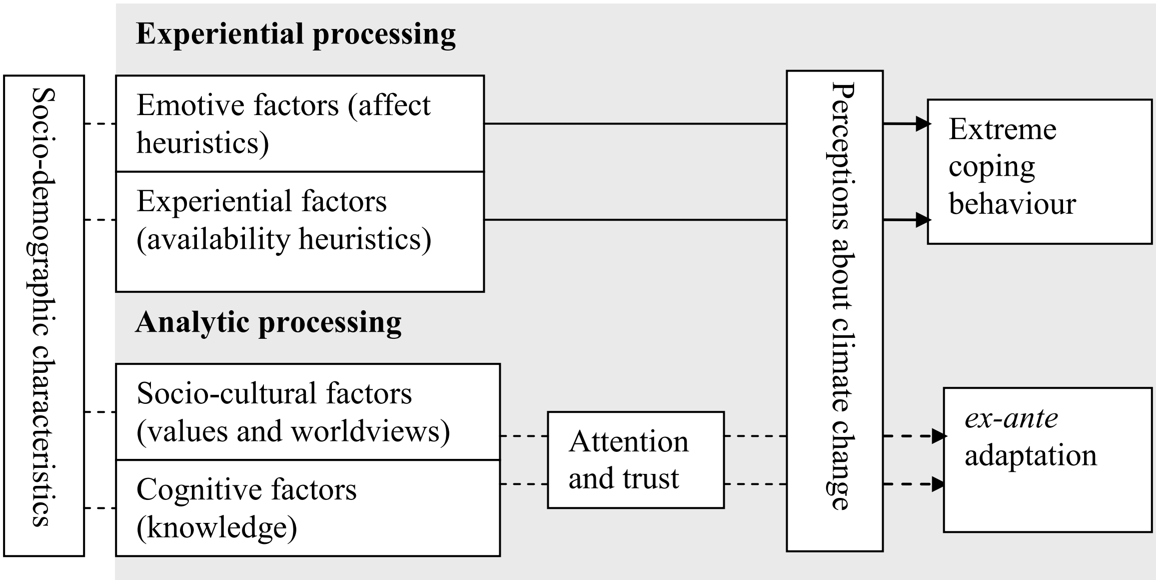

Figure 3.2. A behavioural model of decision-making under climate risk

Source: Author's typology, based on the conceptual literature.

Given that the lay public relies on low-probability extreme weather or climatic events to learn about the changing climate (information availability heuristics), evaluation of adaptation options would follow a classical reinforcement learning that gives recent events more weights than distant ones (Marx et al., 2007; O'Connor et al., 2005; Weber, 2010). This "recency bias" triggers the extreme coping behaviour among the lay public. Another aspect of experiential learning is "affect heuristic" (or risk-as-feelings), defined as the quality of goodness or badness of a certain stimuli experienced as a feeling state (Marx et al., 2007). Affective reaction often happens prior to cognition and plays an important role in the subsequent rational understanding about climatic changes (Leiserowitz, 2006; van der Linden, 2014b).

Description-based perceptions, on the other hand, are learned slowly with information provided by experts (i.e. climate scientists) and their social delegates (such as the media, educators and extension workers), and with personal knowledge. Knowledge is viewed as a cognitive factor of risk judgement (Sundblad et al., 2007). Risk judgement is also influenced by socio-cultural values and norms (van der Linden, 2014a). Assimilation of expert-described CC information by the lay public pertains to two important issues: attention and trust (Weber, 2010). Attention is closely related to personal values, whilst trust factors play when there are multiple sources of (conflicting) information (Weber, 2010). This slow process of external learning warrants *ex-ante* or forward-looking adaptation (the adaptation scenario in Figure 3.1).

Even when perceptions from the two processing do not tally, the experience-based perception and extreme coping behaviour prevails because of its fast and vivid nature (Weber, 2010). Therefore, the behavioural approach hypothesizes that learning about climatic changes with personal experience is more prone to biases, whereas external learning processes with experts' descriptions warrant a good detection of local climatic changes (Weber, 2010).

The experiential and analytical factors of perceptions mediate the effect of socio-demographic characteristics (Whitmarsh, 2011). Socio-demographic characteristics define personal wealth, health, experience, recall, values, worldviews, trust, and knowledge, which in turns determine the perceptions (Dessai et al., 2004).

3.3. Methodology

3.3.1. Study area

The empirical analyses in this study were conducted in the uMshwati local municipality (see Figure 3.3). This is one of the seven local municipalities making up the uMgungundlovu District in the KZN Province. It is a rural municipality of 181 802 hectares located on the north-east quadrant of the district. Economic development in the municipality is centred on commercial agriculture, and most employment opportunities and incomes within the boundary of the municipality are linked to sugarcane, timber and maize farming (Umshwati Local Municipality, 2011). Like in other parts of the midlands region (see Section 2.7.3), this economic reality, coupled with the geographical setup of the area, facilitates an increasing trend in outward migration. According to 2011 census data released by Statistics South Africa (2013), the municipality has recorded a decrease in its population over the last decade, from 108,422 inhabitants in 2001 (with a sex ratio of 88.2 male per 100 female and a dependency ratio of 70.1 per 100 people in working age) to 106,374 people in 2011 (with a sex ratio of 90.3 male per 100 female and a dependency ratio of 61.2 per 100 people in working age). Based on these figures, the municipality records the lowest population density in the province.

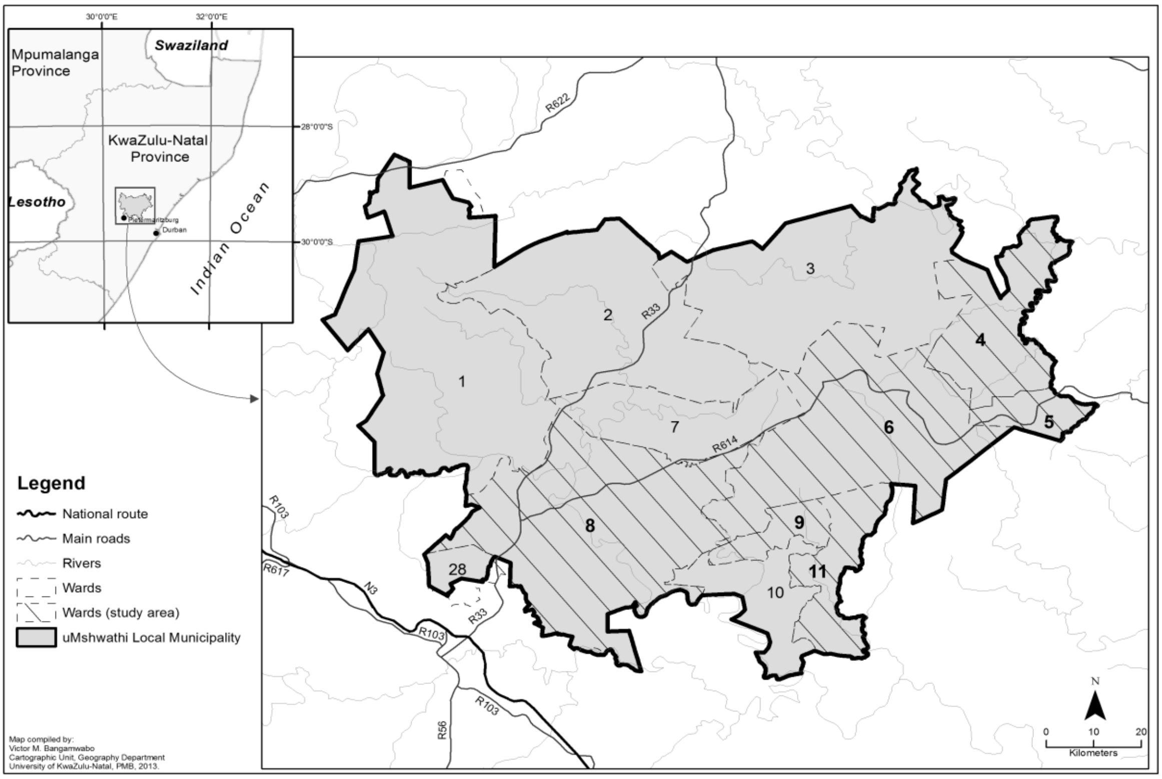

Figure 3.3. Administrative map of uMshwathi local municipality, KZN Midlands, showing sampled wards

Source: Based on shapefiles provided by Municipal Demarcation Board (http://www.demarcation.org.za/)

Based on historical conditions, the region cuts across four agro-climatic zones (Bezuidenhout and Gers, 2002), as shown in Table 3.1. The spatial distribution of agro-climatic zones and soil types in the uMshwati Local Municipality are shown in Figures B1 and B2, respectively, in the appendices[7].

Table 3.1. Characteristics of agro-climatic zones of the uMshwati Local Municipality

Zone	Area (km^2)	Mean annual solar radiation ($MJ.m^{-2}$)	Mean annual heat units (°C.d.)	Mean annual precipitation (mm)	Mean coefficient of variation[8] (%)
New Hanover	458	8095	2760	977	5.0
Wartburg/Fawnleas	561	7890	2772	867	2.4
Windy Hill Mistbelt	244	7720	2668	981	5.3
Hilton / Umgeni Valley	174	8001	2970	892	2.2

Source: Extracted from Bezuidenhout and Gers (2002)

[7] Figure B2 shows that land in the uMshwati Local Municipality are dominated by arcisols, ferralsols and leptosols.

[8] Bezuidenhout and Gers (2002) calculated the coefficient of variation (CV) for each zone by averaging the coefficient of variation for MAP, HU and SR.

The agricultural economy in the municipality is dualistic. The duality is shown in Figure 3.4 capturing the major land cover/use categories in the municipality. As the figure shows, commercial agriculture accounts for the majority of land area in the municipality, including timber plantations (28%) and sugarcane (26%). Detection of land use change between 2005 and 2008 by Isikhungusethu Environmental Services (2012) showed that the transformed land cover increased by 2%, mainly with a sharp increase in the subsistence agriculture (40%) and forest plantations (3%), and a reduction in sugarcane land use (-1%) and other commercial agriculture (-13%). The patterns of ALUC are driven by the land reform policies mentioned in the introductory section.

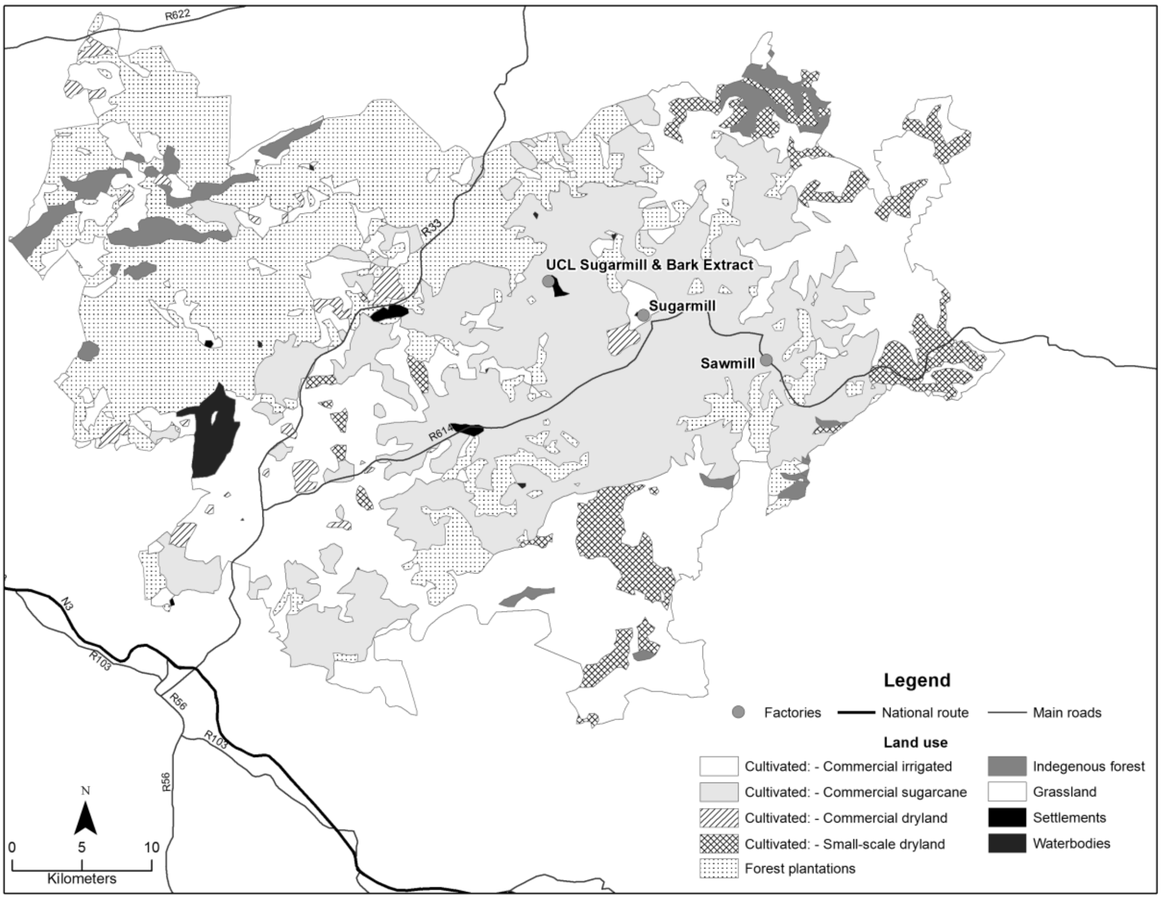

Figure 3.4. Land use/cover map of uMshwati local municipality (2005)
Source: Based on the land cover shapefiles provided by the Ezemvelo KwaZulu-Natal Wildlife (http://www.bgis.sanbi.org/kzn/landcover.asp)

3.3.2. Empirical methods

In the empirical literature of CC perception, attempts to investigate the determinants of climate risk perceptions have mainly used two major strategies. Most economic studies (Bryan et al., 2009; Gbetibouo, 2009; Maddison, 2007) have used binary outcomes regression models (mainly Probit and Logit). Behavioural decision researchers view the binary outcome regression approach as particularly important estimation strategy because there is reason to believe that there would be a class of people who would never perceive CC whatever their characteristics, perhaps as a matter of scepticism (Poortinga et al., 2011). However, the models are empirically limited in terms of explaining the strength of perceptions, given positive perception.

To explain the strength of climate risk perception, most studies in BDR strand use linear regression models (Leiserowitz, 2006; van der Linden, 2015; Whitmarsh, 2011). To that end, they construct a single index of perception using psychometric and statistical techniques such as factor analysis (e.g. Leiserowitz, 2006; van der Linden, 2015). Using a single index of perception about CC, however, does not allow discernment of the factors determining different shapes of perceptions.

Moreover, studies that model both the probability and the strength of perceptions remain scarce. Only a few studies such as Poortinga et al. (2011) have estimated both the selection and intensity models. Poortinga et al. (2011), however, ran the two models separately. Modelling the probability of perceiving and the strength of perception separately fails to control for endogeneity bias arising from self-selection bias. This bias results from some people with certain principles or characteristics self-selecting out of the perceiving group. When self-selection bias is not accounted for, the model could be suffer from misspecification errors in the form of omitted variables (Heckman, 1979).

The empirical strategy of the present study addresses the two weaknesses. Given the interrelated nature of climate variables, the study uses the principal component analysis (PCA) technique to reduce the multi-dimensionality of perceptions into arrays of case-specific scores defining the shapes and strengths of belief in seasonal CC. The indices of two contrasting perceptual shapes (based on the information portrayed and the correspondence with meteorological observations), are then used as dependent variables in a two-step empirical model.

3.3.2.1. Structural representation of CC perceptions: A principal component analysis

This data reduction technique endeavours to reveal the internal structure of multiple variables in a way that best explains the variance in the data with minimum loss of information (Jolliffe, 2005). As Manyong et al. (2006) explain, the results of the PCA stem from an analysis of the correlation matrix of the original variables. At the outset, the analysis standardizes the different units in such way that their mean is 0 and standard deviation is 1.

The starting point of PCA for the eight seasonal climate perception variables ($P_1 \ldots P_8$) can be represented by a set of eight linear structural equations as follows:

$$\begin{bmatrix} P_1 \\ \cdot \\ \cdot \\ P_8 \end{bmatrix} = \begin{bmatrix} \beta_{01} \\ \cdot \\ \cdot \\ \beta_{08} \end{bmatrix} + \begin{bmatrix} \beta_{1j} \\ \cdot \\ \cdot \\ \beta_{8j} \end{bmatrix} x_j + \begin{bmatrix} \varepsilon_1 \\ \cdot \\ \cdot \\ \varepsilon_8 \end{bmatrix}, \tag{3.1}$$

where the eight dependent variables are regressed individually against a vector of j independent variables x.

On the left-hand side of this model, the observable dependent variables of seasonal CC perception are considered to harbour a latent variable that can be estimated using the LISREL method (Jöreskog, 2005). The estimation results in the following reduced form:

$$\begin{bmatrix} P_1 \\ \cdot \\ \cdot \\ P_8 \end{bmatrix} \cong \begin{bmatrix} PC_1 \\ \cdot \\ PC_s \end{bmatrix} = \begin{bmatrix} \beta_{01} \\ \cdot \\ \beta_{0s} \end{bmatrix} + \begin{bmatrix} \beta_{1j} \\ \cdot \\ \beta_{1s} \end{bmatrix} x_j + \begin{bmatrix} \varepsilon_1 \\ \cdot \\ \varepsilon_s \end{bmatrix} \tag{3.2}$$

Where $PC_1 \ldots PC_s$ are retained components of $P_1 \ldots P_8$ with eigenvalues greater than 1, and $s<8$.[9]

Therefore, this data reduction technique consists of using the correlation between the eight variables to generate a vector of uncorrelated principal components (PCs). Assuming that $s>1$, a linear recombination of the components can be used to generate an index based on the principle of orthogonal components in PCA as follows:

[9] s can be as small as 1.

$$\begin{bmatrix} P_1 \\ \cdot \\ \cdot \\ P_8 \end{bmatrix} \cong \begin{bmatrix} PC_1 \\ \cdot \\ PC_s \end{bmatrix} \equiv CCP = \beta_0 + \beta_j x_j + \varepsilon \tag{3.3}$$

where *CCP* is a single array of case-specific scores defining the strength of perception of seasonal climatic variability.

3.3.2.2. Modelling the determinants of CC perception: a Double-Hurdle approach

The most popular sample selection models used to correct the presence of zeros in the empirical literature are the DH, Tobit and Heckman sample selectivity models (Humphreys et al., 2009; Wodjao, 2007). Empirical studies have commonly vindicated the superiority of the DH approach over the Tobit and Heckman sample selectivity models (Humphreys et al., 2009; Wodjao, 2007). To estimate the determinants of CC risk perception, therefore, this study adopts the DH estimation procedure proposed by Cragg (1971). Under this technique, a farmer has to cross two hurdles to perceive CC. First, a farmer becomes a "potential perceiver" after crossing the "first hurdle". Given positive perception, a socio-psychological, institutional and cultural scenario will lead to actual perception. This is termed the "second hurdle". The DH model of CC perception is, therefore, a two-equation framework:

$$\begin{aligned} d_i^* &= Z_i^{'}\alpha + \varepsilon_i \quad \text{first hurdle} \\ CCP_i^* &= X_i^{'}\beta + \mu_i \quad \text{second hurdle} \end{aligned} \tag{3.4}$$

where d_i^* is a binary variable depicting whether a farmer perceives seasonal CC or not; CCP_i^* is a latent variable reflecting perceived intensity (i.e. the observed shape of CC perception determined as $CCP_i = d_i^* \cdot CCP_i^*$); *Z* and *X* are vectors of factors explaining the probability of perceiving CC and the perceived intensity of changes, respectively; α and β are vectors of coefficients to be estimated; and ε_i and μ_i are the two error terms assumed to be independently distributed such that $\begin{pmatrix} \varepsilon_i \\ \mu_i \end{pmatrix} \sim N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & 0 \\ 0 & \sigma^2 \end{pmatrix}\right]$.

The log-likelihood function for the DH model is (Moffatt, 2005):

$$LogL = \sum_0 \ln\left[1 - \Phi(Z_i'\alpha)\Phi\left(\frac{X_i'\beta}{\sigma}\right)\right] + \sum_+ \ln\left[\Phi(Z_i'\alpha)\frac{1}{\sigma}\phi\left(\frac{(CCP_i - X_i'\beta)}{\sigma}\right)\right] \quad (3.5)$$

where $\Phi(\cdot)$ and $\phi(\cdot)$ are the standard normal cumulative and probability density functions, respectively.

The analysis of marginal effects helps to assess the impact of the exogenous variables on the dependent variable. To do so, the unconditional mean is decomposed into the effect on the probability of perceiving and the effect on the conditional level of perception and differentiating these components with respect to each explanatory variable. The unconditional mean can be written as:

$$E[CCP \mid X_i] = P(CCP_i > 0) \cdot E(CCP_i \mid CCP_i > 0) \quad (3.6)$$

The probability of perceiving and the perceived magnitude of climate change conditional on perception are:

$$P(CCP_i > 0) = \Phi(Z_i'\alpha)\Phi\left(\frac{X_i'\beta}{\sigma}\right) \quad (3.7)$$

and

$$E(CCP_i \mid CCP_i > 0) = \Phi\left(\frac{X_i'\beta}{\sigma_i}\right)^{-1} \int_0^{\infty}\left(\frac{CCP_i}{\sigma_i\sqrt{1+\theta^2 CCP_i^2}}\phi\left(\frac{T(\theta Y_i) - X_i'\beta}{\sigma_i}\right)\right) dCCP_i \quad (3.8)$$

For the discrete or categorical variables, the marginal effects are used to calculate percentage changes in the dependent variable when the variable shifts from zero to one, *ceteris paribus*. In the DH framework, the selection model (Equation 3.7) is estimated using Probit regression and the second stage (Equation 3.8) is calibrated using a truncated regression procedure (Cragg, 1971).

3.3.3. Data collection procedures and questionnaire design

To reveal the insights into CC perceptions and adaptive land use management in KZN midlands, this study used both household survey and meteorological data.

3.3.3.1. Survey approach

The survey approach has been proved more robust by recent landscape (Yu et al., 2013) and CC adaptation studies (Below et al., 2012). The survey was based on the sustainable livelihoods approach, as proposed by the DFID (1999a, 1999b). The survey was implemented in two phases. In the first phase, participatory rural appraisals (PRAs) were conducted in May 2013. Key informant interviews with extension workers operating in the area and farmer cooperative leaders were conducted. The participants were two field extension officers from the Illovo Sugar (South Africa) Limited at the Noodsberg Mill, and the leaders of two farmer cooperatives operating in two small-scale grower sub-region of the Midlands North sugarcane growing region. The cooperatives, namely Siphapheme cooperative in Swayimane and a newly formed cooperative in Appelsbosch and Ozwathini, are part of the Project Khula ("Grow") administered by the Noodsberg Cane Growers' Association. Further experts opinions were sought from two members of the Noodsberg Research, Development & Extension Committee (see details in Cockburn et al., 2014), including the head of extension at the Noodsberg Mill, the extension officer in charge of small-scale growers in the midlands regions at the SASRI, and the Managing Director of Awethu Forestry Investment project. The purpose was to understand the industry organization and the impacts of CC on the livelihoods of small-scale farmers.

The key informant interviews were followed by focus group discussions with knowledgeable farmers from various cooperatives, and transect walks. The dual-moderator focus group interview (facilitated by the author and translated by one extension officer from the Illovo Noodsberg Mill who also served as rapporteur) involved 21 selected small-scale farmers from three land use categories, namely seasonal crops, sugarcane and forest producers. Based on a discussion guidelines (see appendix C), the interviews helped to understand farmers' livelihoods and their salient beliefs about CC and ALUC.

Based on this information, a structured farm household survey questionnaire was constructed (see Appendix D). Based on the sustainable livelihoods framework, the survey instrument was structured to capture various aspects of land-based livelihoods, including information about the livelihood assets, strategies, vulnerability, and land use outcome beliefs. Various aspects of seasonal climate risk perceptions were captured as part of the vulnerability context. Some aspects of food insecurity were also recorded under the vulnerability context section.

For the purpose of improving the wording and the structure/flow of the questions, trained field enumerators were used to pilot-test the questionnaire in June 2013.

The improved questionnaire was administered during the second phase spanning from June to July 2013. Farm households were selected for face-to-face interviews using a stratified two-stage random sampling technique. In the first stage, two clusters were selected based on the two contrasting homogeneous agro-climatic zones (see table 3.1): the wetter and hilly Windy Hill Mistbelt region and the dryer and flatter Wartburg/Fawnleas zone. After digitizing the analog map of regional agro-ecological zones developed by Bezuidenhout and Gers (2002) (see appendix B1) and overlaying it with ward demarcation maps, it was observed that these two areas cover six wards (see areas with downward diagonals in Figure 3.3). These wards cut across two major regions, Mthuli area in Windy Hill Mistbelt region, and Gcumisa areas Wartburg/Fawnleas zone.

In the second stage, simple random sampling technique was used to select farmers to be interviewed, based on lists provided by the agricultural extension officers in the respective areas. In order to account for the difference in the size of farmers' populations in the two areas, the farmers were randomly sampled with probability proportional to size. In total, based on the heterogeneity in the farming systems in the region, 152 farm households were selected for interview.

3.3.3.2. Meteorological data

The meteorological data used in this chapter were obtained from the historical weather datasets of the South African Sugarcane Association (SASA). The datasets are available on the public weather data web site (http://portal.sasa.org.za/weatherweb). The nearest weather station was Wartburg - Bruyns Hill Station (29°25'0" S; 30°41'0" E). Monthly observations of rainfall and temperatures for the period of 1972-2013 were selected for this study.

3.3.4. Empirical model

3.3.4.1. Dependent variables used in the Double-Hurdle model

Farmers were asked if they believed that CC is occurring. The responses were categorized as 1 (Yes) and 0 (No), and these values constituted the dependent variable for the Probit model.

In a separate question, farmers reported their perceived experience with "abnormal" seasonal (summer and winter) rainfall and temperature trends over the last three decades. Farmers were free to be subjective in their judgement about "abnormality". Eight questions were posed to each respondent and perceptions were measured on scales ranging from 0 (I don't believe so) to 8 (I strongly believe so). These variables were employed in the construction of indices of perceptions about CC using the PCA technique described above. The indices serve as dependent variables in truncated models.

3.3.4.2. Independent variables

Despite emotive and cognitive factors, the conceptual literature overviewed in section 3.2 defines five categories of socio-psychological, institutional and cultural factors influencing perception of CC, *viz*. wealth and health, personal experience, recall, values and worldviews, trust, and amount of information available (Dessai et al., 2004). These factors, however, influence the nature of perceptual formation in different ways. Personal experience, wealth and health, and recall underlie experience-based perceptual formation, whereas information, trust, values and worldviews define description-based perceptual strength (Weber, 2010). In the empirical model, the indicators of such factors are as follows:

Holistic affect (AFFECT) represents the experiential learning process pertaining to how associative and automatic reactions towards an external stimuli underlie information processing and judgement (Peters and Slovic, 1996; Zajonc, 1980). When risk judgement would involve complex cognitive and mental resources that are not readily available, relying of holistic affective impressions can provide an efficient heuristics (Slovic et al., 2007). Following Peters and Slovic (1996), the information about holistic affect was captured by asking respondents how they feel (i.e. their general impression) about CC. Their answers were recorded on a 5-point bi-polar scale, ranging from -2 (CC is very good/pleasant/advantageous) to 2 (CC is very bad/unpleasant/detrimental).

Knowledge about CC (KNOWLEDGE) represents the cognitive dimension of CC perception in the model. Empirical studies show that increased knowledge is an important predictor of the cognitive judgement of climate risk, although evidence on the direction of the effect of knowledge on climate risk perception remains mixed (see a review by van der Linden, 2014a). van der Linden (2014a) argues that the contradiction in empirical findings can be attributed to measurement errors. Subjective and self-reported knowledge tend to be less reliable and confound different dimensions of knowledge, whilst objective assessment provides a more accurate measure of knowledge (van der Linden, 2014a). With this consideration, respondents in this study were asked about the years in which they may have observed particularly abnormal/strange seasonal rainfall patterns. Following Tobler et al. (2012) and van der Linden (2014a), the responses were checked against actual meteorological observations[10]. A score capturing the number of correct answers was generated for each respondent. Therefore, higher score indicated a better analytic knowledge about CC.

Worldviews are socio-cultural and political attitudes towards the world that guide individual response in complex situations (Leiserowitz, 2006; van der Linden, 2015). The cultural theorists identify four broad categories of worldviews, namely egalitarianism (i.e. values such as equal rights, equal wealth distribution, and affirmative action), individualism (i.e. moral worth of individual, virtues of self-reliance, value of personal independence, and precedence of individual interest over the social or state interests), hierarchism (i.e. principles and authority of hierarchy) and fatalism (i.e. feelings of powerlessness to influence the future, lack of control over one's life, inevitability or predetermination of future events) (Peters and Slovic, 1996). Each worldview represents a distinct set of rationality that identifies and defines risks based on how they threaten the preferred way of life. For example, prototypical individualists and hierarchists may mostly fear events that threatens their autonomy or personal efficacy and the social structure of the status quo, respectively, whilst prototypical egalitarian would fear risks that accentuate injustice in the distribution of risk costs and benefits (Leiserowitz, 2006; van der Linden, 2015). The questionnaire captured various aspects of worldviews with questions asking their importance to a farmer, and responses were measured on a 5-point bi-polar scale, ranging from 1 (very opposed to my values) and 5 (very important). Following Leiserowitz (2006), an index was additively generated for each category of worldview. Based on the Cronbach's alpha estimate of reliability of psychometric tests, EGALITARIANISM (α=0.73) and INDIVIDUALISM (α=0.80) indexes were included in the model. However, HIERARCHISM (α=0.51) and FATALISM (α=0.49) failed to achieve satisfactory Cronbach's alpha[11].

[10] The accuracy of responses was appraised based on the analysis of the root mean squared error (RMSE), per year, of the difference between monthly rainfall and long-term mean, for corresponding months According to the meteorological records, the years with extremely abnormal monthly rainfall were 1980, 1987, 1995, 2002 and 2007 (see Section 3.3.2).
[11] Cronbach's alpha tests for individual and group variables are presented in Appendix A1.

3.3.4.3. Control variables (socio-demographic and agro-ecological factors)

Age of household head (AGE) is a demographic variable representing farmer's experience with farming as well as individual values and worldviews in the model. Older farmers are often more susceptible to environmental threats and have lower adaptive capacity (Brooks, 2003; Cutter, 1996; Ibarrarán et al., 2009). Therefore, the worry about CC can increase with age. In a negative way, however, older people tend to be politically conservative and hold traditional values, and these increase their scepticism about CC (Poortinga et al., 2011; Whitmarsh, 2011). To control the plausible effect of different age brackets, a quadratic form of age (AGE_SQUARED) is also included in the models.

Female headedness (GENDER) is a cultural variable related to social norms and individual values. It represents differences in experience with climatic hazards, as well as differential environmental values and worldviews held by men and women. Social norms confine women to climatically sensitive and natural resource-based activities, exposing them to CC (Denton, 2002). Moreover, women often hold positive values towards ecological management (Arora-Jonsson, 2011). Therefore, whether their perceptions are based on experience or personal values, females heading households are expected to have higher probability to perceive CC than their male counterparts do.

Years of formal education (EDUCATION) is both an experiential and cognitive factor in the model. On the one hand, education decrease the propensity to perceive CC because educated farmers have more ability to diversify their livelihoods into less climatically sensitive activities than their uneducated counterparts do (Saroar and Routray, 2012). In a positive way, on the other hand, education could increase farmers' cognitive ability (Gaurav and Singh, 2012) that facilitates the understanding of scientific information about CC and the engagement in climate-related communication activities.

Extension training and visit (EXTENSION) is an institutional variable representing access to climate information. In many parts of the world, agricultural extension is the major policy strategy used to channel analytical information (e.g. seasonal climate forecasts) from research scientists to farmers (Breuer et al., 2008; Eakin, 1998). The number of extension training and visits received (in 2012), therefore, can determine the amount of information a farmer holds regarding CC.

Generalized level of trust (TRUST) is another institutional variable that measures cognitive social capital (Putnam, 1995). Generalized trust is a reflection of the civic society, quality of institutions, culture and values, and ethnic heterogeneity in the community (Nannestad, 2008; Rothstein and Stolle, 2008). The literature on environmental risk perception shows that trust-based networks are important channels of environmental information, especially when there are multiple and conflicting information sources (Hagen, 2013; Hultman et al., 2010; Slovic et al., 1991; Weber, 2010).

Adult-equivalents (ADULTS)[12] is a demographic variable representing household's labour endowment. Labour is an experiential factor related to the economic adaptive capacity. A larger pool of economically active members in a household is often associated with variation in skills, knowledge, psychological capital and social networks that increase the prospect of livelihoods diversification and reduce the susceptibility to environmental threats (Adger et al., 2004). Therefore, households with more adult members can be less concerned about climate risk.

Size of landholding (LAND) is an experiential factor representing the sensitivity to CC. Larger farmland areas are often associated with heterogeneity in bio-geophysical characteristics (e.g. different slopes and soil fertility) that reduce the susceptibility to climatic changes (Sumberg, 2003). Land resource-rich farmers, therefore, are less sensitive to adverse climatic patterns and less worried about CC than their poor counterparts do.

Walking distance to the nearest river/dam (RIVER) is an experiential factor representing the adaptive capacity in the form of irrigation. Farmers that have access to irrigation water tend to be less worried about CC because of they have a certain level of control over its effect compared to their dryland farmers counterparts (Deressa et al., 2011; Gbetibouo, 2009). The access to irrigation water, therefore, can attenuate the negative affect associated with adverse CC, decreasing the probability of perceiving any changes in climate distribution.

[12] As proposed by Cutler and Katz (1992), adult-equivalents (ADULTS) is computed as $ADULTS = (N_A + cN_C)^{\theta}$, where N_A and N_C represent the number of adults and children in the household, respectively, c is a constant reflecting the resource cost of a child relative to that of an adult, and θ measures the overall economies of scale within the household. Following previous key empirical studies in South Africa (May et al., 1995; Woolard and Leibbrandt, 2006), c was set to 0.5, and θ was set to 0.9 (Streak et al., 2009).

Walking distance to the nearest road (ROAD) is a spatial variable indicating access to market infrastructure. Access to market infrastructure, however, is both an experiential and analytic factor of climate risk perception. On the one hand, access to market infrastructure is a key determinant of vulnerability to CC, given that it facilitates livelihood diversification and access to aid programs in times of crisis (Adger et al., 2004; Gbetibouo et al., 2010). The lower levels of vulnerability among farmers in road proximities attenuate the worry and, therefore, the perception about CC. On the other hand, individuals with access to markets often hold individualist values that promote autonomy and personal gains, and, therefore, have less environmental concerns (Leiserowitz, 2006).

Windy Hill Mistbelt agro-ecology (AGRO-ECOLOGY) is a bio-geophysical variable added to the model in order to control for regional fixed effects, i.e. differences in local agro-ecological conditions between Windy Hill Mistbelt and Wartburg/Fawnleas zones. As described in Table 3.1, Bezuidenhout and Gers (2002) differentiated various agro-ecological zones based on climate (solar radiation, heat units, precipitation and coefficient of variation) and topography criteria.

3.4. Results and discussion

3.4.1. Summary of perceptions and socio-economic characteristics of the interviewed farmers

Table 3.2 presents a T-test of equality of means for original variables used to construct indices of perceptual shapes. With regard to winter season abnormalities, the table shows that believers in CC and non-believers seem to disagree on all perceived trends, to the exception of winter season getting abnormally dryer. In the sample, a typical believer in CC perceived winter season to be getting abnormally colder (mean=4.6), and wetter (mean=5.2), while disagreeing that the season is getting warmer (mean=3.1). A typical non-believer in CC, on the other hand, did not perceive the season to become abnormally colder (mean=2.1), warmer (mean=3.1), or wetter (mean=1.9). Nevertheless, both the believer in CC (mean=2.0) and non-believers (mean=1.8) disagreed with the view that the winter season is getting abnormally dryer.

Table 3.2. Description of self-reported experiences with abnormal seasonal climates among interviewed farmers

Perception	Mean		T-statistic
	Believers in CC	Non-believers in CC	
Winter season is getting:			
Abnormally colder	4.6	2.1	1.7
Abnormally warmer	3.1	1.2	1.6
Abnormally dryer	2.0	1.8	1.3
Abnormally wetter	5.2	1.9	1.8
Summer (farming) season is getting:			
Abnormally cooler	1.2	0.9	1.1
Abnormally hotter	6.5	1.8	2.2
Abnormally dryer	7.3	2.2	2.7
Abnormally wetter	1.4	0.1	0.8

Data source: Household survey data (2013)
Note: number of observations n=152.

With regard to summer season abnormality, a typical believer and a typical non-believer in CC had sharp disagreement with regard to abnormal decrease in summer rainfall and abnormal increase in summer temperature. In the believer category, a typical farmer strongly perceived recent summer rainfall to be abnormally lower (mean=7.3) and summer temperatures to be abnormally higher (mean=6.5). A typical farmer in the non-believers category, however, did not believe in abnormally drying (mean=2.2) and warming summer (mean 1.8). Nevertheless, interviewed farmers in both categories had commonly disagreed that summer season was becoming abnormally cooler and wetter. These descriptive statistics show farmers were not inconsistent in their answers.

With regard to socio-psychological characteristics, Table 3.3 shows that the mean level of negative affect and the average depth of egalitarian values were significantly higher among the perceivers than among the non-perceivers, whilst individualism was significantly more pronounced among non-perceivers of CC. There was no significant difference in the average numbers of correct responses about years with particularly abnormal rainfall across the two groups. Also, the mean ages of the perceivers (60) and non-perceivers (56) in the sample were not significantly different.

Table 3.3. Summary statistics of variables used in the Double-Hurdle model

Variable name	Variable description and/or value labels	Mean		T statistic
		Perceivers	Non-perceivers	
Dependent variables				
PERCEPTION	1 = local climate is changing; 0 = otherwise (dummy)	1	0	-
CCP_1	PCA index from PC_1 of CC perception (contributed 45% to total variation in data)	-0.433	-	-
CCP_2	PCA index from PC_2 of CC perception (explained 24.7% of the variation in data)	-0.060	-	-
Independent variables				
AFFECT	-2= very good/pleasant/advantageous, -1= somehow good/pleasant/advantageous, 0= I have no particular feeling, 1= somehow bad/pleasant/detrimental, 2= CC is very bad/unpleasant/detrimental	1.098	-0.011	1.93**
KNOWLEDGE	Number of correct responses about years with particularly abnormal rainfall	1.752	1.23	1.1
EGALITARIANISM	Index of belief in human equality with respect to social, political and economic rights (α=0.81)	17.712	10.221	2.0**
INDIVIDUALISM	Index of belief in moral worth of an individual (α=0.73)	8.281	11.954	1.7*
AGE	Age of the household head in years (continuous)	60.11	56.12	1.3
AGE_SQUARED	Age of the head of household squared (continuous)	3613.21	3194.45	0.9
GENDER	1 = Female-headed household; 0 = otherwise (dummy)	0.71	0.45	1.6*
EDUCATION	Years spent by a household head in formal education (continuous)	5.21	6.14	1.4
EXTENSION	Number of contact with extension workers in 2012 (count)	4.35	2.22	1.9**
TRUST	1= don't trust anyone, 2 = the majority are not trustworthy, 3 =the majority are trustworthy, 4 = everyone is trustworthy (categorical)	2.21	2.84	0.7
ADULTS	Number of adult-equivalent members of the household (count)	4.61	5.42	1.3
LAND	Total operated area in hectares (continuous)	1.74	1.18	0.9
RIVER	Walking distance (in minutes) to the nearest river/dam (continuous)	50.74	36.68	1.6*
ROAD	Minutes taken on arrive at the nearest tarmac road (continuous variable)	13.59	11.26	1.5
AGRO-ECOLOGY	1 = Windy Hill Mistbelt agro-ecological area (Mthuli); 0 = Wartburg/Fawnleas agro-ecological area (Gcumisa) (dummy)	0.66	0.38	2.2***

Data source: Household survey data (2013)
Note: number of observations n=152.

Gender distribution was significantly different across the two groups, the group of perceivers recoding higher proportion of female-headed households (71%). The mean levels of education in the sample were 5 and 6 for the perceivers and the non-perceivers' groups, respectively, although the difference was not statistically significant. Access to extension services was significantly different across the two groups in the sample. An average non-perceiver had received or made four extension visits, whilst an average non-perceiver had only made/received two visits[13].

On average, a farmer, whether a perceiver or not, believed that the majority of people in his community are not trustworthy. An average household in the perceivers' and non-perceivers' group, respectively, had four and six adult-equivalent members, and owned 1.7 and 1.1 hectares of land, though the difference was not statistically significant. Distance to water sources was significantly different among farmers in the two groups, with an average perceiver walking 12 more minutes to reach the nearest river/dam than an average non-perceiver. Average distance to road (11 – 13 minutes), was not statically significantly different across the two groups. Whilst the majority of farmers perceiving CC were from the Mthuli area, the majority of farmers who did perceive CC were from Gcumisa.

3.4.2. Overview of climate variability and change in the KZN midlands

Based on historical weather records of the Wartburg-Bruyns Hill meteorological station[14], the long-term rainfall and temperature records in Figure 3.5 unveil a typical subtropical oceanic climate. The spring (September – November) and summer (December – February) seasons account for 31% and 41% of total annual rainfall, respectively, whilst the remainder is accounted for by the autumn (March – May) and winter/dryer (June – August) seasons.

[13] Although the empirical studies conducted in the area (e.g. Matungul et al., 2001) suggested that the rates of participation in extension is very poor, Table 3.2 shows that, on average, a farmer had contacted extension agents three times in 2012. This could be due to the large number of sugarcane and timber out-growers in the sample. The out-growers in the study area receive extension services from major companies (e.g. Noodsberg Illovo Sugar Mill), in addition to the government-run extension services.

[14] During the analysis of meteorological records, it was observed that the values of climatic variables (precipitation and temperature) in the Windy Hill Mistbelt region and those of the Wartburg/Fawnleas zone are different. Nevertheless, the variables were remarkably similar in "trends". For simplicity, therefore, this subsection only reports the analyses of meteorological records from a station in the Wartburg/Fawnleas zone.

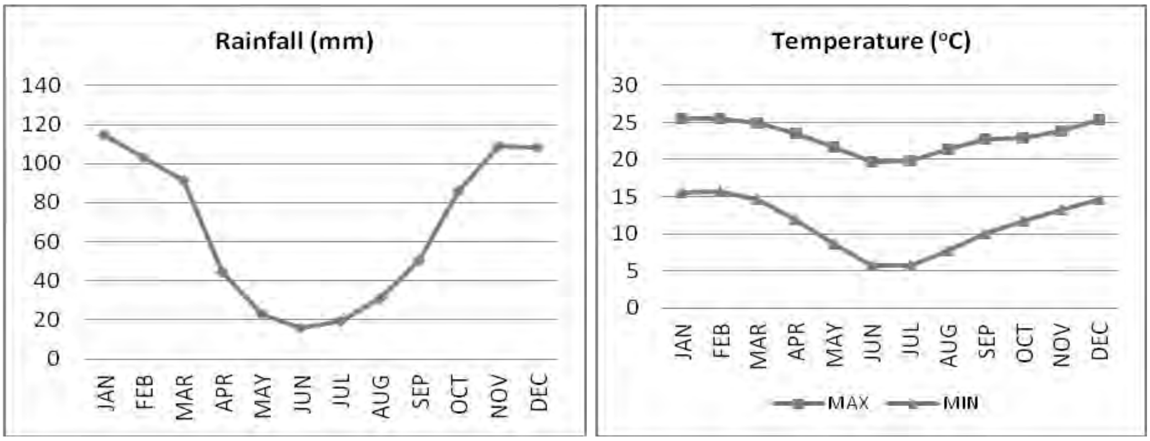

Figure 3.5. Long-term monthly average rainfall and temperature: at Wartburg - Bruyns Hill Station (29°25'0" S; 30°41'0" E): 1972-2013, KZN Midlands, South Africa
Data source: SASRI weather database (http://portal.sasa.org.za/weatherweb).

To pinpoint the seasonal climate variability, analysis based on the coefficient of variation (CV) is presented in Figure 3.6. With CVs ranging between 0.40 and 1.85, monthly rainfall is more variable than minimum and maximum temperature. Minimum temperature is relatively more variable than maximum temperature. Ranges of rainfall and temperature fluctuations during winter are higher than those of the warm and rainy season. Generally, inter-annual rainfall and temperature variabilities increase from late autumn to early spring, peaking during mid-winter period.

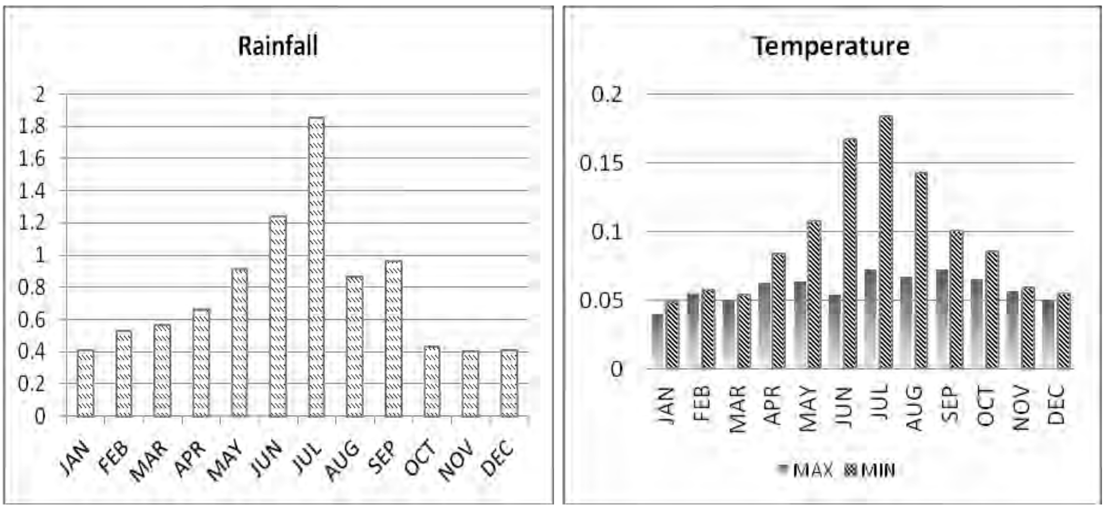

Figure 3.6. Coefficient of variation in historical monthly climate variables at Wartburg - Bruyns Hill Station (29°25'0" S; 30°41'0" E): 1971-2013, KZN Midlands, South Africa
Data source: SASRI weather database (http://portal.sasa.org.za/weatherweb).

The patterns of long-term trends in rainfall and temperature are shown in Figure 3.7. The annual rainfall ranges from 521mm (1992 record) to 1120 mm (2006 record), while temperatures range from 28.2°C (summer maximum) to 3.2°C (winter minimum). The figures unveil a decreasing long-term trend in annual rainfall. The trend is marked by noticeable increase in the frequency of extreme event years when annual rainfall falls outside of two standard deviations of mean annual rainfall. Drought spells were stark in years such as 1992, 1999, 2003, 2008, and 2010, and flood events were evident in 1987, 1988, 2000, and 2006. The decreasing rainfall trend is juxtaposed with a slightly increasing annual minimum temperature. Such figures, however, mask enormous variation in the normal distribution of rainfall and temperature across various seasons.

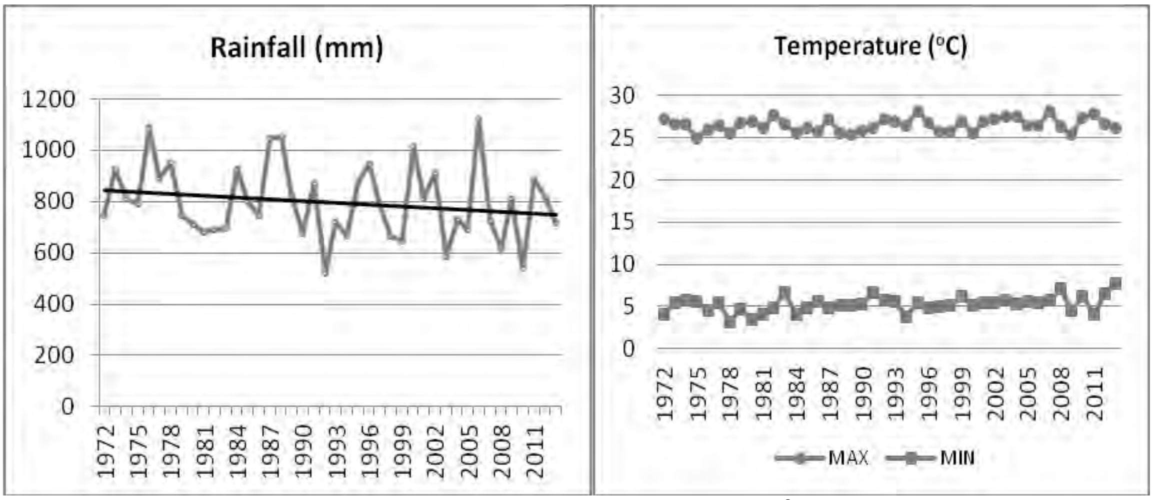

Figure 3.7. Historical annual rainfall (mm) and temperature (°C) at Wartburg - Bruyns Hill Station (29°25'0" S; 30°41'0" E): 1972-2013, KZN Midlands, South Africa
Data source: SASRI weather database (http://portal.sasa.org.za/weatherweb).

To identify the intra-seasonal climatic trends, Figures 3.8 displays a growing length of dry season resulting from a trend towards lower rainfall during the second half of the growing season (i.e. from mid-summer to early autumn) not sufficiently accompanied by opposite trends in early growing season (spring) rainfall. This explains the overall decreasing trends in annual rainfall shown in Figure 3.7. However, the trends in Figure 3.8 also show signs of increase in early winter rainfall. With regard to seasonal temperature trends, Figure 3.9 shows slightly warming trends, marked by increasing minimum temperatures throughout the seasons. These trends are particularly stark for the winter months (April – August). The increasing trends in minimum seasonal temperatures corroborate the increasing annual temperatures previously shown in Figure 3.7. They are well in line with the results of more robust statistical analyses by Kruger and Shongwe (2004) and Warburton et al. (2005).

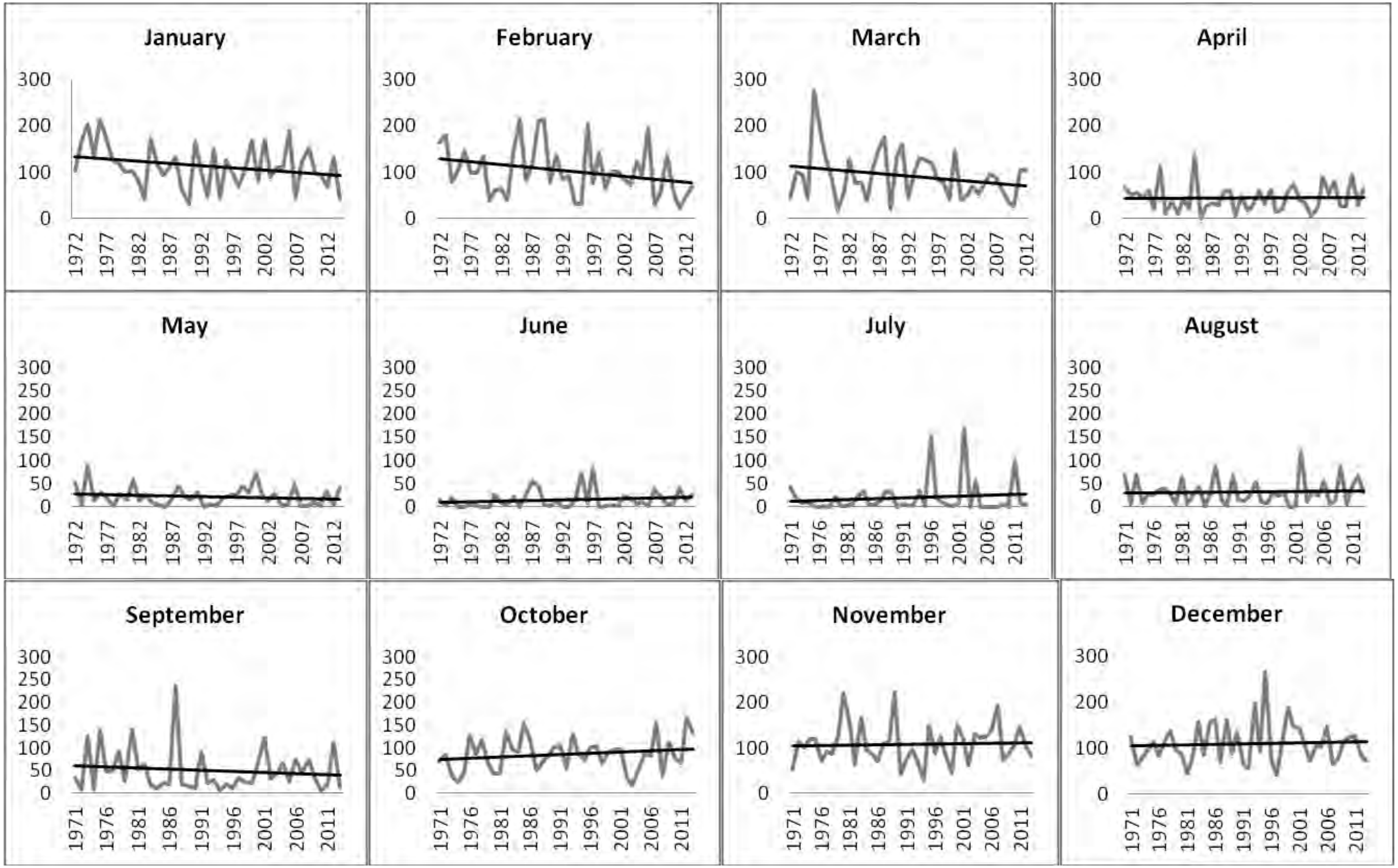

Figure 3.8. Historical monthly rainfall (mm) at Wartburg - Bruyns Hill Station (29°25'0" S; 30°41'0" E): 1971-2013, KZN Midlands, South Africa

Data source: SASRI weather database (http://portal.sasa.org.za/weatherweb).

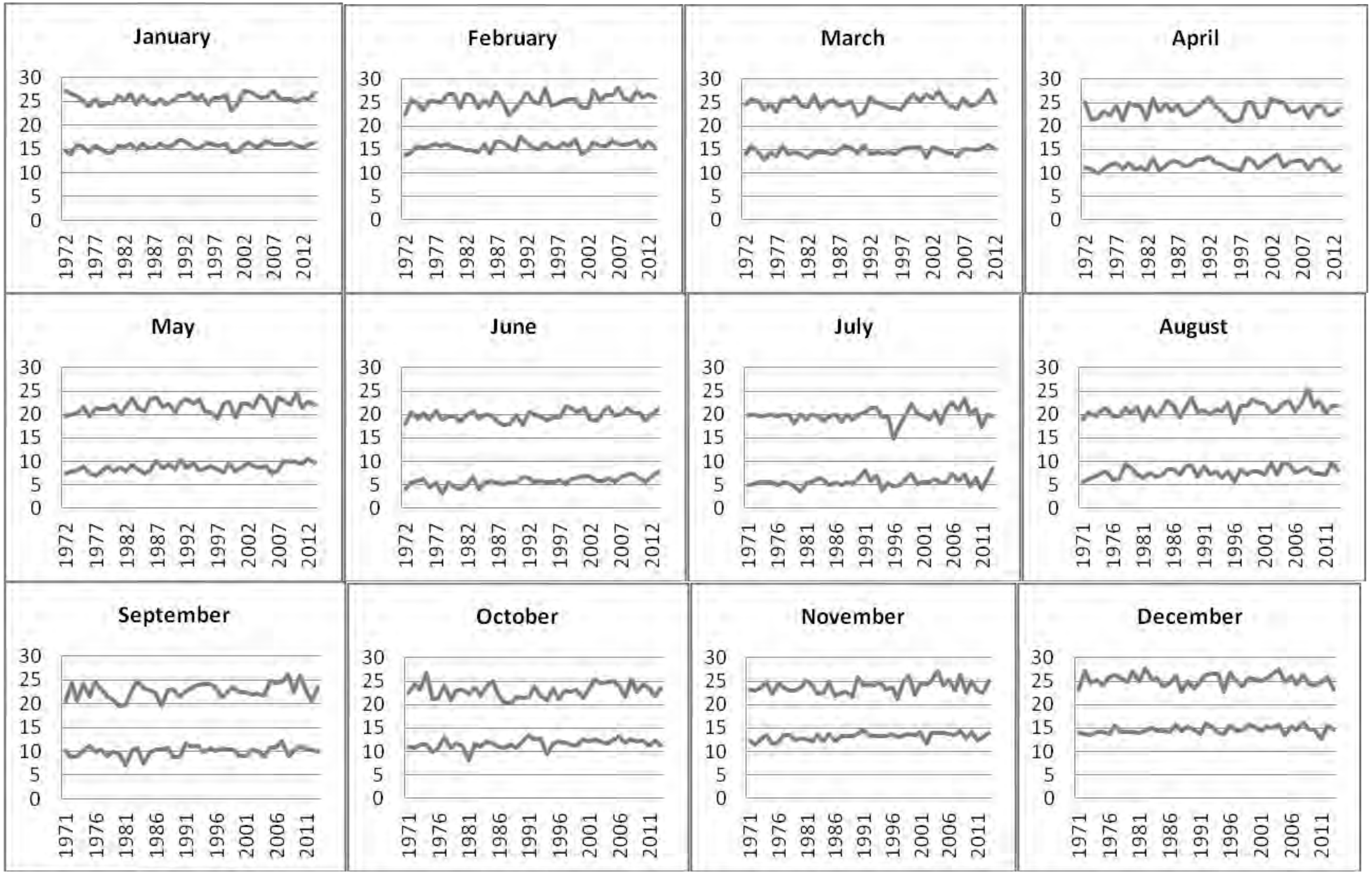

Figure 3.9. Historical monthly minimum and maximum temperatures (^{o}C) at Wartburg - Bruyns Hill Station (29°25'0" S; 30°41'0" E): 1971-2013, KZN Midlands, South Africa

Data source: SASRI weather database (http://portal.sasa.org.za/weatherweb).

Figure 3.10 shows the years with extreme distributions of climate variables[15]. Consistent with the observations of Dube and Jury (2000), the distribution of climate variability shown in the figure indicates that the last four decades were marked with a decreasing intensity of rainfall and temperature abnormality[16], but with noticeable lengthening of the cycles (i.e. duration). It is noteworthy that, over the last four decades, years such as 1996, 2002, 2008, and 2011 had relatively high records of extreme distributions in all variables. As Figure 3.10 shows, 1980 recorded the most extreme rainfall, whilst 1996 and 1981 had the most extreme distributions of maximum and minimum temperatures, respectively.

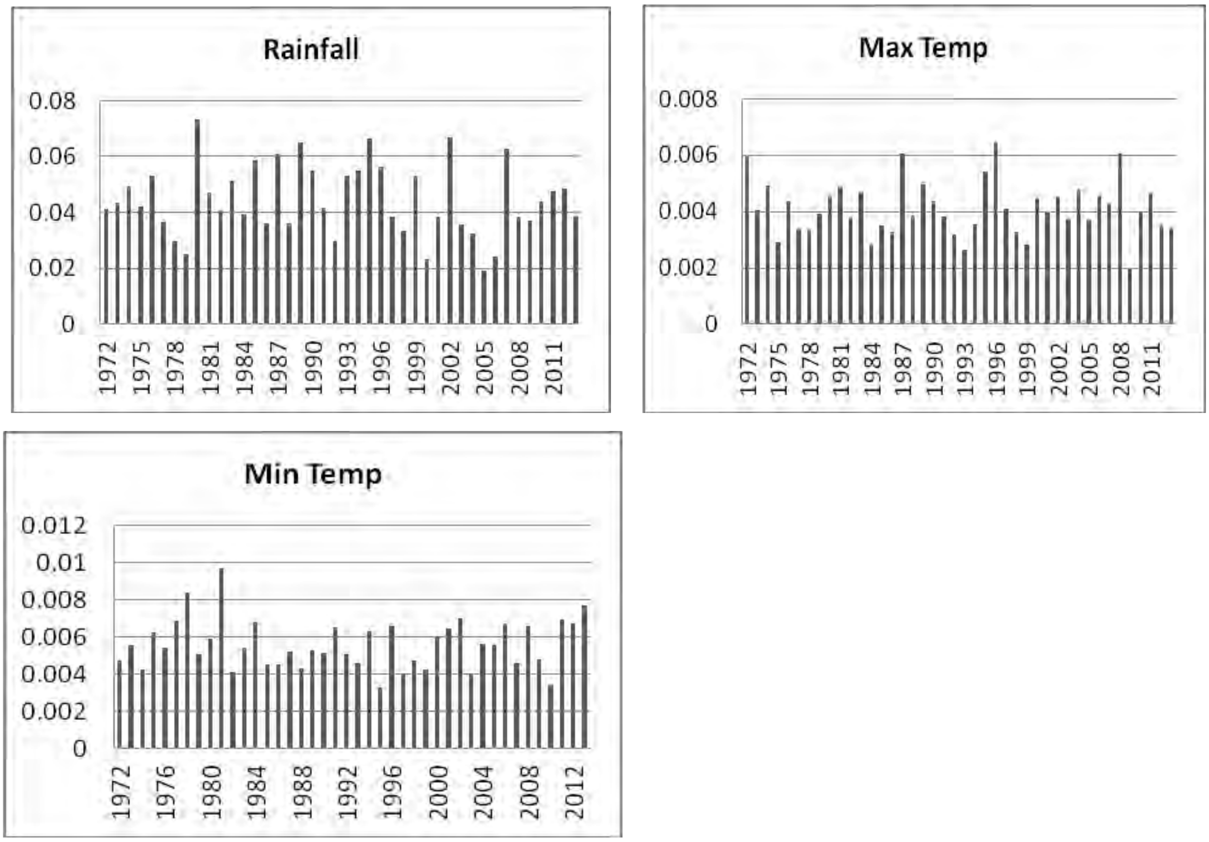

Figure 3.10. Distribution of rainfall and temperature CV at Wartburg - Bruyns Hill Station (29°25'0" S; 30°41'0" E): 1971-2013, KZN Midlands, South Africa
Data source: SASRI weather database (http://portal.sasa.org.za/weatherweb).

[15] The analysis is based on the root mean squared error (RMSE), per year, of the difference between monthly rainfall/temperature and long-term mean, for corresponding months. RMSEs closer to 0 indicate years with rainfall distribution more like the long-term mean, and high RMSEs indicate years with rainfall distribution differing from the long-term mean distribution. However, the calculation used monthly fractions of annual rainfall rather than absolute rainfall values to remove bias from particularly wet or dry years.
[16] The decreasing intensity of rainfall and temperature abnormality in Figure 3.10 could be partly attributed to measurement errors in datasets. In the olden days, rainfall data in KZN were manually collected using manual gauges, a practice that explains many errors in the current records (Nel and Sumner, 2005).

3.4.3. Model diagnostics

Before reporting the empirical results, it would be prudent to verify the underlying statistical assumptions. To test the suitability of the data on perceived climatic changes for the PCA, both the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity (Dziuban and Shirkey, 1974) were used. As shown in Table A2 in the appendices, the value of the KMO test was 0.71, suggesting that the adequacy of input variables for the PCA is good, whilst the test of the null hypothesis that the correlation matrix is an identity matrix reports a p-value < 0.00, suggesting that there is a relationship between the input variables. Therefore, PCA was a suitable method for the analysis of farmers' seasonal CC perceptions.

For the Probit and Truncated regression models, several tests of multiple restrictions (Lagrange multiplier, Wald tests, and likelihood ratio test) revealed that the results gave the best fit. Based on the Stata® module developed by Gould (1998), the null hypothesis of homoscedasticity is conclusively rejected at the 1% significance level. For the Truncated regression models, the values at which the left truncation (i.e. non-perceivers' score) took place was at -1.326 and -0.119 for the first and second PCs, respectively. To curb potential heteroskedacticity, this study used the heteroskedacticity-robust standard errors for parameter estimates. To measure and correct the possible sample selection bias in this model, the probit model in the first stage was used to generate a sample selection correction term referred to as the inverse Mills ratio (IMR), and then used as an explanatory variable in the truncated model (Wooldridge, 2002). The coefficient of the IMR turns out to be statistically insignificant in the truncated model, indicating that self-selection was not an issue.

3.4.4. Dominant shapes of perceptions about seasonal climatic changes in the KZN midlands

Table 3.4 shows the three retained PCs representing the different dimensions of perceived frequency of seasonal abnormality in the local climate. The first PC (CCP_1) contributed 45% to the variation in the data and had an eigenvalue of 2.69. The dominant PC loadings in this component indicate that farmers who perceived an abnormally chilly winter also perceived drying winters, and warming and drying summers. Such agro-climatic conditions are adverse from a farming viewpoint. Therefore, whilst farmers with higher CCP_1 score perceive that farming conditions are becoming adverse, farmers with relatively lower CCP_1 scores do not necessarily perceive climatic conditions as becoming adverse or adverse climatic conditions being abnormal.

Table 3.4. Dimensions of perceived seasonal climatic abnormality, uMshwati Local Municipality, 2013

Perception	CCP_1	CCP_2	CCP_3
Winter season is getting:			
Abnormally colder	**0.390**	0.045	-0.297
Abnormally warmer	0.205	**0.305**	**0.332**
Abnormally dryer	**0.315**	0.169	0.107
Abnormally wetter	0.288	**0.458**	0.086
Summer (farming) season is getting:			
Abnormally cooler	0.193	0.095	-0.104
Abnormally hotter	**0.489**	0.182	**0.399**
Abnormally dryer	**0.852**	**0.390**	-0.087
Abnormally wetter	0.019	-0.067	0.178
Eigenvalue	2.694	1.531	1.060
% of variance	45.1%	24.7%	5.0%
Cumulative	45.1%	69.8%	74.8%

Data source: Household survey data (2013)
Note: number of observations n=152.

The patterns in CCP_1, however, do not correspond well with the meteorological observations in section 3.4.2. Whilst the meteorological observations corroborate the farmers' account of the drying summer season, they do not indicate any long-term reduction in winter temperature or rainfall. It is likely that the impact of recent adverse weather outcomes (such as lengthy heat waves and black frosts) has influenced harder on perceptions of whether or not cold winter and hot summers are abnormal.

The second PC (CCP_2) explained 24.7% of the variation and had an eigenvalue of 1.53. Under the CCP_2 component, the dominant perceptions were warming and wetting winters, and abnormally drier summers. The wetting and warming winter conditions are beneficial to farmers. They can provide a possibility of cultivating certain seasonal crops during winter or reduce the length of growing period for (semi-) perennial crops such as sugarcane and trees. Therefore, farmers with relatively high CCP_2 score perceive that climate change is bringing about beneficial conditions, whereas those with relatively lower CCP_2 scores do not necessarily perceive climatic conditions to become beneficial or beneficial climatic conditions to be abnormal. Interestingly, this variation corresponds well with the actual trends presented in sub-section 3.3.2. In line with the graphical presentations, the sizes of PC loadings suggest that farmers with higher CCP_2 score are aware about the wetting winter season, the drying summer, and, to a lesser extent, the warming winter season.

The third PC (CCP_3) had an eigenvalue of 1.06 but explained only 5% of the variation in the data. Under this component, perceptions were dominated by warming summers and winters. Such trends, however, do not mirror the meteorological observations.

The brief appraisal shows that farmers' perceptions about abnormal trends in local climate are heterogeneous. The heterogeneity is mainly defined in terms of the impact of CC on agricultural production in the region. Farmers with higher CCP_1 score perceive CC as causing abnormally adverse agro-climatic conditions, whilst those with higher CCP_2 scores believe that CC is bringing abnormally beneficial climatic conditions.

It is noteworthy that farmers with similar perceptions about recent climate trends could have differed in what they consider to be within normal ranges vs. what is abnormal, given that they were free to be subjective in their judgement about "abnormality". The construction of PCs has, therefore, allowed such farmers to be distinguished only by a single index of perceptual shape. Given that CCP_1 and CCP_2 explain a good deal of fairly contrasting perceptual shapes, the second stage of the DH model analyse the factors underlying their formation.

3.4.5. Determinants of the probability to perceive seasonal changes in the local climate in the KZN midlands

The results of the Probit model are presented in Table 3.5. The coefficient of affect is significant in the model, suggesting that the probability of perceiving CC increases with farmer's holistic affective impression. Based on the magnitude of the marginal effect, affect is the most important predictor of the probability of perceiving climate change. This finding is not new in the literature. Previous studies on climate risk perception have documented the significance of affect heuristics (Leiserowitz, 2006; O'Connor et al., 1999; Peters and Slovic, 1996; van der Linden, 2015). However, most of these studies were conducted among the general public in developed countries. This study, therefore, is among the firsts to evidence the significance of affect heuristics in the setting of small-scale farming in SSA.

Table 3.5. Probit model estimation results

Variables	Coefficient	S.E.	Marginal Effect	P>|z|
AFFECT	1.025***	(0.359)	0.201	0.005
KNOWLEDGE	0.114	(0.075)	0.005	0.144
EGALITARIANISM	0.445**	(0.224)	0.095	0.046
INDIVIDUALISM	-0.126	(0.092)	0.007	0.227
AGE	0.238**	(0.091)	0.051	0.013
AGE_SQUARED	-0.002	(0.001)	-0.000	0.169
GENDER	0.258**	(0.111)	0.187	0.027
EDUCATION	-0.056*	(0.032)	-0.022	0.082
EXTENSION	-0.012	(0.016)	-0.005	0.830
TRUST	0.021	(0.015)	0.000	0.727
ADULTS	-0.029	(0.025)	-0.010	0.523
LAND	-0.105	(0.098)	-0.036	0.307
RIVER	-0.006	(0.003)	-0.002	0.186
ROAD	0.011	(0.006)	0.003	0.134
AGRO-ECOLOGY	0.204***	(0.075)	0.170	0.008
Constant	2.332	(1.371)	–	0.091
Number of observations	*152*			
Log-likelihood	*-83.908*			
Wald chi^2 *(14)*	*67.95*			
Prob > chi^2	*0.008*			

Note: *** = significance at 1% level, ** = significance at 5% level, * = significance at 10%.
Data source: Household survey data (2013)

The level of knowledge about CC, however, is not significant. Nevertheless, the insignificance of knowledge is not surprising. There are other studies reporting that perception about CC among the public is not a result of knowledge deficit (Brody et al., 2008; Whitmarsh, 2011). However, as van der Linden (2014a) noted, the lack of significance of knowledge could be attributed to measurement problems. Knowledge about CC is not sufficient to trigger perceptions on its own. It is a combination of knowledge about the change, the cause and impacts that can warrant positive perception about CC (van der Linden, 2014a).

The coefficient of egalitarianism in the model is also significant. It suggests that farmers with strong egalitarian values have higher probability of perceiving the risk of CC. Value judgement accounts for 9% of heterogeneity in perceptions in the region. This result is consistent with previous investigations conducted in developed countries (Leiserowitz, 2006;

van der Linden, 2015). However, as previously mentioned, the existing studies mainly focused on the general public and were conducted in the setting of developed countries.

With regard to socio-demographic characteristics, age of the household head is a significant predictor of the probability of perceiving seasonal CC. As the positive marginal effect suggests, one extra year of age is likely to increase a farmer's probability to perceive CC by 5%. This finding suggests that as the head of household gets older and more experienced with farming, he/she is more likely to be aware of abnormal trends in seasonal climate. The effect could be also mediated by the negative affect caused by the feeling of vulnerability that increases the worry about climatic extremes. This result corroborates the findings of similar studies conducted in other parts of Africa (e.g. Deressa et al., 2011; Maddison, 2007).

The coefficient of gender is also significant, suggesting that the probability of perceiving CC increases by 18% for female-headed households. Consistent with the works of Poortinga et al. (2011), van der Linden (2015) and Whitmarsh (2011), this result indicates both experiential and cognitive effects. First, the results could be explained by the varying vulnerability between men and women. In KZN, as documented by Babugura et al. (2010), the congruence of childcare responsibilities and other social expectations force women into home-based, climate-sensitive activities, ranging from subsistence farming (e.g. home gardening) to energy and water provision. The probability of perceiving abnormal CC, in such socio-cultural circumstances, could be associated with their experience of climate-induced changes in their routine activities. For example, climatic extreme events could have direct effects on the distances normally walked by women to gather firewood or fetch water (Denton, 2002). Second, the effect of gender on perception about CC could be explained by the gender differences in values and worldviews. Past studies such as Whitmarsh (2011) in the UK and Sundblad et al. (2007) in Sweden reported similar findings and posited that the gender effect is mediated by the higher emotional content for environmental perception among women, and the heightened propensity to hold anti-egalitarian and individualistic cultural worldview among men.

Table 3.5 further reveals that the effect of education is negative and significant in the selection model. Achieving one extra year of education reduces the probability of perceiving seasonal climatic abnormality by 2%. This negative effect could be explained by a farmer's personal experience. Given that educated farmers in KZN often have more opportunities in the off-farm sector (Lovo, 2011), this result can be explained by the higher levels of vulnerability among unskilled, full-time farmers. This finding, therefore, vindicates Saroar and Routray's (2012) findings that rural dwellers engaging in off-farm activities often perceive higher levels of adaptive capacities compared to farm-dependent households due to their greater ability to diversify livelihoods into less climatically sensitive activities.

The results in Table 3.5 also show that farmers in the Windy Hill mistbelt agro-ecological area are more likely to perceive climatic changes than those in the Wartburg/Fawnleas area. All other factors in the model remaining unchanged, moving from Gcumisa to Mthuli increases a farmer's probability of perceiving CC by 17%. This finding could be explained by the experiential factors associated with local environmental changes. Although the Windy Hill mistbelt area records higher mean annual rainfall and lower mean annual solar radiation and heat units compared to the Wartburg/Fawnleas zone, it has a higher mean coefficient of variation (more than double that of the Wartburg/Fawnleas zone) as shown in Table 3.1. In addition, under such hilly topographies, climatic extremes could have more pronounced environmental and agricultural impacts such as topsoil loss due to heavy rainfall and faster rate of water stress during dry spells. Congruent to the contentions of Osbahr et al. (2011) and Rao et al. (2011), this finding suggests that the perception of climatic changes could be linked to bio-physical vulnerability. Similar results were reported by Deressa et al. (2011) in the highlands of the Nile river basin of Ethiopia.

3.4.6. Factors shaping the perceptions about seasonal CC in the KZN midlands

The estimated influences of selected variables on the case-specific scores of seasonal CC perceptions (CCP_1 and CCP_2), given positive perception, are reported in Table 3.6. Affect, age, and distance to the nearest water source have significant coefficients in the CCP_1 model. The significance of the coefficient of affect in the CCP_1 model suggests that the process of perceiving about CC in the form of CCP_1 (i.e. abnormally cooler and dryer winter season, and abnormally hotter and dryer summer season) is defined by the level of farmer's feeling about how bad CC is. It shows that, of the respondents who perceive CC to be real, farmers who view the effect of CC as relatively bad/unpleasant are less likely to agree that the hotter, dryer weather experienced during the recent summers and the colder, dryer conditions experienced during the recent winters were normal.

Table 3.6. Truncated model estimation results

Variables	CCP$_1$			CCP$_2$		
	Coefficient	S.E.	P>|z|	Coefficient	S.E.	P>|z|
AFFECT	0.902**	0.345	0.010	0.017	0.014	0.452
KNOWLEDGE	0.005	0.004	0.253	0.635***	0.188	0.001
EGALITARIANISM	0.017	0.015	0.427	0.143	0.089	0.126
INDIVIDUALISM	-0.009	0.008	0.184	0.070	0.043	0.189
AGE	0.079***	0.029	0.008	-0.183	0.152	0.494
AGE_SQUARED	-0.000	0.000	0.427	-0.001	0.001	0.517
GENDER	-0.658	0.543	0.445	-0.198	0.123	0.131
EDUCATION	0.103	0.085	0.408	0.578***	0.171	0.001
EXTENSION	0.132	0.083	0.174	0.133**	0.066	0.048
TRUST	0.434	0.328	0.483	0.458*	0.254	0.073
ADULTS	-0.411	0.274	0.197	-0.089	0.065	0.440
LAND	-0.026	0.056	0.912	-0.353	0.220	0.141
RIVER	0.053***	0.018	0.005	0.012	0.008	0.198
ROAD	0.050	0.034	0.290	0.051	0.031	0.114
AGRO-ECOLOGY	0.225	0.140	0.126	-0.350	0.218	0.130
IMR	-0.132	0.101	0.322	-0.343	0.022	0.169
Constant	0.283	0.143	0.050	1.003	5.961	0.347
Number of observations:	*104*			*104*		
Log-likelihood :	*-107.228*			*-139.891*		
Wald chi^2 (12):	*39.57*			*26.46*		
Prob > chi^2:	*0.001*			*0.023*		

Note: *** = significance at 1% level, ** = significance at 5% level, * = significance at 10%.
Data source: Household survey data (2013)

However, for those who view CC as being pleasant or beneficial, such adverse conditions are relatively normal. This finding validates the results of the PCA, suggesting that CCP$_1$ score reflects abnormally "adverse" agro-climatic conditions. The relative magnitude of the coefficient suggests that affect heuristics are important aspects of experiential learning about CC among small-scale farmers in the KZN midlands. Similar findings were reported from the US by Weber (2006), showing that learning CC with personal experiences often leads to biased and inaccurate perceptions.

The positive and significant coefficient estimate of age in the CCP$_1$ model suggests that, given that a farmer perceives CC, his perceived changes in the form of CCP$_1$ tends to increase with his/her age. However, for ages greater than 72,[17] the effect of age is outweighed by the negative coefficient of the quadratic variable on age, i.e. age has an inverted U-shaped

[17] The maximum point is given by the ratio $\beta_{AGE}/(2x\beta_{AGE\_SQUARED})$. In Table 3.5, $\beta_{AGE\_SQUARED}$=0.0005.

effect on CCP_1 score. In other words, very old and very young farmers tend to score relatively lower CCP_1 (i.e. they view recent adverse agro-climatic conditions as being normal). This finding gives a nuanced understanding of the value of experience in formulating subjective probability distributions of weather patterns and events and, therefore, for assessing whether or not particular weather patterns or events are abnormal. Younger farmers could perceive harsh agro-climatic conditions (i.e. hotter, dryer weather experienced during the recent summers and the colder, dryer conditions experienced during the recent winters) as normal perhaps due to the lack of experience with farming. However, younger farmers could also (rightfully) disagree with those who view hotter, dryer summers and colder, dryer winters as abnormal agro-climatic conditions because of increased inclusion of environmental education in the curriculum (Whitmarsh, 2011). A similar disagreement with those who view CC as something to worry about could transpire among very old farmers as a result of inherent conservative values underlying skeptical views about anthropogenic CC (Poortinga et al., 2011; Whitmarsh, 2011).

Table 3.6 shows that the strength of perception in the form of CCP_1 increases with longer distances from the river/dam, c*eteris paribus*. Farmers living in the vicinity of rivers or dams perceive adverse agro-climatic conditions such as hotter, dryer summers and colder, dryer winters as normal, whereas those living far from rivers perceive such conditions as abnormal. The finding reflects a psychological effect related to the greater challenges of coping with adverse weather for people who farm further from the river. When subjectively judging the normal range of weather outcomes of local climate, farmers in such areas would tend to assign more weight to recent extreme weather events that they were unable to cope with.

With regard to the factors affecting the strength of perception in the form of CCP_2, Table 3.6 shows that the perception about abnormally warmer and wetter winters as well as dryer summers is formed with farmer's knowledge, educational attainment, extent of extension training and visits received, and trust levels. Based on the relative magnitude of coefficient estimates, knowledge explains most of the variability in the CCP_2 scores. Farmers that are more able to recognize and remember the years in which extreme weather events occur are more likely to perceive recent warmer, wetter winters and dryer summers (i.e. beneficial agro-climatic conditions) to be outside the normal range. Thus, farmers with lower cognitive ability are less likely to perceive such conditions to be abnormal. The cognitive ability, therefore, is the most important predictor of perceptions about CC that mirror meteorological observations. Similar findings were reported from Sweden by Sundblad et al. (2007).

Based on the relative magnitude of the coefficients, education is the second most important contributor to the heterogeneity in CCP_2. The significance of the coefficient of education in the model suggests that, given position perception, the strength of perceptions in the form of CCP_2 increases with education. Farmers who achieved high levels of education are more likely to perceive the recent warmer, wetter winters and dryer summers to be outside the normal range. To the extent that such climatic trends can mirror correctly the actual meteorological observations, this result can be explained by access to descriptive information about CC. As Gaurav and Singh (2012) explain, farmers' investment in education and training increase their ability to receive and process information, which, in turn, improves their cognitive ability. This ability allows them to understand climate information disseminated by experts and the process through which it is generated (Marx et al., 2007; Weber, 2010). This finding is consistent with the results of an earlier study in the Limpopo River Basin showing that educated farmers are not likely to misperceive the changes in rainfall patterns (Gbetibouo, 2009).

The positive and significant effect of trust in the model suggests that detection of climatic changes in the form of CCP_2 increases with the level of trust. In other words, the level of agreement with the abnormality of recent warmer, wetter winters and dryer summers increases with farmers' trust in their community. As Weber (2010) and Hultman et al. (2010) argue, trust facilitates the acquaintance of someone knowledgeable with environmental changes, and this is an important aspect of description-based perceptual formation. Indeed, given the multiplicity of sources and complexity of information, farmers tend to build their perceptions based on the views of their trusted intermediaries. This is particularly true for South Africa, given the evidence that social capital among smallholder farmers is more cognitive than structural (Jordaan and Grové, 2013). This finding is congruent to the results of Hagen (2013) in a recent study of climate risk perceptions in nine developed countries, including the United States, Canada, Mexico, Brazil, Spain, Germany, UK, Netherlands, and Japan.

Overall, the Truncated regression models in Table 3.6 generate one important insight. They show that learning climatic changes internally, *i.e.* with personal experiences, does not necessarily warrant perceptions that tally with meteorological observations. On the other hand, farmers with better cognitive ability and those who learn about climatic changes from external sources of information (e.g. extension information) tend to have perceptions that are in line with actual meteorological observations. These findings, therefore, provide empirical evidence to the application of the behavioural approach.

3.5. Summary

Empirical evidence suggests that farmers in various parts of southern Africa hardly recognize the changes in their local climates. However, the empirical literature often attributes the misperception to the complex nature of biophysical processes, overlooking the importance of socio-psychological, institutional and cultural processes underlying perceptual formation. Following the literature of the behavioural decision research, this chapter investigates the factors shaping perceptual formation among small-scale farmers in two agro-climatic zones of the KZN midlands region.

Based on household survey data, a principal components analysis of the perceptions reveals two contrasting perceptual shapes: one in portraying abnormally adverse agro-climatic conditions (cooling winter and drying and warming summer - CCP_1), and another one depicting abnormally beneficial agro-climatic conditions (warming and wetting winter, and a drying summer -CCP_2). Probit estimation results suggest that perception about CC is triggered by experiential (affect) and cultural factors (value judgement), as well as socio-demographic (age, gender, education) and agro-ecological factors. The results of first Truncated regression model reveal that the CCP_1 score increases with holistic affect as well as socio-demographic factors that are inherently experiential (age and distance to the river). The results of the Truncated regression model further show that the CCP_2 score tends to increase with cognitive ability (knowledge) and socio-demographic factors that are closely related to the access to descriptive information (including education, extension and trust). To the extent that CCP_2 corroborates the meteorological observation, these findings confirm the hypothesis that learning about climatic changes with personal experience leads to biased and inaccurate perceptions, whereas external learning processes with experts' descriptions warrant a good detection of local climatic changes.

CHAPTER 4 . PATTERNS AND MICROECONOMIC DETERMINANTS OF FARM-LEVEL CROP DIVERSIFICATION IN THE MIDLANDS REGION OF KWAZULU-NATAL, SOUTH AFRICA: APPLICATION OF CLUSTER ANALYIS AND LOGIT TRANSFORMATION APPROACHES[18]

4.1. Introduction

Adaptation to future CC begins with reducing vulnerability and exposure to present climate variability (e.g. through crop diversification) (Stocker et al., 2013). Crop diversification is an important aspect of resilience in the predominantly dryland small-scale farming systems in the face of climatic variability (Gilbert and Holbrook, 2011). The strategy also promotes agro-biodiversity and safeguards the options for livelihoods diversification under future CC (Baumgärtner and Quaas, 2010). Based on the third objective of this thesis, the purpose of this chapter is to understand the crop diversification behaviour among small-scale farmers in the KZN midlands. The chapter explores the prevailing systems of farmland use at household-level and examines the determinants of the intensity of multiple-cropping. Section 4.2 presents an overview of the microeconomics of crop diversification. Section 4.3 presents a short-run land allocation model of a multi-crop household economy, and elicits the empirical strategies used to explore the patterns of land use and investigate the determinants of crop diversification in the KZN midlands. Section 4.4 reports and discusses the empirical findings. Section 4.5 summarizes the chapter. The conclusions and policy implications drawn from the empirical findings are contained in the last chapter of the thesis.

4.2. Microeconomics of multiple-cropping: an overview

4.2.1. Approaches to and economic benefits of crop diversification

There are two complementary approaches to crop diversification, *viz*. horizontal and vertical crops diversification (Behera et al., 2007). The primary and most common approach is horizontal diversification, which consists of addition (in space) and substitution (in time) of crop enterprises, by utilizing techniques such as multiple-cropping and crop rotation (Jayaraman, 1979). The vertical diversification, on the other hand, entails downstream value addition of agricultural commodities in the form of processing, packaging, branding etc.

[18] This chapter gave rise to the following manuscript: Hitayezu, P., E. Wale, G.F. Ortmann. Farm-level crop diversification in the Midlands region of KwaZulu-Natal, South Africa: Patterns, microeconomic drivers and policy implications. *Agroecology and Sustainable Food Systems* (Reviewed, revised, and resubmitted).

(Behera et al., 2007). The complementarity of horizontal and vertical diversifications resides in the fact that multiple-cropping and crop rotation often entail adoption of cash crops that allow downstream value addition (Behera et al., 2007).

The economic advantages of crop diversification pertain to increased efficiency in input use and enhanced productivity (Di Falco et al., 2010; Rahman, 2009). There are two major pathways to the realization of economies of diversification through efficient use of inputs (Rahman, 2009): (i) through effective allocation of household labour to different enterprises (in multiple-cropping) and different seasons (in crop rotation), and (ii) through reduction in the use of purchased inputs at any fixed levels of productivity. The latter is achieved by combining crop enterprises that complement each other in the provision of agro-ecosystem services such as soil fertility restoration and integrated pest management. The productivity effect of crop diversification results from three principal mechanisms (Di Falco et al., 2010). Crop diversification (i) increases the likelihood that key crops that have larger impacts on the performance of the agro-ecosystem would be present in the farming system (the effect is also known as sampling or selection probability effect), (ii) reduces the implications of price and production risk (e.g. through the possibility of marketing different products at different times), and (iii) increases the probability that some crops in the system can react in a functionally differentiated way to external disturbances and changing environmental conditions (also known as niche differentiation effect) (Di Falco et al., 2010; Zuppinger-Dingley et al., 2014).

Therefore, the economic benefits of crop diversification depend on the extent of both spatial and temporal heterogeneity in the system (Di Falco et al., 2010). In the Ciskei and Transkei homelands in the Eastern Cape Province, for example, Gilbert and Holbrook (2011) showed that diversifying using crops with similar functional types (e.g. grain crops) leads to little increase in resilience to rainfall variability, whilst diversifying using crops with different plant functional types (e.g. grain crops and legumes) had some potential for greater diversification advantages. Rahman (2009) also reported that most crop combinations in three agro-ecological zones of Bangladesh exhibit greater diversification advantages, except crops that simultaneously require similar labour and land inputs (e.g. modern rice and wheat).

4.2.2. Microeconomic determinants of crop diversification

Farm-level horizontal crop diversification (through multiple-cropping) is an outcome of interplay between missing markets and the law of diminishing marginal returns (Ahn et al., 1981; Cavatassi et al., 2012; van Dusen and Taylor, 2005). As illustrated by the general equilibrium framework in Figure 4.1, if markets for both crops *j* and *h* exist and risk is absent, the household would be guided by the exogenously determined market price line (M*) when choosing its land allocation pattern among the most technically efficient production mix along the production possibility frontier (PPF). In this case, the optimality with perfect market implies a corner solution at (Q_h*, 0). When risk is present and the product market for crop *j* is missing or the insurance market is absent, however, the household's consumption and insurance demand for that particular crop is satisfied entirely from own production, based on a subjectively valued shadow price (P_j'). This valuation is directly determined by the household's marginal utility and indirectly by household production and consumption constraints. It defines a new price line (M'), culminating into a new optimal crop diversification solution (Q_j',Q_h') (van Dusen and Taylor, 2005).

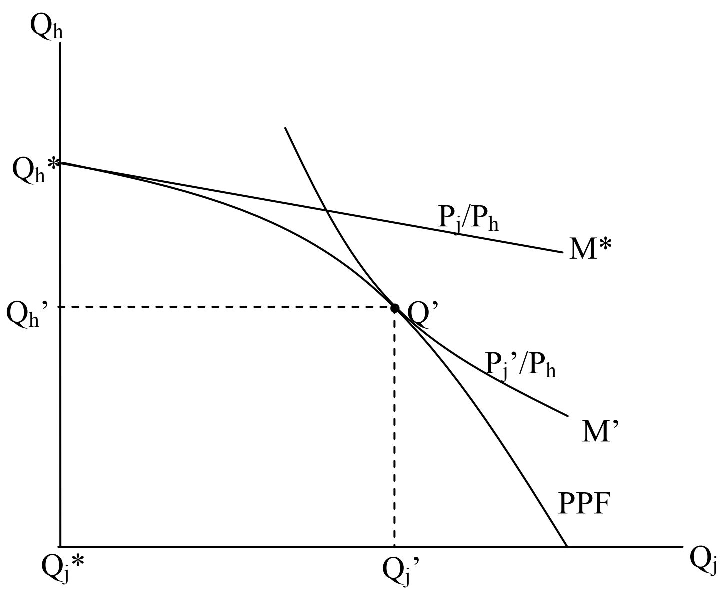

Figure 4.1. Production possibility frontier for two farm commodities (*j* and *h*) showing optimality under perfect (*) and missing (') markets
Source: Adapted from van Dusen and Taylor (2005)

If land is fixed and household can allocate labour among two or more crops, it will supply family labour to the farm until the marginal value product (MVP) of labour is equated between two activities at an endogenous family shadow wage rate (van Dusen and Taylor, 2005). This encourages larger households to diversify. With regard to farm size, households with larger land areas are likely to diversify their cropping enterprises due to decreasing returns to scale. As cropping enterprise expands, the returns to land accumulation (holding other forms of capital constant) decline until there is no more incentives for expansion of the current activity (McNamara and Weiss, 2005). However, economies of scale can be a motivation to specialize at larger farm sizes (McNamara and Weiss, 2005; Mishra et al., 2004).

Nevertheless, the higher propensity to diversify cropping enterprises at larger farm sizes is underscored by the lower probability of entering into the off-farm labour markets (McNamara and Weiss, 2005). Time allocation between on-farm and off-farm activities influences on-farm enterprise diversification through opportunity costs. As Mishra et al. (2004) explain, a full-time farm operator would leverage the comparative advantages (i.e. reduce the opportunity cost) of farming by taking measures to maximize farm revenues and minimize farm income risk such as enterprise diversification. However, the effect is not always unidirectional, as higher income risk associated with specialization can push farmers to diversify in the off-farm sector (McNamara and Weiss, 2005).

The risk addressed by crop diversification is often related to agro-climatic conditions. Crop diversification is an outcome of greater rainfall variability (Bezabih and Sarr, 2012), although the benefits of crop diversification are more pronounced in water-stressed environments (Di Falco et al., 2010). Crop diversification is, therefore, a natural insurance mechanism for farmers facing greater risk of crop failure due to the vagaries of weather (Baumgärtner and Quaas, 2010).

Crop diversification, however, is not only an outcome of production risk but also a reflection of decision makers' risk aversion (Baumgärtner and Quaas, 2010; Bezabih and Sarr, 2012). Farmers often exhibit decreasing absolute risk aversion and increasing partial relative risk aversion preference, i.e. they are more reluctant to engage in risky prospects at lower levels of wealth and greater payoff for a specific lottery (Bezabih and Sarr, 2012). Therefore, risk aversion coupled with wealth level mediate the effect of production risk on crop diversification.

Since wealth is often affected by the farmer's personal characteristics such as age and education, the preference for crop diversification could be defined by socio-demographic factors (McNamara and Weiss, 2005). For example, older and educated (i.e. wealthier) farmers would be less risk averse and more inclined towards one single crop enterprise than their younger and less educated counterparts do. Age also reduces the propensity to diversify due to the preference for reduction of work load over time (McNamara and Weiss, 2005). The age effect, however, could be the opposite, in the sense that younger farmers with less experience with farming (uncertainties) would be expected to be less risk averse (Pope and Prescott, 1980).

Other factors of crop diversification are social and environmental by nature. With regard to gender, Villamor et al. (2014) explain that women in developing countries are driven by household food security, and tend to diversify with food crops, whereas men tend to concentrate on cash cropping. Villamor et al. (2014) and Doss and Morris (2000) also explain that women are constrained by lack of land-tenure rights and sufficient time to participate in training and experimentation required for cash cropping. Other social factors pertain to social capital. Cavatassi et al. (2012) demonstrate how bonding social capital would inhibit crop diversification as it is a risk management in itself, whilst bridging social capital would facilitate access to necessary inputs for crop diversification.

Regarding the factors related to natural resources, studies suggest that access to irrigation water is an important factor of crop diversification. Accordingly, using irrigation water would mitigate the effect of rainfall variability, thereby substituting the prospect of using multiple-cropping (Bezabih and Sarr, 2012). From a dynamic viewpoint, however, access to irrigation water decreases the effect of rainfall seasonality on crop choice, allowing farmers to cultivate winter and summer crops in a single season (Biswas and Mandal, 1993; Bradshaw et al., 2004; Jayaraman, 1979).

4.3. Research methodology

4.3.1. Analytical framework

Two analytical frameworks are appropriate for the crop diversification behaviour, *viz*. the expected utility maximization and the minimization of coefficient of variation. An empirical comparison of these frameworks by Herath (1980) indicates that the expected utility framework is more representative for the actual behaviour. Under the utility maximization framework of a short-run (single agricultural cycle) land allocation model of a multi-crop household economy proposed by van Dusen and Taylor (2005) and later on improved by Cavatassi et al. (2012), the general problem faced by a farm household when deciding upon which of the j crops (j=1…J) to simultaneously produce, and how much (Q_{Fj}), can be represented by the following optimization model:

$$\max_{X_M, X_N, X_C, L, W} U\left(X_F, X_{NF}; Z^H\right) \tag{4.1}$$

subject to

$$P_{NF} X_{NF} = P_F (Q_F - X_F) + Y_{NF} \tag{4.2}$$

$$Q_F = f(L, W_F; Z^E, Z^S) \tag{4.3}$$

$$Y_{NF} = y(W_{NF}; Z^{NF}) \tag{4.4}$$

$$W = W_N + W_{NF} \tag{4.5}$$

The problem consists of maximizing the utility (U) that a farm household derives from the consumption of quantities of home-grown marketable crops (X_F), and quantities of purchased non-agricultural commodities (X_{NF}). This utility depends on household preferences and other exogenous factors that are determined by a vector of household's socio-economic and cultural conditions denoted by Z^H. The utility is maximized subject to a budget constraint (4.2), such that the maximum expenditure on non-agricultural goods and services $P_{NF}X_{NF}$ is equal to the income from farm produce sold plus the non-farm income Y_{NF}. The production constraint (4.3) is such that the quantity of each crop produced is a function of the available land (L), on-farm labour (W_F) (assuming dysfunctional land and labour markets, i.e. land cannot be rented in or out, and labour cannot be hired), depending on agro-ecological conditions (Z^E) and social conditions that provide, for example, non-marketable inputs (e.g. seeds, farmer-to-farmer extension, etc.) (Z^S). The time constraint (4.5) limits the on-farm labour (W_F), non-farm work (W_{NF}) and leisure (L) time to the household's total time endowment (W).

Following Cavatassi et al. (2012), the optimum land and work time allocations satisfying the first order condition can be derived as follows:

$$L_j = L_j^*(L, W, P_F, P_{NF}, Z^H, Z^S, Z^{NF}, Z^E) \text{ for } j=1\ldots J \quad (4.6)$$

$$W_j = W_j^*(L, W, P_F, P_{NF}, Z^H, Z^S, Z^{NF}, Z^E) \text{ for } j=1\ldots J \quad (4.7)$$

Crop diversification will be a direct result of the choice of which crops to produce under the given constraints. The diversity outcome will therefore take the form of derived demand for a number of crops D^C.

$$D^C = D\left[Q_{Fj}^C\left(L, W, P_F, P_{NF}, Z^H, Z^S, Z^{NF}, Z^E\right)\right] \quad (4.8)$$

The model in equation 4.8, therefore, predicts the seasonal crop diversification from initial land and labour endowment, prices of agricultural and non-farm products, household characteristics, regional social capital, regional non-farm market conditions, and agro-ecological conditions. Generally, this relationship is congruent to the model proposed by Cavatassi et al. (2012). However, this model differs from the Cavatassi et al. (2012) model in one key way. In their model, the effect of social capital (Z^S) is only mediated by access to seeds when markets are missing. Their model also explicitly captures time allocated to social networking in the time allocation constraint. However, social capital can also alleviate the levels of transaction costs faced by smallholders in agricultural markets, allowing them to participate in input and output markets (e.g. through access to market information, collective action, etc.) (Key et al., 2000), with effect on crop production decision. Moreover, in the context of South Africa, research shows that social capital is more cognitive than structural, i.e. it accumulates more from relationships of trust, norms, and reciprocity than from formal structures and organizations (Jordaan and Grové, 2013). In the analytical model outlined above, therefore, social capital is not explicitly included in the time constraint. It simply enters in the model as an exogenous shifter in the production function.

4.3.2. Empirical estimation

4.3.2.1. Exploring land use systems: A cluster analysis

The literature identifies two empirical approaches to land use typification, namely *a priori* or pre-specified method (whereby the characteristics for segmentation are based on researcher's knowledge and judgement) and quantitative typification techniques (Iraizoz et al., 2007). The relevance of each farm or land use typification and segmentation techniques is mainly determined by the degrees of heterogeneity between types and homogeneity within particular types (Köbrich et al., 2003). The *a priori* technique, however, fails to make full use of data and lacks statistical foundation to warrant fairly homogenous groups (Iraizoz et al., 2007).

The quantitative typification method consists of four exploratory data analysis techniques, namely PCA, factor analysis, canonical correlation analysis and cluster analysis, commonly used to summarize land use data sets in order to describe the main characteristics of land use systems (Lesschen et al., 2005). PCA, factor and canonical correlation analyses are appropriate when the objectives are, respectively, data reduction, structure detection and relationship detection (Lesschen et al., 2005). When the objective is classification of land use systems, K-means and hierarchical cluster analyses are appropriate (Lesschen et al., 2005). Land use or crop combinations can be clustered by area, production and productivity (Rathod et al., 2012). The formation of clusters, however, can be hampered by multicollinearity amongst original variables. This potential problem can be addressed by a two-stage cluster analysis technique consisting of using factor analysis or PCA methods to generate case-specific scores that are used as basis for clustering (Iraizoz et al., 2007; Köbrich et al., 2003; Thapa and Rasul, 2005).

In this study, the PCA method with varimax rotation was used to generate orthogonal factors that address the problem of multicollinearity among various crop area variables used in the cluster analysis. PC scores with an eigenvalue greater than one were chosen. Given the size of the sample at hand, Koutsoyiannis (1992) recommends to retain coefficients with PC loadings greater than $|0.3|$. Following Iraizoz et al. (2007), cluster analysis was performed in two steps. The first step consisted of identifying the outliers and the number of clusters, and profiling the cluster centres using a hierarchical technique, namely the Ward's method based on squared Euclidean distances. The second stage consisted of clustering the observations based on a non-hierarchical method using cluster centres generated by the hierarchical technique as initial seed points. As suggested by Iraizoz et al. (2007), the decision on the number of clusters followed the two criteria proposed by Fiegenbaum and Thomas (1993), namely (a) that the percentage of intra-cluster variance explained with the obtained clustering being greater than a minimum percentage (say 50%) and (b) that the percentage increase in the explanation of the intra-cluster variance, generated with the inclusion of an additional cluster, does not exceed 5 per cent of number of clusters.

4.3.2.2. Econometric model specification and estimation

To be able to estimate crop diversity as a function of socio-economic and agro-ecological factors, applied economists use two different strategies. Some studies estimate the share of land allocated to individual crops (Bittinger, 2010; Turner, 2014) or simply the number of crops grown (Cavatassi et al., 2012; Ibrahim et al., 2009). Other studies construct indices of interspecific (among different crops) or infraspecific (among crop varieties) diversity based on area shares. The common indices are the Margalef index of richness, the Shannon index of evenness or heterogeneity, the Simpson index of proportional abundance, Berger–Parker index of inverse dominance, the entropy index, and the Herfindhal index of concentration (Benin et al., 2004; Bezabih and Sarr, 2012; Cavatassi et al., 2012; Mesfin et al., 2011; Turner, 2014). In order to provide a simple measure of the relative composition of seasonal crops within the area of active farmland, this study uses the Herfindhal index of concentration (Herfindahl, 1950). Following Bradshaw et al. (2004) and Rahman (2009), the crop diversification index (CDI) was computed as follows:

$$CDI = \sum_{n=1}^{c} L_c^2 \tag{4.9}$$

where L is the proportion of land allocated j^{th} crop relative to the total cropland area. This index ranges from zero (representing complete diversification) to one (reflecting complete specialization). However, the CDI cannot equal zero; it can only approach zero as diversification approaches infinity. Here, the assumption is that the more diversified a cropping portfolio is, the more it would involve crops with different plant functional types, a combination that increases the resilience of the farming system to climate variability (Gilbert and Holbrook, 2011). In addition, it was assumed that more diversified farmland use could involve crops that do not compete over resources, which increases the economic efficiency of diversification (Rahman, 2009).

To calibrate the influence of factors in Equation 4.8 on the *CDI*, estimation methods for fractional response models are appropriate (Lesaffre et al., 2007). Given that the possibility of complete specialization cases (i.e. *CDI*=1) in the sample cannot be ruled out [19], the appropriate estimation technique consists of using the Logit link function (i.e. the Logit transformation of the regressand) along with the binomial distribution, an approach proposed

[19]The survey data used in this study indicates that nearly 6% of interviewed farmers had planted only one crop.

by Papke and Wooldridge (1996). The conditional expectation for the *CDI* is given by Oberhofer and Pfaffermayr (2012):

$$E(CDI_i \mid Z_i) = G(Z_i\beta_i) = \exp(Z_i\beta_i)/[1 + \exp(Z_i\beta_i)], \qquad (4.10)$$

where Z is a vector of explanatory variables, $G(\cdot)$ is a logistic distribution function, and β a vector of Quasi-maximum likelihood estimators (QMLE) of the true population covariates' parameters based on the generalized linear model (GLM) approach.

4.3.3. Data

The empirical analyses in this chapter are based on the study area and the survey data described in subsections 3.3.1 and 3.3.3. The information gathered during the key informant interviews with extension workers and farmer groups' leaders generally corroborated the patterns of subsistence crop diversification documented in Chapter 2 (sections 2.2 and 2.6.3), although the key informants also stressed on the importance of small-scale sugarcane and timber production. The key informants were asked to rank the wards in the municipality according to the degree of diversity of small-scale cropping portfolios. Additional insights on salient motivations and constraints for crop diversification were obtained during the focus group discussions with knowledgeable farmers and transect walks, and corroborated the most of the constraints hypothesized in the economic literature (see Section 4.2.2). During key informant interviews, three of the six wards in which the interviews were conducted (see Figure 3.3) (4, 5 and 6) had scored the highest rank in terms of crop diversification, one (9) had scored a median rank, and two (8 and 11) and had scored the lowest rank (8).

4.3.4. Empirical model

Given that the analytical framework outlined in Subsection 4.3.1 is based on a single agricultural cycle model and panel data were not available, the CDI index captured only the plots allocated to seasonal crops. The decision to cultivate perennial crops and other long-term ALUCs (e.g. fallow, livestock) is determined outside a single agricultural cycle model[20]. To estimate the crop diversification model in Equation 4.8, landholding (L) is represented by the total operated hectares (LAND). This variable is used to test the hypotheses of decreasing returns to scale (McNamara and Weiss, 2005) or economies of scale (Mishra et al., 2004). To

[20] Agricultural land use change is dealt with in Chapter 5.

give a more precise measure of household labour availability (*W*), the study used the number of adult-equivalent household members (ADULTS)[21], with the hypothetical expectation that increased labour availability would encourage crop diversification (van Dusen and Taylor, 2005).

With regard to household characteristics (Z^H), five factors are used. A dummy of female-headedness (GENDER) is used to represent the gender-related lack of access to complementary inputs constraining the addition of more enterprises on the farm (Bezabih and Sarr, 2012; Di Falco et al., 2010; Doss and Morris, 2000). Age of the household head (AGE) is a proxy of farmer's experience. It could also be associated with wealth and, therefore, relative risk aversion (McNamara and Weiss, 2005; Pope and Prescott, 1980). A quadratic form of age (AGE_SQUARED) is meant to capture the life cycle (non-linear) effect in the model.

Agricultural extension trainings and visits (EXTENSION) and years of formal education (EDUCATION) are used to test the effect of informational support and the efficiency effect in the model, respectively (Jamison and Moock, 1984; Lockheed et al., 1980). EXTENSION is used to test whether access to agricultural extension would increase the prospect of diversification by conveying technical information on new crops, or encourage specialization (by giving emphasis on certain crops based on the availability of markets, technologies and inputs). EDUCATION is used to test the effect of managerial efficiency effect. However, education determines efficiency in both farm (encouraging diversification) and off-farm activities (promoting specialization) (Rosenzweig, 1980).

Social capital (Z^S) was also included in the model to test the effect of bridging and bonding social ties on crop diversification (Cavatassi et al., 2012). However, instead of following Cavatassi et al. (2012) and count the time allocated to social group activities, this study uses a measure of farmers' generalized level of trust in their community (TRUST) capturing the effect of civic society, quality of institutions, culture and values, and ethnic heterogeneity on social capital (Nannestad, 2008; Rothstein and Stolle, 2008). This is because social capital amongst South African farmers tends to be more cognitive than structural (Jordaan and Grové, 2013).

[21] The formula to compute the ADULTS variable is described in subsection 3.3.4.

Market conditions (Z^M) are represented by access to roads (ROAD), measured as minutes walked to the nearest tarred road. This variable allows to test the hypothesis that farm households facing missing markets meet their demand for consumption from own production (van Dusen and Taylor, 2005).

To test the relationship between on-farm diversification and off-farm occupation (W_{NF}) (McNamara and Weiss, 2005; Mishra et al., 2004), a dummy variable capturing participation in off-farm income generating activities in 2012 (OFF-FARM) is included in the model. However, there are reasons to think that off-farm occupation could be influenced by household un-observables (and hence correlated with the error term), in addition to being correlated with other explanatory variables such as education, road and region-specific heterogeneity (Hitayezu et al., 2014), leading to a potential endogeneity bias. To account for the endogeneity bias, a control function (CF) approach to the logit transformation estimation can be used (Papke and Wooldridge, 2008). For discrete endogenous variables, however, the procedure requires estimating a Probit model explaining the decision to participate in off-farm activities or not, obtaining the predicted probabilities of participating in off-farm activities, and then using the predicted probabilities in place of the off-farm dummy variable to estimate the effect of off-farm occupation in the second stage (Amemiya, 1985).

Agro-ecological conditions (Z^E) are represented by two variables. Access to water (WATER) was measured as minutes walked to the nearest river/dam to portray the effect of irrigation water availability on enterprise diversification. It was used to test the hypothesis that access to irrigation water reduces the demand for multiple-cropping (Bezabih and Sarr, 2012). To control for the fixed effects of agro-ecological conditions, a dummy variable of Windy Hill Mistbelt agro-ecology (AGRO-ECOLOGY) in the Mthuli community was also included as a regressor. Crop diversification was expected to be more pronounced in the Windy Hill Mistbelt agro-ecological zone where, despite relatively higher average rainfall, the coefficient of variation (CV) is nearly double the CV of rainfall in Wartburg/Fawnleas zone (Gcumisa area).

Given that crop diversification is inherently a risk management strategy, it is important to explicitly account for the diminishing marginal utility of wealth of the expected utility maximization theory (Rabin, 2000). Farmers dislike vast uncertainty in their lifetime because the marginal value of a Rand when they are poor is higher than when they are rich (Dionne and Harrington, 2014). To account for the differences in household welfare, some studies used welfare indicators (e.g. asset index, poverty index, etc.) as independent variables in the crop diversification model (Cavatassi et al., 2012; Turner, 2014; van Dusen and Taylor, 2005). However, wealth could be endogenous in this case, as it is possible that farmers who specialize in one crop will be able to focus more on that crop. The familiarity in crop production then leads to higher yield and wealth. Risk preference does not come into play in this case. Wealth could also be directly related with farmer's personal characteristics such as education and age. To overcome the endogeneity problem, the empirical model in this study is first estimated for the entire sample, and then re-estimated for households in two different income classes: below and above the income median.

4.4. Results and discussion

4.4.1. Summary of socio-economic characteristics of the sampled households

The summary descriptive statistics are presented in Table 4.1. Consistent with the crop diversification patterns documented in other areas of KZN (Kisaka-Lwayo and Obi, 2012), the Herfindhal Index of crop diversification among surveyed households ranged from 0.296 to 1 (with a mean of 0.55), suggesting the presence of highly diversified land uses as well as completely specialized farms in the sample. Higher diversity of cropping enterprises among the sampled households was practiced on an average landholding size of 1.5 hectares. Although the empirical literature does not point out to the viable land size for crop diversification, an earlier study by Mkhabela (2005) found that, in general, the technical efficiency score of small-scale farms in this region starts diminishing at 1 hectare, and crop diversification was among the strategies that can be used to uphold it.

On average, an interviewed household head had five adult-equivalent members who could be potentially employed on the farm to diversify the cropping portfolio. However, an average head of the household was 58 years old and had hardly completed primary school, a major aspect of socio-economic vulnerability in the region (see Chapter 2). On average, an interviewed farmer had contacted extension agents three times in 2012, showing that access to skills and knowledge required to adopt new crops and/or better crop varieties was good (although, as said earlier, agricultural extension in South Africa does not explicitly support crop diversification).

Table 4.1. Summary statistics of the dependent and independent variables

Variables	Variable and value description	Mean	Standard deviation	Minimum	Maximum
Dependent variable					
CDI	Herfindhal Index of seasonal crop diversification	0.557	0.220	0.296	1
Independent variables					
LAND	Total operated area in hectares (continuous)	1.596	1.515	0.1	10.5
ADULTS	Number of adult-equivalent members of the household (count)	5.105	2.591	1	13.481
GENDER	1=Female-headed household; 0=otherwise	0.532	0.400	0	1
AGE	Age of the household head in years (continuous)	58.940	12.834	33	88
EDUCATION	Years spent by the household head in formal education (continuous)	6.552	3.951	0	16
EXTENSION	Number of contact with extension workers in 2012 (count)	3.539	4.557	0	15
TRUST	1= don't trust anyone, 2= the majority are not trustworthy, 3=the majority are trustworthy, 4=everyone is trustworthy	2.743	0.767	1	4
ROAD	Minutes taken to arrive at the nearest tarmac road (continuous variable)	12.559	17.774	0	120
WATER	Walking distance (in minutes) to the nearest river/dam (continuous)	43.723	32.725	0	240
AGRO-ECOLOGY	1= Windy Hill Mistbelt agro-climatic area; 0= Wartburg/Fawnleas zone (dummy)	0.322	0.468	0	1
OFF-FARM	1= head of household participates in off-farm income generating activities; 0=otherwise	0.397	0.201	0	1
Household income	Total income received in 2012 (ZAR)	14 687	6 337	4 750	204 600

Note: number of observations n=152.
Data source: Household survey data (2013)

On average, an interviewed farmer believed that the majority of people in the community were not trustworthy. This indicates poor social capital in the rural areas of South Africa and low reliance on neighbours to secure access to important resources needed to diversify crops (e.g. seeds, labour, etc.). However, it takes a sampled farmer only 12 walking minutes to arrive at the nearest tarred road, showing that accessing such resources for crop diversification through markets was not a difficult option. The majority of interviewed household heads (61%) did not engage in off-farm income-generating activities, i.e. incurred lower opportunity cost of time spent on their farms. For the majority of the interviewed households who lived in the dryer Wartburg/Fawnleas agro-climatic zone (Gcumisa area) and had to walk, on average, 43 minutes to the nearest river or dam where he can obtain irrigation water, crop diversification was a more relevant and compelling option.

Consistent with the empirical evidence documented in Chapter 2, the mean income among surveyed households was ZAR 14,687. Compared to the figures reported in other studies in this region, however, the income range among sampled households was wider. The household incomes ranged from ZAR4,750 to ZAR204,600. The median income was at ZAR 29,000, suggesting a positively skewed income distribution.

4.4.2. Cluster analysis and logit transformation model diagnostics

To test the suitability of the data for cluster analysis, the KMO measure of sampling adequacy and Bartlett's test of sphericity are used (Azevedo, 2003; Dziuban and Shirkey, 1974). As presented in Table A2 in the appendix section, the values of the KMO test suggest that the input variables were adequate, whilst the test of the null hypothesis that the correlation matrix is an identity matrix suggests that there is relationship between the input variables. Therefore, cluster analysis is a suitable method for the analysis of land use system.

The critical assumptions underlying the goodness-of-fit of the GLM are (i) complete determination of the variance of the error term by the mean, and (ii) statistical independence of the observations (Breslow, 1996). Following Bellocco and Algeri (2013), analysis of the deviance test statistics across nested models showed that the current specification significantly reduces the deviance residuals. Moreover, the plot of standardized residuals against fitted values in Figure B3 in the appendixes did not reveal any noticeable trend in the mean of the residuals, implying no missing dependence or wrong link function.

4.4.3. Farmland use systems in the KZN midlands

The retained PCs of land allocation are presented in Table 4.2. Households with higher scores for PC_1 have planted maize, beans, and taro, and have uncultivated portions of land (under livestock or fallow), portraying a mixed farming system. PC_1 factor, therefore, pertains to subsistence farming of which the main objective is food security. Cultivation of high-energy crops such as maize and taro are combined with leguminous crop (beans) as source of proteins and livestock as an insurance against unforeseen income shocks.

Table 4.2. Dominant factors of land use systems among surveyed small-scale farmers, uMshwati Local Municipality, 2013

Land use	PC_1	PC_2	PC_3
Seasonal/annual crops			
Maize	**0.619**	0.229	0.114
Sorghum	0.231	0.190	-0.134
Vegetables (cabbages, spinach, etc.)	0.291	**0.412**	0.003
Beans	**0.565**	0.124	0.119
Cowpeas	0.192	0.103	-0.168
Potatoes	0.234	**0. 307**	0.012
Taro (*madumbe*)	**0.400**	0.145	0.078
Perennial crops			
Sugarcane	0.252	**0.471**	-0.017
Fruit trees (avocado)	0.193	0.094	**0.302**
Plantation forest	0.207	0.111	**0.364**
Others			
Uncultivated (under fallow or livestock)	**0.374**	0.028	**0.301**
Eigenvalue	2.890	1.603	1.412
% of variance	38.9%	13.3%	7.4%
Cumulative	38.9%	52.2%	59.6%

Note: number of observation n=152.
Data source: Household survey data (2013)

In the second principal component (PC_2), high-loading farmland use includes vegetables, potatoes, and sugarcane farming. Households with higher PC_2 score would seem to practice a semi-commercial agriculture, whereby short-season marketable crops (vegetables and potatoes) are used to meet protein and short-term cash demands, whilst the perennial sugarcane serves as a medium to long-term source of income. Households with higher PC_2 score, therefore, depicts emerging farmers.

The third principal component (PC_3) is dominated by tropical and subtropical fruit trees and timber plantations, and uncultivated (fallow or livestock) land. PC_3 could represent a group of agro-foresters who often combine short-rotation trees (e.g. eucalyptus) with livestock. This component plausibly portrays a fallow land system, or a silvopastoral system of planting/collecting some pasture species under trees in order to secure fodder for animals during the dry/winter months (Everson et al., 2011). However, under small-scale timber out-grower schemes, farmers are discouraged to plant food crops under the trees or collect non-timber forest products (Cairns, 2000). Therefore, as suggested by the lower percentage of variance, this system is rare because available resources are highly demanded for the survival of human population.

These PCs formed the basis for cluster analysis. Using the criteria for choosing the number of clusters discussed in the 4.3.2, a five-cluster solution was obtained, as shown in Table 4.3. The table profiles the clusters, showing average size of land allocated to each of the crops/land uses included in the PCA. Cluster 1 accounts for the 28 per cent of farms in the sample. The farmland use system reflected under this cluster is characterised by larger tracts of land allocated to maize and beans productions, coexisting with smaller pieces of land areas allocated to taro and vegetables production. This is a diversified land use system. Maize and beans cultivation is mainly done using crop diversification techniques such as intercropping or multiple-cropping.

Cluster 2 consists of 11 per cent of farmers in the sample. The land use system of Cluster 2 is characterised by major portions of farmland under fallow or livestock production, and smaller land areas allocated to maize production. This land use system reflects the classic agro-ecosystem for soil fertility management. As Mkhabela (2005) noted, in this region, maize production is not only practiced for household food security. Maize grains used as chicken feed and stover harvests stored for cattle winter-feeds. Waste from livestock production, in turn, is used as manure for soil fertilization.

Table 4.3. Distribution of land areas across clusters of land use, uMshwati Local Municipality, 2013

Farmland use	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Total/ Mean	F^2
Number of households	43	16	66	27	152	-
Percentage of total sample	28	11	43	18	100	-
Maize	1.2	0.4	-	-	0.4	3.94***
Vegetables	0.2	0.3	0.2	-	0.2	1.54
Beans	0.8	-	-	-	0.2	4.9***
Potatoes	-	-	-	0.3	0.1	3.5***
Taro (*madumbe*)	0.3	-	-	-	0.1	1.98**
Sugarcane	-	-	1.3	-	0.5	7.8***
Plantation forest	-	-	-	0.7	0.2	14.4***
Uncultivated (under fallow or livestock)	-	0.9	-	-	0.3	6.5***

Note: number of observation n=152; *** = significance at 1% level, ** = significance at 5% level, * = significance at 10%.
Data source: Household survey data (2013)

Cluster 3 constitutes the majority (43 per cent) of farmers in the sample. Farmer in this cluster practice sugarcane mono-cropping. They supply their cane harvest to the Noodsberg sugarcane mill. They also allocate smaller land parcels to vegetable production, again, as home gardens. Cluster 4 accounts for 18 per cent of the total sample. Farmers in this cluster are mainly engaged in plantation forests, but allocate part of their lands to potatoes production. Table 4.3 further reports the results for the analysis of variance for ascertaining the significance of differences between the clusters. Highly significant differences in land use across the clusters emanated from land areas under maize, beans, sugarcane, plantation forest, fruit trees and fallow/livestock. Clusters were relatively indifferent in the areas allocated to vegetables (perhaps as a results of home gardening). Overall, the farmland use systems in Table 4.3 portray a diversified agricultural economy.

4.4.4. Determinants of multiple-cropping intensity in the KZN midlands

The results of the QMLEs of the Logit transformation model are reported in Table 4.4[22]. Most of the coefficients have expected signs. A visual observation of the log-likelihoods in the table suggests that the Logit transformation model fits the combined and low-income household models better than the high-income household model.

[22] The results of the reduced form equations are presented in Table A3 in the Appendix setion. They show that off-farm occupation is driven by landholding, education, trust, and distance to the nearest road.

Table 4.4. Transformed logit estimation results, uMshwati local municipality, 2013

Covariates	All households			Below-median-income households			Above-median-income households		
	QMLE	Standard error	Elasticity	QMLE	Standard error	Elasticity	QMLE	Standard error	Elasticity
LAND	-0.086***	(0.030)	0.052	-0.144***	(0.049)	0.071	-0.100***	(0.023)	0.040
ADULTS	-0.265**	(0.109)	0.086	-0.199***	(0.066)	0.132	-0.186*	(0.103)	0.027
GENDER	0.076	(0.065)	0.004	0.037	(0.028)	0.004	0.053	(0.044)	0.006
AGE	-0.012	(0.010)	0.009	-0.039	(0.026)	0.011	-0.013	(0.010)	0.006
AGE_SQUARED	0.001	(0.001)	0.000	0.002	(0.002)	0.000	0.003	(0.002)	0.000
EDUCATION	0.093	(0.061)	0.034	0.025	(0.017)	0.023	0.031*	(0.016)	0.024
EXTENSION	0.032	(0.022)	0.003	0.031	(0.025)	0.007	0.019	(0.015)	0.004
TRUST	0.014	(0.011)	0.020	0.004	(0.003)	0.010	0.025	(0.019)	0.021
ROAD	-0.003	(0.002)	0.006	-0.001	(0.001)	0.000	-0.007	(0.005)	0.017
OFF-FARM (prob)	0.391*	(0.219)	0.001	0.099**	(0.048)	0.007	0.122	(0.101)	0.004
WATER	-0.010	(0.007)	0.018	-0.048*	(0.025)	0.033	-0.006	(0.005)	0.009
AGRO-ECOLOGY	0.197	(0.125)	0.009	0.334	(0.212)	0.009	0.180	(0.137)	0.008
Constant	-0.537	(0.426)		-0.623	(0.451)		-0.479*	(0.290)	
Number of observations	*152*			*76*			*76*		
Log-likelihood	*-58.45*			*-33.71*			*-79.91*		

Note: *** = significance at 1% level, ** = significance at 5% level, * = significance at 10%.
Data source: Household survey data (2013)

Table 4.4 reveals some interesting insights. The coefficients of basic factors of production are significant in all the three models. The negative coefficient (i.e. positive effect) of landholding suggests that multiple-cropping intensity increases with farm size, confirming the hypothesis of diminishing returns to scale (McNamara and Weiss, 2005; Pope and Prescott, 1980). It is also in line with the findings of a qualitative investigation in KZN by Wilk et al. (2013) suggesting that, during bad-weather years, small-scale farmers generally stick to maize production, whilst commercial farmers react by expanding and diversifying their cropping portfolios. In the (South) African context where markets are often missing, a plausible explanation pertains to biophysical characteristics of the land. Sumberg (2003) argues that in African small-scale farming systems, land fragmentation is often related to substantial variations in bio-geophysical characteristics (slopes, soil fertility, etc.). According to Ahn et al.'s (1981) model, this heterogeneity provides an opportunity for maximizing profitability or utility of an extra plot of land acquired through crop diversification. van Dusen and Taylor (2005) elicit this by arguing that the marginal productivity of the principal crop declines as extensive margins with different slopes and soils are brought into production, necessitating the cultivation of additional crops.

Similar findings were reported from Mozambique (Turner, 2014) and Ethiopia (Benin et al., 2004; Bezabih and Sarr, 2012; Di Falco et al., 2010). In Ethiopia, Bezabih and Sarr (2012) showed that the positive effect of farm size on crop diversity prevails even under various risk aversion scenarios. Di Falco et al. (2010) further showed that the positive effect of farm size persists even under different model specification (poisson, poisson and fixed effects, 3-stage least squares and fixed effects). Benin et al. (2004) showed that the positive effect of land size also prevails across various measures of crop diversity. The present study, therefore, confirms the literature, and shows that the positive effect of land size also prevails under different welfare positions. However, it is noteworthy that the magnitudes of coefficient and elasticity suggest that the effect of farm size on crop diversification is greater among low-income households than among wealthier households.

The negative coefficients (i.e positive effect) of labour endowment are also significant in all the models, showing that, other factors remaining unchanged, access to labour induces multiple-cropping. This confirms the hypothesis that households supply family labour to the farm until the marginal value product (MVP) of labour is equated between two activities at an endogenous family shadow wage rate (van Dusen and Taylor, 2005). However, the significance and elasticity of labour are lower among households in the upper income category, probably due to their ability to substitute household labour for hired labour or to adopt labour-saving technologies. Based on the magnitude of the marginal effect, labour explains most of the heterogeneity in multiple-cropping among low-income households. Cultivation of land is a labour intensive activity, involving time- and energy-demanding activities such as land preparation, planting, weeding, harvesting, and storing farm produce. With the dysfunctional labour markets characterizing South Africa's rural economy, multiplying these activities with hired labour is a difficult option. Therefore, as Rosenzweig and Wolpin (1985) demonstrate, larger household labour force facilitates occupational diversification. This finding also supports the evidence that labour availability is a major concern among small-scale farmers in the region (Kisaka-Lwayo and Obi, 2012).

The significance of labour in crop diversification is not a new finding in the empirical literature. Similar results were reported in Mozambique (Turner, 2014) and Ethiopia (Di Falco et al., 2010). What is empirically new with the present findings is that the significance of labour effect is attenuated as the household moves to the high-income classes, plausibly due to differences in farm asset positions.

The estimated coefficient of education in the income-rich household model is positive and significant. This suggests that the prospect of specialization increases as a richer farmer gets more and more educated. This result is in line with the findings of Mkhabela (2005), showing that education decreases the technical inefficiency of diversified farms in the midlands region of KZN. Mkhabela (2005), however, simplistically argued that the negative effect of education could be due to the fact that educated people tend to be part-time farmers, allocating part of their work time to off-farm employment. As mentioned in Section 4.2.2, the negative effect of education can also be mediated by risk aversion (McNamara and Weiss, 2005). A similar argument was asserted by Huang et al. (2014) who found that, in China, the extent of diversification of cropping portfolios reduced with education.

However, none of the above-mentioned arguments explains why the effect of education is more significant among wealthier households than among low-income households. A plausible explanation pertaining to asset position can be borrowed from Sadoulet et al. (1998). They demonstrate that without assets, both skilled and unskilled labour should work off-farm, but as farm assets (i.e. wealth) become abundant, unskilled labour is absorbed on the family farm due faster shadow wage rise. The increase in time allocated to farming activities among unskilled labour facilitates the introduction of additional cropping enterprises.

The estimated coefficients of the instrument for OFF-FARM are positive and significant in the general and poor household models. This suggests that, generally, the extent of crop diversification decreases with the prospect of off-farm occupation. This finding confirms the hypothesis that access to off-farm work increases the opportunity cost of diversification efforts (Mishra et al., 2004). Previous empirical studies (e.g. Mishra et al., 2004; Weiss and Briglauer, 2000; Windle and Rolfe, 2005) found that part-time farmers have potentially more ability to self-insure, i.e. to spread the income risk outside the farming business, which reduces their preference for crop diversification. For the case of KZN, however, the results show that the heterogeneity of off-farm occupation prospects corresponds more to the variance of crop diversification among poorer households than among richer households. This finding reveals that, whilst reducing income risk could be a major motivation for crop diversification, wealthier farmers might have other (non-economic) motivations (e.g ecological sustainability).

The estimated coefficient of access to water is significant in the low-income household model. As expected, the result that the intensity of crop diversification increases with the distance to water sources suggests that on-farm diversification of crop portfolio is more pronounced in areas where access to irrigation water is difficult. This can be explained by the geographic difference in production risk across the two areas. With access to irrigation water, households living in the proximity to water sources have better control over water and depend less on rainfall. This reduces their demand for multiple crops as a production risk mitigation strategy.

Interestingly, the results suggest that crop diversification in regions with hard access to water is more appealing to households in the low-income category than to their richer counterparts. Holding relative risk aversion constant, this finding portrays the self-insurance against rainfall unreliability through crop diversification as an inferior / Giffen good i.e. more appealing to poor farmers (Dionne and Harrington, 2014). A similar behaviour was observed in Limpopo by Bharwani et al. (2005). The authors noted that richer farmers often adopt few but high-input risk mitigation strategies, whereas their poor counterparts tend to adopt a wider variety of low-input strategies. However, it is noteworthy that some previous studies have reported opposite results. In Mozambique, for example, Turner (2014) reported a significantly positive effect of wealth on crop diversification. The author, however, acknowledged that the unexpected result was due to the dominance of basic household items (lamps, tables) in the asset index.

Overall, the empirical results of this investigation suggest that crop diversification in the midlands region of KwaZulu-Natal is constrained by technological factors (land and labour). They further indicate that mitigating income and production risks are key motivations for crop diversification among income-poor households.

4.5. Summary

Crop diversification is a practical and cost effective strategy to enhance resilience among South Africa small-scale farmers facing missing markets and intensive climatic extremes. However, the empirical studies on crop diversification in rural South Africa remain too few to provide necessary information indispensable for the design of agricultural policy strategies. The objective of this chapter, therefore, is to investigate the household-level farmland use systems and the determinants of seasonal crop diversification among small-scale farmers in the KZN midlands. The results of two-stage cluster analysis reveal a diversified farmland use matrix dominated by largely food-crop and mixed farming coexisting with emerging small-scale sugarcane mono-croppers and foresters.

Based on the short-run (i.e. a single agricultural cycle) land allocation model of a multi-crop household economy, the estimation results of a Logit transformation model of multiple-cropping portray some interesting insights. They show that the intensity of seasonal crop diversification increases with landholding, and the significant effect of landholding is not deterred as the household moves to the upper income class. The results also suggest that household labour significantly influences positively crop diversification, but the significance of the labour effect is attenuated as the household moves to a higher income class. The results further show that, among richer households the multiple-cropping intensity significantly decreases with education. Among poorer households, the estimation results show that the crop diversification intensity decreases with off-farm occupation and increases with distance to water sources. Overall, the empirical results suggest that, in general, crop diversification in the midlands region of KwaZulu-Natal is constrained by technological factors (land and labour), and mitigating income and production risks are key motivations for crop diversification among income-poor households.

CHAPTER 5 . ASSESSING AGRICULTURAL LAND USE CHANGE IN THE MIDLANDS REGION OF KWAZULU-NATAL, SOUTH AFRICA: APPLICATION OF MIXED-MULTINOMIAL LOGIT MODEL[23]

5.1. Introduction

Understanding farm-level incentives and constraints that govern ALUC decision-making is an important input for the design of sustainable land use policy in South Africa. Based on the fourth objective of this study, the purpose of this chapter is to investigate the attitudes towards LUFs among small-scale farmers, and socio-economic and agro-ecological factors constraining land use conversion in the KZN midlands. Section 5.2 overviews the literature. Section 5.3 elicits the empirical methodology used. Section 5.4 reports and discusses the empirical findings. Section 5.5 summarizes the chapter. The conclusions and policy implications drawn from the empirical results are contained in the last chapter of the thesis.

5.2. Farmland afforestation in the context of climate change: underlying and proximate drivers

5.2.1. Forests and synergies between adaptation and mitigation

Land use plays a central role in climate systems. The AR5 shows that around 40% of emitted GHGs remain in the atmosphere, whereas the rest is removed by oceans (causing ocean acidification) and land use (plants and soils) (Stocker et al., 2013). Thus, due to their capacity to remove and store carbon from the atmosphere, forests are landmarks of CC mitigation (Ravindranath, 2007). The IPCC mainly recognizes three types of mitigation activities in the forestry sector: (i) afforestation (converting long-time non-forested land to forest), (ii) reforestation (converting recently non-forested land to forest), and (iii) avoided deforestation (avoiding the conversion of forests to non-forested land) (Locatelli et al., 2010). The role of the AFOLU sector in the CC mitigation, however, extends beyond net carbon sequestration. The AFOLU sector contributes total non-CO_2 emissions to levels of 17 – 31%, and has a significant potential for CC mitigation through (i) reducing non-CO_2 emissions, as well as provision of low-carbon bio-energy (Smith et al., 2013).

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[23] This chapter gave rise to the following manuscript: Hitayezu, P., E. Wale, G.F. Ortmann. A mixed-multinomial Logit model of agricultural land use change: Evidence from the midlands region of KwaZulu-Natal, South Africa. *Environment, Development and Sustainability (In press).*

The AFOLU sector, however, is also affected by CC. In a direct way, CC affects AFOLU through yield changes and spatial shifts in agricultural potential (Bradley et al., 2012; Dale, 1997; Olesen and Bindi, 2002; Viglizzo et al., 1997), particularly in regions where the performance of primary agriculture is mainly constrained by climate (Audsley et al., 2006), or where crop production responds well to inter-annual rainfall variability (Viglizzo et al., 1997). Climate change also causes land use change indirectly under the form of climate-driven population migration (Oppenheimer, 2013). ALUC can be also driven by a shift in market demand for agriculture crops induced by climate-driven productivity changes in neighbouring regions (Dale, 1997), policies exploring options for increasing biomass and soil carbon, as well as reducing and offsetting fossil fuels consumption (Paustian et al., 1998). In the forestry sector, adaptation to CC takes two main forms (Locatelli et al., 2010): (i) responding to climate-driven expansion of forest optimum growth conditions and safeguarding threatened ecosystem resources, and (ii) providing the necessary EGS for ecosystem-based adaptation (EBA), i.e. managing the impacts of CC using a wide range of ecosystem services (e.g. non-timber forest products) as safety nets.

5.2.2. Economics of farmland afforestation

Even though CC and/or land degradation are underlying drivers of ALUC, it is changes in socio-economic conditions that eventually trigger land use change (Berry et al., 2006; Dale, 1997; Ostwald and Chen, 2006). For example, an increase in the profitability of a certain crop can cause the expansion of its cultivation to a land cover that is otherwise climatically unsuitable (Audsley et al., 2006). The socio-economic factors are commonly referred to as proximate drivers of ALUC (Lambin et al., 2003).

The economics of agricultural land afforestation are based on two fundamental relationships (Alix-Garcia and Wolff, 2014; Sobool, 2004). First, when markets are perfectly competitive (i.e. producers are price takers and the demand function is perfectly elastic) and land can be allocated to either traditional agricultural practices or afforestation at a particular point in time, the optimum farmland afforestation is reached at levels where private marginal cost for conversion to afforestation (including the cost of planting and maintaining the trees, as well as the opportunity cost of the land) (MCp) equals private marginal benefit received from the conversion of agricultural land to afforestation (MBp). Second, the net social benefits to the society are maximized when marginal social benefits (MBs) (i.e. a sum of MBp plus marginal external benefits - MB_E) and marginal social costs (MCs) (i.e. a sum of MCp plus marginal external cost – MC_E) are equal [i.e. ($MBp + MB_E$) = ($MCp + MC_E$)]. External benefits include local and regional public goods such as hydrological services and erosion prevention, as well as global public goods such as carbon sequestration and biodiversity (Alix-Garcia and Wolff, 2014).

From a purely private producer perspective, the decision under the first relationship is graphically presented in Figure 5.1. Point *c* represents the lowest cost of converting marginal land with meagre opportunity cost, and *b* shows the optimum forestland allocation point beyond which no additional land could be converted to afforestation without making economic loss. The upward sloping MCp curve indicates the increasing opportunity cost of converting more farmland to afforestation.

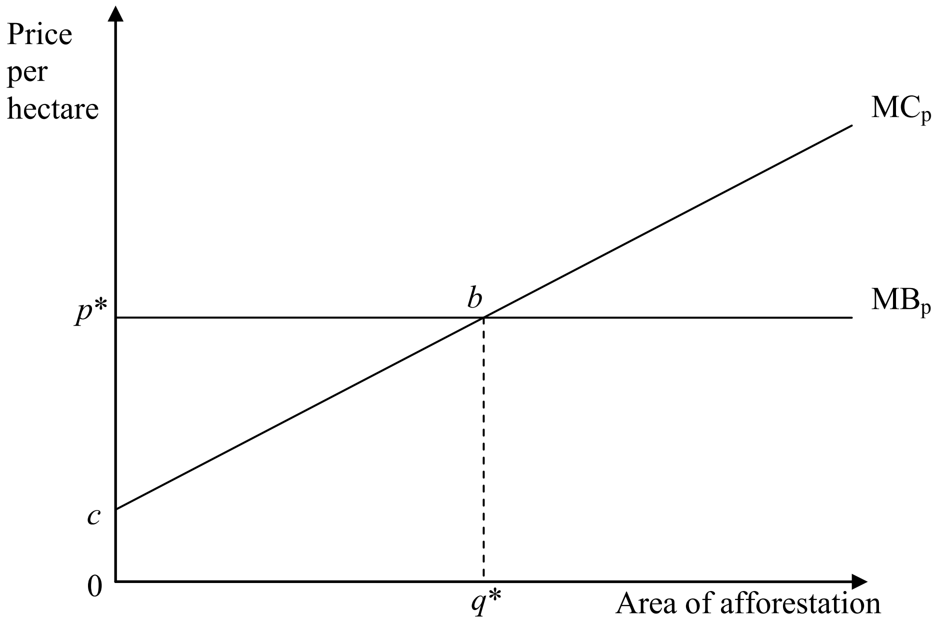

Figure 5.1. Private marginal cost and marginal benefits of farmland afforestation
Source: Adapted from Sobool (2004)

From a societal perspective, however, the presence of external marginal benefits and costs in the second relationship can cause a market failure, resulting in a sub-optimal allocation of farmland to afforestation. Figure 5.2[24] shows that, although the allocation q^p may remain optimal to the producer, the presence MB_E not reflected in MBp could increase the optimum

[24] For simplicity, Figure 5.2 assumes no external marginal cost of converting farmland to afforestation.

land allocation to q^s. The downward sloping MBs curve indicates that extra land converted to forest plantations provides lesser benefits to the society[25].

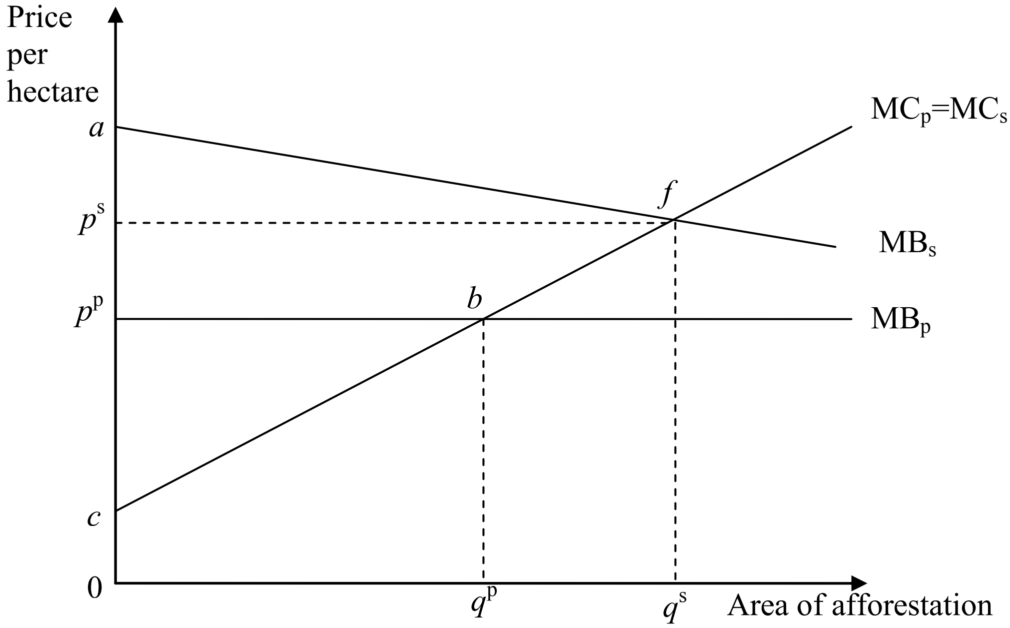

Figure 5.2. Private and social marginal costs and benefits of farmland afforestation
Source: Adapted from Sobool (2004)

Economic incentive for afforestation in the form of payment for ecosystem services (PES) are often justified based on the difference p^s-p^p (Alix-Garcia and Wolff, 2014; Sobool, 2004). PES have both private and public buyers (Alix-Garcia and Wolff, 2014). Private buyers often provide incentives for local or regional public goods such as hydrological services and erosion prevention. Examples of private buyers include PES schemes initiatives by water bottling companies for private farmers in catchment areas feeding the spring sources. Private as well as public buyers are also involved in the market for global public goods such as carbon sequestration and biodiversity.

Private buyers are involved in the Clean Development Mechanism (CDM) proposed by the UNFCCC and implemented by the Kyoto protocol (Alix-Garcia and Wolff, 2014). The CDM only recognizes afforestation and reforestation as eligible projects for the Certified Emission Reduction (CER) units traded in emissions trading schemes (Locatelli et al., 2010). The REDD is a large-scale PES program initiated in 2005 by the UNFCCC during the 11th

[25] For simplicity, the downward sloping MBs curve disregards marginal increase in some benefits such as carbon sequestration (Sobool, 2004).

Conference of the Parties (COP) in Montreal, with the aim of transferring funds from developed to developing countries. Initially, the scheme focused on deforestation and forest degradation projects, but during 2007 COP negotiations in Bali, the scheme was extended to reforestation and afforestation projects, and renamed REDD+ (Rahlao et al., 2012).

5.2.3. Farm-level determinants of farmland afforestation

A vast empirical literature on farmland conversion from agriculture to forestry has drawn from established theories to show how farm-level factors influence ALUC decisions. A review by Edwards-Jones (2006) concluded that, at smaller spatial scale, the pure profit maximization behaviour loses its predictive power (partly due to missing markets for EGS), and non-financial motives and attitudes intrinsic to individual decision maker determine the preferences for farmland conversion. Edwards-Jones (2006) thus defined four categories of determinants of the demand for ALUC: (i) the characteristics of the land use, (ii) farmer characteristics, (iii) farm structure, and (iv) wider social milieu. Based on Edwards-Jones's (2006) typology, a descriptive model of ALUC is graphically represented in Figure 5.3.

Regarding the characteristics of the land use, behavioural studies draw from the Lancaster's (1966) characteristic-based demand theory and the assumption that land use is differentiated by its multifunctionality (Pérez-Soba et al., 2008) to show how farmers' intentions to convert farmland use is closely related to their subjective evaluation of economic, social, and environmental outcomes of alternative land uses. In various parts of the world, evidence suggests that farmers prioritize economic functions such as income generation and cost saving (Irshad et al., 2011; Martínez-García et al., 2013), whilst required financial investment and the difficulty of management are important disincentives (Martínez-García et al., 2013; Zubair and Garforth, 2006). Social functions of land use such as food security, health, and work provision are also found among the priority functions (Purushothaman et al., 2013). Farmers also highly value the provision of ecosystem services such as biomass production, prevention of soil erosion, improvement of water quality, and biodiversity conservation (Irshad et al., 2011; Poppenborg and Koellner, 2013; Zubair and Garforth, 2006).

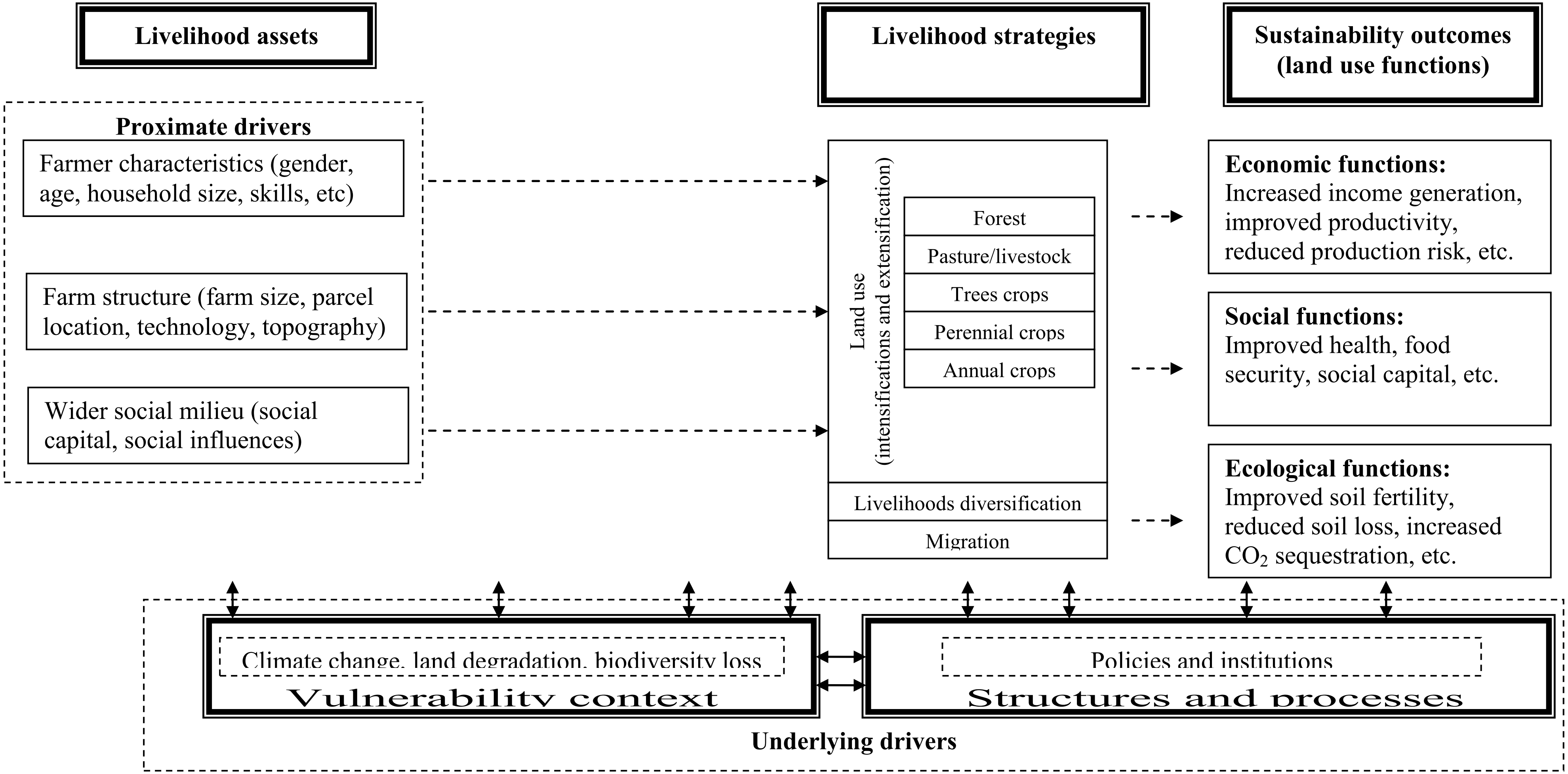

Figure 5.3. A descriptive model of agricultural land use change
Source: Based on Edwards-Jones's (2006) typology

The actual farmland use conversion decision, however, is controlled by factors endogenous to the household. Gender is among the key factors of ALUC. Research shows that gender effect in land use decision-making is mediated by differences in values, attitudes towards risk, entitlements and learning processes. Women in developing countries are more risk averse, and tend to control food crops production, mainly driven by household food security and constrained by lack land-tenure rights and sufficient time to participate in training and experimentation required for market-orientated agriculture (Villamor et al., 2014). Age is another factor of ALUC. The effect of age on ALUC is mediated by attitudes towards investment and risk. High dependency makes early investment problematic, disposing younger farmers to high discount rates and risk aversion, thereby increasing their preference for short-rotation cultivation (Perz et al., 2006; Walker et al., 2002).

Regarding household characteristics, economists argue that the effect of household size is defined by market conditions. When households are not well integrated into the market economy, the Chayanovian model posits that households tend to intensify (or deforest) as they increase in size due to increased labour availability and demand for household consumption (Angelsen, 1999; Klemick, 2011; Perz et al., 2006). When the market exclusion assumption is relaxed, empirical studies show that market access factors associated with skills, wealth, and risk aversion dictate land use change through flexibility of inputs substitution (Parks, 1995; Walker et al., 2002). Off-farm incomes generated from labour markets loosen up household liquidity constraints and increase their flexibility of inputs substitution (e.g. by using hired labour) (Parks, 1995; Walker et al., 2002). The effect of liquidity constraint on ALUC, however, is not unambiguous (Kaimowitz and Angelsen, 1998). In some cases (e.g. Klemick, 2011), liquidity constraint has discouraged intensification, whilst in others (e.g. Uchida et al., 2009) it has accentuated reliance/pressure on farmland resources.

With regard to farm characteristics, studies show that the effect of farm size is mediated by the levels of technological risk and fixed cost associated with each alternative land use (Just and Zilberman, 1983; Schatzki, 2003). With increasing (decreasing) relative risk aversion, the share of land devoted to the modern technology would be decreasing (increasing) in farm size if the modern technology is more risky and/or require high fixed costs outlays (Just and Zilberman, 1983). Masuku et al. (2001), for example, reported a positive relationship between the high-fixed-cost sugarcane plantation and farm size in Swaziland. Farm location also influences ALUC through land rents. The von Thünen model suggests that only high-value crops can be cultivated near the roads and cities, given that land value increases with proximity and ease of access to physical markets (due to decreasing cost of production or transport) (Erenstein et al., 2006; Walker, 2014). Access to technology also governs ALUC. Empirical studies (e.g. Kajisa and Payongayong; 2013) have vindicated the Boserupian model that explains the process from extensification towards intensification based on the prevailing material conditions (i.e. access to technology).

Spatial characteristics also influence ALUC. Spatially-explicit models associate the steepness of terrain to the conversion cost, hence the attractiveness of an area for conversion to crop cultivation (López and Sierra, 2010). Moreover, given that potential land productivity is associated with topography, land use often exhibits patterns characterised by farmlands on hill foots and forest and grasslands on hill slopes and mountain tops (Fu et al., 2000).

Regarding the social milieu, empirical studies show that social capital facilitates land use conversion through cooperation and litigation mitigation (Libby and Sharp, 2003). Empirical studies also show that farm-level ALUC decision is governed by social influences (i.e. the influence of behaviour, beliefs, and preferences of other people in the farmer's peer group). Based on the innovation diffusion models, studies show that social influence is channelled through knowledge and persuasion that reduce uncertainty about the outcome of land use conversion, and support optimal management of new technology (Deffuant et al., 2002; Foster and Rosenzweig, 2010; Wuepper et al., 2014).

5.3. Research methodology

There are two major quantitative methods in the literature on non-market valuation: the behavioural (or indirect) approaches and stated preference (or direct) methods (Haab and McConnell, 2002). In the landscape literature, behavioural studies calibrate farmer's attitudes towards LUFs based on the behavioural theories such as the theory of planned behaviour (Martínez-García et al., 2013; Poppenborg and Koellner, 2013; Zubair and Garforth, 2006). This approach, however, fails to account for "actual" controls (Lynne et al., 1995). To address this setback, studies have increasingly used discrete choice models with flexible substitution patterns such as the Nested Logit (NL) (Greiner, 2014; Windle and Rolfe, 2005). Others have adopted the Mixed-Multinomial Logit (MMNL) model (Brey et al., 2007; de Valck et al., 2014; Goibov et al., 2012). The superiority of MMNL over the NL model lies in its capacity of recognizing correlated alternatives and preference variations expressed through random parameters (Munizaga and Alvarez-Daziano, 2001).

The studies using the MMNL model often rely on DCE data. However, this approach has some limitations such as the potential endogeneity bias (Bhat and Gossen, 2004; Hess, 2012), as well as other common biases in welfare measurement such as informational and hypothetical biases (Adamowicz et al., 1994). Combining SP and revealed preference (RP) data can reduce the biases and improve the consistency of parameter estimates (Antolín et al., 2014; Whitehead et al., 2008). Although this combination has attracted the attention of researchers in various fields of environmental valuation (Whitehead et al., 2008) and technology adoption (Useche et al., 2009), it has been hardly applied in ALUC modelling. Inspired by the work of Useche et al. (2009), the present study uses a combined SP-RP technique to the analysis of ALUC.

5.3.1. Analytical framework: a behavioural household model for ALUC

The behavioural household model of ALUC outlined in this subsection draws from the utility maximization framework of the integrated adoption model of technology traits and producer heterogeneity (Useche et al., 2009). Under this non-separable household model, farmer *i* is assumed to maximize his utility U_i by comparing the utility provided by an alternative land use j over the current land use *k*. Farmer i will adopt land use j if $U_{ij} > U_{ik}$ or $\Delta U_{ik} > U_{ij} - U_{ik} > 0 \;\; \forall j \neq k$. The indirect utility of an alternative land use is assumed to be a linear function of the characteristics x of the innovation j ($U_{ij} = \beta_i x_{ij}$) (Lancaster, 1966), which, in the case of land use, is the perceived outcome. This implies the following behavioural model indicating that land use change is driven by the difference in the characteristics (or outcomes) across land uses:

$$\Delta U_{ik} = \beta_i \Delta x_{jk} \tag{5.1}$$

Due to potential heterogeneity in the farmers' preferences, the vector of preference parameters (β_i) varies over individuals according to both observable (z_{1i}) and unobservable (υ_i) farm and farmer characteristics, i.e.

$$\beta_i = b + \delta z_{1i} + \phi \upsilon_i . \tag{5.2}$$

Also, farmers with some observable characteristics z_2 (such as larger household or farm sizes) may have intrinsic preferences for a specific land use j (γ_j) that affect the utility of each of the alternative land uses and the adoption choices, as shown in equation 5.3 below.

$$U_{ij} = \beta_i x_{ij} + \gamma_j z_{2i} \text{ or } \Delta U_{ik} = \beta_i \Delta x_{jk} + \gamma^*_{jk} z_{2i} \quad (5.3)$$

where $\gamma^*_{jk} = \gamma_j - \gamma_k$

Following Useche et al., (2009), substituting equation 5.2 into equation 5.3 yields:

$$\Delta U_{ik} = (b + \delta z_{1i} + \phi \upsilon_i) \Delta x_{jk} + \gamma^*_{jk} z_{2i} \quad (5.4)$$

Equation 5.4 depicts a behavioural model of ALUC as a function of land use attributes (x_{ij}) (which vary across individuals *i* and across land use *j*) and given farmers' own preferences for land use based on perceived outcome (β_i) and intrinsic preferences for a specific alternative (γ_j) and own farm and farmer characteristics (z_i).

5.3.2. Econometric model specification and estimation

The indirect utility of farmer *i* for land use *j* is expressed as $V_{ij} = U_{ij} + e_{ij}$, where e_{ij} is an unobserved stochastic error made by the researcher. The choice probabilities are specified as $P_{ij} = \Pr(V_{ij} > V_{ik})$ or $\Pr(V_{ij} - V_{ik} > 0)$ or $\Pr(e_{ij} - e_{ik} < U_{ij} - U_{ik})$ $\forall j \neq k$ which depends only on the difference in utility. The difference $\Delta e_{jk} = e_{ij} - e_{ik}$ follows a logistic distribution if the error component is extreme-valued distributed (Hoffman and Duncan, 1988).

The MMNL model provides a practical econometric approach for analysing discrete choices arising from utility maximization (McFadden and Train, 2000). The MMNL combines the conditional Logit (CL) model with the multinomial logit (MNL) model (Hoffman and Duncan, 1988). Unlike the commonly used MNL model in the land use change literature, the MMNL model relaxes the assumption of independence of irrelevant alternatives (IIA) by explicitly considering the unobserved heterogeneity in preferences (i.e. the random deviation of an individual's tastes from the average tastes). This allows land uses to be related through certain characteristics. The MMNL choice probabilities are:

$$P_{ij} = \int \frac{\exp(\beta' x_{ij} + \gamma_j z_i)}{\sum_k \exp(\beta' x_{ik} + \gamma_j z_i)} f(\beta) d\beta \qquad (5.5)$$

For $i=1,\ldots,I$, and $j,k=1,\ldots,J$

There are two statistical procedures of simulating MMNL: the maximum simulated likelihood estimation and the method of simulated moments (McFadden and Train, 2000). This study used a Stata® module written by Hole (2007) to fit the MMNL model using a maximum simulated likelihood.

5.3.3. Data

The empirical analyses in this chapter are based on the study area and the survey data described in subsections 3.3.1 and 3.3.3. To identify the salient LUFs that critically influence small-scale farmers' decision-making in the KZN midlands, this study used a consultative process (Greiner and Ballweg, 2013). Based on the literature review summarized in the subsequent section, two long lists were compiled, one containing agricultural land uses and another one of LUFs. The lists were refined through the PRA mentioned in section 3.3.3. This information allowed the author to categorize agricultural land use into three categories: (*a*) annual/seasonal cropping (Ac), if the farmer continues to cultivate traditional annual crops such as maize, beans, potatoes, and taro; (*b*) sugarcane farming (Sc), if the farmer has planted sugarcane; and (*c*) on-farm forest plantation (Tc), if the farmer has cultivated trees. Among the sampled farmers, no one belonged to the two groups of land use changers (i.e. sugarcane -Sc- and tree farmers -Tc-), although some land use changers had some plots allocated to annual crops (Ac). In the majority of cases, however, the size of land allocated to annual crops (mainly in the form of home gardening) among sugarcane and tree growers was negligible (~0.1ha)[26].

The salient beliefs about LUFs unveiled during the PRA phase comprised the five indicators of land use sustainability in Table 5.1. It is noteworthy that CC mitigation did not appear to be a salient criterion for ALUC evaluation.

[26] Under such circumstances of non-negligible "boundary observations", a discrete choice model is advisable compared to a fractional response regression (Cook et al., 2008; Xiong, 2014).

Table 5.1. Farm-level indicators of sustainability impacts of ALUC in the KZN midlands, 2013

Sustainability dimension	Land use function	Indicator
Economic sustainability	Economic production	Farm income generation (Y)
	Land-based production	Crop productivity/suitability (Q)
Social sustainability	Food security	Food availability (F)
	Provision of work	Family labour employment (L)
Ecological sustainability	Provision of abiotic resources	Soil loss mitigation (S)

Source: Author's PRA (2013)

As mentioned previously, this chapter uses a method that combines RP and SP data. The non-market valuation literature proposes two alternative approaches to the combination of RP and SP data in choice analysis (Antolín et al., 2014; Whitehead et al., 2008). The first approach consists of stacking two datasets (one with DCE data and another with RP data) (Adamowicz et al., 1994). However, this method violates the assumption of independent and identically distributed (IID) error terms (Whitehead et al., 2008). A simpler approach assuming IID error terms consists of combining the SP technique with RP methods using data from the same respondents (Cameron, 1992). The latter method was employed in the survey. Following Useche et al. (2009), the survey instrument contained information on actual behaviour and questions that directly ask the respondent what attributes/outcomes they find important, using Likert-scale rating.

Based on the PRA information, 15 different questions about perceived outcomes of the three land uses were constructed for a structured survey questionnaire. Following Vagias (2006), Likert-type scale response anchors were used for each question as follows: (1) extremely unlikely, (2) unlikely, (3) neutral/not sure (4) likely, (5) extremely likely. The "neutral" or "not sure" option was meant to reduce the cognitive burden to the interviewee, increase participation (i.e. reduce the problem of attrition), and reduce the problem of misreporting behaviours based on social desirability/sensitivity. For outcome beliefs, however, farmers were asked to provide their responses based on personal experience and available information from 2011, whilst the questionnaire recorded actual land use choices in the 2012-2013 agricultural season. This technique further allowed to reduce the scope of endogeneity with self-reported performances (Useche et al., 2009). As noted in Section 3.3.3, the questionnaire also captured livelihood characteristics.

5.3.4. Empirical model

The expected utilities (EVs) from the LUFs are estimated as follows:

$$EV_i(Ac) = \alpha_{Ac} + \beta_{i1}EY_{Ac} + \beta_{i2}EQ_{Ac} + \beta_{i3}EF_{Ac} + \beta_{i4}EL_{Ac} + \beta_{i5}ES_{Ac} + \sum_{k=1}^{7}\gamma_{Ac}^{k}z_{ki} \qquad (5.6)$$

$$EV_i(Sc) = \alpha_{Sc} + \beta_{i1}EY_{Sc} + \beta_{i2}EQ_{Sc} + \beta_{i3}EF_{Sc} + \beta_{i4}EL_{Sc} + \beta_{i5}ES_{Sc} + \sum_{k=1}^{7}\gamma_{Sc}^{k}z_{ki} \qquad (5.7)$$

$$EV_i(Tc) = \alpha_{Tc} + \beta_{i1}EY_{Tc} + \beta_{i2}EQ_{Tc} + \beta_{i3}EF_{Tc} + \beta_{i4}EL_{Tc} + \beta_{i5}ES_{Tc} + \sum_{k=1}^{7}\gamma_{Tc}^{k}z_{ki} \qquad (5.8)$$

In the empirical models above, Ac, Sc and Tc are the alternative land uses. α is a constant specific to each alternative, capturing the average effect of unobserved factors for an alternative with respect to all others. *EY*, *EQ*, *EF*, *EL* and *ES* are expected values attached to the five indicators of LUFs, i.e. income generation (*Y*), crop productivity (*Q*), Food availability (*F*), labour requirement (*L*), and soil loss mitigation (*S*). Based on standard microeconomic principles, as well as the review of literature in Section 2, the demand for ALUC was expected to increase in *Y, Q, F*, and *S*, but decrease in *L*.

Following a review by Edwards-Jones (2006), the determinants of ALUC are classified into three categories: (i) farmer and household characteristics, (ii) farm structure, and (iii) the wider social milieu. Vector *z* depicts farmer ($z_1 - z_3$) and household (z_4) characteristics, farm structure ($z_5 - z_7$), and wider social milieu ($z_8 - z_9$). To control for agro-ecology's fixed effect, a dummy variable of Windy Hill Mistbelt (z_{10}) is also included in the model. The variable measurements and theoretical expectations are as follows:

- z_1 captures the gender of the head of household (GENDER).
- z_2 represents the age of the head of household (AGE)..
- z_3 captures the number of years the head of household spent in formal education (EDUCATION).
- z_4 represents household consumption using the number of adult-equivalent members of the household (ADULT)[27] to reflect the economies of scale associated with larger households.

[27] The formula for calculating the ADULT variable is given in Section 3.3.4.

- z_5 uses the operated hectares (LAND) as a proxy of farm size.
- z_6 is a measure of average walking distance (in minutes) to the nearest tarred road (ROAD). It represents access to physical markets in the model.
- z_7 measures the distance to the nearest river/dam (in walking minutes) (WATER) to portray access to irrigation water.
- z_8 measures the generalized level of trust (TRUST) (Putnam, 1995)[28] is an indicator of social capital in the model.
- z_9 measures the proportion of households that have converted land use to sugarcane and forestry plantations in the ward (PROPORTION) as an indicator social influences (Walker et al., 2011).
- z_{10} is a dummy variable of Windy Hill Mistbelt region area (AGRO-ECOLOGY) controlling for the fixed effects of differences in agro-ecological conditions.

The model specified above, however, suffers from potential endogeneity bias. First, farmers living in the same community (i.e. ward) or in the same agro-ecological area face the same attribute of alternative land use (e.g. crop productivity) and constraints (e.g. access to water). Therefore, both observed and unobserved factors (e.g. aesthetic value of the landscape) will be similar for the farmer and his neighbours. Disregarding such endogeneity caused by locational effect could lead to a considerable flaw in the estimation of the true population parameters (Louviere et al., 2005).

To address this potential bias, the Berry-Levinsohn-Pakes (BLP) approach was used (Berry et al., 1995). The BLP approach is a three-step estimation procedure that consists of: (i) estimating the location-specific constants from the choice model, (ii) using a two-step instrumental variable (IV) approach to obtain the coefficient estimates for location-specific variables, and (iii) manually inserting the estimated coefficients into the results of the first stage to portray endogeneity-corrected results.

Following Walker et al. (2011), an assumption of spatial continuity (i.e. the land use shares in an area is socially influenced by land use shares in adjacent zones due to spatial continuity of social structures) was made, and average land use share in adjacent wards was defined as an instrument of land use shares in the respective ward. Regarding agro-ecological conditions,

[28] Detailed explanation of the generalized level of trust is given in Section 3.2.5.

ward-level population density (based on the 2011 population census data published by Statistics South Africa, 2013) was used as an instrument for agro-ecological location, based on a rich literature linking agro-ecological factors (e.g. productivity, proximate environmental hazards) to residential choices and human population density (Hunter, 2005; Vačkář et al., 2012). With 6 communities and 2 agro-ecological groups, 14 constants were estimated for these groups: 6 community-sugarcane constants, 6 community-timber constants, 1 agroecology-sugarcane constant (one group is constrained for identification), and 1 agroecology-timber constant (again, one group is constrained).

5.4. Results and discussion

5.4.1. Summary of attitudinal and socio-economic characteristics of farmers

Based on the household survey data discussed in section 3.3.3, Tables 5.2 and 5.3 respectively summarize the descriptive statistics of the attitudinal and structural variables used in the econometric model. Table 5.2 shows that interviewed farmers generally believed that (i) annual crops demand more family labour and secure more food to the family, (iii) adding sugarcane to the annual cropping portfolio increases crop productivity and farm income, (iii) planting trees reduces the demand for family labour and soil loss mitigation.

Table 5.2. Descriptive statistics for attitudinal data used in the MMNL model

Outcome beliefs (LUF indicators)	Mean	Std. Dev	Min	Max
Farm income generation from Ac	1.203	0.648	1	3
Farm income generation from Sc	3.532	0.585	1	5
Farm income generation from Tc	1.815	0.493	1	4
Crop productivity from Ac	1.421	0.776	1	4
Crop productivity from Sc	3.572	0.705	1	5
Crop productivity from Tc	1.519	0.660	1	4
Food availability from Ac	4.131	0.903	2	5
Food availability from Sc	1.756	0.983	1	5
Food availability from Tc	2.003	0.908	1	4
Family labour employment from Ac	3.943	1.006	2	5
Family labour employment from Sc	1.45	0.823	1	5
Family labour employment from Tc	1.015	0.937	1	2
Soil loss mitigation from Ac	1.776	0.621	1	3
Soil loss mitigation from Sc	2.065	0.547	1	3
Soil loss mitigation from Tc	4.559	0.638	3	5

Note: number of observations (n) = 152
Source: Authors' survey data (2013)

Table 5.3 shows that the majority of interviewed households were headed by women and 58 years old farmers that had completed primary school (6 years). An average household had 5 adult-equivalent members. The landholding size in the interviewed communities was positively skewed, with an average of 1.5 ha per household, and a minimum of 0.1 ha (mainly home gardens)[29] and a maximum of 10.5 ha. On average, a farmer walks 12 minutes to arrive at the nearest tarred road and 43 minutes to arrive at the nearest river/dam. On average, a farmer believed that the majority of his neighbours were not trustworthy. On average, about 62% of farmers in a ward had converted their land use, although in some wards all or none of the farmers had converted. The majority of the interviewed farmers were located in the dryer Wartburg/Fawnleas agro-climatic zone.

5.4.2. The empirical results

The results of the MMNL estimation are presented in Table 5.4. Model 1 presents the results without accounting for endogeneity, and Model 2 gives the results of the third step of the BLP procedure. The marginal effects of farmer, household, farm and locational characteristics in Model 2 are also provided in Table 5.5.[30] In Model 1, three LUFs (crop productivity, food availability and labour requirement) have the expected signs. Crop productivity and food availability are significant, suggesting that they are the most prioritized LUFs. The magnitudes of coefficients suggest crop productivity explains more the heterogeneity in land use than labour availability. Farm income and soil loss mitigation do not have the expected signs, but their coefficients are not significant in the model.

[29] Home gardens were mainly observed among sugarcane farmers. Such non-negligible boundary observations vindicate the adoption of discrete choice models prior to fractional analyses (Cook et al., 2008; Xiong, 2014).

[30] The marginal effect were computed following Bhat and Gossen (2004). To compute the elasticity of a dummy exogenous variable (e.g. GENDER), the value of the variable was changed to one for the subsample of observations for which the variable takes a value of zero and to zero for the subsample of observations for which the variable takes a value of one. The shifts in predicted probabilities are recorded in after reversing the sign of the shifts in the second subsample and compute an effective marginal change in predicted probability in the entire sample due to a change in the dummy variable from 0 to 1. For an ordinal variable (such as EDUCATION), the value of the variable was increased by 1 and the predicted probability of land use outcome computed was computed. Finally, the elasticity effect of a continuous exogenous variable (such as ROAD) is obtained by increasing the value of the corresponding variable by 10% for each individual in the sample, and computing a percentage change in the predicted probability of forest and sugarcane cultivation due to the increase in the continuous variable.

Table 5.3. Descriptive statistics for structural variables used in the MMNL model

Structural variable	Variable/value description	Mean	Std. Dev	Min	Max
GENDER	1=Female-headed household; 0=otherwise (dummy)	0.532	0.400	0	1
AGE	Age of the household head in years (continuous)	58.940	12.834	33	88
EDUCATION	Years spent by the household head in the formal education system (continuous)	6.552	3.951	0	16
ADULTS	Number of adult-equivalent members of the household (count)	5.105	2.591	1	13.481
LAND	Total operated area in hectares (continuous)	1.596	1.515	0.1	10.5
ROAD	Minutes taken on arrive at the nearest tarmac road (continuous variable)	12.559	17.735	0	120
WATER	Walking distance (in minutes) to the nearest river/dam (continuous)	43.723	32.725	0	240
TRUST	1= don't trust anyone, 2= the majority are not trustworthy, 3=the majority are trustworthy, 4=everyone is trustworthy (categorical)	2.743	0.766	1	4
PROPORTION	Proportion of interviewed households that have cultivated sugarcane or trees in a ward	0.62	0.31	0	1
AGRO-ECOLOGY	1 = Windy Hill Mistbelt agro-ecology (Mthuli); 0 = Wartburg/Fawnleas agro-ecology (Gcumisa) (Dummy)	0.243	0.430	0	1

Data source: Household survey data (2013)
Note: number of observations (n) = 152

Table 5.4. Mixed multinomial logit estimation results, uMshwati local municipality, 2013

	Model 1 (without accounting for endogeneity)		Model 2 (corrected for endogeneity)			
	Average β	S.E.	Average β	S.E.	St. Dv. β	S.E.
Preferences for attributes (LUFs)						
Farm income generation	-0.029	(0.939)	-0.035	(0.943)	-0.039	(1.327)
Crop productivity	2.546***	(0.570)	2.500***	(0.566)	2.063***	(0.690)
Food availability	0.272**	(0.136)	0.281**	(0.132)	0.641**	(0.251)
Family labour employment	-0.172	(0.108)	-0.193*	(0.112)	-0.453**	(0.202)
Soil loss mitigation	-0.658	(1.308)	-0.745	(1.299)	-0.125	(1.311)
Intrinsic utility effect of farmer, household, farm and locational characteristics						
GENDER (Sc)	-0.590	(0.422)	-0.606	(0.431)	–	–
GENDER (Tc)	1.139	(0.900)	1.104	(0.882)	–	–
AGE (Sc)	0.030	(0.022)	0.028	(0.021)	–	–
AGE (Tc)	0.048	(0.040)	0.043	(0.047)		
EDUCATION (Sc)	0.087	(0.059)	0.079	(0.055)	–	–
EDUCATION (Tc)	0.108	(0.121)	0.098	(0.119)	–	–
ADULTS (Sc)	0.099	(0.859)	0.102	(0.823)	–	–
ADULTS (Tc)	-0.429**	(0.218)	-0.488**	(0.225)	–	–
LAND (Sc)	1.005***	(0.117)	0.996***	(0.113)	–	–
LAND (Tc)	-1.301	(0.873)	-1.327	(0.880)	–	–
ROAD (Sc)	-0.192	(0.741)	-0.200	(0.749)	–	–
ROAD (Tc)	-0.131*	(0.079)	0.127	(0.086)	–	–
WATER (Sc)	-0.111	(0.081)	-0.119	(0.077)	–	–
WATER (Tc)	0.315	(0.203)	0.307	(0.199)	–	–
TRUST (Sc)	1.029*	(0.620)	1.007	(0.618)	–	–
TRUST (Tc)	0.278	(0.773)	0.254	(0.769)	–	–
Location-specific effects						
PROPORTION (Sc & Tc)	2.425***	(0.151)	1.290**	(0.645)	–	–
AGRO-ECOLOGY (Sc & Tc)	3.792***	(0.896)	0.668*	(0.403)	–	–
Alternative-specific constants						
Sc	-5.559**	(2.822)	–	–	–	–
Tc	-3.293*	(1.996)	–	–	–	–
Number of estimated location-specific constants	–		14			
Number of cases (= n x 3)	456		456			
Log-likelihood	-42.603		-37.152			

Note: *** = significance at 1% level, ** = significance at 5% level, * = significance at 10%.

Data source: Authors' survey data (2013)

Most of the coefficients of farmer, household, farm, social and locational characteristics have the expected signs. The exception is the coefficient of operated hectare on tree farming, although it is not significant. In Model 1, adult-equivalents and distance to road have negative and significant coefficient in tree choice, whilst operated hectares and trust are positive and significant for sugarcane choice. The coefficients of proportion of land use changes in the ward and agro-ecology are also positive and significant for tree and sugarcane choices. However, the significant and negative coefficients of alternative-specific constants mean that unobserved factors reducing the preference for sugarcane and tree cultivation are not well explained by the socio-economic factors in the model.

As mentioned in the previous section, the proportion of ALUC in the peer group and agro-ecological effect are suspected to be correlated with the error term, and this could create inconsistency in the parameter estimates of these factors and potentially other variables in the model. The results of Model 2 in Table 5.4 represent the outcomes of the third step of the BLP approach. The results of the second stage are also presented in Table A4 in the appendices. They show that the instrumental variables (in Models 2a and 2c) worked well, as they were both significant and had the expected signs. The results in Table 5.4 show a decrease in the magnitude of the effect of ALUC proportions in the peer group and agro-ecological conditions (as estimated from Models 2b and 2d in Table A4). This suggests that the parameter estimates of peer pressure and agro-ecological conditions in Model 1 were biased upward, overemphasizing their actual affects. Nevertheless, the effects of both variables remain significant after correcting for endogeneity.

Most other parameter estimates and their significances did not change substantially as a result of BLP procedure. The exceptions are the increased significance of labour/employment function, as well as the reduction in the significance of trust and distance to road. These variables are affected probably due to their respective collinearity with peer group and agro-ecological conditions. The Log-likelihood has obviously increased as large number of constants were estimated in Model 2.

Table 5.5. Percentage of utility variation explained by structural factors in the MMNL Model

Source of heterogeneity	Sugarcane plantation	Tree plantation
GENDER	-0.67	0.90
AGE	0.38	0.71
EDUCATION	1.54	0.32
ADULTS	0.74	-11.59
LAND	14.61	-1.10
ROAD	0.40	-6.33
WATER	0.29	2.50
TRUST	4.54	0.38
PROPORTION	21.33	19.35
AGRO-ECOLOGY (Sc & Tc)	-1.22	17.43

Data source: Authors' survey data (2013)

5.4.3. Discussion

The results in Table 5.4 suggest that social sustainability outcomes of land use dominate pure income generation and ecological incentives, the frequent foci in agricultural policy in South Africa. This predominance of social motives over financial incentives, however, is not new in the ALUC literature (e.g. see Purushothaman et al., 2013). The strong appeal for cropland productivity has also been found in other study cases (e.g. Martínez-García et al., 2013). In the KZN midlands, this strong appeal could be a reflection of the limited access to alternative livelihood assets in the region, as documented in the review in Chapter 2. Also, productive use of land is an important means of preserving land rights and ensuring tenure security in communal land areas in South Africa (Armitage et al., 2009; Cairns, 2000).

Food availability is also a priority function of land use in the KZN midlands. This is partly because most of households are producing mainly for their household consumption, not for the market. This finding is consistent with the results of other studies such as Purushothaman et al. (2013) in India. The critical importance of the food provisioning function of land use in the KZN midlands is accentuated by other pillars of food security such as food access and utilization that are not manifest in region. For example, Sinyolo et al. (2014a) found that, on average, farm households spend only ZAR5990 (equivalent to USD550) per adult-equivalent per annum. Misselhorn (2009) also reported that small-scale farm households have lower scores of dietary diversity. Therefore, food availability is the backbone of food security in the region.

The stated preference for labour saving is also consistent with the findings of previous studies (e.g. Useche et al., 2009). The heightened demand for labour saving land uses could be explained by the staggering emigration trends in the region. In the KZN midlands, many economically active men leave communal land areas to work in major urban centres, leaving women, children and the elderly to work on the land.[31]

Interestingly, the sixth column of Table 5.4 shows that the standard deviation of the coefficient (St. Dv. β) for some function indicators are significant, indicating that the preferences for outcomes are heterogeneous and significantly different from the average preferences. These results show the extent to which diverse interests in LUFs create some trade-offs at household-level. For example, although 82% of the farmers prefer labour-saving land use, the remaining 18% are willing to adopt labour-intensive land uses, provided they can secure other beneficial functions such as food production or higher yield[32]. This trade-off explains the extent to which household-level agricultural land uses are often diversified.

Concerning the structural characteristics, the results of the MMNL model indicate a nuanced understanding of the influence of socio-economic and agro-ecological factors on land use change. The hypothesis that household size influences ALUC is only confirmed for tree farming. Table 5.5 suggests that, *ceteris paribus,* an extra adult-equivalent person reduces by 11.5% the chance of planting trees for an average farm household. In line with the Chayanovian model, the results infer that households engage in on-farm tree cultivation when their consumption needs are lower. The marginal effects are reported Similar findings were reported in shifting cultivation in Brazil (Klemick, 2011).

[31] A detailed discussion of the household labor constraint in the KZN is provided in Chapter 2.
[32] The trade-off is calculated based on the normal distribution of the coefficient of family labour requirement (with a mean of – 0.933 and standard deviation of – 0.545). Following Hole (2007), the percentage of people preferring land-saving land use is obtained by multiplying the cumulated standard normal distribution by the ratio of 0.933/ -0.545.

Consistent with the findings of previous studies (e.g. Masuku et al., 2001), the results further suggest that the utility gained from planting sugarcane increases with farm size. Table 5.5 suggests that, *ceteris paribus*, a one-hectare increase in land size would produce almost a 15% increase in the likelihood of planting sugarcane for an otherwise average farmer. This finding vindicates Just and Zilberman's (1983) ALUC model, showing that high fixed cost of sugarcane plantation implies that only farmers owning large tracts of land would prefer to adopt sugarcane planting since they are able to spread those costs and take advantage of economies of size. Previous studies (e.g. Mbowa and Nieuwoudt, 1998) have also documented the extents of economies of size in sugarcane plantation in South Africa.

As expected, proportion of ALUC in a farmer's peer group has a significantly positive effect on the utility of sugarcane and forest cultivation. Table 5.5 suggests that peer group pressure is the most important predictor of ALUC in the model. *Ceteris paribus*, increasing the proportion of ALUC in the community by 10% would increase the expected probability of sugarcane and tree plantation by 21.3% and 19.3%, respectively. This suggests that farmers benefit from the cumulative experience of other farmers in the community. This results is in line with the findings of various case studies cited in Foster and Rosenzweig (2010). This result is not surprising, given that timber and sugarcane farming are relatively new enterprises to the majority of small-scale farmers in South Africa. In many cases, the outcomes have been very uncertain, and many small-scale growers continue to lack the necessary managerial skills (Cairns, 2000; Dubb, 2014; Howard et al., 2005).

Lastly, Table 5.4 shows that the coefficient of agro-ecology is significant for sugarcane and forest plantations. Table 5.5 suggests that, for farmers living in the Windy Hill Mistbelt agro-ecology, the predicted probability is -1% lower for sugarcane and 17.4% higher for tree cultivation. The finding that land use change is controlled by agro-ecological conditions (e.g. rainfall variability, slopes, etc.) is not unique in the literature. Similar findings are reported from other regions (Arslan et al., 2014; López and Sierra, 2010; Nahuelhual et al., 2012). Farmers in the Windy Hill Mistbelt region could face high cost of intensifying with annual crop cultivation (López and Sierra, 2010). Acute soil erosion process due to the combination of steeper slopes and higher rainfall variability could also be more pronounced (Hoffman and Ashwell, 2001). Therefore, hilly and wetter regions provide fewer opportunities for alternative land uses.

5.5. Summary

South Africa's agricultural policy recognizes the importance of promoting on-farm tree plantation as a pathway to sustainable development. This recognition is of crucial importance to small-scale farmers living in the areas facing CC and land degradation such as the KZN midlands. However, little remained known about farmers' attitudes towards land use functions and the constraint they face in their land use decision-making process. The objective of this chapter was, therefore, was to investigate the attitudes of small-scale farmers towards LUFs and the structural constraints they face in their decision to add trees or sugarcane on their cropping portfolios.

Based on the SP and RP data from the household survey in the Midlands region on KZN, the results of the MMNL model suggested that decisions about ALUC are rationally derived and driven by clear but heterogeneous preferences and trade-offs between crop productivity, food security, and labour requirements. With regard to constraints, the findings suggested that the utility of planting sugarcane increases with farm size, whilst the preference for forest plantation decreases with household size. Land use change is also governed by social influences and agro-ecological conditions.

CHAPTER 6 . CONCLUSIONS AND RECOMMENDATIONS

This chapter first gives a summary of the research problems, objectives, and methods of the study. The chapter also concludes the major findings and provides some key policy recommendations. Based on identified methodological limitations, the chapter also proposes some avenues for further research.

6.1. Recapping the purpose of the study and methods employed

Although the proportional contribution of the agricultural sector to the South African economy is small and declining, the small-scale farming sector has been expanding over the last decades due to the on-going land reform policies. The future of small-scale farming, however, is facing challenges of feeding a growing population, coupled with land degradation and agro-biodiversity loss. These challenges are exacerbated by CC. Under such circumstances, agricultural land use change offers climate-resilient pathways to sustainable development. Climate-driven ALUC, however, is a complex process, involving environmental, cognitive, behavioural, and economic factors. The pathways to ALUC start with climate-related vulnerability of farming systems, and translate into behavioural change through farmers' perceptions about the climate risk. Behavioural responses are characterised by two major steps: (i) reducing vulnerability and exposure to present climate variability, and (ii) integration of adaptation and mitigation into (farm) planning. Understanding the process of climate-driven ALUC is key to the design of effective strategies for the South Africa's CC response policy.

The process of climate-driven ALUC in the context of small-scale farming in South Africa, however, remained under-explored in the scholarly literature. First, although studies have identified the KZN midlands as a hotspot of CC in South Africa, mapping climate-related vulnerability of the farming sector in this region was a scarce endeavour in the literature. Second, past studies had attributed the small-scale farmers' misperception about CC to the complexity of biophysical factors, overlooking the importance of socio-psychological, cultural and institutional factors. Third, the patterns and determinants of crop diversification among small-scale farmers in the hotspots of CC such as the KZN Midlands were under-explored. Lastly, empirical studies on ALUC were still dominated by spatially explicit, non-economic models, overlooking individual farmers' attitudes towards land use and the constraints they face in the land use conversion decision-making.

To address the knowledge gaps, this study was set out to assess small-scale farmers' vulnerability to CC, climate risk perceptions and adaptive land use management. Taking the Midlands region of KZN as an illustrative case, the specific objectives of his study were:

(i) to explore some meso-level aspects of climate-related agricultural vulnerability;
(ii) to investigate the perceptions of small-scale farmers about CC and their socio-psychological, institutional and cultural determinants;
(iii) to analyse the current farmland use systems and assess the microeconomic determinants of seasonal crop diversification; and
(iv) to assess the attitudes of small-scale farmers towards land use and constraints governing ALUC decision-making.

To achieve the specific objectives, this study proposed innovative methodological approaches. Unlike most studies assessing the climate-related agricultural vulnerability, this study applied an indicator approach by using a systematic review of the available empirical evidence from the KZN midlands. Other objectives were empirically investigated based on primary data from a farm household survey conducted in the uMshwati Local Municipality. With regard to the second objective, Chapter 3 applied a behavioural decision approach to the assessment of perceptions about CC among small-scale farmers in the KZN midlands. Unlike other studies in this strand, Chapter 3 of this study used a principal component analysis to construct two contrasting indices of perceptual shapes, and a Double-Hurdle estimation technique that controls for self-selection bias.

With regard to the third specific objective, Chapter 4 of this study presented a simplified short-run (single agricultural cycle) land allocation model of a multi-crop household economy. After exploring the household-level farmland use systems using a two-stage cluster analysis technique, the study applied the Logit transformation model in the analysis of the effect of socio-economic factors on the intensity of multiple-cropping. To account for the potential endogeneity of off-farm occupation in the model, a two-stage estimation approach was used. Predicted probabilities of off-farm occupation generated from a Probit model were used as proxies of off-farm occupation in the Logit transformation model. To examine the wealth effect, the empirical model in this study was first estimated for the entire sample, and then re-estimated for households in two income groups: below and above the income median.

Regarding the fourth specific objective, chapter 5 of this study applied a Mixed-Multinomial Logit estimation technique. Unlike previous studies that mainly use discrete choice experiments of the stated preference technique, this chapter adopted a method that uses a combination of revealed preference and stated preference data in order to produce more robust estimates and better identification of attributes, and reduces the potential endogeneity and other biases. The chapter also applied the Berry-Levinsohn-Pakes approach to address the potential endogeneity bias in spatial variables.

6.2. Conclusions

The systematic review in Chapter 2 suggested that climate-related agricultural vulnerability is acute in the study region. With regard to exposure, the reviewed evidence suggest clear warming trends as detected by climate scientists, and the projected warming and wetting trends towards the end of the 21st century. The research evidence further suggested that this acute exposure overlaps with highly sensitive farming systems, indicated by high population densities, high rates of small-scale farming, low irrigation rates, and susceptibility to land degradation. In spite of such acute levels of sensitivity, the highly diversified crop portfolios constitute a major aspect of the resilience of the farming sector. The synthesis also suggested that the adaptive capacity of rural people in the KZN midlands is confounded by inadequate access to infrastructure (for example, roads and electricity), rural exodus, skills shortages, poor health, and lack of social capital among farmers.

The empirical analyses in the subsequent chapter were based on farm household survey data collected in six wards/communities of the uMshwati local municipality. The results of PCA of perceptions about CC in Chapter 3 revealed two contrasting perceptual shapes. Whilst meteorological data indicated that the area has experienced drying trends in summer coupled with warming and wetting trends in winter over the last four decades, CCP_1 score portrayed the perception of winter as cooling and drying and summer as warming and drying. CCP_2 score depicted the perception of winter as warming and wetting and summer as drying. The latter exhibited stark similarity with meteorological observations. The results of the Probit model suggested that climate risk perception is triggered by emotive factors (holistic affect), value judgement, and socio-demographic factors such age, gender, education, and agro-ecological conditions. In line with the conceptual expectations from the behavioural approach, the results of the Truncated regression model showed that, given positive perception, the CCP_1 score increases with holistic affect and inherently experiential socio-demographic factors such as age and distance to the rivers, whilst the CCP_2 score is determined by cognitive and socio-cultural factors, including knowledge, education, extension, and trust.

The importance of affect heuristics signified the need for analysing extreme coping behaviour among small-scale farmers in the KZN, the third objective of the study. The results of cluster analysis of land use systems in Chapter 4 showed that household-level land use matrices are dominated by patterns of mixed crop-livestock systems, and emerging small-scale sugarcane mono-cropping and agro-forestry. Based on a short-run (single agricultural cycle) land allocation model of a multi-crop household economy, the estimated results of the Logit transformation model indicated that, for both income-poor and income-rich households, the intensity of seasonal crop diversification increases with landholding and labour availability. For income-richer households, the results also showed the multiple-cropping intensity decreases with education. The estimation results further showed that, among poorer households, the crop diversification intensity decreases with off-farm occupation and increases with distance to water sources. Overall, the empirical results suggested that crop diversification in the midlands region of

KwaZulu-Natal is constrained by technological factors (land and labour), and mitigating income and production risks are important motivations for crop diversification among poor households.

The estimated results of the MMNL model in Chapter 5 suggested that decisions about ALUC are rationally derived and driven by clear but heterogeneous preferences and trade-offs between crop productivity, food security, and labour saving. The results also revealed a trade-off between the priority LUFs. For example, although 82% of farmers prefer labour-saving land use, the remaining 18% are willing to adopt labour-intensive land uses, provided they can secure other beneficial functions such as food production or higher yield. The findings further suggested that the utility of planting sugarcane increases with farm size (suggesting economies of size), whilst the preference for forest plantation decreases with household size (indicating a Chayanov-like afforestation pattern). Proportion of farmers that have converted land use (to forest and sugarcane plantation) in the community and wetter and hilly agro-ecological conditions also influence the land use conversion decision, suggesting that ALUC is controlled by the peer group influence as well as the opportunity cost of land use.

6.3. Policy recommendations

These results can serve as inputs for the development of evidence-based policy interventions to promote climate-smart agriculture in rural areas, taking farmers' perceptions and needs into account. The evidence of agricultural vulnerability to CC in the KZN midlands documented in Chapter 2 signifies the importance of formulating region-specific CC adaptation and mitigation strategies. This endeavour could ensure the appropriateness and effectiveness of interventions and warrant the support and uptake by the local stakeholders (including farming communities, land use planners, and agricultural extension workers). The strategies should focus on the facets of vulnerability that are more pronounced, and leverage upon the existing resilience of small-scale farming systems to devise more effective interventions.

The different shapes of perceptions about CC among small-scale farmers, as revealed in Chapter 3, underscores the need for designing more effective regional CC communication strategies. The strategy should aim at providing a conducive environment within which the cognitive processes of CC perception formation can flourish. For this purpose, dissemination of CC information as well as engagement of small-scale farmers with the CC debate through extension services are of crucial importance insofar as raising awareness of the real threat posed by climatic changes is concerned.

Before dissemination, the CC information packages should be examined carefully based on the specific requirements and needs of their audience. Given that experiential factors dominate in the perceptual process, information on extreme weathers can be more persuasive than just daily or mean values, because the extreme climatic events are less abstract and farmers can easily relate to them. The information should be prepared in such a format and way that farmers can effectively understand with minimum cognitive efforts. For example, to ensure proper adaptation planning at farm level, the forecast information disseminated through the media and other local channels could be more useful if communicated in terms of seasonal rather than daily/monthly forecasts.

The significance of the holistic affect suggests that the information packages should frame CC as a risk about which to worry. However, a “fear-based” approach (i.e. framing CC as a risk about which to fear) should be avoided, as it can lead to maladaptation. The effect of worldviews in the model suggests that perceptions about CC are deeply entrenched in people’s values. Therefore, the communication should be well aligned to local beliefs, values and norms (e.g. religious beliefs). It should be framed in such a way that it does not stimulate the existing religious, socio-political or cultural differences. In this regard, techniques such as value-congruent information processing, audience segmentation and message tailoring can potentially contribute to the identification of particular information that is appealing to different audiences.

Moreover, the dominantly experience-based perceptions in the KZN midlands indicate how important it is for the regional CC information communication and engagement strategy to relate with local farming realities (e.g. local changes in rainfall variability, local pest and disease outbreaks, local soil erosion) rather than abstract and distant impacts (such as sea level rise, melting glaciers, etc.). In this regard, awareness campaigns should involve affected farmers sharing their real-life stories in the form of farmer-to-farmer agricultural extension (e.g. farmer field schools). The effect of trust in the perceptual model emphasizes that, during the awareness campaigns, the descriptive information should be communicated by locally trusted sources (e.g. local extension workers, local intellectuals, locally elected officials, and other role models) rather than scientists external to the system. Such information could help farmers to not only cope *ex ante* with the changing seasons, but also plan their on-farm long-term investments accordingly.

Given that perception is a learning process, the CC communication strategy should be built on a result-based monitoring and evaluation system. The system should be capable of securing regular information to capture the changes in the way farmers' perceptions tally with records from weather stations as a result of the CC communication strategy. The platform should also regularly capture important information on psychological and behavioural responses as environmental impacts of CC unfold. Based on such provision, the efficacy and efficiency of the communication strategy can be appraised, and accountability and learning by the local stakeholders can be promoted.

With regard to crop diversification, the findings of Chapter 4 have major implications for regional strategies of resilience in the small-scale farming systems. The significant effect of landholding on multiple-cropping practices of both income-rich and low-income households infers that enhanced short-term resilience in the face of climatic variability (and sources of risk) and increased range of agro-biodiversity reservoirs could be some of the major co-benefits of the on-going land restitution and other land reform programs. The negative effect of access to water on poor farmers' multiple-cropping practices infers that explicit efforts to promote crop diversification should be directed towards areas with high concentration of low-income, dryland farmers. In such areas, local agricultural extension offices should design a system of regular communication about the optimum crop combinations based on seasonal rainfall forecasts. Given the positive effect of labour and land in the model, the extension officers should encourage diversification with high-yield, labour-saving crops or crop varieties. This strategy can achieve multiple objectives of rural development strategy, including CC adaptation and income poverty alleviation, while safeguarding food security and agro-biodiversity. In that endeavour, however, caution should be exercised so as not to jeopardize farmers' relationship to the market. Maximum priority must be given to the consistency of the quantity and qualities supplied in order to maintain trust-based relationships in their commercial agri-food chains.

With regard to farmland use change, the results presented in Chapter 5 infer that, in order to align the private incentives with public goals, policymakers should promote timber-based agroforestry systems (agri-silviculture) as an alternative to the current timber monoculture. Policymakers should invest more resources into research and extension of intercrop systems that optimize both timber and food crop productivity, secure higher returns to labour, and maintain the quality of the soil (e.g. trees in block vs. trees in hedgerows, selective weeding, and selective felling). Given that such practices are often discouraged under the timber out-grower schemes, alternative arrangements to commercial forestry (i.e. social forestry) should be envisaged.

The significantly negative effect of labour in the afforestation model infers that incentive-based schemes (e.g. payment for ecosystem services or REDD) should be designed on a per-capita or equivalent-consumption basis. This strategy can ensure that the payment is equivalent to the opportunity cost of planting trees to the farmer. For a zoning approach to agricultural land use planning, the significance of agro-ecology-fixed effects suggests that afforestation policies should target farmers in sloping landscapes or in areas with higher rainfall variability where the opportunity cost is relatively low and the risk of soil degradation is higher.

Where sugarcane plantation is zoned, the significance of farm size signifies the need for policy strategies to assist small-scale farmers to overcome the challenges associated with economies of size. This underscores the relevance of strategies such as land use consolidation and cooperative farming. However, policymakers should be aware of decreasing returns to scale, as increase in farm size without proportionate changes in input levels can lead to a decrease in technical efficiency. Therefore, efforts to overcome diseconomies of scale should be accompanied by concurrent efforts to access other inputs such as credit.

To achieve the land use change strategies, the effect of social influence in the model signifies the importance of taking into account the innovation diffusion process in the community. To leverage on the significance of peer group influence, a policy emphasis on innovation diffusion and community-based agricultural extension models (e.g. through farmer field schools) can be effective. Subsidizing experimentation at village-level could reduce the scope of free riding behaviour that undermines the efficient provision of information on agro-forestry.

6.4. Avenues for further research

The information and recommendations provided by this study, however, have noteworthy limitations. First, the regional agricultural vulnerability discussed in Chapter 2 needs to be reassessed. Whilst the indicators of exposure go as far as the end of the 21^{st} century, most of the indicators of sensitivity and adaptive capacity were explored within the historical or current conditions, assuming that the existing socio-economic conditions would persist. Therefore, it would be desirable to discuss the potential impacts of future climatic changes within the context of plausible future socio-economic scenarios. The scenarios should capture region-specific agriculture and economic development conditions that are consistent with the assumptions used to generate CC simulations.

Second, although the PCA of perceived abnormal trends in climate has reported meaningful results, a potential bias pertaining to self-reported experiences with local climate has not been taken into account. Some respondents with relatively strong beliefs about CC might have perceived the questions as too demanding in terms of cognitive efforts and, in order to guard against being "wrong", tended to report neutral or moderate levels of perceptions. Giving credence to the present findings and recommendations, therefore, requires formal tests for misreporting bias, an avenue for further research.

In addition, although the hypotheses about socio-psychological, institutional and cultural influences in the Double-Hurdle model fit the data well, an interesting avenue for future research would be to test the validity of the model under different socio-economic, cultural and agro-ecological contexts. Given that this study relied on demographic and agro-ecological variables as proxies for socio-psychological and cultural factors, it could be desirable to examine the validity of the behavioural approach in an experimental setting. Indeed, factors such as values and beliefs hypothesized in the model are very hard to measure. Experimental studies, therefore, could be instrumental in the investigation of better measures of socio-psychological, institutional and cultural factors.

A third drawback in the seasonal crop diversification model pertains to the use of Herfindhal Index. This was limiting due to the fact that it could not capture the specific patterns of crop diversification. Notably, the index could not capture the relative importance of certain categories of crops based, for example, on plant functional types. This information is crucial for understanding the crop diversification as an indicator for the resilience of farming systems in the face of climatic variability. More ambiguity in diversification index pertains to the failure to distinguish market-orientated crop diversification vs. subsistent crop diversification. A similar crop diversity score, say complete specialization, could portray different information for two different farmers. For example, whilst a specialization in a market-orientated crop could mean a positive outcome for one small-holder farmer, a complete specialization in a subsistence-orientated crop could indicate food-insecure subsistence farmer. Unpacking such complexity of diversification provides an interesting avenue for future crop diversification research.

In modelling ALUC, although the BLP approach has helped correcting for the endogeneity bias pertaining to spatial factors, the endogeneity bias caused by biases in self-reported measures of outcome beliefs (e.g. attrition bias, misreporting behaviours based on social desirability/sensitivity) remains at large. A formal test for such non-negligible endogeneity requires techniques such as multiple imputations that use auxiliary or longitudinal data, another important avenue for future research.

Also, further elaboration of the integrated approach can deepen the understanding of ALUC, but requires a reorientation in the survey design and model specifications. Since global and regional drivers (e.g. CC, globalization, and land use policy change) can bring new set of issues to the forefront, there is a need for integrating more indicators of LUFs into the model and disaggregating the existing ones. Future studies should reengineer the model to explicitly allow for the interaction between the parameters of LUF indicators and the testing of their significance. For example, the model should be able to disentangle the perceived crop productivity effect of soil mitigation versus the crop productivity effect of labour use.

Lastly, further research is needed to link and quantify the impacts and implications of CC on ALUC in the region. From a methodological viewpoint, the constraints to ALUC revealed in this study (e.g. access to markets) are typically difficult to observe and quantify. There is an avenue to simulate how the observable heterogeneity in socio-economic and bio-physical characteristics determines the value of farming systems and the farmer's willingness to adopt ALUC under different climate-driven system change scenarios. This endeavour can be undertaken using techniques such as trade-off analysis for multi-dimensional impact assessment. It requires concerted and collaborative efforts among climate scientists, agro-ecological and/or crop modellers, and agricultural economists.

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APPENDICES

APPENDIX A. TABLES

Table A1. Reliability of psychometric measures of worldview indices

Measure	Mean	Std Dev	Cronbach's alpha if item deleted	Cronbach's alpha
EGALITARIANISM index	13.29	2.59		0.84
Equal rights	4.02	0.64	0.81	
Equal wealth distribution	3.24	0.58	0.83	
Affirmative action	2.04	0.94	0.71	
Equal opportunities	3.99	0.87	0.73	
INDIVIDUALISM index	9.34	3.02		0.79
Moral worth of individual	2.87	0.96	0.76	
Virtues of self-reliance	1.06	0.75	0.78	
Value of personal independence	3.09	0.82	0.82	
Precedence of individual interest over the social interests	2.32	0.94	0.77	
HIERARCHISM index	11.98	3.70		0.59
Authority of hierarchy	3.35	0.99	0.56	
Top-down management	2.99	0.93	0.58	
Patriarchy	2.43	0.97	0.49	
Technocracy	3.21	0.89	0.53	
FATALISM index	7.20	2.74		0.51
Powerlessness to influence the future	2.22	0.97	0.42	
Lack of control over one's life	1.91	0.92	0.50	
Inevitability or predetermination of events	3.07	0.87	0.49	

Note: number of observation n=152.
Data source: Household survey data (2013)

Table A2. Kaiser-Meyer-Olkin (KMO) and Bartlett's tests results for data used in the principal component analyses

	KMO	Bartlett's test
Land use	0.759	P<0.002
Climate change perceptions	0.712	P<0.001

Data source: Household survey data (2013)

Table A3. Estimation results of Probit models of off-farm occupation in the uMshwati local municipality, 2013

Covariates	All households		Below-median-income households		Above-median-income households	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
LAND	-0.105*	0.058	-0.733**	0.372	-0.053	0.119
ADULTS	0.029	0.024	0.041	0.033	0.008	0.056
GENDER	0.258	0.172	0.310*	0.182	0.419	0.288
AGE	-0.238	0.149	-0.237	0.157	-0.396	0.305
AGE_SQUARED	0.002	0.001	0.002	0.001	0.003	0.002
EDUCATION	0.006***	0.002	0.075*	0.041	0.039**	0.020
EXTENSION	-0.002	0.001	-0.032	0.065	-0.006	0.032
TRUST	0.014**	0.005	0.384***	0.120	-0.203	0.201
ROAD	0.011***	0.003	0.001*	0.001	0.053***	0.017
WATER	-0.006	0.006	-0.013	0.008	-0.007	0.007
AGRO-ECOLOGY	-0.204	0.281	-0.412	0.177	-1.204	0.904
Constant	7.117	5.684	6.443	4.003	12.109***	4.372
Number of observations	*152*		76		76	
Log-likelihood	-83.908		-19.418		-54.523	

Note: *= significant at 10% level; **= significant at 5% level, ***= significant at 1% level
Data source: Household survey data (2013)

Table A4. Second stage of BLP approach (two-step IV regression)

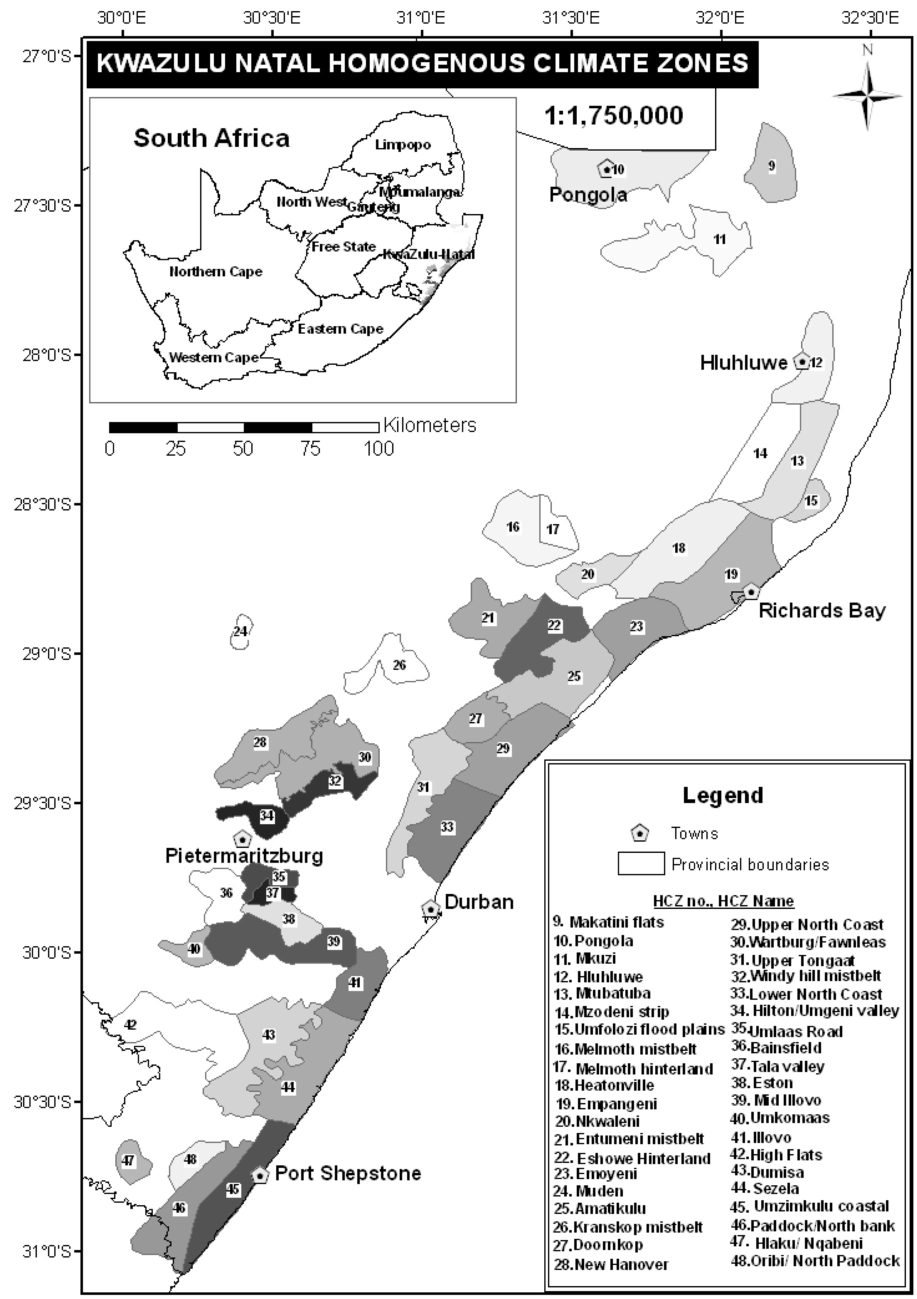
Model 2a (Dependent variable: Proportion of ALUC in a ward)			Model 2c (Dependent variable: location in Windy Hill Mistbelt agro-ecology)		
	β	S.E.		β	S.E.
Intercept – sugarcane plantation	-0.109	0.182	Intercept – sugarcane plantation	1.873*	0.101
Intercept – tree plantation	0.187**	0.098	Intercept – tree plantation	0.914***	0.293
Average proportion of ALUC in surrounding wards	0.745***	0.275	Ward's population density	-0.009***	0.003
Adjusted R Square	0.559		Adjusted R Square	0.967	

Model 2b (Dependent variable: Ward - specific constants)			Model 2d (Dependent variable: Market specific constants)		
	β	S.E.		β	S.E.
Intercept – sugarcane plantation	0.201**	0.099	Intercept – sugarcane plantation	-0.455	1.123
Intercept – tree plantation	0.087*	0.051	Intercept – tree plantation	0.097	0.769
Fitted value of proportion of ALUC (from model 2a)	1.290**	(0.645)	Fitted probabilities for locating in Windy Hill Mistbelt agro-ecology	0.668*	(0.403)
Adjusted R Square	N/A		Adjusted R Square	N/A	

Note: number of observation n=152. *** = significance at 1% level, ** = significance at 5% level, * = significance at 10%.
Data source: Household survey data (2013)

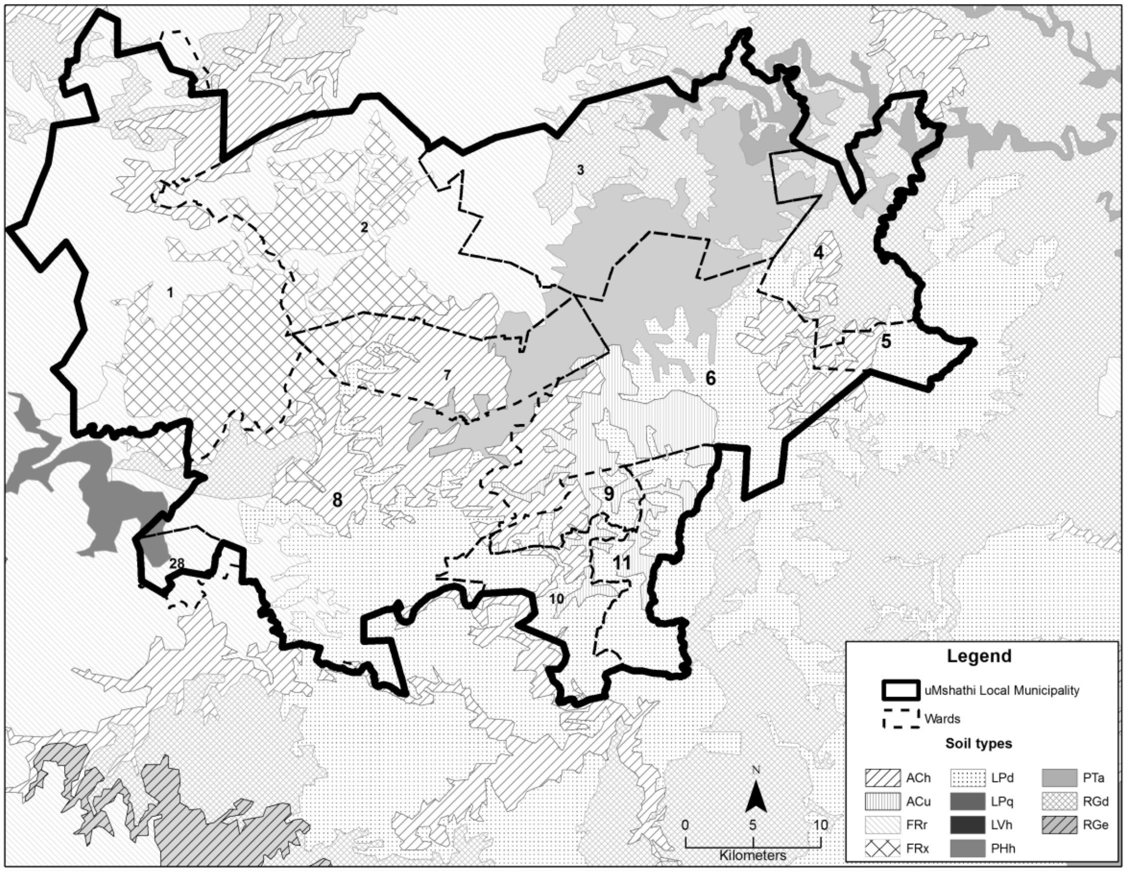
APPENDIX B. FIGURES

Figure B1. Some homogeneous agro-climatic zones in KwaZulu-Natal



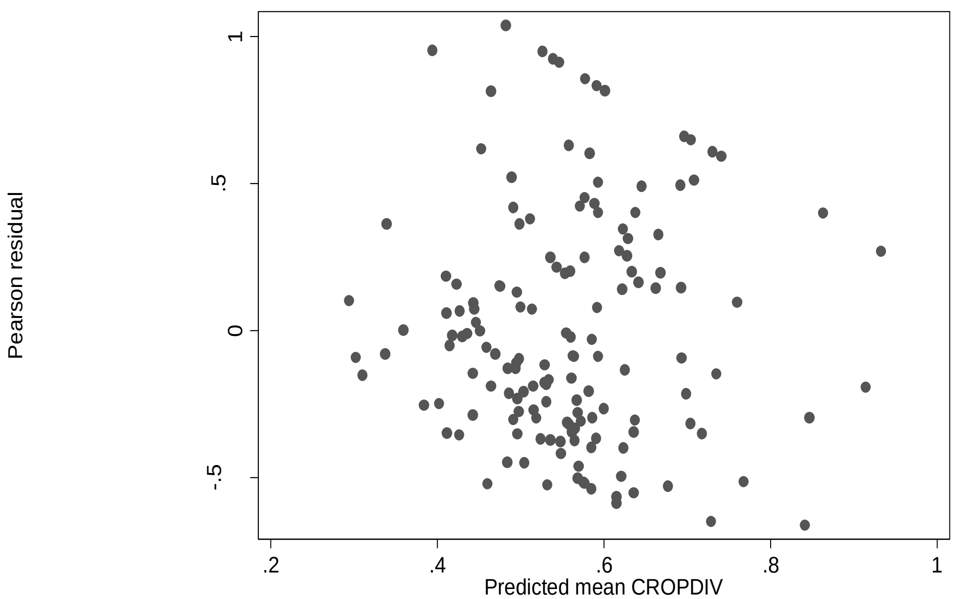
Source: South African Sugarcane Association (www.sasa.org.za)

Figure B2. Soil map of uMshwati local municipality



Source: Based on soil and terrain database of the FAO's Land Degradation Assessment in Drylands (LADA) program (http://www.isric.org).

Figure B3. Residual plot tests for the goodness-of-fit of the Logit transformation model



Data source: Household survey (2013)

APPENDIX C. GUIDELINES FOR DUAL-MODERATOR FOCUS GROUP DISCUSSION

a) Introduce yourself and briefly explain the objectives of the research and the activity programme.
b) Discuss the interviewees' personal experience with sugarcane/timber production in the area. Categorize them in groups (e.g male and females, NFG and SSG, etc…)
c) **Livelihood outcomes:** Discuss the general (wellbeing) objectives pursued by small-scale cane/timber farmers (criteria based on which they judge "success" or "wellbeing" in their living) (e.g. (a) economic sustainability – **generating more incomes** and accumulating things that money can buy – (b) social sustainability, i.e. things that money cannot directly buy - feeling of social/political inclusions (such as **participation in decision making** – i.e. voiced -, **land tenure security**, dignity/respect in social life), self-esteem (reduced state of dependence and a lack of psychological well-being through knowledge and health), occupation for the household members, (c) **reduced vulnerability to the downside risk** following assets accumulation (external events – such as war, droughts, etc- that reduces your wellbeing), d) **environmental and natural resource sustainability** (long-term benefits of prudent resource use).
d) **Livelihood vulnerability context**: Discuss the key (positive or negative) socio-economic and environmental events (*i.e.,* single-points) (using a historical timeline) and trends (using trend lines) in the history of the village that have considerably affected sugarcane/timber farmers in the region. Start from the current situation (now) going backwards to 30 years or so.
e) **Livelihood assets**: Discuss the "unique" livelihood assets accrued from sugarcane/forestry farming.

i) **Natural capital**: What are **the property rights regimes** and the **rules of access** to customary land and communal lands? What are **alternative land-use** prevails in this region? How is land access different between those uses? Compared to other land-uses, is planting cane/timber believed to be a more **environmentally viable** land use option (infers the external impact of a livelihood on other livelihoods, that is its effects on local and global resources and other assets)? Which **additional "natural" goods** does sugarcane/timber farming allow the community access to (e.g. Hay/animal feed, firewood/, wild vegetables and fruits, medicinal/cosmetic plants, water, etc...)? Which **"natural services"** does sugarcane/timber farming allow the community access to (e.g. reduction of erosion, waste decomposition, flood control, etc...)? Which **"cultural" and "amenity" resources does** sugarcane/timber farming allow the community access to (e.g. aesthetically pleasing landscape, sacred places/forest/species, outdoor recreation/ ecotourism etc...)? Do most farms still have vegetable patches to supply them with what they always used to grow? Do schemes around cane/timber farming enable **education** of rural people about the threats of sugarcane/forestry to natural resources (soil, water, animals, etc.)?

   (Use a *Matrix/preference ranking* to show the relative priority people attribute to given natural capital*)*?

ii) **Social capital:** What **social linkages and networks** (kin-based networks, farmer's organizations) exist for sugarcane/timber growers? Which cane/timber farmer's associations prevails in this area? What capacity and to what extent these groups (formal and informal) **improve land-based livelihoods**, i.e. constrain or facilitate achievement of livelihood outcomes with **tangible resources and services** that support livelihoods? Do they participate in political and other decision making processes? To what extent do farmers participate in these groups' decision making processes? **I**s cane/timber farming a socially viable land-use option (which concerns the internal capacity of a livelihood to withstand outside pressure. E.g a) Relations among people in the present generation (including intra- or within-household relationships such as resource (labor, food, material, natural resources) sharing networks, gender (are women/children encouraged or discouraged to participate in cane/timber farming par rapport to men/elderly ?, differences in power and status among different people in the community (e.g. improved land-tenure security – relationship with the chiefs) b) Relations between the current and future generation; are cane/timber farmers less or more concerned about environmental degradation and its impact on the livelihood of future farming families and possibly on the whole of society?
(Use a *Matrix/preference ranking* to show the relative priority people attribute to given social networks*)*?

iii) **Human capital (Skills and their transfer)**: Generally, how is the provision of services such as schools, healthcare facilities, and sanitation facilities in this area? Are they available (location) and accessible (cost)? Does cane/timber farming provides secondary benefits to the community in the form of employment? What intellectual capacity do farmers have to manage cane/timber business (experience, education, trainings, etc…). Does cane/timber growing contribute to increased capacity (ability to perform economic activities) amongst rural people (e.g. commercial farming related knowledge – business/financial management, agronomic and environmental management)? Are the majority of growers able to offer their physical skills and advice to other farmers or vice versa? Does cane/timber farming empower farmers?
(Use a *Matrix/preference ranking* to show the relative priority people attribute to given human capitals*)*?

iv) **Financial capital:** Is cane/timber farming a financially viable economic activity (i.e. can itself provide regular flow of money to the household now and in the future without external intervention)? What is the regularity of the income (once a season, lumpsum, etc.) and which mode of payments (cheque, through coops, etc) prevail? Does cane/timber farming allow to access to financial assets (including credit, savings, insurance and other social protection measures)?? use *Preference ranking* and *matrix scoring to compare* the importance of different credit sources or savings, sources of cash and insurance options. Does cane/timber farming promote income diversification (does cane/timber farming provide the ability to invest time in additional employment opportunities), and structural diversification: (Do **i**ncomes from timber provide income to invest the surplus in alternative economic activities)? Is the mode of payment suitable for financial progress (e.g.

paid for in lump sums to invest whilst cash from other economic activities could cover day-today expenses)?

v) **Physical capital:** Generally, do people have access to piped water, electricity, telecommunication networks, waste disposal and other services? Which house quality and facilities (wall, floor, roof construction materials, cooking utensils, furniture) prevails in this area? Which personal/household items enhance incomes (implements, bicycles, etc...)? Which personal consumption items (e.g. radios, refrigerators, televisions) are often good indicators of relative wealth or poverty? Does cane/timber farming allow development of economic infrastructure (e.g. roads, bridges, electricity, mobile networks) in the region? Does cane/timber farming allow to pay basic household infrastructure such as cars, furniture, etc (meaning, are cane/timber farmers wealthier in terms of household assets)…?

Transforming structures and processes:

vi) Are there cultural or religious preferences for a specific sugarcane/timber management practice (e.g. in livestock, the practice of keeping animals as a store of wealth to be used in a time of need, rather than being sold on a regular basis)?

vii) Cultural or religious taboos against specific crop management practices (e.g. a) having to delay ploughing at the beginning of the rainy season until the village leadership gives permission, b) restriction placed on farmers from working the land after deaths and funerals?

viii) What patterns of activity distinguish the lives of women/men? What distinct status and roles are assigned to men and to women, boys and girls, and how do they affect activities?

ix) What is the role of the ward chairman, the village head or the council of elders on sugarcane/timber farming?

x) How do ordinary villagers make their problems known to those in authority? What is the likelihood that such problems will be acted upon? To whom in the community is authority most and least responsive?

xi) Which actors have the greatest influence on policy change?

xii) How does the community or neighbourhood deal with conflicts and grievances?

xiii) Which policy/support programmes can have either negative or positive influences on environmental stability of sugarcane/timber in the region (giving explicit concern for conserving the productivity of the soil)?

xiv) Which policy/support programmes can have either negative or positive influences on economic stability of sugarcane/timber in the region (e.g. financial institutions, etc)?

xv) Which policy/support programmes can have either negative or positive influences on social stability of sugarcane/timber in the region?

xvi) How have access to the assets above influenced these processes?

Livelihood strategies

Season / Month Activity	Drier season				Wetter season							
	M AY	JU N	JU L	AU G	SEP	OC T	NO V	DE C	JA N	FE B	MA R	AP R
<u>Normal season</u>												
On-farm: Sugarcane/forestry production												
On-farm: Alternative land-uses												
On-farm: Hay/manure preparation												
Off-farm: Seasonal farm labor												
Off-farm: Short-term migration for seasonal work												
Off-farm: Seasonal food for work, public works & relief												
Off-farm: Casual labor/piece work												
Off-farm: home gardening												
Off-farm: others												
Child care												
Cooking foods												
Water fetching												
Fuel wood collection												
Wild food (vegetables, fruits, honey, etc) collection												
Other NR-based activities												
Water fetching												
Residual/available labor												
<u>Abnormal season (with climate change)</u>												
On-farm: Sugarcane/forestry production												
On-farm: Alternative land-uses												
Off-farm: Seasonal farm labor												
On-farm: Hay/manure preparation												
Off-farm: Short-term migration for seasonal work												
Off-farm: Seasonal food for work, public works & relief												
Off-farm: Casual labor/piece work												
Off-farm: home gardening												
Off-farm: others												
Child care												
Cooking foods												
Water fetching												
Fuel wood collection												
Wild food and fruits collection												
Other NR-based activities												
Water fetching												
Residual/available labor												

Labor codes:

●: Mostly an adult male task
○: Mostly an adult female task
⦿: Mostly a child male task
⊙: Mostly a child female task
─: Continuous activity
═: Intermittent activity
▬: Tense labor activity

Farm operation codes:

LP: Land Preparation
P: Planting
W: Weeding
H: Harvesting
S: Stumping
S: Storage
SH: Shelling
TR: Threshing
PR: Processing

Livelihood Vulnerability

1. Which and how external events and trends that cause stress (either regularly or intermittently) and to which different groups in the community are most prone (e.g. food insecurity, informal legal status, drought, eviction, political conflicts, etc)?
2. Distinguish between factors that may be susceptible to change (in direction or intensity), and those that appear likely to continue on their current trajectory, making livelihood adaptation inevitable.
3. Distinguish between the 'local' trends and national or more global trends.
4. To what extent to cane/timber growers are exposed to particular trends/shocks/seasonality; and
5. What is the sensitivity of their livelihoods to these factors (this relates directly to resilience)?
6. What are the coping strategies and potential solutions (insurances, land-use changes, etc)?

Effect of alternative land-uses on the overall livelihoods

Discuss the effect of land-use change on the vulnerability, strategy, assets, and livelihoods (going backward), using matrix ranking/scoring.

f) Discuss the key (positive or negative) climate-related events (*i.e.,* single-points) (using a historical timeline), and trends (using trend lines) in the history of the village that have considerably affected the land-use. Start from the current situation (now) going backwards to 30 years.

g) Using the following matrix, discuss with farmers the relationship between the events/trends and their land-uses (LUs). For each identified LU, ask farmers to rank events/trends from the most (1) to the least affecting/impacting event/trend (for those with equal rank, use equality sign after the rank, e.g. 3=).

Identified events/trends / Land-use	Event 1	Event 2	Event 3	Trend 1	Trends2
LU_1					
LU_2					
LU_3					
LU_4					
Etc					

h) For each event/trend that scores a rank greater than the mean rank, discuss with the group the effects/impacts in details. For the trends, outline the major starting and turning points/dates/events (e.g., migration, law passing, *etc*.), if any.

i) Discuss the institutional aspect of LUs (e.g. (1) top down bureaucratically managed schemes fully administered by government or an agency of government; (2) jointly managed schemes on which some functions are performed by the irrigation development agency, while others are the function of project participants; (3) community schemes, usually small in size operated by water users themselves; (4) State or corporation financed schemes, such as sugar cane/timber, where farmers are selected and Government provides infrastructure to field edge; and (5) large estate schemes, State or privately financed, and then managed by agents producing high return cash crops).

j) For each land-use change strategy, "broadly" discuss the direct and future financial costs involved, including the initial outlay cost, the maintenance work, replacement of items that reach their design life, contractors, and other costs.
k) Discuss the impact of LUs on livelihood strategies using the following gender-disaggregated activities calendar.

l) Using the following matrix, discuss with farmers the relationship between the land-use change (due to climate change) and the achievement of their livelihoods objectives (livelihood outcomes such as more income generation, more employment opportunities, less vulnerability to climate change, environmental sustainability – external/ecological impact of livelihood activities; social sustainability – internal capacity to withstand outside pressures such as thefts, exclusions, etc) (C_1, C_2, etc). For each identified livelihood criteria, ask farmers to rank LUs from the most (1) to the least appealing LU (for those with equal rank, use equality sign after the rank, e.g. 3=).

Land-use / Criteria	LU_1	LU_2	LU_3	LU_4
Economical (productivity, land-use, efficiency *etc.*)				
C_1				
C_2				
Social (employments, networking, gender, conflicts, schooling, *etc.*)				
C_3				
C_4				
Environmental (Ecosystem goods and services)				
C_5				
C_6				

m) For each land-use that scores a rank greater than the mean rank, discuss with the group the effects/impacts in details.
n) Using an institutional diagram, assess the relationship between institutions that contribute to land use change in the area and rank them accordingly.
o) Discuss other major livelihood stresses and shocks experienced by local sugarcane/forestry growers.

****************THANK YOU****************

APPENDIX D. HOUSEHOLD SURVEY QUESTIONNAIRE

INFORMED CONSENT

This survey is part of a research project entitled "Livelihood Impacts of Climate-driven Land-use Changes: Cost-benefit Analysis for Small-scale Sugarcane and Forestry Production in KwaZulu-Natal". The project was commissioned by the Applied Centre of Climate and Earth Systems Sciences (ACCESS) of the National Research Foundation (NRF), and it is being implemented by the University of KwaZulu-Natal (UKZN). The project is led by Professor Edilegnaw Wale Zegeye (☏ +27332605410) and Professor Gerald Ortmann (☏ +27332605492) of the UKZN's School of Agricultural, Earth, and Environmental Sciences (SAEES), and the Research Fellow is Mr Patrick Hitayezu (☏ +27791197259).

The purpose of the research is to study the vulnerability of small-scale sugarcane and timber farmers to climate change and identify the most socioeconomically and environmentally appealing land-use adaptation strategies. The findings of this study will be widely disseminated to stakeholders (including farmers and their organizations, agricultural extension personnel, researchers, local government councils, tribal authorities, and other policymakers) through workshops and conferences.

Participation in this survey is absolutely voluntary, and the respondent is free to withdraw at any time without any undesirable or negative consequence to him/herself. Individual responses will be treated with maximum confidentiality. In this regard, the identity of the interviewee or his/her household will be coded during the analyses to preserve strict anonymity. If needed, additional information on sugarcane production will be obtained from the respective cooperative.

The interview will take approximately 2 hours.
Please express your full consent to participate in this survey by writing your name and singing below.

Mr/Ms…………………………………………… Signature: ……………………………………….
Tel:…………………………………..

SURVEY QUALITY CONTROL

Household/questionnaire number: (………..) …………	Cluster: …………..(1=Small scale grower; 2=new freeholder)	Respondent is the head of household (yes/no):
Date of interview: Duration of interview: min	Ward:……………….	Entered (yes/no):

A. LIVELIHOOD ASSETS AND STRATEGIES

A1. Household human capital

A1a. Size of the household (number of people who currently live in the household, sharing the facilities and foods)

In total	Male	Female	0-6 years old	7-15 years old	16-65 years old	Over 66 years old	Attend school	Regularly work on farm	Have non-farm jobs	Not employed	Disabled or permanently sick

A1b. Head of household and spouse

	Birth year	Gender	Highest education qualification (grade) achieved in the formal education system (for tertiary, add the years to grades)	Disabled or permanently sick	Years of experience with farming	Number of contact with extension workers in 2012
Head						
Spouse						

A2. Social capital

A2a. Relationship of trust and reciprocity in the community (household head)

Number of years living in the community?		Number of languages spoken?		Generally, are people in this community trustworthy?*		How many people in this community can you revert to in case of need?	

* 1= don't trust anyone, 2= the majority are not trustworthy, 3=the majority are trustworthy, 4=everyone is trustworthy

A2b. Formal group membership

Group	Are you a member of this group?		How many people are in this group?	Frequency of meeting attendance*	Average cash contribution in a year
	Head	Spouse			
Sugarcane farmers' group Specify:……………………………					
Other farmers' group Specify:……………………………					
Credit and savings group (stokvel)					
Religious group					
Local governance					
Traditional/tribal authority					
Community organizations (women, education, groups)					

*(0= never, 1=once in five years, 2=once in four years, 3=once in three years, 4=once in two years, 5=once a years, 6=twice a year, 7=thrice a year, 8=once a month, 9=twice a month, 10=once a week, 11= twice a week, 12= every weekday, 13=everyday)

A3. Natural Capital

A3a. Household's farmland utilization during the 2012 – 2013 season (NB: if one parcel has different crops, consider each crop as a separate plot)

Plot ID	Crops or plants currently grown on the plot*	Size (ha)	Walking (minutes) distance to nearest river/dam	Unmanaged ecosystem products and services*
	Seasonal/annual crops			
1.	Maize			
2.	Sorghum			
3.	Vegetables (cabbages, spinach, tomatoes, butternuts, pepper etc)			
4.	Beans			
5.	Cowpeas			
6.	Potatoes			
7.	Taro (*madumbe*)			
	Perennial crops			
8.	Sugarcane			
9.	Fruit trees (avocado, etc)			
10.	Plantation forest			
	Others			
11.	Uncultivated (under fallow or livestock)			

* 1= Edible wild crops/plants (infino/fruits/ insects), 2= Medicinal/cosmetic plants, 3= Hay/animal feeds, 4= Biomass energy (fuel wood, biogas, etc), 5=access to fresh water supply (spring, river, etc)

A3b. Current livestock

Type	Cattle	Donkey	Horse	Pigs	Goats/sheep	Chicken/ducks/turkeys
Current herd size						

A3c. Access to ecosystem goods and services

	River/dam	Natural forest				
Walking distance (in minutes) from the household to the nearest….						

A4. Physical capital

A4a. Farm assets

	Tractor	Harrow	Plough	Row marker/riggers	Boom sprayer	Peri-loader	Haulage crane	Cane/ combine harvester	Trailer
Number owned									
Current resale market value									

A4b. Farm equipment

	Hoes	Shovels	Pick s	Cane knives	Roguing hoes	Slash ers	Rakes	Siphon pipes	Knapsack	Cutting smocks	Gum boots
Number owned											
Current resale market value											

A4c. Basic household goods (not for income generation)

	Burnt brick houses	Cement block house	Clay bricks house	Mud /earth house	Thatched house	Vehicles	TV	Radio	Fridge	Cell phone	Computer	Electricity meter
Number owned												
Current resale market value												

A4d. Access to infrastructure

	Spazza shops	Tarred road	School	Health clinic	Water pipe	Electricity poles	Mobile phone network
Walking distance (in minutes) to the nearest							

A5. Financial capital

A5a. Sources of incomes and top five most important income utilizations (in 2012)

Source of income	Own farming activities	Salaried farming labour	non-farming wage work	Self-employment in non-farm activities	Remittances from family and friends	Social grant	Rented out properties
Total amount received/earned in 2012	R	R	R	R	R	R	R

A5b. Savings and credit (in 2012)

	Bank	Savings and credit societies (stokvel)	Other organizations (e.g. MAFISA)
Account balance in this financial institution	R	R	R
Total amount of other loan contracted from this source.	R	R	R

** 1= Farm asset (tractor, implement, equipment) purchase, 2=Sugarcane production (land prep, planting, harvest etc) activities, 3= Other crop production 4= children education, 5= Agricultural land purchase, 6=House/vehicle purchase, 7=Household consumer goods (refurbishing, house maintenance, etc), 8=Loan repurchase, 9= consumables (foodstuffs, clothes, etc), 10=other (specify)

A6. Psychological capital

B4. How important is the following values to you?

	very opposed to my values (1)	somehow opposed to my values (2)	Neutral/Not an important value (3)	Somewhat an important value (4)	Very an important value (5)
Egalitarianism					
Equal rights					
Equal wealth distribution					
Affirmative action					
Equal opportunities					
Individualism					
Moral worth of individual,					
Virtues of self-reliance,					
Value of personal independence,					
Precedence of individual interest over the social interests					
Hierarchism					

Authority of hierarchy					
Top-down management					
Patriarchy					
Technocracy					
Fatalism					
Powerlessness to influence the future due to uncertainty					
Lack of control over one's life					
Inevitability or predetermination of events					

B. LIVELIHOOD VULNERABILITY

B1. Do you believe that the following changes in local climatic patterns have been occurring over the last 30 years?

	0 (I don't believe so) to 8 (I strongly believe so).
Winter season getting abnormally colder	
Winter season getting abnormally warmer	
Winter season getting abnormally dryer	
Winter season getting abnormally wetter	
Summer season getting abnormally cooler	
Summer season getting abnormally hotter	
Summer season getting abnormally dryer	
Summer season getting abnormally wetter	

B2. In which years have you observed particularly abnormal rainfall patterns. (1)…….. (2) ……. (3)……… (4)……. (5)…… (6) …… (7)…… (8)……. (9)……. (10)……. (11)…….

B3. In general, do you believe that climate change, i.e. “abnormal” trends in the normal climate variability, is occurring?................ (0=No; 1=Yes).

B4. In general, what is your feeling about climate change:

	Very positive pleasant	Somewhat positive	Neutral	Somewhat negative	Very negative
To me, CC is something…					
	Very pleasant	Somewhat pleasant	Neutral	Somewhat unpleasant	Very unpleasant
I see CC as something…					
	Very favourable	Somewhat favourable	Neutral	Somewhat favourable	Very favourable
I feel that CC as something..					

B5. What do you think is the reason behind the change: ………………………………….. 1= Land use/land cover change, 2=Carbon emission, 3=Volcanoes, 4=God, 5=Other…………………… (specify))

B6. If no, explain the reason why you don't believe in climate change: ………………………………………………………………
……
…….

B7. Household food insecurity access:

Type	Yes/No	How often did this happen?*
In the past four weeks, did you worry that your household would not have enough food?		
In the past four weeks, were you or any household member not able to eat the kinds of foods you preferred (e.g. meat, fish, etc) because of a lack of resources (i.e. no means through either purchasing or growing it)?		
In the past four weeks, did you or any household member have to eat a limited variety of foods (e.g. putu and sugarwater – umbhubhudlo three times, leafy veges,) due to a lack of resources?		
In the past four weeks, did you or any household member have to eat some foods that you really did not		

want to eat (e.g. porridge without sugar, ichelane) because of a lack of resources to obtain other types of food?		
In the past four weeks, did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?		
In the past four weeks, did you or any other household member have to eat fewer meals in a day (normal is three meals a day) because there was not enough food?		
In the past four weeks, was there ever no food to eat of any kind in your household because of lack of resources to get food?		
In the past four weeks, did you or any household member go to sleep at night hungry because there was not enough food?		
In the past four weeks, did you or any household member go a whole day and night without eating anything because there was not enough food?		

* 1 = Rarely (once or twice in the past four weeks); 2 = Sometimes (three to ten times in the past four weeks); 3 = Often (more than ten times in the past four weeks)

C. LAND-BASED LIVELIHOOD OUTCOMES

C1. Based on your personal experience and information from 2011, how likely would each land use in the column increase the criteria in each row? *

Land-use: / Outcome:	annual crops cultivation	cultivation of annual crops and sugarcane	cultivation of annual crops and trees
Increase your farm income generation?			
Increase your crop productivity?			
Increase your food availability?			
Increase your family labour employment?			
Increase your soil loss mitigation?			

*Give any value in a scale of (1) extremely unlikely, (2) unlikely, (3) neutral/not sure (4) likely, (5) extremely likely.

C2. Mention any other information of interest:

************* **THANK YOU************