Climate change and wildlife utilization on private land: Evidence from wildlife ranching in South Africa

By

Jackson Ongong'a Otieno

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Supervisor:

Professor. Edwin Muchapondwa

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Declaration

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Abstract

This thesis focuses on the economics of climate change and wildlife utilization in privately owned parcels of land in South Africa. A significant proportion of agricultural land in the Southern Africa region has undergone transition with many farmers opting to move away from livestock farming to either wildlife farming, ranching or conservancies. In other instances, farmers in areas which were predominantly under irrigation are also switching to wildlife land use. One of the biggest claims to this transition has been the effects of climate change on livestock and crop production. The increasing cost of production associated with worsening climate continue to force farmers into abandoning livestock and crop production in favor of wildlife, which has been considered more profitable in the marginal areas in the southern Africa region. However, several uncertainties engulf wildlife utilization on private land, this may hinder its ability to bring about development that might improve the welfare of the communities and those individuals who directly participate in wildlife conservation in the private areas.

The most pressing issue in wildlife utilization on private land includes; i). Its effects on the welfare of the communities living around the wildlife farms, ranches or conservancies. The livelihood of these communities revolved around livestock and livestock production for employment, food provision and other socioeconomic and cultural provisions. Therefore, the transition from livestock to wildlife production inevitably can improve or worsen the living standards of these communities, ii). Sustainability of wildlife production as alternative land use in the face of prevailing and future climate scenarios. While it has been cited that wildlife and wildlife revenues are more resilient to climate change, there is every indication that climate change affects wildlife conservation, iii). The role of wildlife in climate change adaptation. Farmers in South Africa are known to mix wildlife with livestock as one way of adapting to climate change. Over time, such farms have transited into wildlife ranches. The issue therefore is how vulnerable are wildlife ranches compared to livestock and mixed wildlife-livestock ranches? These issues are explored in three substantive chapters included in this thesis. The thesis consists of five chapters starting with an introduction, followed by the three substantive chapters and finally conclusion and policy recommendations.

The second chapter of this thesis has evaluated the impact of private wildlife ranches on socioeconomic outcomes of communities living in the Eastern Cape Province of South Africa. Specifically, the chapter examines the contribution of private wildlife areas to the

changes in poverty levels within the communities around the ranches by considering its impact on three mechanisms; employment creation, infrastructure development and population dynamics. In order to achieve these objectives, the chapter used data on wildlife establishments in Eastern Cape Province, together with socioeconomic indicators derived from the three censuses of 1996, 2001 and 2011. A mechanism-based approach to impact evaluation is applied to estimate the causal mechanism effects of wildlife ranching on poverty. The average treatment effect on the treated and the mechanism average treatment effect on the treated are estimated. The results show that private wildlife ranches contributed approximately 2.7% to the proportion of poor people in Eastern Cape Province between 1996-2011. It turns out that the increase in the proportion of poor people was as a result of lost employment opportunities and displacement of people. The presence of ranches contributed 0.7 per cent to unemployment. Despite this, it also emerges that individuals in areas where wildlife ranches have been established have access to better infrastructure than those individuals in areas where no ranches have been established or those in areas where state protected conservation networks are established in the Eastern Cape Province. Establishment of wildlife ranches in these areas contributed 12.83% in improved access to infrastructure. The results of the net average treatment effect on the treated suggests that a lot of changes in areas where wildlife ranches are established do not seem to be attributed solely to the wildlife ranches, they would have happened anyway because of other factors. For example, most wildlife ranches are established in rural areas where the communities are generally poor and lack access to markets and infrastructure.

In comparing these results to poverty or welfare conditions in communities around protected area networks of national parks and reserves, the study found that poverty levels had gone down in communities around the state protected parks and reserves. The reduction in poverty was as a result of increased accessed to employment. However, the infrastructure conditions in communities around the state protected area networks had deteriorated over the same period. The chapter ends by looking at what would have happened in homeland areas of Eastern Cape Province had wildlife ranches been established in them. This is a counterfactual situation. The study postulates that had wildlife ranches been established in homeland areas, poverty level would have gone up in the homeland areas.

The third chapter examines the effects of climate change on wildlife utilization on private land. One of the reasons cited for land use change is that wildlife and wildlife revenues are

more resilient to climate change. However, in the state protected area networks, there is clear evidence that climate change is affecting wildlife. This chapter applies quantile regression by using the median Ricardian model to investigate the effects of climate change on wildlife revenues. The chapter further uses three Atmospheric-Oceanic Global Circulation models, which include the Coupled General Circulation Model, the Parallel Circulation Model and the Hadley Centre Coupled model that have been used to predict the impact of climate change for South African agriculture to estimate the future impact of climate change on wildlife revenues. The chapter finds evidence that temperature and precipitation have a large and significant effect on the net revenues of wildlife ranchers. There exists a non-linear relationship between wildlife revenues and temperature and precipitation. It emerges that summer temperature has a U-shape relationship with net revenues while the summer and winter precipitations have a hill-shaped relationship with net revenues. Across all the provinces in South Africa, wildlife ranches seem to generate the most revenues in summer. However, extended summer conditions and winter reduce the average farm income to about R494/ha. From the quantile regression, it can also be deduced that high value farms are affected differently by climate change when compared to low value ranches. For example at τ=0.25 and τ=0.75 winter precipitation is beneficial to both low value and high value ranches, but it is significantly more beneficial to ranches on the higher quantiles than those on lower quantile ranches. Finally, the study predicts that towards 2050, climate change could reduce net revenues of wildlife by up to 28 percent. In contrast, in the Northern Cape Province, the revenue per hectare could increase towards 2100. This could be due to differences in regional adaptation. Revenues of wildlife only ranches could be more affected in the long run when compared to revenues of ranches that practice mixed wildlife ranching.

The forth chapter examines the role of wildlife in adaptation. Most land currently under wildlife use was once used for crops or livestock, but South Africa has a long history with wildlife on private land. Legislation also recognizes wildlife ranching as an agricultural activity. However, studies have not included wildlife as an adaptation option especially in the marginal areas. The chapter applies both the probit and multinomial logit models to first evaluate the determinants of land use change in the marginal areas where wildlife and livestock ranching are predominantly practiced. Secondly, the chapter uses the multinomial choice model to evaluate the performance of conditional net revenue of the three types of farms in the marginal areas (wildlife, mixed and livestock farms) after correcting for selection bias using the Bourguignon, Fournier and Gurgand (2007) selection bias correction approach.

The study finds that biophysical, economic and social factors all influence the decision to change land use from livestock to wildlife. Specifically, areas receiving lower rains and characterized by poor soil conditions such as leptosols are more likely to be used for wildlife ranching. Farmers with large tracks of land are also likely to adopt wildlife utilization given their capital outlay. However, farmers who extract higher turnovers from their current livestock activities are less likely to move to wildlife ranching. Wildlife or mixed farms with larger turnovers are 2.067 odds of choosing mixed ranches when compared to livestock ranches. The study also finds that social networks play a significant role in influencing farmers' decision to change land use. Farmers who are in any association are more likely to change land use if others are changing. In terms of regional differences, farms that are located in the Free State and North West Provinces of South Africa are less likely to change land use when compared to farms located in Limpopo Province.

The results of the multinomial choice model indicate that mixed livestock-wildlife farms are less vulnerable to climate change when compared to specialized livestock or wildlife farms. However, net farm revenues per hectare are higher for specialized wildlife ranches when compared to mixed wildlife-livestock ranches or livestock ranches under similar climate conditions. The results further show that increase in temperature will influence most livestock farmers to change land use from livestock to wildlife ranching. Using climate models, it shows that there will be significant adjustments across farms, especially livestock farms. The probability of livestock ranches moving will increase substantially by up to 74 per cent in some cases. Furthermore, up to 18.5 per cent of current mixed ranches are likely to move to wildlife ranching. It is also noted that most land use change would be experienced in Eastern Cape Province which is also known to have the most livestock production activities.

This thesis set out to investigate wildlife use on private land, how it affects livelihood of people living around, how it is affected by climate change and what role it plays in adaptation. The thesis makes three main contributions to the body of literature. Firstly, it makes contribution to climate change and agriculture literature. Several studies have looked at the impact of climate change on agriculture especially in the southern Africa region. These studies have considered various adaptation options in agriculture, but so far the role of wildlife has not been explored. The current level of wildlife utilization has reached a critical mass and its omission in literature imply that the current estimates may have overestimated the effects of climate change given that more than 10,000 farmers in South Africa alone keep

wildlife. Secondly, the thesis makes contribution in the resource economics literature by examining the welfare implication of private wildlife areas on the communities. There exist qualitative narratives on the effects of private wildlife ranches on communities living around private wildlife areas. This study extends this literature by providing an in-depth empirical investigation into the welfare impact of wildlife ranches. Thirdly, the literature on climate change and wildlife conservation has focused on protected area networks especially the national parks and reserves. This thesis delves into the effects of climate change on wildlife in private land, an area that little research has been done particularly in southern Africa region.

Several policies implications can be drawn from this thesis. First, land transformation from livestock or crops to wildlife use has serious implications in terms of food security and poverty reduction. While promoting private wildlife utilization, there is need to design policies that ensure equitable distribution of wildlife resources in the private hands to the communities whose sources of livelihood may be affected by establishment of wildlife ranches. One such strategy would be to come up with benefit sharing modalities either through a social corporate responsibility framework or a social fund in which a share of annual revenues from wildlife ranches is deposited and utilized to improve on communities' social and economic facilities. There is also need to critically evaluate the extent to which growth in wildlife affects food security. Policy can be designed to provide for both food security and wildlife conservation either through land sparing or land sharing.

A second policy implication is on wildlife conservation and climate change. In many instances, wildlife has been considered resilient and tolerant to harsh weather conditions. This assumption has been overtaken by current realities. Studies have shown that several species of wildlife are in danger of extinction due to climate change. There is need for policy reforms that target mitigation and adaptation options in wildlife conservation, both in private land and the state protected areas. Since there are both small scale and large scale farmers, such policies should be configured to provide the maximum benefits to farmers who are most affected.

In a climate impacted environment, making wildlife to pay will be too expensive for small scale farmers due to the capital outlay required. In this thesis, it has been established that revenues of mixed ranches are less vulnerable to climate change when compared to wildlife only ranches or livestock ranches. A middle ground for small scale farmers would be to have

policies that encourage mixed ranching rather than to pursue wildlife only ranching. Since wildlife on private land directly compete with other land uses, it is important that agricultural policies are seen to actually support wildlife production and not conflict with existing policies governing the sector.

Land reforms in South Africa is a topical issue given the apartheid legacy. Wildlife utilization on private land is hotly debated because in the eyes of many people, wildlife ranching has been used by the formally white farmers to slow down or stop the process of land restitution and land reforms. For this reason, many white farmers are thought to change land from livestock to wildlife for the reasons of holding on to the land. It is however important that a clear distinction is made and stakeholders sensitized on the need to promote wildlife utilization on private land as outlined in such important policy documents like the Intergovernmental Panel on Climate Change Assessment Reports as one way of promoting wildlife conservation. There is need to provide communities and the general public with information on the important role the private sector plays in wildlife conservation. One strategy would be to provide incentives that can encourage more communities to directly participate in community-led wildlife conservation within the framework of private sector.

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Dedication

I dedicate this work to my wife Lucy Wanyama, sons Ryan Mumbo, Riddel Amimo, Robin Kerry and Dwayne Nyamkore and to my late brother Josiah Otieno.

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List of Acronyms and Abbreviations

ABSA	Amalgamated Banks of South Africa
AERC	African Economic Research Consortium
ANOVA	Analysis of Variance
AOGCM	Atmospheric-Oceanic Global Circulation
AR5	Fifth Assessment Report
ATT	Average Treatment Effect on the Treated
BMR	Bureau of Market Research
CBNRM	Community-based Natural Resource Management
CHASA	Confederation of Hunters Association of South Africa
CGCM	Coupled General Circulation Model
CDF	Cumulative distribution frequency
CGE	Computable General Equilibrium
CPI	Consumer Price Index
CSIR	Council for Scientific and Industrial Research
CSIRO2	Commonwealth Scientific and Industrial Research Organization
CSR	Corporate Social Responsibility
DAFF	Department of Agriculture, Forestry and Fisheries
DEAT	Department of Environmental Affairs and Tourism
EfD	Environment for Development
EPRU	Environmental Policy Research Unit
ERSA	Economic Research Southern Africa
FAO	Food and Agriculture Organization

GCM	General Circulation Model
GIS	Geographical Information system
GLTFCA	Great Limpopo Trans frontier Conservation Area
HadCM	Hadley Center Coupled Model
IIA	Independence of Irrelevant Alternatives
IPCC	Intergovernmental Panel on Climate change
IUCN	International Union for Conservation of Nature
LSU	Large Stock Unit
MATT	Mechanism Treatment Effect on the treated
Mm	Millimeter
NAMC	National Agricultural Marketing Council
NATT	Net average treatment effect on the treated
OLS	Ordinary Least Squares
PCM	Parallel Circulation Model
PHASA	Professional Hunters Associations of South Africa
PPAs	Public protected areas
PSM	Propensity Score Matching
SAL	Small Areas Layers
SD	Standard Deviation
Stats SA	Statistics South Africa
UCT	University of Cape Town
WRSA	Wildlife Ranching South Africa
^{0}C	Degree Celsius

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CHAPTER ONE: INTRODUCTION

1.1 Background

In South Africa, wildlife ranching[1] has been part of the agriculture sector since the 1960s, although for a long time only a small number of landowners used wildlife on commercial basis (Carruthers, 2008a; Taylor et al., 2015). It was not until 1987 that wildlife ranching officially became a fully-fledged agricultural activity in South Africa and in 1996, the Marketing of Agricultural Product Act 47 of 1996 allowed for game to be considered as an agricultural product in South Africa (NAMC, 2006). Currently, it is estimated that South Africa has over 10,000 wildlife ranches (Cousins, Sadler & Evans, 2008; Child et al., 2012; Taylor et al., 2015). This includes the extensive wildlife ranches and the game farms[2]. Literature on the current state of wildlife ranching in South Africa notes that up to 20.5 million hectares of land equivalent to an area of 170,000km^2 is under wildlife use (Dry, 2010; Taylor et al., 2015). Across South Africa, 50 per cent of the wildlife ranches are located in the Limpopo Province, 19.5 per cent are in the Northern Cape Province while 12.3 per cent are in the Eastern Cape Province. The remaining ranches are spread across the remaining provinces. It is also estimated that wildlife ranching contributes R7.7 billion directly to the economy and is ranked sixth in the agricultural sector (Dry, 2010).

Despite over 25 years of experience with wildlife as an agricultural activity in South Africa, wildlife utilization on private land continues to be treated in isolation of crops, livestock or other subsectors of agriculture. The contribution of agriculture towards growth and development is made with reference to crops or livestock, but not wildlife. The threats to agriculture is also tied to other subsectors, but not wildlife. It is for this reasons that studies in the sector continue to look at wildlife and agriculture as two distinct and mutually exclusive

[1] Wildlife ranching involves scientific management of certain species of wild animals in their natural habitat without an effort to domesticate them (Meine, 2010). Animals are not provided with supplementary food or veterinary care, except during severe drought or under extraordinary conditions. Population are expected to survive with little or no food subsidy (Taylor et al., 2015). According to Garnett, Sayer and Du Toit, (2007), wildlife ranching can also be defined as a large privately owned or communal area, either fenced or unfenced that is extensively managed in order to utilize wildlife product through hunting, sales, tourism or other indirect use generally of ungulate species.

[2] Game farm generally refers to small properties (<5000ha) where some form of constant management is necessary and implies a relatively high degree of control over animals. Extensive wildlife ranching includes conservancies.

land uses. It is therefore not clear what contribution wildlife ranching makes to welfare development or how threats and uncertainty such as climate change affects the growth of wildlife ranching sector.

The growth of wildlife ranching in South Africa has actually arisen from the opportunities created by recurrent droughts affecting crops and livestock farmers (ABSA, 2003; Carruthers, 2008b). Farmers have increasingly preferred wildlife land use to livestock in the marginal areas. The transfer of land from the traditional production and domestic stock to a more nature based wildlife pursuit is likely to accelerate with climate change and political uncertainty around land issues in South Africa (Van der Merwe, Saayman & Krugell, 2004). But since there is a disjoint between agriculture and wildlife, this will have an effect on the overall contribution of agriculture to food security, employment and the general welfare development of the communities whose lives are based on agricultural production. It also raises the question about the potential contribution of wildlife ranching and how this contribution will be affected by such threats as climate change as land use incentives in wildlife diminishes.

In recent times, the contribution of wildlife ranching to socioeconomic and conservation outcomes has come under scrutiny from the fields of anthropology, sociology, ecology and political history (Chaminuka, McCrindle & Udo, 2012; Spierenburg & Brooks, 2014; Zulu, 2015). However, such scrutiny has not been witnessed in the field of economics even though a few studies have used integrated approach to evaluate the contribution of wildlife to economic and biodiversity conservation (Shogren, Parkhurst & Settle, 2003; Langholz & Kerley, 2006; Child et al., 2012; Lindsey et al., 2013). The growing literature on wildlife utilization is highly polarized. Like in cases involving protected area networks and community based natural resource conservation schemes, the contribution of wildlife ranching to the welfare of rural communities is vigorously debated (Smith & Wilson, 2002; Langholz & Kerley, 2006; Dry, 2010; Brooks et al., 2011; Chaminuka et al., 2014; Taylor et al., 2015), but unlike such cases, empirical evidence is either weak or lacking.

The link between agriculture, wildlife use on private land and climate threat is a topical issue worth investigating from a developmental and conservation point of view. A majority of sub-Saharan Africa's population live in rural areas where poverty and deprivation are most severe. Almost all these rural households depend directly or indirectly on agriculture, and given the sector's large contribution to the overall economy, it might seem obvious that

agriculture should be a key sector in development. Wildlife land use in Southern and Eastern African regions is rapidly growing and in the process displacing the traditional land uses in these areas especially in the rural areas. This brings a new perspective to rural livelihood given that currently climate change has become the greatest threat to agriculture with limited adaptation options. The hypothesis therefore is that the growth of wildlife land use and its effects on livelihoods is likely to differ from the contribution of livestock to the communities. While the current climate conditions continue to be unfavorable for agriculture, whether or not it is favorable for wildlife land use cannot be said without investigation.

This thesis is motivated by the realization that very few studies have made any attempts to highlight the contribution of private sector led wildlife utilization and how this contribution relates to welfare improvement. Ecosystem services are important to the lives of rural communities and some have proposed that there may be a strong link between ecosystem services and sustainable development (Flores & Flores-Lagunes, 2009). The UN General Assembly in 2010 unanimously adopted a resolution stressing that "ecotourism can, within the framework of sustainable tourism, contribute to the fight against poverty, the protection of the environment and the promotion of sustainable development[3]" (UN, 2011). This makes the case for wildlife ranching very important because one of the key activities in wildlife ranching is ecotourism. The three key issues in wildlife use on private land are its contribution to development and welfare improvement; its role in climate change adaptation and the effects of climate change on the sector. These issues require further analysis which can subsequently lead to stronger evidence to influence policy direction.

Since wildlife ranches are established in rural communities where poor households reside, their effects on poverty and their interaction with other livelihood activities within these communities, such as crops and livestock farming are subjects of concern and debate. So far, a majority of the integrated economic studies that have looked at the contribution of wildlife ranching have either focused on its contribution to GDP through tourism revenues or its contribution to the agriculture sector (ABSA, 2003; Dry, 2010). Other studies have made a comparison between the contribution of wildlife ranching to those of livestock in terms of revenue generation by the two sectors (Dry, 2010; Child et al., 2012). A closely related set of studies have looked at the contribution of wildlife ranching to the welfare of those directly employed or involved in its production (Smith & Wilson, 2002; Langholz & Kerley, 2006;

[3] http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/65/173. Accessed on 21/04/2016

Dry, 2010; Child et al., 2012; Taylor et al., 2015). We are only aware of Zulu (2015) and Spierenburg and Brooks (2014) who have made attempts to shed light on the contribution of wildlife ranching to the welfare of the communities. These studies are qualitative in nature and cannot be subjected to any statistical significance. Furthermore, they do not measure what benefits or losses the communities have incurred as a result of the establishment of the wildlife ranches.

Since there is an almost exponential growth in wildlife use on private land, the first issue therefore is to evaluate the impact of private wildlife ranches on local communities' welfare in South Africa. The actions of local communities influence the success or failure of biodiversity initiatives for many reasons. One major reason is that local communities own land around wildlife ranches and continuously interact with the private wildlife ranches as they work for their livelihood. The existence of pervasive incentives as a result of creation of wildlife ranches could discourage communities from playing a positive role in complementing such conservation efforts. The growth of wildlife ranches may also create an environment where communities sell off their land which could lead to further welfare loss. The success of wildlife ranching therefore hinges on how best the communities benefit from ranching not just those individual directly involved. Child et al., (2012) notes that if landowners and communities can be placed at the junction of benefit and management, wildlife resources can pay for themselves and simultaneously address rural poverty and environmental injustices.

The growth of wildlife ranching is inadvertently attributed to declining productivity of livestock production, with climate change cited as playing a big role in the decline in agriculture and upsurge in wildlife utilization in areas originally used for livestock production (Child et al., 2012). Africa is one of the most vulnerable continents to climate change and climate variability. This situation is aggravated by the interaction of multiple stresses such as endemic poverty, complex governance dimensions and ecosystem degradation occurring at various levels in different countries (Boko et al., 2008). Crops and livestock are known to optimize yield at a particular temperature, soil condition and humidity setting (Morison, 1996). The agricultural sector is a critical mainstay of local livelihoods and national GDP in many countries in Africa. In order to respond to the changing climate, farmers have developed several mitigation and adaptation strategies to cope with current vulnerabilities, but scientific evidence suggests that such adaptations may not be sufficient for future changes

in climate. Currently, climate models predict up to 50 per cent decline in agricultural yield by 2020 and crop net revenues could fall by as much as 90 per cent by 2100 with small farmers being the most affected (Boko et al., 2008).

The biggest threat to agriculture and by extension rural livelihood is climate change. It is generally assumed that wildlife could perform better than crops or livestock in the marginal areas, but this is without evidence. The second issue this thesis sets out to investigate is the effects of climate change on wildlife ranching. Though a number of studies have looked at the effect of climate change on agriculture, little is known of the impact climate change has on the revenues of wildlife ranchers or the role of wildlife in climate change and adaptation. Wildlife is considered more resilient to prevailing climate, but an assessment of sensitivity of African mammals in 141 national parks in Africa using climate change model (SRES A2 and B2 emission scenarios with HadCM3 GCM for 2050 and 2080) found that 10-15% of species are projected to fall within the International Union for Conservation of Nature (IUCN) Critically Endangered or Extinct categories by 2050 increasing to 25-40% by 2080 (Thuiller et al., 2006). In South Africa, Erasmus et al., (2002) found that up to 66% of the 179 species of wildlife in their study of Kruger National park would be lost to climate change. In particular, what is of concern is that only few adaptation options exist in wildlife utilization (IPCC, 2013). On the backdrop of this, it is therefore important to understand how climate change affects the revenues of ranchers who opt to use their land for wildlife ranching. Moving from livestock to wildlife may turn out to greatly affect communities and those directly depending on wildlife if the subsector is affected by climate change, yet mitigation and adaptation policies are either weak or missing. If climate change compromises the viability of wildlife ranching, this is likely to have a knock-on effect on other sectors that relate with wildlife for example agriculture. Consequently, welfare of those directly involved and the community are likely to get worse.

Climate change will become one of the major drivers of extinction in the 21st century (IUCN, 2008)[4]. Climate change is also predicted to have harmful impact on the agriculture sector (Mendelsohn, Nordhaus & Shaw, 1994). The agricultural sector is a critical mainstay of local livelihoods and national GDP in many countries in Africa (Mendelsohn et al., 2000a, b; Devereux and Maxwell, 2001). The contribution of agriculture to GDP varies across

[4]https://cmsdata.iucn.org/downloads/species_susceptibility_to_climate_change_impacts_factsheet_en.pdf accessed on 15/05/2016

countries but assessments suggest an average contribution of 21% (ranging from 10 to 70%) of GDP (Mendelsohn et al., 2000b). According to Mendelsohn et al., (2000a, b) and Biggs et al., (2004), agriculture sector is likely to experience periods of prolonged droughts and /or floods during El-Nino events. It is therefore expected that agriculture losses of between 2-7% of GDP will be realized by 2100 in parts of the Sahara, 2-4% & 0.4-1.3% in Western and Central Africa and Northern and Southern Africa respectively. Arid and semi-arid land could expand in coverage by 60-80 Million ha (Boko et al., 2008). The productivity of the sector in Africa will be further undermined by a reduction in fertile agricultural land available and an expansion in the coverage of low potential land. In many parts of Africa, farmers and pastoralists also have to contend with other extreme natural resource challenges and constraints such as poor soil fertility, pests, crop diseases, and a lack of access to inputs and improved seeds.

Climate change, interacting with human drivers such as deforestation and forest fires, are also a threat to Africa's forest ecosystems. Changes in grasslands and marine ecosystems are also noticeable. It is estimated that, by the 2080s, the proportion of arid and semi-arid lands in Africa is likely to increase by 5-8% (IPCC, 2007). Climate change impacts on Africa's ecosystems will probably have a negative effect on tourism as, according to one study, between 25 and 40% of mammal species in national parks in sub-Saharan Africa will become endangered (Boko et al., 2007). In South Africa, with a +2.5 per cent increase in warming over the current climate, areas suitable for beef cattle in the south-eastern part of the country will reduce dramatically; and a +5 per cent warming could result in beef cattle disappearing almost entirely in Africa (Seo & Mendelsohn, 2007). Current statistics on commercial farms in South Africa show that crop and livestock farms have declined in numbers by about 31 per cent between 1993 and 2007 (own calculation from Stats SA reports)[5]. The rate at which livestock, crops, habitat and species are lost due to climate change is increasing. This confirms the need to explore alternative adaptation options in agricultural production and wildlife conservation especially in the marginal areas.

[5] It is estimated that the number of farms declined further to 50 per cent by 2010 there by reaching 37,000 farm units (Dry, 2011)

http://www.sawma.co.za/images/Dry_Gert_Commercial_wildlife_ranching's_contribution_to_a_reseource_efficient_low_carbon_pro-employment_green_economy.pdf

The third issue which we investigated in this thesis is the role of wildlife ranching in adaptation especially in agriculture sector. The current debate on agriculture has downplayed the role of wildlife ranching in adaptation. Adaptation to climate change in agriculture is known to include irrigation (Bryant et al., 2000), planting of drought resistant crop varieties (Bryan et al., 2009), use of modern technology (Maddison, 2007) and in livestock production, farmers have changed land use from bigger animals to smaller animals or breeding drought tolerant livestock varieties such as the Boran[6] cattle. There are also farmers who have switched from crop production to livestock production (Ickowicz et al., 2012; Rust & Rust, 2013) and from crop or livestock to either wildlife or mixed ranching (Child et al., 2012). Even though farmers have changed land use from crops or livestock to wildlife use or mixed-livestock-wildlife, the role of wildlife as an adaption option has not been considered in the literature. Therefore, it is not known how the revenues of farmers who either switch to wildlife or adapt integrated wildlife ranches behave when compared to livestock ranches. In policy circles, little attention has been given to the role of wildlife ranching as an adaption option.

1.2 Research objectives

The goal of this study is to investigate the role of wildlife use on private land[7] in agriculture and rural development given the current climatic conditions. It is believed that in order to harness the benefits of wildlife ranching, landowners need to understand its ability to withstand the prevailing and future climate. However, to effectively bring on board communities, governments and conservation agents need to quantify its contribution to community development. Hence, the specific objectives of this research are,

1. To evaluate the impact of private wildlife ranches to human and social welfare outcomes in South Africa;
2. To undertake an economic analysis of the impact of climate change on wildlife utilization on private land in South Africa;
3. To investigate the role of wildlife ranching in climate change adaptation in the agricultural sector.

[6] http://landbou.com/boereblogs/boran-indigenous-african-cattle-with-potential/ accessed on 5th May 2016.

[7] In this thesis, wildlife ranching, private sector led wildlife utilization and wildlife utilization on private land have been used interchangeably to represent wildlife that is in the private hands and not the state.

1.3 Research hypotheses

The overall hypothesis of this study is that wildlife ranching plays an important role in wildlife conservation, welfare development and climate change adaptation. The following specific hypotheses were addressed by the thesis;

1. H_o: the impact of private wildlife ranches on the welfare of local communities does not differ from the impact of state owned protected areas on the welfare of local communities in Eastern Cape province.
2. H_o: the effects of climate change on wildlife in private wildlife ranches is the same as the effects of climate change on livestock in the marginal areas.
3. H_o: the role of wildlife in climate change adaptation especially on privately-owned land is not different from the role of livestock in adaptation in the marginal region.

1.4 Contribution of the study

This thesis makes key contributions in three specific areas in the literature. Firstly, the study makes contribution to agriculture and climate change literature. Previous studies on the effects of climate change on agriculture have delved more on crops, livestock and other subsectors(Seo & Mendelsohn, 2007; Mendelsohn, Nordhaus & Shaw, 1994; Seo, S.N. 2010a). This studies have however not looked at the effects of climate change on wildlife or the role of wildlife as one of the subsectors in agriculture. The results of various Ricardian and Structural Ricardian models besides other integrated models especially in Southern Africa region did not consider wildlife ranching even though it comprises more than 10,000 farmers most of who had move from livestock or crop farming. The estimates generated by these models may have underestimated or overestimated the effects of climate change. If for example a farmer had both wildlife and livestock or crops, it meant that the only activities captured by earlier studies was livestock or crops and not wildlife. Therefore, policies that have been formulated on this basis may not necessarily address the needs of such farmers who had wildlife. Furthermore, exclusion of wildlife from these studies could impair the growth of the sector due to conflicting policies or lack of policies to facilitate growth in wildlife.

This thesis makes the second contribution in the areas of economics of climate change and wildlife use outside the protected area networks. Previous studies have looked at the effects of climate change on wildlife within the state protected areas (Thuiller et al., 2006; Erasmus

et al., 2002). The limitation in the application of the findings of these studies is that state protected areas are largely driven by conservation outcomes. Climate change mitigation and adaptation strategies applicable in these scenarios are focused on conservation of biodiversity. Wildlife ranching in private land is undertaken both for conservation and profit motives. The landowner is interested in putting the land to a use that generates the greatest returns. The study therefore makes contribution by looking at the effects of climate change on wildlife in the private areas where there is considerably high level of intervention as farmers pursue higher profits.

Finally, the study makes contribution to the resource economics literature by examining the effects of wildlife income (especially in the private areas) on household welfare, by operationalizing the causal inference mechanism approach to impact evaluation developed by Ferraro and Hanauer (2014a). Causal inference-based research is a growing field in environmental and natural resource economics which is being wildly used to evaluate the impact of conservation areas on welfare (Ferraro and Hanauer, 2014; Flores & Flores-Lagunes, 2009). This is probably the first application of causal inference methodology in evaluating the impact of private sector conservation areas.

From a policy perspective, this thesis shed light on gaps that have arisen in mitigation and adaptation measures as well as human-wildlife systems. It also provides result comparable to other studies on state protected areas and the community based wildlife conservation areas. Furthermore, the findings of this study will allow policy makers to interrogate their policies and strategies while at the same time identifying areas that need to be improved on.

1.5 The structure of the thesis

The outline of the thesis is as follows; Chapter one presents the introduction of the study and sets the tone on the areas of focus and the research objectives. The research issues are thereafter dealt with in the three subsequent chapters. The first objective is presented in Chapter two. Chapter two looks at the causal mechanism effects of wildlife ranching on the welfare outcomes in communities around wildlife ranches in the Eastern Cape Province in South Africa. Evaluating the impact of wildlife ranching sets the right foundation for the study because it helps establish how important wildlife ranches are to socioeconomic development and biodiversity conservation. The chapter also fleshes out how wildlife ranching affects various mechanisms such as infrastructure development, employment creation and displacement of people from the community which could exacerbated or reduce

poverty.

Chapter three delves in the performance of agriculture sector under the prevailing and projected climatic conditions. The chapter takes cognizance of research efforts in crop and livestock farming, but goes on to evaluate the impact of climate change on wildlife ranching, a key subsector under agriculture. It investigates whether wildlife ranches are affected by the current climate and to what extent these effects are felt by large and small scale wildlife ranchers. We apply econometric techniques used in studies that have evaluated the effects of climate change on other agriculture sub-sectors especially the modified median Ricardian approach. The chapter ends with a simulation of the impact of climate change using various climate models.

Chapter four, builds onto the previous chapter's conceptual framework. The role of wildlife ranching is discussed in climate change and adaptation. Wildlife ranching is considered as one of the adaptation options just like the case of irrigation or use of different varieties of livestock to adapt to climate change. In the first part of the chapter, the determinants of land use change and how they influence land use conversion in wildlife-livestock nexus is evaluated. Part two of this chapter gives an in depth analysis of the performance of farms with wildlife ranches when compared to those farms with livestock or the mixed ranches[8].

Chapter five concludes the study with a summary of the findings and the modeling techniques. It also highlights challenges encountered and the limitations of the study. Furthermore, it considers important policy implications from the study as well as areas for further research.

1.6 Data

In this thesis, various datasets have been used. Data on commercial wildlife ranching comes from the last census of commercial agriculture for South Africa conducted in 2007 (Stats SA, 2010). The dataset provides statistics on employment, production, finance and general information with regards to active commercial farming enterprises in South Africa. The dataset is obtained from Statistics South Africa. Data on livestock and wildlife or mixed farms from six of the nine provinces was used in chapter three and four of the thesis.

[8] A property that ranches wildlife alongside domestic livestock (Taylor et al., 2015).

In chapter two, the dataset of private wildlife ranches in Eastern Cape Province of South Africa comes from Smith and Wilson (2002). The dataset was collect between August 2001 and January 2002. The details of the dataset are provided in the section of data for each specific chapter. Data on climate and soil variables are publicly available from the links provided in the various sections on data for each of the chapters.

CHAPTER TWO

EVALUATING THE IMPACT OF PRIVATE WILDLIFE RANCHES ON SOCIOECONOMIC OUTCOMES IN THE EASTERN CAPE PROVINCE OF SOUTH AFRICA

Abstract

Whether private wildlife conservation areas benefit or impose costs on the local communities and farm dwellers depends upon the underlying relationship between poverty in the local communities and private wildlife areas. While the recent boom in privately owned wildlife areas in South Africa has the potential to contribute to conservation, their sustainability hinges on how well private wildlife areas benefit communities. This chapter explores the impact of wildlife ranching to community welfare using Eastern Cape Province in South Africa as a case study. Using data on wildlife establishments in Eastern Cape Province, together with socioeconomic indicators derived from the three censuses of 1996, 2001 and 2011, a mechanism-based approach to impact evaluation is applied to estimate the causal mechanism effects of wildlife ranching on poverty. This involves use of propensity score matching to match control units to treated units. This is followed by regression adjustment to impute outcomes for treated units had treatment not affected mechanisms. The study finds that private wildlife ranches have contributed approximately 2.7% to the proportion of poor people in Eastern Cape Province. The increase in poverty is attribute to loss in employment opportunities and displacement of people. Despite this, it emerges that individuals in areas where ranches have been established have access to better infrastructure than those individuals in areas where no ranches have been established or those in census zones around the state protected area networks in the Eastern Cape Province. The overall policy implication associated with accelerated transition from livestock land use to wildlife will be on food security, land reforms and poverty reduction initiatives. While promoting private wildlife utilization, there is need to design policies that ensure equitable distribution of wildlife resources in the private hands to the communities whose sources of livelihood may be affected through the establishment of wildlife ranches.

2.1 Introduction

The Convention on Biological Diversity (the Aichi targets[9]) clearly points out to the need to increase to 17% the terrestrial and inland water areas conservation by 2020[10]. Several other studies and reports have also raised the need for more land to conserve biological diversity. But given the constraint on the amount of state land to meet this target, a significant fraction will have to come from privately owned land (Von Maltitz et al., 2006). However, one of the contentious issues about the expansion of protected areas has always been how they affect human welfare (Brockington, et al., 2006). Private wildlife areas can increase the supply and reduce pressure on wildlife species threatened by poaching and habitat transformation (Biggs et al., 2013; Challender, Harrop & MacMillan, 2015). This can result into greater biodiversity conservation[11] and economic outcomes. Unlike conventional strategies which focus on regulation and enforcement (for example wildlife conservation within the state-protected areas and trade bans), private wildlife ranching encourages landowners to conserve wildlife through sustainable use (Challender, Harrop & MacMillan, 2015). However, the long-term sustainability of this approach is dependent on how well local communities around private wildlife areas benefit, not just the direct beneficiaries. For example, if local poverty around private protected areas worsen, it could increase poaching pressure (Milner-Gulland & Leader-Williams, 1992). It could also antagonize efforts to promote wildlife utilization in areas outside the protected networks especially private land.

It is therefore important to critically evaluate the contribution of private wildlife areas to social welfare and economic outcomes. It is still not clear how the economic and social welfare of poor rural households who live around wildlife ranches have been affected by the

[9] Target 11: By 2020, at least 17 per cent of terrestrial and inland water, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes.

Target 14: By 2020, ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable.

[10] https://www.cbd.int/sp/targets/ accessed on 06/06/2016.

[11] Currently a quarter of the world's remaining rhino population is located in private wildlife areas in South Africa (Emslie, et al., 2012).

establishment of the ranches. The current debate over the contribution of wildlife ranches to social welfare is polarized. However, given that more agricultural land is being turned into wildlife ranches especially in the marginal areas, the main question that should be asked is what local residents lose and what new opportunities compensate for these losses especially where wildlife has replaced alternative livelihood opportunities (Spierenburg & Brooks, 2014). This chapter argues that wildlife ranching will play an important role as farmers strive to balance economic objectives with conservation outcomes, but how the gains trickle down to the communities will significantly influence how wildlife ranching is perceived.

The objective of this chapter is to evaluate the impact of wildlife ranches on socioeconomic welfare outcomes of the community living around wildlife ranches using the Eastern Cape Province of South Africa as a case study. This subject matter is important as little is known about the effects of private wildlife areas on socioeconomic outcomes especially poverty levels (Ferraro & Hanauer, 2014a). At least there is no known empirical evidence to support the hypothesis of social contribution of private wildlife areas. The study sought to shed light on whether the growth of wildlife ranches was socially optimal given that most communities in Eastern Cape province were experiencing the surge in wildlife ranching. The different channels through which wildlife ranching affects livelihood needs to be investigated in order to inform rural development.

In this study, the channels through which wildlife ranches could contribute to poverty reduction included improve access to good services (infrastructure), employment opportunities and migration or displacement. In the language of Ferraro and Hanauer (2014a), the channels have been referred to as 'mechanisms'. In order to establish a basis for comparison, the study uses data on communities living around the state protected areas to also look at the impact of state protected areas on the welfare of the community. In terms of impact evaluation strategy, this study relates to and follows the methodological approach on causal mechanisms of protected areas (Ferraro & Hanauer, 2014b). The unique dataset used in this study allows for a concurrent comparison between the welfare of households in areas where wildlife ranches have been established to the welfare of counterfactual households where wildlife ranches had never been established over the period 1996-2011.

This study is important because poor rural communities are known to have troubled relationship with conservation groups where wildlife is involved whether in areas where state

protected zones are located or where community based natural resource management areas (CBNRM) are involved (Brockington et al., 2006). Social advocates contest establishment and management of protected areas because they consider them taking away the property and rights of usage of the communities which affects their current and future welfare (Colchester, 2004; Wilkie et al., 2006). In earlier cases involving state managed parks and reserves, the advocates also state that even if they do generate economic values, the distribution of their benefits is skewed against the poor rural people (McShane, 2003).

Similar views are already permeating the discourse of wildlife ranching as alternative land use. Private wildlife ranching is seen as an enterprise for the rich white landowners in South Africa with no benefits to the communities within the vicinity of these ranches (Brooks et al., 2011). Brooks et al., (2011) note that establishment of private wildlife ranches could have inadvertently lead to displacement of communities and farm workers in areas where they have been established since a key feature of the generic wilderness landscape is that it must have on it as little evidence as possible of human beings.

Those who see wildlife ranching as a positive direction towards conservation and better land use in the marginal areas believe that it has made important contribution to conservation and welfare development through employment creation and infrastructure development which have contributed to poverty reduction (Mitchell, 2006). In addition, wildlife ranches stood a better chance to contributed immensely to conservation of wildlife given challenges faced by public protected areas (Krug, 2001; Langholz & Lassoie, 2001; De Alessi, 2005). Others note that though there is a strong case for the positive contribution of private wildlife ranches, it is more difficult to draw a conclusion to its contribution to the ecological processes (Sims-Castley et al., 2005). According to Lindsey et al., (2013), in Namibia, wildlife land use occurred in over 287,000 km^2. Employment was positively related to income from ecotourism and negatively related to income from livestock. While 87% of meat from livestock is exported, more than 95% of venison from wildlife land use remains in the country, contributing to food security. The uptake of wildlife farming by younger farmers is also increasing with increase in revenues from tourism.

As the debated goes on, there is little empirical[12] evidence to substantiate the contention that

[12] The closest impact evaluation study although not empirically grounded is one by Spierenburg and Brooks (2014) who draw from their background in social anthropology, geography and history of wildlife utilization to

private protected areas are good or bad for the community's social welfare and economic outcomes in South Africa or globally as far as we know. It is also not possible to make conclusions about the channel or mechanisms through which one can say that wildlife ranches have contributed to welfare or environmental conservation gains or loss. While wildlife ranching may have made contribution to economic development as outlined in the literature, it would be harder to attribute welfare changes in the communities to only wildlife ranches and not other exogenous factors. The status of people around the ranches may simply reflect the fact that ranches are often established in marginal areas where resources are less abundant or productive and where households have little access to markets and social services (Ferraro, 2013).

The remainder of this chapter is organized as follows. In section 2.2, a literature review is done with a focus on wildlife ranching and community welfare together with literature on mechanism-based explanation of the impact of wildlife ranching. In section 2.3, the methodology used is outlined followed by a detailed description of the data used. Section 2.4 presents the result and discussions. Finally, a brief conclusion of the study is made in section 2.5.

address various aspects associated with land use change. These range from labor-relations and employment opportunities to impact on land based livelihood strategies and tenure security.

2.2 Literature review

2.2.1 Introduction

In South Africa, wildlife ranching has received attention from different groups working in the sector (ABSA, 2003; Dry, 2010). There exists a general consensus that indeed wildlife ranching is playing an important role in conservation and economic development (Cousins, Sadler & Evans, 2010; Dry, 2010; Child et al., 2012). Some of the specific contributions attributed to wildlife ranching are employment creations and income generation. For example, a typical commercial game ranch generates approximately R220/ha of economic output compared to R80/ha for conventional livestock farm (ABSA, 2003; Dry, 2010). Wildlife ranching has also transformed more than 20 million hectares of marginal land into thriving land use. These contributions besides others are considered welfare changing with far reaching multiplier effects.

South Africa is one of the best known examples of wildlife ranching on private land (Cousins, et al., 2008). About a quarter of the world's remaining rhino population is located in South African private protected areas (Emslie et al., 2012). These development in South Africa have been attributed to changing laws about farm labor minimum-wages and tenure rights, withdrawal of generous agricultural subsidies, reduced protection from international imports, and increases in the number of foreign tourists wanting to hunt and view wildlife (Smith & Wilson, 2002; ABSA, 2003).

2.2.2 The role of land-based strategies in rural livelihoods

Households in rural South Africa have depended on diverse livelihood strategies which included arable farming, livestock husbandry, consumption and trade in natural resources both financially and in social terms (Shackleton et al., 2001). Nevertheless, agriculture has faced numerous challenges which has seen its contribution steadily decline over time both in terms of farmers engaged and those employed in the sector (ABSA, 2003). In its place, wildlife ranching has picked up and is rapidly growing in South Africa. In deed some of the cited reasons for the growth of wildlife ranching is the problem of degradation of rangeland due to decades of overgrazing livestock which has reduced its productivity; increased stock theft of small domestic stock which has rendered stock farming less economical and also change in the labor legislation which stipulated increased wages for workers on farms

(ABSA, 2003). These factors made landowners regard wildlife ranching as an alternative to stock farming as it is considered less labor intensive than traditional stock farming (Smith & Wilson, 2002; Langholz & Kerley, 2006). The bottom-line is that economic incentives have been the predominant factor driving the switch from livestock to wildlife ranching.

From the literature, it is clear that agricultural land use and wildlife ranching are closely related. In several instances livestock farms have been replaced with wildlife ranches while in some cases livestock farming is practiced alongside wildlife either on the same land or separated by fence (Taylor et al., 2015).

There are perceptions that wildlife ranching threatens food security because it displaces traditional forms of agriculture production (Lindsey et al., 2013). But, there is also the belief that governments are not supportive of wildlife ranching. Without interventions to raise awareness among politicians of the potential benefits of wildlife-based land uses, there is risk that reforms may cause a reversal to livestock in marginal areas that are best suited for wildlife ranching than livestock (Taylor et al., 2015).

Demonstrating the contribution of wildlife ranching to social, economic and conservation outcomes is now firmly in the agenda of domestic and regional discourse in Southern Africa (Sims-Castley et al., 2005; Spierenburg & Brooks, 2014; Taylor et al., 2015). The livelihood of communities living adjacent to wildlife ranches heavily depends on how well these ranches are structured to benefit them not just those directly involved.

Several studies have identified ways through which ranching contributes to economic and conservational outcomes in South Africa. It has been shown that wildlife ranching contributes more to employment than cattle farms of similar sizes (ABSA, 2003; Langholz & Kerley, 2006; Dry, 2010; Taylor et al., 2015). Despite this, several other studies are quick to point out that not all subsectors of wildlife ranching generate positive employment. While hunting was known to generate the most revenue, it is ecotourism that is known to generate most jobs. Most of these jobs, though are seasonal (Andrew et al., 2013; Spierenburg & Brooks, 2014).

In the Eastern Cape Province, the closest land use alternative to wildlife has been in livestock. Several studies have looked at the relationship between wildlife and livestock ranching in marginal areas (Cloete et al., 2007; Jivanji, 2013; Chaminuka et al., 2014). Chaminuka et al., (2014) analyses the contribution of cattle to livelihood and the potential of

wildlife use in rural areas near Kruger National Park in South Africa. What they find is that cattle production has important livelihood role, but it is not sufficient as a driver of economic development. One of the reasons why cattle farmers consider wildlife as a threat is that there is no tangible welfare benefits or mechanisms to compensate communities that suffered wildlife related losses, (Anthony, 2006; Chaminuka et al., 2012). Cloete et al., (2007) also finds that even though game ranching could be profitable when compared to cattle ranching, it is not always financially viable to convert from cattle to wildlife due to financial implications. Vetter (2013) notes that agriculture alone was not sufficient to achieve rural development and could not achieve employment creation. A multisector development approach that considers wildlife could therefore play an important role in livelihood diversification (Chaminuka, 2013). Evidently the discussions around welfare contribution of wildlife seems to be untested.

Andrew et al., (2013) suggest that wildlife subsectors do not generate more employment than the livestock ranches that they replace, and that most local dwellers can only access low paying jobs. For subsectors, such as hunting, venison production and breeding, there is net loss of employment opportunities when compared to the agricultural enterprises they replace. Most of these subsectors are less labor intensive (Langholz & Kerley, 2006; Andrew et al., 2013).

Closely related to employment creation and conservation outcomes is the general social and community development. Langholz and Kerley (2006) highlight the need for wildlife ranches to commit to people by coming up with programs that can benefit local communities such as socially uplifting programs, programs that can be audited and which target employment and development of local people with positive socioeconomic benefits in their proposition of "Towards a Private Game Ranchers code of ethics[13]". Muir, Skowno and Kerley (2011) found that unlike the earlier scenarios, most ranches had some kind of involvement in community development projects though most of the projects were short-term in nature and most ranches had no formal corporate social responsibility policy framework in place.

In summarizing this literature, a number of issues related to CBNRM and state protected natural resources management and which could be applicable to the case of private wildlife utilization can be highlighted. First, establishment of nature reserves or parks have always

[13] Code of ethics was proposed to provide guidelines that help maintain the credibility and reputation of the profession or industry, particularly against external critics (Langholz & Kerley, 2006).

been contested whether they are based on the management structure of the community or the state (Mac-Donald, 2004; Brockington et al., 2006). Individuals and communities have protested their establishment because they are considered to interfere with different value systems in the local economies. The commodification of wildlife and nature into things which tourists can purchase but the locals can no longer afford has always been protested (Mac-Donald, 2004).

The displacement resulting from the establishment and enforcement of protected areas is also questioned (Brockington et al., 2006). Economic displacement as a result of conservation displacement always excluded people from particular areas in their pursuit for livelihood (Horowitz, 1998; Cernea & Schmidt-Soltau, 2006). People living at the edges of parks would be unable to gather firewood or wild food, unable to walk to their farms on the other side of the park or just live the way they did before the establishment of the park. While CBNRM was formulated with a strategic objective for the local economic empowerment of the communities with expectation that it would secure community support for and involvement in natural resource management, it was also met with challenges. Critics pointed out that it could not fulfill the dual of objectives of conservation and economic empowerment using the same model.

The changing land conditions in the marginal areas and the institutional and legislative changes may turn out to make wildlife ranching a more economic and conservational viable alternative. However, this raises the question of social consequences of land use transition, an area that has not received much attention in literature. There exists no empirical evidence to support claims made about the impact of wildlife ranching. The point of emphasis is that both state and CBNRM approaches have undergone various evaluations to determine the socioeconomic impacts to the communities living in the vicinities of them. They have been found to provide welfare opportunities, but at the same time they have also been found to result into welfare loss. It is with the same breadth that wildlife utilization in private land need to be evaluated.

2.2.3 A conceptual framework

Like most CBNRM and programs associated with protected areas networks, wildlife ranching aims to achieve various objectives for example conservation of natural resources and economic empowerment of those directly involved and the communities. It is argued that a move away from non-farm sector could have substantial welfare effects on rural communities

or households (Barrett et al., 2001; De Janvry & Sadoulet, 2001). Some of the results of a successful conservation program would be increased wildlife population which then could attract more tourists and thereby generate more income. The local people could benefit through employment in the various wildlife enterprises such as working as hunting guides or working in the lodges. Other benefits to the households could trickle-down in the form of opportunities to play a role in the whole wildlife value chain. The presence of the ranches, however may also result in lost opportunities due to its effect on the alternative land use value chain for example livestock.

Private sector-led wildlife conservation makes two assumptions: Firstly, that given the strong profit motives, individuals are likely to pursue optimal land use measures that maximize profits. This means that the approach would be sustainable. Secondly, it amounts to decentralization of natural resource management. In reality, some of the benefits that could accrue out of this may be offset by losses due to challenges already mentioned in the forgoing sections. It could also result in influx of immigrants who are attracted by the new employment opportunities and who could possess superior skills than the local community members. Therefore, there is no guarantee that existence of wildlife ranch would lead to increased employment, access to better services or infrastructure, or better conservation outcomes. In the end, the observable outcome of the wildlife ranches would be the net effects of the potential benefits and costs associated with their presence. It is possible that the benefits derived from hunting, ecotourism, breeding or live sales could be outweighed by loss of employment in the alternative sectors, limited access to good services or poor infrastructure conditions or displacement. For example, Brooks (2011) finds little evidence of employment generation by wildlife ranches. It could be that employment in the crop-livestock value chain outweighed wildlife ranching value chain in real terms even though wildlife ranching may employ more individuals directly than comparable livestock farm. Studies show that not all subsectors of wildlife ranching have the ability to employ more people. In actual sense one of the reasons for land use transition is because wildlife is considered less labor intensive (Langholz & Kerley, 2006).

In order to evaluate changes in welfare of individuals exposed to wildlife ranching, we use change in the proportion of poor people in a given census track as a measure of welfare change. Since poverty is linked to other conditions such as employment, access to good infrastructure or displacement of people, we use changes in these mechanisms as a measure

of changing socio-economic factors.

2.2.4 The mechanism-based explanation of impact of wildlife ranching

Many factors affect household welfare. Living in a wildlife ranching zone and participating in wildlife ranching activities are but some of them. Other factors include socio-demographic characteristics of the households, levels of physical capital in infrastructure, available alternative land uses and access to markets. Under such circumstances, it is important to separate out the effects of the various confounding factors.

Many of the same factors that affect household welfare also influence the probability that a household lives in such areas. Selection bias arises because some households may choose to move into wildlife ranching areas while other conditions may not allow some households to move away from the wildlife ranching zones. Therefore, once in the zone, they self-select themselves to participate in the socio-economic activities of the zone. Other unobserved factors could also lead to selection bias. The important implication of selection bias is that the simple difference in average welfare between household living in zones with wildlife and zones without wildlife is not an accurate measure of respective impacts (Ravallion, 2001).

Mechanism-based approach of analyzing ways through which protected areas could affect welfare outcomes in protected areas is an emerging area of research. Though sustainable development of private protected areas is critical, mechanism-based explanation of their contribution to social and environmental outcomes is lacking (Ferraro & Hanauer, 2014b). This study is grounded on mechanism-based explanation of causal nature of environmental programs.

According to Ferraro & Hanauer (2014b), some of the widely hypothesized mechanisms through which reduction of poverty has been achieved in areas where protected areas are established include revenue generation through tourism and recreational services, infrastructure development and other ecosystem services. More specifically, provision of tourism and recreational services is one way that the private protected areas could affect poverty. Infrastructure development in areas around private protected areas may be enhanced or blocked by the establishment of protected areas. This could influence access to markets and other social services. While protected areas could bring about positive environment benefits, they could also contribute to exacerbation of poverty within the communities through wildlife depredation and forgone agricultural activities.

It is clear from earlier discussions that the three mechanisms mentioned may not capture all dimensions through which private protected areas could reduce poverty or exacerbate it. The mechanisms may as well achieve different result across different countries. It is therefore important to extend the literature on mechanisms through which private protected areas are contributing to economic development and conservation by exploring other mechanisms and dimensions. In South Africa, discussions on wildlife ranching has projected that it makes contribution to employment creation and infrastructure development while others see it as a way through which local communities are being dispossessed of their land through displacement. This study seeks to explore the causal linkage between welfare change and the following three mechanisms;

Employment

Employment creation is cited as one mechanism through which wildlife ranches are contributing to welfare development in areas where they are established (Alderman, 1991; Sims-Castley et al., 2005; Langholz & Kerley, 2006). Changing from livestock farming to wildlife-based ecotourism is said to increase employment by a factor of 4.5 in Eastern Cape Province with an average of 1.0 employee per square kilometer. Such increases in employment coupled with better pay in wildlife-based sector could significantly contribute to poverty reduction. The issue of transition from livestock farming to wildlife is not just about jobs or livelihoods, but such transition could displace people from the land and lead to loss of employment, especially to community members with skills that are not required, (Brooks et al., 2011).

On average there has been a dynamic shift in employment across South Africa (Krug, 2001; Langholz & Lassoie, 2001; De Alessi, 2005). It cannot be concluded without further interrogation that changing dynamics of employment in areas where wildlife ranches are established is wholly as a result of wildlife ranching. Langholz and Kerley's (2006) study found that although there was evidence that some original employees of livestock and crop farms had moved to urban centers or lost their jobs, there was no significant evidence of farm workers being laid off. Therefore, using changes in employment between 1996 and 2011 in census zones in Eastern Province one can evaluate the contribution of private protected areas to employment creation.

Infrastructure development and access to good services.

Infrastructure development may be enhanced or blocked by establishment of private protected areas (Ferraro & Hanauer, 2014b). In the Eastern Cape Province, wildlife ranches are known to establish foundations or charitable trusts which focus on development of infrastructure, such as constructing and supporting primary schools, provision of water, roads and electricity (Langholz & Kerley, 2006; Muir et al., 2011). These social development projects are capable of reducing poverty. Motala (2010) found that lack of government support with regard to basic services such as water has seen private protected areas contribute their resources to the communities.

However, it is also known that establishment of private protected areas may limit road development which may affect poor communities who rely on the roads for movement of inputs, outputs and consumptive goods (Keeler et al., 2012). Dams previously relied on by the communities to water livestock and domestic use were now reserved for wildlife use, which led to conflicts between communities and private protected areas (Langholz & Kerley, 2006; Brooks et al., 2011).

Change in infrastructure development (for example availability of roads, electricity, water and other amenities) is a good indicator of the broader level of access to good services or infrastructure development. In this study, change in the provision of infrastructure over the period 1996-2011 within the census zone is used to measure change in the provision of services in areas occupied by ranches.

Migration

Private protected areas have been noted to contribute to re-population of rural areas (Langholz & Kerley, 2006). Establishment of private wildlife ranches also lead to displacement of people and disruption of livelihood resulting in more poverty in areas where they have been established. Brooks et al., (2011), for instance notes that key feature of the "generic wilderness" landscape is that it must have in it as little evidence as possible of human beings. This means that human displacement, either voluntary or forcefully is inevitable in some cases.

Andam et al., (2010) considered migration as one of the potential explanation for the finding that protected areas reduced poverty. They observed that emigration from protected areas to

the unprotected areas by individuals most affected by protection could have led to the false conclusion that protected areas were beneficial to the surrounding population. However, when testing this hypothesis, they find no statistically significant evidence that protection had an impact on population density. They hold that if poor people were leaving protected census tracts, they must have been replaced by wealthier immigrants.

Even though Andam et al., (2010) find no evidence that migration could be driving the average treatment on the treated (ATT), Ferraro and Hanauer (2014a) note that there may be patterns of migration systematically linked to the mechanisms that could be accounted for in the mechanism average treatment effect on the treated (MATT) and therefore the ATT. But they also find no statistical difference in population density for the matched census tracks.

In this study, we use changes in population density between 1996 and 2011 in areas where private protected areas are established to explain what role private protected areas have played in exacerbating or reducing poverty.

2.2.5 Defining outcome measures, covariates and selection of control group

We measure the change in respective outcomes (proportion of people with access to better infrastructure, proportion of individuals employed and population density) for the period 1996 and 2011 between census zones that were covered by wildlife ranches and a comparison group that did not have ranches established in them. In order to select zones for the comparison group, we use a matching algorithm (propensity score matching) that maximize the similarity between the selected comparison zones and the zones where wildlife ranches were located in the Eastern Cape Province. Similarity is defined as the distribution of confounding variables. Confounding variables are factors that jointly affect census zones in which wildlife ranches and human welfare are established. These include average potential number of livestock units per hectare; distance to closest service town; distance to closest main road; the zones which were former homeland area; proportion of zone un-transformed, proportion of zone that had protected areas established before 1996 and the baseline measures of human welfare in 1996.

2.3 Methodology

2.3.1 Introduction

To measure the true impact of protected areas, one would need to measure not only what happened to human welfare where the ranches were established but also what would have happened in their absence; a counterfactual scenario (Ferraro, 2009). For example, rural population and employment might have declined or increased regardless of whether private ranches were established or not. Because the counterfactual is unobservable, a comparison group that could be used as a surrogate for the counterfactual was selected. The comparison group needed to have similar characteristics to areas with private ranches so that there are no confounding differences between where wildlife ranches were established and the comparison group.

2.3.2 The theory

The interest is to estimate the average treatment effect on the treated (ATT); the effect of wildlife ranches on poverty or welfare in areas where ranches are located. This study aims to disclose what the welfare outcomes for areas where ranches are located would be had the ranches not been established in them. The analysis is extended by exploring how wildlife ranches affect various mechanisms in the society and how these effects contribute to exacerbation or decline in poverty levels in these communities. This means that mechanism average treatment effect on the treated (MATT) must also be estimated. In order to estimate the causal mechanisms through which private protected areas have affected welfare, the potential outcome framework is followed (Flores & Flores-Lagunes, 2009).

The ATT is defined as;

$$ATT = E[Y_i(1) - Y_i(0)|T_i = 1] \qquad (1)$$

Where $Y_i(1)$ and $Y_i(0)$ are potential outcomes for each census zone in our sample under treatment $T_i = 1$ and control conditions $T_i = 0$ respectively. The *ATT* estimates the difference between observed outcomes for the treated units and the counterfactual outcomes. The fact that counterfactual outcome $[Y_i(0)|T_i = 1)]$ are unobserved requires that;

$$E[Y_i(0)|X_i, T_i = 1)] = E[Y_i(0)|X_i, T_i = 0)] \qquad (2)$$

This implies that on average the observed outcomes of untreated units represents the counterfactual outcomes for the treated units had the treatment not been administered to the treated units with similar value of covariates(X_i)[14]. These covariates included the average potential number of livestock units per hectare; distance to closest service town; distance to closest main road; proportion of zone un-transformed; proportion of zone that had protected areas established before 1996 and the baseline measures of human welfare in 1996. Let us denote the mechanisms by S_i where $i = 1,2,3 \ldots . n$. By definition, *S* is affected by treatment, it is not unconditionally independent of the treatment and therefore similar to outcome of interest(Y_i). In other words, the mechanism for example infrastructure is affected by establishment of ranches and the effects of ranches on infrastructure have similar outcome scenarios to the effects of ranches on poverty. *S* therefore has two potential outcomes, $S_i(1)$ and $S_i(0)$ for each *i* depending on the assignment to treatment or control (the mechanism outcome for each unit is dependent on the administered treatment).

This implies that for each unit of census zone where these ranches are allocated, there are four potential outcomes, $Y_i(1)$, $Y_i(0)$, $S_i(1)$ and $S_i(0)$. $Y_i(1, S(1))$ is a potential outcome when the zone is exposed to treatment and the mechanism is affected by the treatment? That is, the census zone has wildlife ranches and these wildlife ranches provide employment or access to good infrastructure or causes displacement. $Y_i(1, S(0))$ is the outcome when the unit is exposed to treatment but the mechanism is not affected by treatment. That is, the zone has ranches, but the ranches cannot provide employment or access to good infrastructure services nor do they cause people's displacement. According to Flores and Flores-Lagunes

[14] The conditional independence assumption

(2009), this is the outcome the unit would experience were it to be exposed to treatment but hold the value of the mechanism at its no-treatment value. In other words, the mechanism is blocked. $Y_i(0, S(0))$ is the outcome when the unit is not exposed to the treatment. Finally, $Y_i(0, S(1))$ is the outcome of the unit when the unit is not exposed to treatment but mechanism is affected as would be the unit were it treated. In general, only $Yi(1, S(1))$ and $Y_i(0, S(0))$ are observed in practice. $Y_i(1, S(0))$ and $Y_i(0, S(1))$ are not observable. They are counterfactual that require estimation.

Estimation of a single mechanism may be influenced by inclusion or exclusion of other mechanisms (Ferraro & Hanauer, 2014a). By allowing for joint mechanisms analysis, joint potential mechanisms outcomes and identification of causal mechanism can be evaluated. Having said this, Flores and Flores-Lagunes (2009) point out that the primary estimand, (mechanism average treatment effect on the treated) requires that we estimate outcomes for treated units had the mechanism been blocked. In order to find suitable counterfactual mechanism values for treated units, we need the assumption of conditional mechanism isolation, (Ferraro & Hanauer, 2014a). That is,

$$E[S_i(0)|X_i, T = 1] = E[S_i(0)|X_i, T = 0] \quad (3)$$

We assume that conditional on the covariates(X_i), ranches are not assigned based on expectations that employment or infrastructure, or displacement will be different under treatment and control conditions. If covariates X_i jointly determine selection into treatment, outcomes and mechanism outcomes, then the assumptions in *eq*.2 and *eq*.3 allow for identification of mechanism effects. A principal stratum is defined as $S(0) = s_0, S(1) = s_1$ which states that units located within a common principal stratum would have similar mechanism outcomes had they been in the control group$(S(0))$, independent of actual treatment received. Therefore, the mechanism average treatment effect on the treated (MATT) is given by,

$$MATT = E\{E[Y_i(1, S_i(1)) - Y_i(1, S_i(0))|S_i(0) = s_0, S_i(1) = s_1, X_i = x, T_i = 1]\} \quad (4)$$

To estimate the MATT one must ask what the outcome for the treated would have been had they remained treated but had treatment not affected the mechanism. Estimation of the MATT answers this question by estimating all sources of variation in the outcome other than that which is due to a change in the mechanism.

2.3.3 Estimation strategy

In order to estimate MATT, we follow the method suggested by Flores and Flores-Lagunes, (2009) and also applied by Ferraro and Hanauer (2014b) in the Costa Rican case. We therefore proceed in two stages. In the first stage, we use propensity score matching with the nearest neighbor in order to match control zones to the treated zones (Census zones with wildlife ranches). The first stage gives us the overall ATT which can later be compared to MATT. It also provides us with a set of matched control units within the same principal strata.

In the second stage, we use regression adjustment to impute outcomes for treated units had treatment not affected the mechanism (Ferraro & Hanauer, 2014a). Therefore, in addition to the assumptions in eq 2 and *eq*3, to execute this stage, we evoke a further assumption about the mechanism; that the mechanism has to have a similar effect on the potential outcomes $Y_i(1, S_i(1))$ and $Y_i(1, S_i(0))$ such that if;

$$E[Y_i(1, S_i(1))|S_i(1), X_i = x, T_i = 1] = [a_1 + b_1 S_i(1) + c_1 X_i] \qquad (5)$$

Then,

$$E\left[Y_i\left(1, S_i(0)\right)\middle|S_i(1), X_i = x, T_i = 1\right] = [a_1 + b_1 S_i(0) + c_1 X_i] \qquad (6)$$

This implies that the marginal effect of a change in the mechanism outcome has the same effect (on average) on zones for whom exposure to treatment affects the mechanism as it does on zones for whom exposure to treatment does not affect the mechanism.

2.3.4 Empirical estimation

The three hypothesized mechanisms are first separately considered then subsequently considered jointly in the estimation. For each mechanism, estimation of the counterfactual entails two steps. In the first step, we estimate the matched zones without ranches:

$$S_{i:T=0} = X_{i:T=0}\beta_{1c} + \varepsilon \qquad (7)$$

Where $S_{i:T=0}$ and $X_{i:T=0}$ are observed mechanism and baseline covariates respectively of the matched zones without ranches. β_{1c} represents the coefficient of the control (c) group, which are matched zones without ranches. The coefficient from equation 7 is then used to impute counterfactual mechanism outcomes for each mechanism as follows:

$$[\hat{S}_i(0)|T=1] = X_{i:T=1}\hat{\beta}_{1c} \qquad (8)$$

Where $X_{i:T=1}$ is the observed covariate values of the areas where ranches are established? The counterfactual values from equation 8 is then used to calculate the counterfactual of interest; the outcomes for the zones with ranches had the presence of ranches never affected the mechanisms ($\hat{Y}_i(1, S(0))$. In the single mechanism estimation, the influence of the covariates and the single mechanism is regressed on the outcomes but only for the areas with ranches. This estimation gives us among other results, the marginal effect of the mechanism on the outcome:

$$Y_{i:T=1} = X_{i:T=1}\beta_{1T} + S_{i:T=1}\beta_{1T} + \varepsilon \qquad (9)$$

Where $Y_{i:T=1}$, $X_{i:T=1}$ and $S_{i:T=1}$are the observed outcomes, covariates and the mechanisms whose value we net out from the observed mechanisms between 1996 and 2011, but only for the areas with ranches.

Now to determine the counterfactual of interest, we use the results of equation 8 and then obtain the fitted values from;

$$\hat{Y}_{i:T=1} = X_{i:T=1}\hat{\beta}_{1T} + \hat{S}_{i:T}\hat{\beta}_{2T} \qquad (10)$$

Where $\hat{S}_{i:T} = [\hat{S}_i(0)|T=1]$ are the counterfactual mechanism values from equation 8 and therefore$\tilde{Y}_i = \hat{Y}_i(1, S(0))$. Finally, the MATT is now obtained by getting the difference between the means of the fitted values of $(\tilde{Y}_{i:T=1})$from the mean of the observed zones with ranching outcomes$(Y_i(1)) = (Y_i(1, S(1))$. In the single mechanism case, however, the estimated impact of a particular mechanism may be influenced by the inclusion or omission of additional mechanisms (Ferraro & Hanauer, 2014a). Therefore, by doing a joint mechanism estimation, we allow the coefficients for each mechanism to reflect the presence of the other mechanisms. Assuming that the mechanisms are denoted by I, E and M for access to good infrastructure, employment and change in population density respectively, the joint mechanism estimation is given by extending equation 11 as follows;

$$Y_{i:T=1} = X_{i:T=1}\beta_{1T} + I_{i:T=1}\beta_{2T} + E_{i:T=1}\beta_{3T} + M_{i:T=1}\beta_{4T} + \varepsilon \qquad (11)$$

Where all variables represent the observed values from the areas protected. The counter factual for each mechanism is then calculated in the following series of imputation;

$$\tilde{Y}^{E}_{i:T=1} = X_{i:T}\hat{\beta}_{1T} + I_{i:T=1}\beta_{2T} + \underbrace{\hat{E}_{i:T=1}\hat{\beta}_{3T}}_{Counterfactual} + M_{i:T=1}\beta_{4T} \quad (12)$$

$$\tilde{Y}^{I}_{i:T=1} = X_{i:T}\hat{\beta}_{1T} + E_{i:T=1}\beta_{2T} + \underbrace{\hat{I}_{i:T=1}\hat{\beta}_{3T}}_{Counterfactua} + M_{i:T=1}\beta_{4T} \quad (13)$$

$$\tilde{Y}^{E}_{i:T=1} = X_{i:T}\hat{\beta}_{1T} + I_{i:T=1}\beta_{2T} + \underbrace{\widehat{M}_{i:T=1}\hat{\beta}_{3T}}_{Counterfactual} + E_{i:T=1}\beta_{4T} \quad (14)$$

Where $\hat{E}$, $\hat{I}$ and $\widehat{M}$ are the imputed mechanism values from equation 8, $\hat{S}_i(0)|T = 1$ for the respective mechanisms.

2.3.5 Description of data and variables

This study considers wildlife ranches in the Eastern Cape Province that were not officially registered as protected areas but had been granted a certificate[15] of adequate game enclosure. Most (>90%) wildlife ranches in South Africa fall into this category occupying about 16% of the total land area (Dry, 2010). This paper uses two different sets of data on wildlife ranching, population and socioeconomic dynamics in South Africa for the period 1996-2011[16]. Full description of data on wildlife ranching is given in Smith and Wilson (2002). The Council for Science and Industrial Research (CSIR), gives detailed description of the construction of data on socioeconomic attributes using the three most recent national statistics censuses. Smith and Wilson's, (2002) dataset is on land use transition from pastoralism to game farming in the Eastern Cape Province of South Africa. Data collection on farms that had transited from stock farming to either mixed wildlife-stock farming or wildlife farming was conducted between August 2001 and January 2002 (Smith & Wilson, 2002). In their study, all farms with a 'game farm' status were targeted and 63 of such farms across the Eastern Cape were consulted. Information gathered from that survey captured the opinions and attitudes of farmers regarding the apparent boom in the game farm industry taking place

[15] Certificate of adequate enclosure is a type of permit issued by the provincial nature conservation authorities in South Africa to landowners (Mostly private landowners on freehold) to convey certain rights over the use of wildlife. The certificates are issued if the landowner can demonstrate that the property is adequately fenced for the species included in the permit. The permit is issued for a period of three years and renewable upon expiry (Taylor et al., 2015).

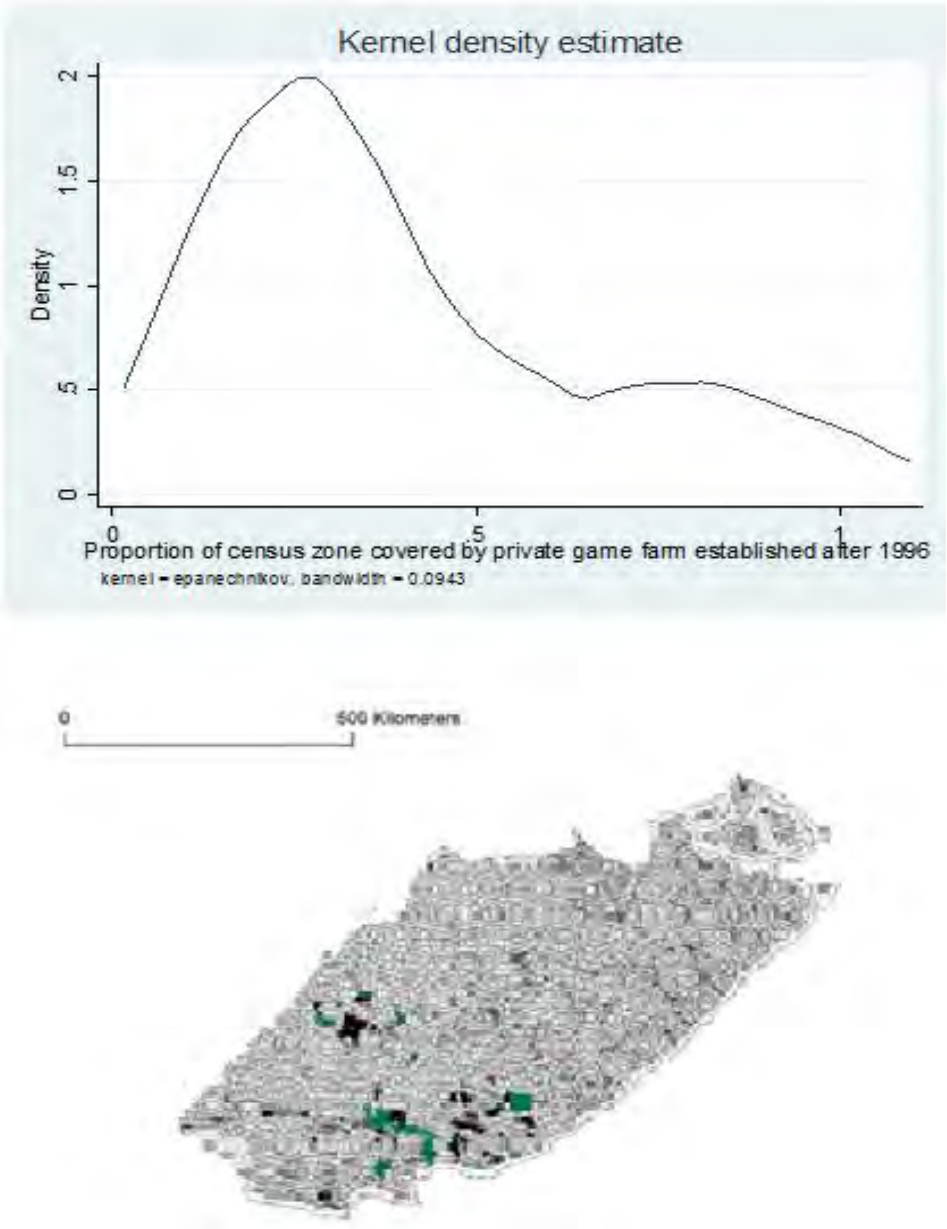
[16] In constructing the dataset, CSIR did not use census data before 1996 because it only included detailed human welfare measures for white people. Most (>90%) wildlife ranches were established after 1996. In our case, census zones where private wildlife ranches were established after 2001 (<5% of total wildlife ranches) were excluded to allow for enough time to detect an impact on the outcomes measures.

in South Africa especially in the thicket Biome (Smith & Wilson, 2002). Besides that, information on the geographical or spatial aspects of the game farms and attributes of each farm were also collected. The attribute data comprised of the name of the farm, details of owner/manager, the year that the farm changed status from stock to wildlife, type of game on farm and finally type of game utilization on farm. The attributes were linked with geometric data. Most game farms identified in the survey were concentrated in the South and Central regions of the Eastern Cape Province (see Figure 2.1 for the map of the distribution of ranches and a kernel distribution of the proportion of land in the Eastern Cape Province under wildlife ranching).

A second dataset from CSIR used the Temporal Analyses Tool (CSIR, 2013)[17] to develop a settlement typology where they aligned and compared South Africa's census data from the three most recent census years namely 1996, 2001 and 2011 to any spatial unit courser (larger) than the small areas layers (SAL) used by Statistic South Africa for the collection and reporting of data for the 2001 and 2011 censuses. The outcome of this process is a synthesized data that provides national and provincial patterns of population movement, demographic and socioeconomic changes. It provides the spatial shifts of population and how it is likely to change in the future. For example, how population and household numbers of different areas across the rural-urban spectrum are growing or declining. The data explores population movements by analyzing age profile, household size and number, access to employment and service delivery quality changes over time and between places using 1996 as the base year. The settlement typology approach developed provides a mechanism that enables the identification, calculation and analysis of a set of development information and trends as they pertain to the range of towns and cities. It also incorporates high density rural as well as all other settlements types across South Africa. As such, the settlement typology enables understanding and analyses of the network of settlements, towns and cities and the hierarchical and functional relationships between them, especially as it relates to government and economic service provision and migration.

[17] http://stepsa.org/spatial_indicators.html. / http://www.gap.csir.co.za/about-gap-1 Accessed on 24/02/2016. Spatial transformation indicators analyze and compare spatial changes and transformation within cities, towns and regions in South Africa since 1996.

Figure 2.1: Distribution of wildlife ranches in the Eastern Cape Province after 1996



Note: *The Kernel Distribution shows that there are more areas with low proportion of wildlife ranch coverage. Another distinctive feature is that a number of census zones have a higher proportion of ranch coverage. This is also supported by the section of the map that represents the Eastern Cape Province. The dark spots are areas where wildlife ranches have been established.*

Variables of interest

The outcome variable that could measure welfare changes in communities where a boom in game farming is experienced is the proportion of households living on less than $4000 a year. However, other mechanisms that represent change in the community include the proportion of job seekers employed, the proportion of people migrating in or out of the zones where ranches are established, and the proportion of households with good services (weighted according to access to energy, water, refuse removal and toilet type). The construction of these measures are explained as follows.

Poverty indicator

To establish the proportion of households living in poverty, the 'Poor' income category as defined by Bureau of Market Research at Unisa (BMR) is used.

Access to service delivery infrastructure

A composite index for access to services is determined by calculating the average number of households which received either good or not-so-good services based on the level of access to energy for lighting, refuse removal, toilet facility and water services. After the binary classification of all four types of services the average number of households receiving good and not-so-good services is calculated. Based on this, the change from 1996 to 2011 can be determined. The definition of good or not so good service is defined in CSIR (2013).

Employment

Regarding data preparation for access to employment, the question on employment and unemployment is extracted and compared over time to derive the level of changes in employment from the 1996, 2001 and 2011 censuses (Naudé et al., 2007; Van Huyssteen et al.,2013).

Independent variables

The control variables include: (1) average potential number of livestock units per hectare; (2) distance to closest service town; (3) distance to closest main road; (4) proportion of the zone which was a former homeland area; (5) proportion of zone un-transformed; (6) proportion of zone that had protected areas established before 1996 and (7) the baseline measures of human

welfare in 1996 (Poverty measure).

Summary statistics

In the study, a final sample of 3206 census zones in the Eastern Cape Province was obtained. Out of this, only 55 zones had wildlife ranches on them with a coverage for each census zone ranging from 0- 100 per cent. The remaining 3151 did not have wildlife ranches but was used to draw the control units. Besides, there were 202 census zones within state protected areas. We began by giving descriptive statistics for the whole sample, but later on narrowed down our analysis by using matched sample only. The descriptive statistics are given in table 2.1.

Table 2.1: Descriptive statistics of outcome variables and covariates before matching

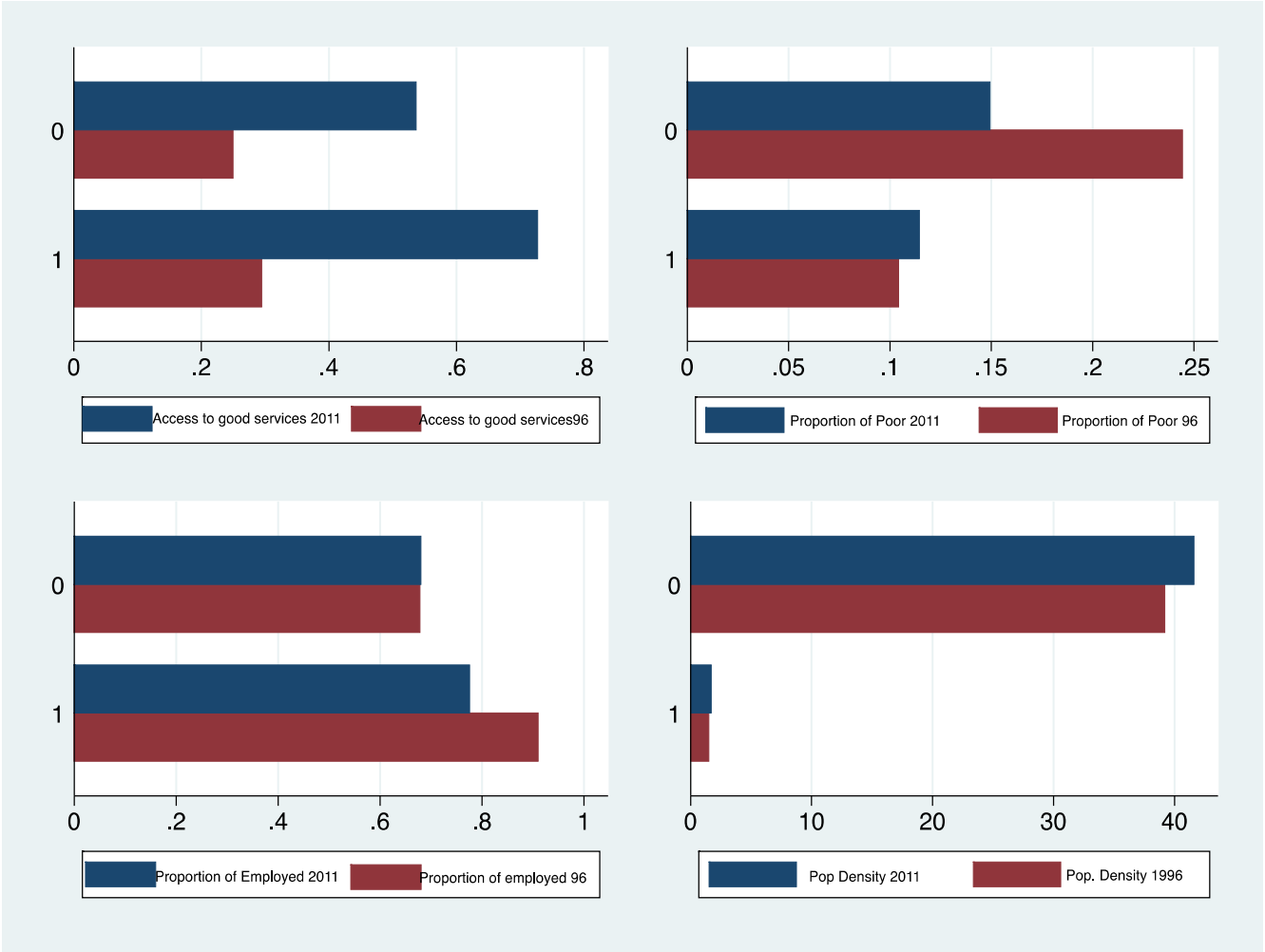
	Zones with Wildlife ranches		**Zones without Wildlife Ranches**		**P-value**
Variable	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	
Proportion of poor in 1996	0.1043	0.0765	0.2443	0.1876	0.000***
Proportion of poor in 2011	0.1145	0.0467	0.1494	0.0911	0.005***
Proportion of Individuals employed in 1996	0.9104	0.0849	0.6784	0.3050	0.000***
Proportion of Individuals employed in 2011	0.7756	0.0742	0.6805	0.147	0.251
Assess to good services in 1996	0.2945	0.0951	0.2498	0.2043	0.105
Assess to good services in 2011	0.7275	0.1082	0.5368	0.2716	0.000***
Population Density/km2 1996	1.513	2.295	39.21	153.74	0.070*
Population Density/km2 2011	1.708	3.671	41.60	166.41	0.076*
Grazing capacity per ha	6.307	4.867	11.90	6.259	0.000***
Distance (meters) to closest service town	30649.68	13091.21	34612.97	18853.27	0.121
Distance (meters) to closest road	4309.70	5575.94	3776.83	5081.28	0.442
Proportion of land under cultivated land	0.0276	0.0555	0.0864	0.1310	0.001***
Proportion of Untransformed areas	0.9565	0.0783	0.7904	0.2724	0.000***
State protected area established before 1996	0.0205	0.0883	0.0114	0.0749	0.374

Note: The table gives the mean, the standard deviation and the p-values of the outcome variables and the covariates for the zones with wildlife ranches and those zones without wildlife ranches before matching is done. The baseline years for the outcome variable is 1996.

Description of outcome variables

From table 2.1, in 1996, the average proportion of households classified as poor was 24.2 per cent in the Eastern Cape Province. However, for areas with wildlife ranches, only 10.4 per cent of the population was classified as poor while 24.4 per cent were classified as poor in areas without ranches. In 2011, the proportion of poor people had increased in the treated zones while decreasing in zones without wildlife. For example, in the treated zones, the proportion of poor people increased to 11.45 per cent while in the control zones, the number decreased to 14.9 per cent from 24.43 per cent. In figure 2.2, we compared the changes in four of our key variables between 1996 and 2011 for the treated and the untreated census zones that is; proportion of poor people; proportion of those employed; proportion of those with access to good services and the change in population density.

Figure 2.2: Key Outcome Variables



As illustrated in figure 2.2, the proportion of poor people, employment and access to good infrastructural services increased in both treated and potential control zones. The proportion of individuals employed in 1996 was about 91 per cent in the treated areas while it was 67.8 per cent in the potential control areas. However, in 2011, the proportion of individuals employed in the protected areas had reduced to 77.6 per cent while in areas where ranches had not been established, the proportion of those employed increased slightly to 68.1 per cent.

In terms of access to good infrastructure services, only 29.5 per cent of the population in protected areas had access to what has been defined as good services in 1996. While only 25 per cent of the population in the unprotected areas had access to good services in 1996, in 2011, those with access to good services had increased in both areas. About 72.8 per cent and 53.7 per cent had access to good services in protected areas and unprotected areas respectively.

Population density per Km^2 also changed within the census zones across the period of study. In the protected areas, the population density in 1996 was about 1.5 per Km^2 while it was 39.2 per Km^2 in the unprotected areas. This figure increased in both tracks to 1.7 and 41.6 in protected and unprotected areas respectively in 2011. Obviously protected areas seem less populated when compared to unprotected areas.

Since agriculture is the most important livelihood source in these areas, we also look at other variables that capture agricultural activities in these areas such as proportion of land under cultivation and livestock grazing capacity per hectare. It turns out that areas where private protected areas were established were on average less suitable for both crops and livestock with only 2.7 per cent of land under cultivation at the time of the survey and with a grazing capacity of about 6 animals per hectare compared to 12 animals in the unprotected areas. However, protected areas were located closer to service town and closest roads when compared to areas where ranches were not established. Our correlation analysis seems to confirm that private protected areas do actually compete with livestock and crop production. Having said this, protected areas complement state protected areas as they are established closer to these areas. After matching, our controls within the common support reduces to 1868 and the comparable summary statistics is now given by;

Table 2. 2: Summary statistics of outcome variables and covariates after matching

	Zones with Wildlife ranches		**Zones without Wildlife Ranches**		**P-value**
Variable	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	
Proportion of poor in 1996	0.1043	0.0765	0.1294	0.0995	0.065*
Proportion of poor in 2011	0.1145	0.0467	0.1078	0.0695	0.471
Proportion of Individuals employed in 1996	0.9104	0.0849	0.8542	0.1686	0.014**
Proportion of Individuals employed in 2011	0.7756	0.0742	0.7504	0.1102	0.091*
Assess to good services in 1996	0.2945	0.0951	0.3505	0.1598	0.162
Assess to good services in 2011	0.7275	0.1082	0.6947	0.1729	0.010***
Population Density/km2 1996	1.513	2.295	15.2280	99.646	0.308
Population Density/km2 2011	1.708	3.671	19.0922	134.08	0.337
Grazing capacity per ha	6.307	4.867	9.927	6.3033	0.000***
Distance (meters) to closest service town	30649.68	13091.21	33318.19	18083.47	0.278
Distance (meters) to closest road	4309.70	5575.94	3337.96	4663.61	0.130
Proportion of land under cultivated land	0.0276	0.0555	0.0353	0.0669	0.402
Proportion of Untransformed areas	0.9561	0.0783	0.9355	0.0997	0.121
State protected area established before 1996	0.0205	0.0883	0.0167	0.0905	0.753

Note: The table gives the mean, the standard deviation and the p-values of the outcome variables and the covariates for the zones with wildlife ranches and those zones without wildlife ranches after matching is done. The baseline years for the outcome variable is 1996.

In table 2.2, after matching it becomes evident that indeed, the proportion of those employed declined in the unprotected areas as well as in the protected areas. Poverty also increased in both cases, but it is clear that the proportion of the poor increased in areas where ranches

were established. Therefore, there seems to be a common trend across all outcome indicators both in the treated and control census units.

2.3.6 Summary of descriptive statistics

Even though there has been a boom in wildlife ranching, the outcome measures suggest that the proportion of poor people and unemployed individuals had increased in areas where wildlife ranches were established between 1996 and 2011. Poverty and unemployment also increased in those areas where no wildlife ranches had been established. Therefore, it is not possible to attribute these changes to the presence or absence of wildlife ranches without further analysis.

In the following section, we provide the results of the test of balancing for the first stage one-to-one covariates matching. The test checks the success of the matching for the exogenous variables. This is a t-test on the hypothesis that the mean value of each variable is the same in the treated and the non-treated group. A bias before and after matching is calculated for each variable. The 'bias' is the difference of the mean values of the treatment group and the non-treatment group divided by the square root of the average sample variance in the treatment group and the not matched non-treatment group.

Table 2.3: Checking the success of propensity score matching

Variable	Sample	Mean Treated	Mean Control	%Bias	% reduct. Bias
Proportion of poor in 1996	Unmatched	0.1043	0.2443	-97.7	83.9
	Matched	0.1060	0.0834	15.8	
Grazing capacity per ha	Unmatched	6.3066	11.92	-100.1	97.4
	Matched	6.484	6.628	-2.6	
Distance (meters) to closest service town	Unmatched	30650	34613	-24.4	42.0
	Matched	30945	28645	14.2	
Proportion of untransformed area	Unmatched	0.9565	0.7903	82.9	99.4
	Matched	0.9565	0.9552	0.5	
Change in Population density	Unmatched	0.1950	2.3981	-6.8	94.7
	Matched	0.2158	0.3324	-0.4	
Change in Employment	Unmatched	-0.1348	0.0021	-83.8	97.6
	Matched	-0.1321	-0.1355	2.0	
Change in Infrastructure	Unmatched	0.4329	0.2870	105.9	93.6
	Matched	0.4296	0.4203	6.7	

By matching, the difference between treatment group and non-treatment group considerably change across all variables. For example, 10.43 per cent of the treatment group is the proportion of poor people in 1996 before matching. After matching, the figure changes to 10.5 per cent while for the control group it reduces to 8 per cent from 24.4 per cent for the unmatched control. Appendix A1 presents, an alternative balanced result for the first-stage Mahalanobis one-to-one covariate matching results with replacement.

2.4 Empirical results

We began the analysis by using one-on-one matching method to find comparable census zones that were never affected by the establishment of ranches. Matching controls for observable differences in pre-treatment confounding variables by creating a matched set of treated (areas with ranches) and controls (areas without ranches) that have similar distribution across the key confounders. Matching ensured that the remaining variation in outcome is due solely to variation in treatment status (Ferraro & Hanauer, 2014b). We ran a logit model from which we estimate the propensity score. Using the propensity scores, we determined the matched set which we then used to estimate the average treatment effect on the treated (ATT). Estimating ATT helps us answer the counterfactual question of what poverty would be in areas with ranches had ranches not been established in them. The following results for ATT is obtained;

Table 2. 4: Average treatment effects on the treated (ATT)

Variable	Sample	Treated	Controls	Difference	T-stat
Proportion of Poor people in 2011	Unmatched	0.1145	0.1494	-0.0348	-2.83
	ATT	0.1145	0.0878	0.0267	3.35

Note: the table provides the ATT and the T-value

Using post-match regress bias adjustment, the estimated ATT is 0.0267. ATT is used because it is more appropriate since there may have been census zones in the Eastern Cape Province where ranches may never be established even in the very long run such as urban areas. The estimated effect is given by the post treatment variable 'proportion of poor people in 2011'. The results indicate that census zones in areas where wildlife ranches were established after 1996 had a higher level of poverty on average than comparable census zones in areas where there were no ranches. However, this may not give a complete picture of what role wildlife ranching may have played in poverty reduction since ATT is compounded by unobserved factors not associated with wildlife ranching. As Ferraro and Hanauer, (2014b) observe, ATT is composed of mechanism average treated effect on the treated (MATT) and net average treatment effect on the treated (NATT). This decomposition states that the proportion of the treatment effect is due to a change in the mechanism induced by the treatment (MATT) and the proportion that is due to other mechanisms or solely the effect of treatment (NATT).

We therefore turn to the effects of wildlife ranching on infrastructure, employment and migration or displacement of people to determine what would have happened to these issues had wildlife ranches not been established in the zones. Table 2.6 presents the results,

Table 2. 5: Results of single and joint- mechanism estimation

			Single Mechanism		All Mechanisms	
Mechanism	Observed Mechanism	Counterfactual Mechanism	Mechanism Coefficient	MATT	Mechanism Coefficient	MATT
change in Infrastructure	0.30775	0.1785	-0.0069***	-0.0067**	0.00967***	-0.0054**
			(0.001)	(0.003)	(0.001)	(0.003)
change in Employment	-0.12821	-0.1213	0.0191	0.068	-0.0234	-0.0065**
			(0.026)	(0.003)	(0.032)	(0.003)
change in population Density	0.07819	1.3241	0.0161*	-0.0268*	0.01803*	-0.0292*
			(0.0095)	(0.012)	(01063)	(0.0133)

The second and third columns of table 2.6 list the observed and counterfactual mechanisms values for census zones with wildlife ranches. The estimated counterfactual for change in infrastructure (the proportion of people with access to good infrastructure services) is statistically different from the observed values. The average access to infrastructure attributed to the presence wildlife ranches is 30.78 per cent. It is estimated that had ranches not affected infrastructure development, the proportion of people with access to infrastructure would only be 17.85 per cent. Therefore, establishment of wildlife ranches in these areas contributed 12.83 per cent in improved access to infrastructure.

Turning to absolute change in employment, estimated counterfactual change in the proportion of those employed is not statistically different from what is observed in areas where wildlife ranches are established. Unemployment was on average 12.82 per cent in areas with wildlife ranches. Our estimation is that had wildlife not affected employment, unemployment would have been 12.12 per cent (the combination of avoiding unemployment and creating additional employment was approximately 0.7%). The presence of ranches contributed 0.7 per cent to unemployment.

Finally, we looked at the changes in population density which proxies for migration within the census zone. The estimated counterfactual for change in the population density is

statistically different from what is observed from the wildlife ranching areas. The average density is 0.08 person per square kilometer. If wildlife ranches had not been established, the average density would be about 1.3 persons per square kilometer.

The results for the joint mechanism estimation strategy shows that inclusion of all mechanisms changes the estimated influence of each mechanism compared to single mechanisms. The coefficients on the infrastructure mechanism increases in absolute term (0.00697 to 0.00967), an indication that relative poverty reduction is attributed to infrastructure development. The coefficient on employment also increases from 0.0191 to 0.023 indicating that relative poverty is exacerbated by unemployment. Lastly, population density changes from 0.016 to 0.018 which also exacerbates poverty.

Under the joint mechanism estimation, MATT for employment accounts for much of the factors that increased poverty in areas where the wildlife ranches were established. Loss of employment or alternative livelihood could be associated with increase poverty in areas where wildlife ranches were established. However, this effects may be trivial because it was not statistically significant.

In summary, census areas where wildlife ranches were established experienced increased poverty. The ATT has shown that poverty went up by 0.0267 in areas where wildlife ranches had been established. What MATT tells us is that loss of employment in these areas was responsible for 0.0268 increases in poverty; however, infrastructure development offset this increase by 0.0067. The loss of employment could be explained by the effects of transition from livestock to wildlife ranching and incompatibility or transferability of skills from livestock farming to wildlife ranching. Adjusting to the new environment may also have affected livelihood. However, wildlife ranches played an important role in infrastructure development which could have ameliorated the effects of poverty.

Robustness checks

Sensitivity analysis using Rosenbaum Bounds

Unbiased heterogeneity is a concern in any non-experimental study (Rosenbaum, 2002; Andam et al., 2010). The results from propensity score matching is based on the conditional independence or unconfoundedness assumption. Here it is assumed that we have observed all variables simultaneously influencing the decision to participate (in our case, to live in the census zones with wildlife ranches) and the outcome variables. According to Becker et al.,

(2007), there is need to check the sensitivity of the estimated results with respect to deviations from this identifying assumptions. The idea is that there could be a possibility of selection bias into the census zones with wildlife ranches due to unobserved factors and this could happen even in a well-matched comparison group from control groups.

If there are unobserved variables that simultaneously affect assignment to zones with wildlife as well as the outcomes we see, then as stated by Rosenbaum (2002), a hidden bias might arise and our matching estimators will not be robust. However, estimating the magnitude of selection bias with non-experimental data like ours is not possible, we address this problem with the bounding approach proposed by Rosenbaum (2002). The approach does not test directly the presence (absence) of unobservable but it tests how stable our estimated treatment effects are to a range of changes to the odds of participation under the assumption that individuals are identical in observed characteristics X.

To understand the Rosenbaum bounds, let us assume that the individual's i probability of receiving treatment (being in a zone with wildlife ranches) is given by;

$$P_i = P(x_i, u_i) = P(D_i = 1|x_i, u_i) = F(\beta x_i + \gamma u_i) \dots\dots\dots\dots\dots\dots\dots\dots 15$$

Where X_i the observed characteristics are for individual's i ,u_i is the unobserved variable and γ is the effect of u_i on the participation decision. If our treatment estimates are free from hidden bias, γ will be zero and the participation probability will be determined solely by X_i. However, if there is hidden bias, then it is possible that two individuals with the same observed characteristics X have different chances of receiving treatment (being in a census zone with wildlife).

Let us assume that we have a matched pair of identical individuals i and j and further assume that F is the logistic distribution. The odds that the two individuals being in a census zone with wildlife is then given by $\frac{p_i}{1-p_i}$ and $\frac{p_j}{1-p_j}$ respectively and the odds ratio is given by;

$$\frac{\frac{p_i}{1-p_i}}{\frac{p_j}{1-p_j}} = \frac{P_i(1-P_j)}{P_j(1-P_i)} = \frac{exp(\beta x_i + \gamma u_i)}{exp(\beta x_j + \gamma u_j)} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 16$$

If both individuals have identical observed characteristics—as implied by the matching procedure— the X vector cancels out, implying that;

$$\frac{exp(\beta x_i + \gamma u_i)}{exp(\beta x_j + \gamma u_j)} = exp[\gamma(u_i - u_j)] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 17$$

But still, both individuals differ in their odds of receiving treatment by a factor that involves the parameter and the difference in their unobserved characteristics u . So, if there are either no differences in unobserved variables ($u_i = u_j$) or if unobserved variables have no influence on the probability of participating ($\gamma = 0$) the odds ratio is one, implying the absence of hidden or unobserved selection bias. Sensitivity analysis now evaluates how changing the values of γ and ($u_i = u_j$) alters inference about the effects of wildlife ranching on the outcome variable.

Following Aakvik (2001) as well as Becker et al., (2007), we assume for simplicity that the unobserved covariate is a dummy variable with $u_i \in \{0,1\}$. Rosenbaum (2002) shows that equation 16 implies the following bounds on the odds ratio that either of the two matched individuals will receive treatment:

$$\frac{1}{e^{\gamma}} \leq \frac{P_i(1-P_j)}{P_j(1-P_i)} \leq e^{\gamma} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 18$$

In this, both matched individual i and j have the same probability of participating only if $\Gamma = e^{\gamma} = 1$. If this is the case, the results are considered free of bias from selection on unobservables and the model is said to be free of hidden bias. Otherwise, if for example $\Gamma = e^{\gamma} = 2$, individuals who appear to be similar (in terms of X_i) could differ in their odds of receiving the treatment by as much as a factor of 2. In this sense, only $\Gamma = e^{\gamma}$ is a measure of the degree of departure from a study that is free of hidden bias (Rosenbaum, 2002). The Rosenbaum sensitivity analysis results for the test of hidden bias in our case is given in table 2.7;

Table 2.6: Sensitivity analysis for the unobserved bias in wildlife ranching

Gamma (Γ)	sig+	sig-	CI+	CI-
1	0.000	0.000	0.143956	0.14991
1.5	0.000	0.000	0.126075	0.163783
2	0.000	0.000	0.108921	0.173484
2.5	0.000	0.000	0.097786	0.181982
3	0.000	0.000	0.091413	0.189497
3.5	0.000	0.000	0.08725	0.196257
4	0.000	0.000	0.083828	0.202565
4.5	0.000	0.000	0.081054	0.208417
5	0.000	0.000	0.078684	0.21357

Note: the table gives unobserved biases of various magnitudes with range of possible significance levels. Gamma - log odds of differential assignment due to unobserved factors; sig+ - upper bound significance level; sig- - lower bound significance level; CI+ - upper bound confidence interval (a= .95); CI- - lower bound confidence interval (a= .95).

Form table 2.7, it is observed that even if the matching of individuals in areas with wildlife ranches and those in areas without wildlife ranches had failed to control for unobserved characteristic strongly related to the presence of poverty and $\Gamma = 5$ times more common among individuals in the wildlife areas, this would still not explain the higher level of poverty in areas with wildlife ranches.

Sensitivity analysis using additional covariates

A second sensitivity test involved the expansion of the list of probable covariates. After adding other covariates such as the proportion of land under cultivation, distance to the nearest road and the proportion of land which is degraded, the resultant ATT estimates are nearly similar but it is only the precision of the estimates which is now lowered. The results are outlined in table 2.8

Table 2.7: Average treatment effect on the treated results with different covariates

Variable	Sample	Treated	Controls	Difference	T-stat
Proportion of Poor people in 2011	Unmatched	0.1145	0.1494	-0.0348	-2.83
	ATT	0.1145	0.1049	0.01	0.94

Note: Additional covariates have been included in the estimation of the ATT

Sensitivity analysis using different coverage levels

Finally, another sensitivity test involved using different coverage threshold. So far the study has looked at the impact of wildlife ranches given the average proportion of ranches across the Eastern Cape Province. A census zone was considered protected if at least 10% of it is covered with private wildlife conservation. But given the differences in coverage of ranches in each zone, the results generated so far may be sensitive to the difference in the distribution of the proportion of census zone occupied by ranches. In census areas where the proportion of coverage is low, the impact of ranches may be different from to areas where the proportions of coverage is high or zones which are entirely covered by ranches. Since the data can be disaggregated by the proportion of coverage per census zone, we seek to evaluate how sensitive our results are to different levels of coverage[18]. We vary the coverage threshold from 10% to the following cutoff levels;

1. Census zones with a proportion of 10-40% covered with wildlife ranches established after 1996;
2. Census zones with a proportion of 10-50% covered with wildlife ranches established after 1996;
3. Census zones with a proportion of 50-100% covered with wildlife ranches established after 1996.

We also investigate what would have happened to the welfare outcomes in the homeland areas had wildlife ranches been established. This is a counterfactual situation because no wildlife ranches were established in the homeland areas.

[18] The choice of the boundary limits of between 10-40%, 10-50% and 50-100% have been arbitrarily made.

We repeat the process of propensity score matching to identify a right match for each case. The results are presented in table 2.9,

Table 2.8: Logit result for PSM in the sensitivity tests

Proportion (10-40%)	**Variable**	**Coefficient**	**Std. Err.**
	Proportion of poor people 1996	-6.010***	2.487
	Land Grazing Capacity/ha	-0.119***	0.034
	Distance to Nearest Town Service (meters)	-0.00002**	0.000
	Proportion of land Untransformed	4.397**	1.911
	Constant	-5.887***	1.809
Proportion (10-50%)	**Variable**	**Coefficient**	**Std. Err.**
	Proportion of poor people 1996	-5.979***	2.254
	Land Grazing Capacity/ha	-0.122***	0.031
	Distance to Nearest Town Service (meters)	-0.00002***	9.46e-06
	Proportion of land Untransformed	4.893***	1.841
	Constant	-6146***	1.746
Proportion (10-50%)	**Variable**	**Coefficient**	**Std. Err.**
	Proportion of poor people 1996	0.4061	4.111
	Land Grazing Capacity/ha	-0.112**	0.048
	Distance to Nearest Town Service (meters)	-0.0002	0.00001
	Proportion of land Untransformed	8.240**	4.2365
	Constant	-11.31***	4.111
Homeland areas	**Variable**	**Coefficient**	**Std. Err.**
	Proportion of poor people 1996	10.1069***	0.4961
	Land Grazing Capacity/ha	0.0822***	0.0140
	Distance to Nearest Town Service (meters)	-0.00002***	3.86e-06
	Proportion of land Untransformed	-6.7391***	0.3629
	Constant	1.559***	0.3042

In table 2.9, we have maintained the covariates earlier used to generate the propensity scores using the near neighbor matching. This was to ensure that we are able to compare the ATT in table 2.8 to that in table 2.4. About 33 census zones had a coverage of private wildlife ranches of between 10-40 per cent, while up to 41 census zones had a coverage of between 10-50 per cent. Finally, only 14 zones had a coverage of between 50-100 per cent. On the other hand, a total of 1134 census zones were in the homeland area.

Table 2.9: Average treatment effects on the treated for the sensitivity analysis

Area	Variable	Sample	Treated	Controls	Difference
10%-40%	Proportion of Poor 2011	Unmatched	0.1090	0.1492	-0.0402**
		ATT	0.1090	0.1026	0.0064
	Change in infrastructure	Unmatched	0.7013	0.5384	0.1628***
		ATT	0.7013	0.6928	0.0084
	Change in Employment	Unmatched	0.7637	0.6812	0.0825***
		ATT	0.7637	0.7853	-0.0216*
	Change in Population Density	Unmatched	2.4536	41.3191	-38.87
		ATT	2.4536	0.9394	1.5141*
10%-50%	Proportion of Poor 2011	Unmatched	0.1175	0.1492	-0.0317**
		ATT	0.1175	0.1124	0.0051
	Change in infrastructure	Unmatched	0.7016	0.5379	0.1636***
		ATT	0.7016	0.6896	0.0119
	Change in Employment	Unmatched	0.7757	0.6809	0.0948***
		ATT	0.7757	0.7722	0.0035
	Change in Population Density	Unmatched	2.1539	41.4212	-39.267
		ATT	2.1539	18.3286	-16.175
50%-100%	Proportion of Poor 2011	Unmatched	0.1058	0.1490	-0.0431*
		ATT	0.1058	0.1291	-0.0233

Area	Variable	Sample	Treated	Controls	Difference
	Change in infrastructure	Unmatched	0.8032	0.5389	0.2644***
		ATT	0.8032	0.6681	0.1352**
	Change in Employment	Unmatched	0.7755	0.6817	0.0938**
		ATT	0.7755	0.7579	0.0175
	Change in Population Density	Unmatched	0.4019	41.0968	-40.695
		ATT	0.4019	8.4824	-8.0804
Homeland	Proportion of Poor 2011	Unmatched	0.2335	0.1024	0.1311***
		ATT	0.2204	0.1417	0.0787***
	Change in infrastructure	Unmatched	0.2431	0.7026	-0.4596***
		ATT	0.2892	0.5398	-0.1814***
	Change in Employment	Unmatched	0.5308	0.7649	-0.2341***
		ATT	0.5574	0.7388	-0.1814***
	Change in Population Density	Unmatched	77.905	20.677	57.228***
		ATT	59.331	158.23	-98.89**

In table 2.10, the results are fairly straightforward. In census zones with coverage of between 10-40 per cent on average, there were rising levels of poverty coupled with increasing unemployment. However, access to better infrastructure services improved. The zones had 0.06 per cent more in the proportion of people who were poorer than what would have been

the case had ranches not been established there. The proportion of those with access to employment may have decreased by 2.2 per cent. In areas with between 10-50 per cent coverage, even though poverty went up, wildlife ranches may have contributed to increased employment and access to good services by 0.1 per cent and 0.04 per cent respectively.

Finally, in areas with coverage of between 50-100 per cent, the result is dramatically different; the proportion of poor people declined in such areas by almost 2.3 per cent while access to better services went up by 13.5 per cent and employment up by 1.75 per cent. From this it can be concluded that the higher the proportion of coverage the more likely that wildlife ranches will benefit the communities, whereas areas with lower coverage are less likely to benefit from private wildlife ranching.

Effects of state protected areas on the welfare of the communities

Though the study was not designed to investigate or compare the welfare outcomes in communities around the state protected areas, we nonetheless used the same data for 1996-2011 to evaluate the effects of parks and state run reserves on the communities around them. Using time invariant covariates, we match the 202 census tracks within the state controlled areas to the set of census tracks used as control. We make the less credible assumption that this accounts for biases. We follow the mechanism based approach to evaluate the impact of state run parks in Eastern Cape Province. The results are outlined in table 2.11.

Table 2. 10: Results of single and joint- mechanism estimation for communities around state run parks and reserves

			Single Mechanism		All Mechanisms	
Mechanism	Observed Mechanism	Counter-factual Mechanism	Mechanism Coefficient	MATT	Mechanism Coefficient	MATT
change in Infrastructure	0.07612	0.10526	0.0027*	-0.0008	-0.0311*	0.0009
			(0.0154)	(0.004)	(0.018)	(0.004)
change in Employment	0.04258	0.01326	0.2261	0.068	-0.235	0.00689
			(0.1555)	(0.003)	(0.1616)	(0.004)
change in population Density	1.39469	1.64905	0.0019	-0.0005	0.002	-0.0005
			(0.005)	(0.004)	(0.0054)	(0.004)

There is a stark difference in the impact of state protected areas on welfare outcome in the Eastern Cape Province between 1996 and 2011. First, the ATT is -0.0046, which implies that in census areas where state protected areas were located, poverty levels were actually lower. This can be explained by existing relationship between state protected areas and local communities in terms of benefit sharing modalities since most of these state protected areas have existed for a longer time than most of the wildlife ranches. The proportion of poor people would have been 0.005 more had wildlife ranches not been established. We estimated that if state protection did not affect infrastructure development, then about 10.5 per cent of the people would have had access to good infrastructure. Therefore, it can be said that state protection contributed to about 2.91 per cent in deterioration of infrastructure. The proportion of people with access to employment in state protected areas contributed to the reduction in poverty as shown by the magnitude of MATT. First, the observed access to employment in state protected areas was about 4.36 per cent. If this was not the case, then only 1.3 per cent of people would have had access to employment. Joint MATT confirms that employment played a bigger role in poverty reduction than the other two mechanisms since it was the biggest.

One of the key hypothesis that this chapter sought to test was that the impact of private wildlife ranches on the welfare of local communities does not differ from the impact of the

state owned protected areas on the local communities, in Eastern Cape province. Based on the analysis this far, it has been established that it is deed true that the impact of wildlife ranches on the welfare of the communities living around the ranches was significantly different from those of the communities living around the state-owned wildlife protected areas.

Limitations of Propensity Score Matching (PSM).

In using PSM, two possible benefits accrue over other possible standard regression methods; first, matching estimators highlight the problem of common support, since treatment effects can only be estimated within the common support. Where there is poor overlap in support between the treated and the non-treated, this raises questions about the robustness of traditional methods relying on functional form to extrapolate outside the common support. Secondly, matching does not require functional form assumptions for the outcome equation (that is, it is non-parametric). Regression methods impose a form on relationships (usually linear) which may or may not be accurate and which PSM avoids: this is valuable since these functional form restrictions are usually justified neither by economic theory nor the data used (Dehejia and Wahba, 1998; Smith and Todd, 2000).

However, it is important to highlight the limitations associated with PSM. PSM has two clear disadvantages relative to experimental techniques. The first is the need to make the conditional independence assumption. In the case of random assignment, properly conducted, there is confidence that the treated and non-treated populations are similar on both observable and unobservable characteristics. This is not true in the case of PSM, which takes account of selection on observables only. Second, whereas PSM can only estimate treatment effects where there is support for the treated individuals among the non-treated population, random assignment ensures that there is common support across the whole sample. These considerations make experimental techniques unambiguously superior to PSM (Bryson et al.,2002). Therefore, there are three questions which PSM cannot address, but which may be of crucial importance to the policy maker. First, in common with the experimental and all the non-experimental techniques, PSM cannot answer questions relating to the distributional effects of the establishment of wildlife ranches, such as the percentage of those individuals in the communities who benefit. This is because none of these techniques allows for reliable assumptions to be made about the distribution of impacts (Heckman, Smith and Clements,

1997). PSM can only recover mean effects. Second, as is the case with other partial equilibrium evaluation techniques, it cannot establish the impact of wildlife ranches beyond the eligible group. General equilibrium effects may bias partial equilibrium estimators such as random assignment and PSM which assume that the outcomes observed for eligible non-participants in the comparison or control group are unaffected by the existence of the wildlife ranches. Whether any wildlife ranches will influence outcomes for people beyond the eligible communities depends on the spread of the ranches, how effective it is in benefiting communities, and the extent to which the communities are capable of benefiting from employment, infrastructure development or migration compared to non-participating communities. Thirdly, PSM cannot estimate the local average treatment effect, which is the mean impact of the program on those whose participation status changes due to a change in policy. So, it is less useful than IV techniques when considering broadening (or narrowing) eligibility for a program in a targeted way (Bryson et al.,2002).

2.5 Conclusion and policy implications

The objective of this chapter was to estimate the impact of wildlife ranching on welfare outcome and by extension conservation of wildlife. The hypothesis was that in order for the community to accept, support and play a positive role in wildlife conservation outside the protected areas, then wildlife ranching needed to benefit communities as much as those directly involved. Several studies and report have attributed employment creation, infrastructure development and displacement of people to wildlife ranching, but no empirical evidence existed to show the causal nature of wildlife and welfare outcomes or to support or validate these claims.

The study was based on the case of Eastern Cape province. The choice of Eastern Cape province was due to data availability; however, the study can be generalized to the whole of South Africa because the institutional and legal framework governing wildlife ranching is the same. The study can also provide relevant policy knowledge to the whole of Eastern and Southern Africa because most of these areas share some significant similarities in terms of agroecological characteristics, besides political and institutional similarities.

In this chapter, we have shown the nature of causal relationship between wildlife and welfare outcomes. The study further investigated the causal relationship between welfare outcomes and state protected areas in the Eastern Cape Province of South Africa. Using change in the proportion of poor people, people with access to infrastructure, employment and the number

of people per square kilometer, we established that although areas where wildlife ranches were established on average experienced higher levels of poverty, wildlife ranching contributed more to infrastructure development, a fact that may have lessen the burden of poverty. However, wildlife ranching may have contributed to loss of livelihoods though unemployment. One possible explanation for this is that previous cattle farms which changed to wildlife ranches may have laid off workers whose skills were incompatible with activities in wildlife ranching. Since wildlife ranching is also associated with the need for pristine environment (Brooks et al., 2011), there establishment may have led to displacement of people. It is also known that most wildlife ranches have no corporate social responsibility policy (Muir et al., 2011). They therefore do not have any obligation to provide support to the communities.

Using different proportions of census areas covered by ranches, we have established that areas where ranches are widespread, poverty levels have gone down and employment has increased, but it has also led to displacement of people. We have also established that state protected areas played a central role in job creation, but wildlife ranches contributed to better access to infrastructure on average. Finally, had wildlife ranches been established in the homeland areas, the proportion of people exposed to poverty may have gone up amid deteriorating infrastructure conditions and increasing unemployment.

The results of this chapter can help shed light on the complex relationship between wildlife use on private land and the communities' welfare. The growth of wildlife utilization on private land has the potential to contribute to wildlife conservation in South Africa and the rest of Africa, besides the economic benefits. The key policy message from this chapter is that increased transformation of agriculture land will have substantial effects on food security, land reform process and poverty among the communities living around the private protected areas. Policy reforms will be required to institute a benefit sharing scheme that can increase access to wildlife resources for the communities. The reforms should target empowerment of communities through provision of employment, strengthening of social infrastructure development and integration of communities to actively participate in wildlife utilization on the private land.

Further policy reforms should mainstream food security concerns into wildlife utilization. It is envisaged that wildlife is able to contribute to food security if policy framework is put in place to encourage and promote wildlife use for food or dietary provisions.

Land reforms is likely to affect the women, youth and the vulnerable groups whose life are anchored on land use such crops and livestock which is in direct competition with wildlife use. Since the land use change is likely to affect these group, it will be increasing important that attention is directed towards cultural, ethical and right considerations by increasing the participation of these groups in wildlife utilization. There is also an obvious feeling among the black communities that wildlife utilization of private land is skewed towards the interest of the white community. It is important to come up with policies that address constraints to broader wildlife ranching adoption by the black communities by enhancing access to credit and markets, capital, gender oriented wildlife use as well as identifying perverse policy incentives that limit sustainable exploitation of wildlife resources by the black communities.

CHAPTER THREE: AN ECONOMIC ANALYSIS OF CLIMATE CHANGE AND WILDLIFE UTILIZATION ON PRIVATE LAND IN SOUTH AFRICA[19]

Abstract

Studies on climate change and agriculture especially in Africa have concluded that sub-sectors of agriculture especially livestock and crops production suffer most from climate change. However, there is a dearth of evidence concerning whether other emerging subsectors such as wildlife ranching suffer from similar consequences and what implication this has for future efforts in wildlife conservation and agriculture. In this chapter, we investigate the effects of climate change on the revenues of wildlife ranching in South Africa. This chapter applies a median Ricardian modelling approach on net farm revenues using a sample of 716 wildlife ranches drawn from the latest version (2007) of Census of Commercial Agriculture data for South Africa. This involved running quantile regression for the wildlife ranches. In order to predict the impact of climate change in the future, the chapter uses three Atmospheric-Oceanic Global Circulation models, which include the Coupled General Circulation Model, the Parallel Circulation Model and the Hadley Centre Coupled model, which have been used to predict the impact of climate change for South African agriculture. The study confirms that current climate affects the net revenues of wildlife ranches across South Africa especially in cases where small scale wildlife ranches are involved. The study predicts that towards 2050, climate change could reduce net revenues of wildlife by up to 28 percent. In certain regions, the models predict modest gains in revenues towards 2100. Revenues of specialized wildlife ranches could be more affected in the long run when compared to revenues of ranches that practice mixed wildlife ranching. The main policy message from the results of this chapter is that agriculture sector in south Africa should be reconfigured to address the emerging issue of climate change in wildlife utilization on private land. Issues on climate change should be mainstreamed into existing policies in wildlife utilization by targeting mitigation and adaptation in wildlife ranching. Policies could be designed to provide potential pathways for strengthening adaptation capacities for climate change.

[19] Note: An extract of this chapter has been disseminated as ERSA working paper No.553

3.1 Introduction

Agriculture is vulnerable to climate change both physically and economically. Recent studies on climate change and agriculture have concluded that sub-sectors under agriculture such as crop and livestock suffer most from the effects of climate change (Mendelsohn, Nordhaus & Shaw, 1994; Gbetibouo & Hassan, 2005; Kabubo-Mariara, 2008). Studies done on South Africa have arrived at similar conclusion on the effects of climate change, mitigation and adaptation on agriculture especially in relation to crops and livestock (Gbetibouo & Hassan, 2005; Dube et al., 2013). With the current predictions, it is expected that this will affect food security and the general livelihood strategies for the rural communities whose lives depend on agriculture.

In the southern Africa region, commercial wildlife utilization has emerged as an important sub-sector under agriculture, environment and natural resource use. Commercial wildlife farmers occupy 27.8 per cent of the total agricultural land or an equivalent of 22.9 per cent of total area of South Africa (Dry, 2011)[20]. In its current growth trajectory, commercial wildlife ranching is expected to continue to grow. One of the reasons commonly cited for the growth of wildlife ranching has been the effects of climate change on agriculture; this makes livestock sector more vulnerable and push wildlife ranchers to replace livestock with wildlife (ABSA, 2003; Van der Merwe, 2004).

In NAMC, (2006: 37), it is noted that there has been a move away from horticulture and field crops to livestock and in the livestock sector. There is also a move away from domesticated livestock to wildlife. With its growth, however, an empirical question that needs to be asked is what effects do climate change have on wildlife especially those in the private protected areas? It is difficult to draw conclusion about the effects of climate change on wildlife ranching based on finding related to livestock or crops because, besides differences in the value chain, there are also differences in management needs and practices governing wildlife ranching.

This chapter evaluates the economic impact of climate change on wildlife ranching in the current scenario given that ranchers' practices differ (for example, there are mixed livestock-

20 http://www.sawma.co.za/images/Dry_Gert_Commercial_wildlife_ranching's_contribution_to_a_reseource_efficient_low_carbon_pro-employment_green_economy.pdf accessed on 14th November 2014

wildlife ranchers and those ranchers who keep only wildlife) and that they may be at different stages of growth. This chapter therefore makes and tests the following arguments; the first issue to test is the economic impact of climate change on commercial wildlife ranching and how different it is from the effects of climate change on livestock or wildlife in the public protected area networks. While it is already known that climate change affects wildlife ecosystem components and processes (Kappelle, Van Vuuren & Baas, 1999); individual species of wildlife in terms of their physiology, distribution as well as shift in range of species (Heller & Zavaleta, 2009) and wildlife husbandry decisions (Lovejoy & Hannah, 2005; Musengezi, 2010), what is not known is the effects of climate change on wildlife ranches under the private property regime. The results from studies on agriculture or wildlife in protected areas may not be representative of what happens in the private wildlife areas. This is because of the differences in the level of interventions or differences in motivation by the agents involved in wildlife ranching. It can also be argued that contrary to the belief that wildlife is more resilient to climate change, wildlife in the private ranches are exposed to a different level of intervention.

Exposure to climate change could affect farmers' revenues given existing evidence from agriculture and wildlife conservation in the public protected areas. An economic analysis of climate change and wildlife ranching on private land is therefore linked to the discussion on the existing literature on agriculture in South Africa. This is because wildlife ranching is practiced alongside agriculture in some of the areas. Not including climate change in this debate raises two issues. The first is the role of wildlife in adaptation[21] decision in agriculture husbandry since more livestock ranchers are moving into wildlife ranching in South Africa (Dry 2010). The other important issue is the contribution of wildlife ranching to wildlife conservation and social and economic development.

South Africa on average has become hotter and drier in the past 15 years compared to the 1970s (Aronson, Ueckermann & Blignaut, 2009). Areas initially suitable for crops are now under irrigation or alternative land use such as livestock. A number of farmers, both small scale and large commercial farmers, have moved to wildlife ranching as the income margins from crop and livestock shrank. While wildlife ranching provides important avenue for

[21] The issue of adaptation and the role of wildlife has been addressed in chapter four.

biodiversity conservation in South Africa[22], viability of wildlife ranching is vital, more so in an environment where climatic conditions are expected to deteriorate further. It is evident in South Africa that ranchers are sensitive to factors that negatively impact on their revenue even though when some may be pursuing conservation objectives (Cousins, Sadler & Evans, 2010). The implication is that there may be further land use adjustments as climate changes. This is why it is important to explore how far climate change affects the sector.

According to the Inter-Governmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5), given current levels of adaptation in wildlife conservation, there is very high risk in the near term (2030-2040) and long term (2080-2100) as the global increase of temperature will shift biome distribution and have severe impact on wildlife due to diseases and species extinction. Already such effects have been predicted for the case of South Africa. For instance, Erasmus et al., (2002) estimates that up to 66 per cent of the 179 species in their study on Kruger National Park will be lost due to climate change while Thomas et al., (2004) predicts that between 15-35 per cent of species in their sample would be at risk of extinction as a result of climate change.

The IPCC report also notes that, going forward, very few adaptation options will exist beyond migration corridors, protected areas or better management of natural resource. Even if adaptation could be enhanced, a temperature increase of 2℃ and 4℃ above preindustrial levels would still lead to medium risk. One of the adaptation options proposed in the AR5 report is ex-situ conservation initiative. Private sector-led wildlife conservation is emerging as an alternative avenue for conservation. Its competitive edge lies in its balance between conservation objectives and socioeconomic objectives. It has to compete with other land-use options by providing opportunity for wildlife conservation as well as financial and social developments (Mitchell, 2006).

There are indications that wildlife like domestic animals face various climate related changes although diverse views exist on their resilience in such scenarios. However, unlike wildlife in public protected areas, ranchers with wildlife in enclosed ranches or conservancies may provide certain interventions such as supplement feed during drought, water or strategic medication where necessary. Most of these provisions are climate related and the cost may

[22] Only a third of wildlife is currently protected by the State in South Africa, the remaining two thirds are in private wildlife ranches. It also provides an alternative land use option given limited options livestock farmers, especially cattle farmers, have in the arid and semi-arid areas of South Africa. Around the world, land outside the PPAs provide the alternative avenue for conservation (Langholz et al., 2000).

vary with climate change. Climate change, though currently not emphasized on as an economic challenge to the sector, is known to influence wildlife population outcome more so in protected areas and land values in crops and livestock. There is need to understand the extent to which wildlife ranching sector perform under various climate scenarios, since the decision to conserve wildlife on private land is an economic decision. This implies that wildlife on private land compete with other land use options. It would also be important to shed light on how mixed ranches perform when compared to wildlife ranches under the different climate scenarios.

South Africa provides an excellent opportunity for understanding how climate change affects land use under wildlife ranching or the performance of land under mixed wildlife ranching. South Africa has a well-developed private sector-led wildlife conservation and is considered to contribute immensely to economic and conservation initiatives.

The remainder of this chapter is organized as follows. In section 3.2 the literature on climate change and wildlife conservation with reference to the linkage between agriculture and wildlife ranching is reviewed. In section 3.3, the theory of median Ricardian and its application in modeling effects of climate change on agriculture is introduced. Data analysis follows with empirical results presented in section 3.4. Finally, discussions and conclusion for this chapter is presented in section 3.5.

3.2 Literature review

3.2.1 Introduction

Most activities on wildlife ranching have been carried out in marginal areas of South Africa that are known to be highly susceptible to the effects of climate variability or climate change. However, wildlife ranching is now practiced even in areas, which were traditionally meant for crop or livestock farming. There productivities, however, have gone done because of the changing land conditions.

The growth of wildlife ranching in South Africa has been attributed to a number of policies and legislative changes that reduced barriers to entry and which eliminated the perverse incentives that undermined private investment in wildlife ranching. Other factors that supported the growth of wildlife ranching were the legislative changes that gave consumptive and non-consumptive rights to wildlife ranchers and the deregulation of the agricultural sector which drastically reduced agricultural subsidies to 4 percent (ABSA 2003). Across South Africa, about 50 per cent of commercial wildlife ranching is practiced in Limpopo province, 19.5 per cent in the Northern Cape, 12.3 per cent in Eastern Cape and the remaining 19.2 per cent are distributed across the remaining provinces.

3.2.2 Measuring the impact of climate change: theoretical and empirical development

Measuring the impact of climate change and the search for adaptation options has been going on in various sectors for the last two decades (Mendelsohn & Dinar, 2009). It is expected that climate change will affect the agriculture sector more than any other sector and therefore there has always been the need to fully understand its impact and adaptation options. Several estimation models have been used to evaluate the impact of climate change on agriculture. The models, however, have not been used to evaluate the impact of climate change on wildlife ranching. That is to say, studies on agriculture have not evaluated the impact of climate change on wildlife ranching. This implies that the results of the impact of climate change on the agriculture sector may have been overestimated. Some of the agronomic and economic models used included:

1. Crop simulation models: These models use functions that capture the interactions between crop growth and climate, soil and management practices. Crop simulation models are attractive because they are developed based on a deep understanding of

agronomic science. (Rosenzweig & Iglesias, 1998; Iglesias et al., 2007). One of the limitations of the crop models is that they do not capture the behavior of the farmer. The underlying crop simulation is purely an agronomic relationship (Mendelsohn & Dinar, 2009).

2. Empirical yield models: These models measure sensitivity of output to climate by measuring the actual yield under different climate conditions (Gbetibouo & Hassan, 2005).
3. Economic management models: They are also referred to as farm behavior models. These models assume that farmers wish to maximize their profits. From thus assumption, one can then determine what farm behavior could lead to profit maximization or which farm adaptations would maximize profits in response to climate change. Farm simulation models make the first attempt to address the critical issues of adaptation. However, since only a limited number of alternatives are considered, it is likely that the models do not capture the full range of adaptations that farmers can practice (Mendelsohn & Dinar, 2009).
4. Intertemporal net revenue approach: This model focuses on measuring the changes in net revenues and how change in climate affect net revenues. The approach is an ideal method to measure short term responses to sudden changes in weather (Deschenes & Greenstone, 2007).
5. Ricardian analysis: The Ricardian technique named after David Ricardo (1772-1823) estimates the net productivity as a function of climate, soils and other control variables (Mendelsohn, Nordhaus & Shaw, 1994). The technique relies on a cross-sectional sample of farms that span a range of climates, to measuring the sensitivity of land value or farm net revenue per hectare to climate. One of the principal advantages of the Ricardian technique is that it incorporates efficient adaptations by farmers to climate change. The technique captures how farmers modify their production practices in response to changes in water availability, rainfall pattern and temperature.
6. Computable General Equilibrium models (CGE): CGE is an economy-wide approach to measuring the effects of climate change. It can predict how large shifts in supply and demand can alter prices. It thus captures changes that the partial equilibrium models miss.

In this study, the model of choice is the Median Ricardian approach recently applied by Passel et al., (2012) in the study of climate change on European agriculture. The model is founded on the land rent theory propagated by Von Thunen et al., (1966) and earlier on Ricardo (1822). The

reason for choosing median Ricardian is because of its ability to handle the effects of outliers and distribution characteristics associated with data on revenues of wildlife.

3.2.3 Wildlife conservation and climate change

The major strands of literature on climate change and wildlife conservation has looked at the impact of climate on wildlife under the state managed national park and reserves. Some of the issues considered so far include ecosystems and processes (Kappelle, Van Vuuren & Baas, 1999; Walther et al., 2002). For example, Christensen et al., (2004) use a simulation model to investigate a coupled system of plants and grazers under different climate conditions. They determine that grassland are likely to undergo transition to shrub-lands if the density of grazers are maintained. Other studies have used bioclimatic envelope models, which use current species distribution to predict future distribution as a function of climate (see Hannah et al., 2007). Finally, mathematical models have also been used with integrated demographic and climate data to determine whether climate change is appropriate to harvesting or stocking schedules (Garcia & Holmes, 2005). Since there are differences in management approaches and motives that drive managers in the protected area networks and private wildlife ranches, the models used so far to evaluate the impact of climate change on wildlife may not capture the differences brought about by the economic and conservation motives. These models also have their own limitations. For instance, a limitation is that most conservation policies and management plans do not explicitly consider climate change in their design, implementation and reviews (Scott & Lemieux, 2007; Groves et al., 2002; Chambers, Hughes & Weston, 2005).

A closely related literature on climate change and decision-making processes is one on agriculture and climate change especially on livestock husbandry in Africa. These studies use economic and agronomic models to evaluate how farmers change their behaviors in response to climate change (Mendelsohn, Nordhaus & Shaw, 1994; Gbetibouo & Hassan, 2005; Kabubo-Mariara, 2008). The economic models such as Ricardian and structural Ricardian are used extensively to study the sensitivity of African animal husbandry decisions to climate albeit with their own limitations as well. The results of these studies show that large and small farmers respond to climate change differently and that selection of species of animals to keep, the number of animals to keep and the net revenue are all climate sensitive decisions (Seo & Mendelsohn, 2008a). The studies find that in a climate impacted scenario cattle farmers have limited alternatives in other species or in crops. One can argue however that in

the case of South Africa and the Southern African region, the role of wildlife ranching if considered for the case of commercial livestock ranchers or pastoralist communities may bias these results. We investigate the effects of climate change when farmers' incorporate wildlife and livestock under mixed ranching. All the agronomic and economic literature on agriculture in Southern Africa and South Africa in specific have never extended these investigations to wildlife ranches which occur side by side to most of the livestock or crop farms. This means that the findings of these studies may have overestimated the effects of climate change in cases where a farmer had wildlife on the same parcel of land, but which was never reported during the surveys.

One would also expect that studies on climate change and agriculture especially those studies on climate change and livestock, would provide wildlife managers with relevant policy information on climate change. The findings of most of these studies, however, are specific to livestock and therefore provide little comparable results. For example, Seo and Mendelsohn, (2008b) found that in warmer places, Africa farmers switch from beef cattle to more heat tolerant goats and sheep and in wetter places farmers switch from cattle and sheep to goats and chickens (see Gbetibouo & Hassan, 2005; Kabubo-Mariara, 2008; Seo, 2010) for related literature. Given the perception that wildlife is more tolerant to heat, one would expect commercial livestock ranches to move to wildlife ranching in the event of warmer conditions. The results, however, indicate that large commercial livestock farmers have limited adaptation options unlike the small scale farmers. In these studies the role of wildlife ranches as land use option was not considered even though wildlife ranching plays a crucial role in the Southern African region.

Though wildlife is considered more resilient to climate change or variability when compared to livestock under the similar conditions, from an economic perspective, there is need to explore the performance of wildlife revenues when compared to livestock revenues within the same climate conditions. Literature on the profitability of wildlife over livestock on marginal land gives mixed results. For instance, Child et al., (2012) found that though wildlife systems may have ecological advantages over modern livestock production systems, these may be difficult to quantify in complex dry land ecosystems. This is despite that the ecological advantages are trumped over by economic and political processes. Conversely, Kreuter and Workman, (1997), in a study on cattle, wildlife and mixed ranching in central Zimbabwe, found that in areas with abundant wildlife, the greatest net revenue per hectare was earned by

mixed ranches and that profitability of wildlife ranching depended on access to off ranch wildlife resources. The study did not support claims that wildlife ranching is more profitable than cattle ranching in semi-arid savannas. In South Africa, according to Carruthers (2007), though wildlife was envisaged as a solution to challenges facing cattle farmers, the rising profile of wildlife ranching thought to be due to drought in the 1960s may have been an exaggeration. This chapter seeks to empirically corroborate these findings by explicitly modeling the effects of climate change on the value of wildlife ranching.

Finally, the current research frontier on agriculture and wildlife conservation is on whether policies should encourage land sparing or land sharing or wildlife friendly farming (Green et al., 2005; Fischer et al., 2008). The dominant view is that in land sparing, biodiversity is largely restricted to nature reserves often occurring on government land which are intentionally set aside. It would be in the best interest of biodiversity conservation and agriculture if wildlife friendly farming were promoted, even if this means provision of subsidies to farmers to provide more non-cultivated land as wildlife habitat around the world (Norris et al., 2012). This argument can lend more strength when one looks at the drivers of land use change such as climate change.

Investigating the impact of climate change therefore, contribute evidence in support of this literature. Conceptualization of wildlife as an economic land use option is uniquely different from livestock ranching. Unlike livestock production, which is limited to meat and milk production, wildlife ranches are highly diversified in most case, with multiple revenue sources, such as meat and game products, tourism activities and game breeding, hunting among other activities. There are also vertical integration such as provision of lodging services and backward linkages such as provision of food and transport. This makes the sector different from other forms of agricultural activities and therefore, likely to be affected differently by climate change.

3.2.4 A review of seasonal weather variations and their influence on wildlife ranching activities

In this section, the variations in temperature and rainfall across the four seasons, namely summer, winter, autumn and spring for South Africa is reviewed. It is know that the biophysical conditions are endogenously linked to wildlife revenues. Summer in South Africa begins in October and extend to March every year. It is the beginning of rainy seasons, but it can be dry and humid if rains delay. Summer, therefore, can be very hot if rains are late.

Temperatures during summer can rise from between 16-36℃ (mostly in January). It is the period during which most wildlife animals calve and migratory birds arrive due to abundance of vegetation and water. The ease of game viewing reduces with increasing summer rains and temperature. The cost of repairs of roads and other infrastructure increases with summer rains. The effects of rains can be severe in National parks or reserves sometimes leading to closure of parks due to bad road conditions. The arrival of tourists to private reserves and game farms mostly increase with rains as private ranches provide alternative destination to most tourist with diverse demands. Ranches incur less costs on supplementation of water and feeds since these are abundant as summer rains increase. Autumn begins in April and there is a noticeable temperature drop to 13-29℃. All animals are in peak condition and the vegetation is dense. Winter begins in May and rainfall drops off dramatically with temperatures going to 8-24℃. Internal migration of animals towards warmer areas is experienced as animals move away in search of food and water. Predators perform much better during this season, as prey is weak and easily visible due to low vegetation density especially in large ranches. Viewing is good and the repair costs reduces substantially. However, the cost of providing water and supplement feed increase during this period. Many winter birds begin to fly from high-veld (cold climate) to lowveld, which is warmer. August is the beginning of spring with cool morning and evening, but temperatures and humidity rise during the day. There is good game viewing at waterholes and along the river lines. Temperatures are between 10 and 28℃. There are occasional showers but water is still scarce. Migratory birds begin to come in. Game animals are still concentrated at water points. Spring ends in September.

3.3 Methodology

In assessing the impact of climate change on agriculture, the Ricardian theory has been used most often because the land rent reflects the productivity of farms (see Mendelsohn, Nordhaus & Shaw, 1994; Gbetibouo & Hassan, 2005; Kurukulasuriya et al., 2006; Deschenes & Greenstone, 2007; Seo & Mendelsohn, 2008b; Massetti & Mendelsohn, 2011; Passel et al., 2012). Most of these studies have used either cross sectional data or repeated cross sectional data. Most recently panel data was used by Massetti and Mendelsohn (2011).

In this study, we used the Median Ricardian approach which recently was applied by Passel et al., (2012) in the study of climate change on European agriculture. The reasons for using median quantile regression for this study are twofold. Firstly, it is because of the need to address the influence of the outliers in revenues. Wildlife ranching, as earlier stated, encompasses a number of on-farm value adding activities that significantly raise the value of some ranches. Such onsite activities include hospitality and ecotourism, game meat processing, packaging and export game breeding of disease free wild animals for sale, as well as hunting among other activities. The vertical and backwards linkages in ranching means that some ranches would have very high value compared to others. The median quantile regression does not allow activities that generate high revenues to have undue influence on the regression results. Secondly, relaxing the assumption of the error term allows us to acknowledge heterogeneity in ranches and consider the possibility that estimated slope parameters vary at different quantiles of the conditional net farm value distribution.

3.3.1 Median Ricardian theory

In the Ricardian model, the assumption is that the value of land per hectare (H) of each farm i is equal to the present value of future net revenues from farm activities.

$$V_i = \int_0^{\infty} \left[\sum_{i=1}^{n} PQ_i(X_i Z) - \sum_{i=1}^{n} HX_i \right] e^{-\delta t} dt \ldots\ldots\ldots\

The rancher chooses the outputs and inputs that maximizes net revenues. By solving equation (1) to maximize net revenues and by collapsing the vectors of values and inputs H and P into a vector of exogenous variable Z, V_i can be expressed as a function of only exogenous variables:

$$V_i = f(Z) \dots\dots\dots\

Where Q_{V_i} is given by

$$Q_{V_i} = \exp(\propto(\tau) + \beta(\tau)T + \gamma(\tau)T^2 + \beta(\tau)R + \gamma(\tau)R^2 + \eta(\tau)S + \theta(\tau)G_r) \ldots\ldots\ldots (6)$$

and ΔV_i is a change in net wildlife revenue per hectare of land.

3.4 Data and description of dependent and explanatory variables

The dataset used in this chapter is part of the census for commercial agriculture collected in 2007 by Statistics South Africa from the district municipalities in South Africa (Stats SA, 2010). In the previous census of 2002, only a few ranches practicing game farming reported on their activities. In 2007, a similar situation occurred, but the reporting was an improvement over the 2002. In this study, observations from 716 commercial game farms were obtained. Other observations were dropped because they did not make complete reporting on their revenues which is a key variable in this chapter. The 716 farms came from across six of the nine provinces in South Africa and represents more than 80 per cent of the game ranching activities.

Wildlife ranches which had only wildlife on them were 221(30.9%), while the mixed ranches which had wildlife and livestock on them were 495(69.1%). In order to capture the different types of mixed ranching, the sample of mixed ranches was further divided into mixed ranches with wildlife and cattle, mixed ranches with wildlife and small stock (goats and sheep) and finally, mixed ranches with wildlife, cattle and small stock. Mixed farms are defined as ranches or farms that have wildlife and livestock in a single ranch separated by a fence or in open field. The sample, therefore, included 133 wildlife and cattle mixed ranches, 62 wildlife and small stock ranches and 300 ranches with wildlife, cattle and small stock.

Climate[23] variables (average rainfall and temperature) is obtained from the Climate System Analysis Group[24]. In order to cluster the rainfall and temperature data at the district municipality level, the Geographic Information System (GIS) has been used. This has allowed for the farm level data to be aligned to climate variables. Consistent with earlier

[23] The mean temperature and precipitation for over a period of 30 years

[24] http://cip.csag.uct.ac.za/webclient2/datasets/africa-merged-cmip5/ on 26/08/2014

studies on climate change, climate data has been broken down into seasonal averages. The four seasons commonly experienced in South Africa are summer, autumn, winter and spring. Soil data for the districts have been obtained from the Food and Agriculture Organization (Gbetibouo & Hassan, 2005). FAO defines 26 major soil categories out of which about ten are found in South Africa (Benhin, 2008). For the purpose of this study, we use seven of the ten major soil categories in South Africa, which are found in most regions where livestock and wildlife farming takes place.

The key variable of this study is the net revenue. Net revenue which is the dependent variable is defined as net revenue per hectare of land under wildlife use or net revenue per hectare of land under mixed ranches. Net revenue is measured as gross wildlife or mixed ranches revenue less total cost of production. As Seo and Mendelsohn (2006) observed, it is ideal to examine cases where farmers jointly maximize the combined profits from different forms of farming activities. It is therefore important to look at the net revenues from mixed ranches. The net revenues for all farms used in this study were positive and therefore a case necessitating transformation of negative net revenue did not arise. As one would expect of revenue data, there were a number of outliers in terms of net revenues. In order to address this possible challenge, quantile regression has been applied to address the distribution issues and the outliers. Therefore, there was no need for dropping the outliers. Instead, all net revenues were also log linearized as part of the transformation. The cost element is mainly total variable costs.

In the following section, we provide a summary of the descriptive statistics of the key variables in table 3.1.

Table 3.1: Summary of descriptive statistics[25]

Variable	Wildlife-only Ranches	Wildlife and Cattle	Wildlife and Small animals	Wildlife, cattle and small animals
	Mean	Mean	Mean	Mean
Log of Net rev	11.84	11.76	12.22	12.40
	(1.66)	(1.70)	(1.45)	(1.41)
Log of Land size	7.21	7.54	7.74	8.02
	(1.46)	(1.34)	(1.12)	(1.04)
Stream Flow	0.047	0.059	0.064	0.192
	(0.211)	(0.238)	(0.247)	(0.395)
Purchase of Water	0.031	0.089	0.064	0.070
	(0.174)	(0.286)	(0.247)	(0.256)
Remedy Forage	0.202	0.188	0.106	0.319
	(0.403)	(0.393)	(0.312)	(0.467)
Remedy Drought	0.318	0.564	0.681	0.498
	(0.467)	(0.498)	(0.471)	(0.501)
Membership	0.419	0.406	0.596	0.825
	(0.495)	(0.494)	(0.496)	(0.381)
Observation	**221**	**133**	**62**	**300**

Note: The table provides summary statistics for the logs of continuous and discrete variables. Only the means are presented here. Standard deviations is in the parenthesis.

First, the sample has been divided into four farming categories, which include ranches with only wildlife, mixed ranches with wildlife and cattle; mixed ranches with wildlife and small animals; and finally mixed ranches with wildlife, cattle and small animals. On average, mixed ranches with wildlife, cattle and small animal' farms generate more net revenues when compared to other farms. These mixed ranches are also bigger in size when compared to either ranches with only wildlife or mixed ranches with cattle.

[25] Mixed ranches refer to any ranch with wildlife and cattle or wildlife and small animals or wildlife, cattle and small animals. The definition of mixed ranches arises from the inclusion of any species of livestock in a wildlife ranch.

As it would be expected, wildlife farms depend less on water purchase when compared to mixed ranches. This is an indication that the livestock component of mixed ranches take much of the water purchased on farms. Mixed farms with cattle depend more on water purchases to subsidize on other sources than farms with wildlife only or mixed farms with small animals such as goats and sheep, which are known to perform in marginal areas.

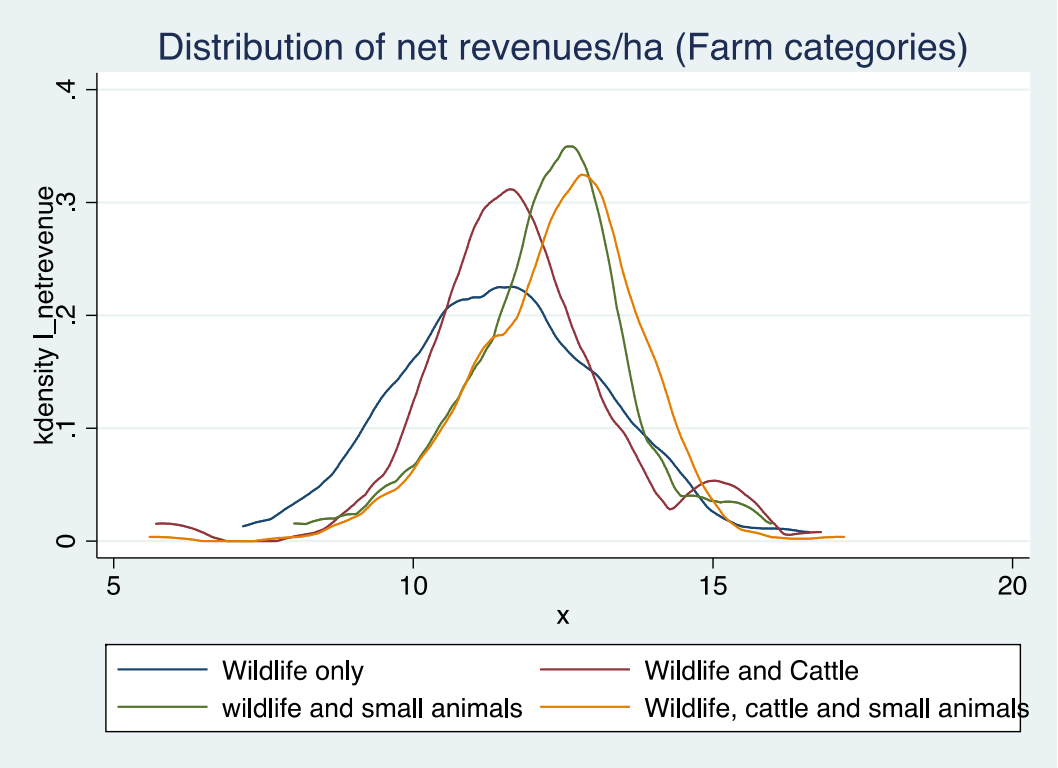
Membership to an association was treated as a discrete variable. It was either 1 or 0 to indicate whether a farm was in an association or zero otherwise. Mixed farms with wildlife, cattle and small animals are more likely (82 per cent) to be involved with social networks dealing in wildlife and livestock activities. Associations such as WRSA, CHASA or PHASA provide information to game farmers and those who look to invest in the sector. They also serve as a platform to advocate for better support to members (Zulu, 2015). The high levels of enrolment by mixed ranchers could be due to multiple memberships, both in wildlife and livestock associations.

One other test that has been carried out was on whether the differences in means of the attributes are statistically different when income groups[26] (Income groups ranged from 1-4) are considered. It was found that the difference in means between net revenue per ha and land size of farms from the four income groups were statistically different and this difference was significant for the income groups.

In order to shed more light on the distribution of farm revenues, a distribution plot for the revenues of all farms are shown in figure 3.1.

[26] Stats SA classify commercial farms into four distinct income groups based on annual turnover. The four income groups have the following cut-off points: R5,000,000 and more (Income group 1); R3,000,000<=N<R5,000,000 (Income group 2); R500,000<=N<R3,000,000 (Income group 3) and 0<=N<R 500,000 (Income group 4).

Figure 3.1: Kernel densities of log of net revenue per ha for different farms



The distribution of wildlife farms show a normal distribution with a thick tail and a wide spread. However, there is a distinctive difference in the distribution of net revenues of mixed ranches with both wildlife and cattle. The two-hump distribution shows that a proportion of farmers earn very high income on average while the left tail suggests that a number of other ranches in this category earn very low net revenues. There seems to be no difference in the distribution between wildlife and small animals and wildlife, cattle and small animals. The kink on the latter, however, suggests that these farms are more efficient or at least generate more revenues than the former. The kinked tail could also suggest endogenous efficiency in management of wildlife ranches. This raises the possibility of endogeneity. However, since the interest is on the net profits of the farms, it is assumed that farms with better management are able to generate more revenues.

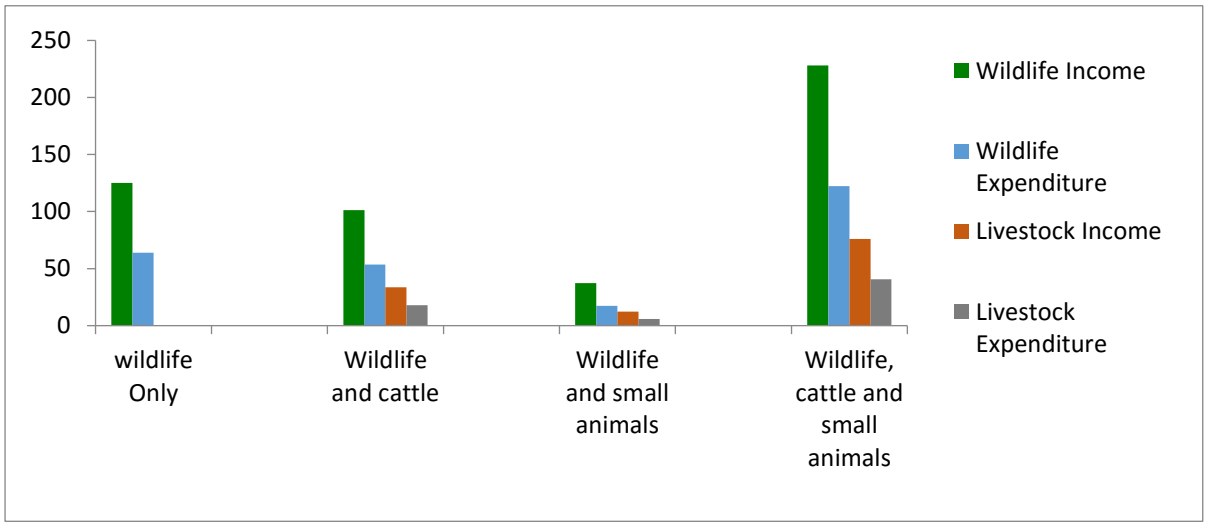
An ANOVA test is carried out to see if the means of the net revenues for the four farms were statistically different. The analysis showed that the means were statistically different between ranches with only wildlife and those with wildlife and smaller animals. This difference could be compared to those ranches with only wildlife or mixed ranches with wildlife cattle and

small animals. Lastly, there was also a significant difference between the means of ranches with wildlife and cattle when compared with wildlife, cattle and small animals.

Contribution of wildlife revenue to net farm revenues of mixed ranches

In order to determine how much revenues wildlife activities generated to farmers, especially the mixed farms, income and expenditure was disaggregated by source that generated them. In figure 3.2, it can be seen that most revenues from farms were generated through wildlife activities while most expenses on farm were incurred on livestock related activities.

Figure 3.2: Contribution of wildlife revenue to total ranching revenue (Million Rands)



Note: This figure represents the proportion of income generated from wildlife and livestock ranching activities and expenditure on livestock and wildlife ranching activities.

In table 3.2, the descriptive statistics for the different soils available in the ranching areas are defined.

Table 3.2: Descriptive statistics for soil types

Variable	Specialized Wildlife	Wildlife and Cattle	Wildlife and small animals	Wildlife, cattle and small animals
	Mean	Mean	Mean	Mean
Soil: Fluvisols	0.395	0.347	0.809	0.672
	(0.491)	(0.478)	(0.398)	(0.470)
Soil: Ferralsols	0.054	0.465	0.106	0.114
	(0.501)	(0.501)	(0.312)	(0.318)
Soil: Lixisols	0.938	0.871	0.830	0.638
	(0.242)	(0.337)	(0.380)	(0.482)
Soil: Arenosols	0.659	0.683	0.681	0.314
	(0.476)	(0.468)	(0.471)	(0.465)
Soil: Luvisols	0.450	0.525	0.851	0.840
	(0.499)	(0.502)	(0.360)	(0.377)
Soil: Leptosols	0.946	0.911	0.957	0.973
	(0.227)	(0.286)	(0.204)	(0.160)
Soil: Durisols	0.705	0.713	0.936	0.913
	(0.458)	(0.455)	(0.247)	(0.283)
Observation	221	133	62	300

Note: standard deviations is given in the parenthesis

Ranches with only wildlife are more likely to be found in areas where the soil is characterized by lixisols and leptosols. Some of the mixed ranches though are also found in these soil types especially in areas with leptosols. These soils are generally of poor quality and more suitable for wildlife utilization. Areas with ferralsols are less utilized for wildlife activities. These areas are better suited for crops and livestock activities.

Finally, in the next section, table 3.3 gives the descriptive statistics for the farms based on the climate variables.

Table 3.3: Descriptive statistics- Climate Variables

Variable	All Farms	Specialized Wildlife		Wildlife and Cattle			Wildlife and small animals			Wildlife, cattle and small animals		
	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
Summer Temp	28.64	15.87	22.58	29.33	15.26	22.08	28.94	13.03	20.76	28.55	12.80	20.30	27.84
Winter Temp	20.22	4.55	13.04	21.59	4.40	12.64	20.95	2.64	10.48	18.37	3.01	10.70	18.43
Autumn Temp	27.18	14.57	21.16	27.79	14.14	20.78	27.46	12.47	19.74	27.03	12.34	19.38	26.46
Spring Temp	24.54	9.76	17.94	26.17	9.16	17.22	25.34	6.14	14.40	22.71	6.40	14.44	22.54
Summer Rains	203.04	-	80.29	-	-	72.98	-	-	40.48	-	-	51.73	-
Winter Rains	53.36	-	10.31	-	-	12.40	-	-	14.98	-	-	16.69	-
Autumn Rains	188.7	-	68.33	-	-	65.12	-	-	48.80	-	-	55.84	-
Spring Rains	99.8	-	23.33	-	-	25.18	-	-	20.51	-	-	26.54	-

Note: The table presents the means, maximum and minimum distribution of temperature across the four seasons. Only means of seasonal rainfall is given.

Generally, wildlife ranches are located in areas with higher temperature coupled with very low rainfall when compared to average temperature and rainfall across South Africa. Most mixed ranches are located in areas with lower temperatures and lower rainfalls when compared to specialized ranchers which are in areas with higher temperatures but on average have higher rainfall when compared to areas with mixed farms.

3.5 Empirical results

The Median Ricardian results are based on equation (3) where the study investigates the impact of climate change on the net revenue per hectare. One cited advantage of the Ricardian approach is that it includes not only the direct effect of climate on productivity, but also adaptation responses by farmers to local climate since it takes into account the costs of different alternatives (Kurukulasuriya et al., 2008). For example, if the rancher decides to incorporate any type of livestock with wildlife as the weather conditions or the economic environment is changing, the Ricardian model assumes that the rancher will pay the transition cost associated with the livestock species introduced. At this point the assumption is that the rancher has considered the costs of alternative livestock species and the choice made gives the highest rent. That is, if a farmer chooses to incorporate wildlife with cattle, it is because the rancher considers wildlife and cattle to better perform when compared to sheep or goats with wildlife in the prevailing environment. If it turns out that the introduced livestock activities fails to be productive, the cost of this learning process is not included in the Ricardian model (see Kurukulasuriya et al.,2008).

In the regression, we control for the climate variables and regional differences. However, since not all ranches rely on purchase of water or enrolled themselves into an association dealing with wildlife or livestock activities, we create dummy variables to identify farms which procure water and those farms which enrolled in associations. These factors are known to influence farm-based revenues.

In the following section, the study proceeded in two stages. In the first stage, the net farm revenues were regressed on climate and soil variables only. In the next stage, the study controlled for region dummies and farms specific variables. In the first results (Table 3.4), net farm revenue for all farms regressed on climate and soil variables are presented. Since the study uses median regression, the OLS results are also presented for robustness check.

Table 3.4: Ricardian regression for South Africa wildlife ranching - all ranches

VARIABLES	Median Regression	Std. error	OLS Regression	Std. error
Summer Temperature	6.763**	2.78	6.857**	3.397
Summer Temperature Sq.	-0.123**	0.049	-0.120**	0.059
Winter Temperature	1.859***	0.713	1.381	0.870
Winter Temperature Sq.	-0.036**	0.017	-0.025	0.020
Autumn Temperature	-6.886**	3.117	-5.187	3.850
Autumn Temperature Sq.	0.126**	0.057	0.093	0.070
Spring Temperature	-2.514**	0.994	-2.780**	1.211
Spring Temperature Sq.	0.049***	0.018	0.0513**	0.021
Summer Precipitation	-0.184***	0.052	-0.131**	0.063
Summer Precipitation Sq.	0.001**	0.000	0.001	0.000
Winter Precipitation	-0.309**	0.123	-0.203	0.149
Winter Precipitation Sq.	0.003*	0.002	0.002	0.002
Autumn Precipitation	0.148**	0.074	0.116	0.090
Autumn Precipitation Sq.	-0.001	0.001	-0.001	0.001
Spring Precipitation	0.170**	0.077	0.105	0.093
Spring Precipitation Sq.	-0.001	0.001	-0.001	0.001
Soil: Fluvisols	-0.488***	0.176	-0.341	0.215
Soil: Ferralsols	-0.480**	0.209	-0.536**	0.257
Soil: Lixisols	-0.365**	0.182	-0.257	0.225
Soil: Arenosols	-0.339*	0.190	-0.356	0.231
Soil: Luvisols	0.330*	0.189	0.143	0.233
Soil: Leptosols	-0.057	0.264	-0.332	0.328
Soil: Durisols	-0.115	0.179	-0.105	0.220
Constant	24.14**	12.17	5.650	16.03
R2	0.1438		0.159	
Observations	716		716	

*Note: In this table, the results of pooled median and OLS regression using climate and soil variables are presented. Temperature is measured in degrees Celsius while precipitation is measured in mm. Significance level are at *** p<0.01, ** p<0.05, * p<0.1*

The results in table 3.4 shows that temperature and precipitation have a large and significant effect on the net revenues of wildlife ranchers. Summer temperatures are known to increase up to 36 ℃ in areas where livestock and wildlife ranching is practiced. The results show that net revenues initially increase with rising summer temperature. The quadratic term of the summer temperature is negative. This implies that eventually the net revenues decline with increasing temperature. The turning point at which revenues decline is given by dividing the linear coefficient with twice the quadratic coefficient. From the result, this turning point is at 27.49℃ during summer and 25.82℃ during winter. On average the maximum temperature is 28.64℃, which is just above the turning point. This suggests that warmer summer temperatures are generally harmful. The autumn temperature confirms that extended summer temperatures are detrimental to farm revenues. If these results are compared to the earlier studies done on the effects of climate change on livestock in Africa, then there is no significant difference. Seo and Mendelsohn, (2008b), for instance found that for the case of beef cattle and sheep, summer temperatures have a damaging effect on the value of land. This implies that the value of beef and sheep revenues decline with increasing summer temperatures.

The results of summer precipitation, however, suggest that net farm revenues initially decrease with increasing precipitation. As shown by the quadratic term, the relationship between the revenues and precipitation is U-shape with the turning point at 92 mm of summer rains. The turning point for the winter precipitation is 51 mm. At this point, wildlife revenues increase with winter rains which is significant and U-shaped.

The effects of summer rains and temperatures on net revenue can be summarized as follows. From the production point, there is an endogenous relationship between farm revenues and climate variables. Summer rains provide the right opportunity for both wildlife and livestock to thrive (since the biophysical conditions of the landscape is ideal, more food and water is easily available). The economic effects of this is that farmers incur less in provision of water and other interventions relating to biophysical challenges. Another source of revenue is the flow of tourists interested in bird watching. Summer migratory birds are also known to occupy these ranches during this time. From the economic perspective, while revenues increases with rainfall, this carries with it additional costs of road maintenance and diseases associated with excess rains.

In the following section, a regression of ranches with only wildlife ranches is done. In this section, regional dummies and farm-specific variables have been introduced besides the soil and climate variables. It has been shown so far that the results of the entire sample give similar results as earlier Ricardian studies on climate change and livestock production though with different magnitudes. At this stage, what is investigated further is how wildlife ranches perform under the same climate scenarios. In order to do this, the sample has been split into two and separate regressions run for ranches with only wildlife and mixed ranches. The results of ranches with only wildlife is presented in table 3.5.

Table 3.5: Ricardian Regression for ranches with only wildlife

VARIABLES	Median Regression	Std. error	OLS Regression	Std. error
Summer Temperature	-14.23***	5.179	-6.381	10.47
Summer Temperature Sq.	0.282***	0.092	0.128	0.184
Winter Temperature	0.427	1.705	-1.466	3.920
Winter Temperature Sq.	-0.003	0.036	0.042	0.083
Autumn Temperature	22.56***	5.203	14.41	11.07
Autumn Temperature Sq.	-0.443***	0.096	-0.291	0.202
Spring Temperature	-1.781	3.370	-0.575	6.419
Spring Temperature Sq.	0.0241	0.062	0.013	0.116
Summer Precipitation	0.320***	0.092	0.058	0.175
Summer Precipitation Sq.	-0.001***	0.000	0.001	0.001
Winter Precipitation	0.286	0.229	0.296	0.449
Winter Precipitation Sq.	-0.004	0.003	-0.003	0.007
Autumn Precipitation	-0.403***	0.117	-0.100	0.223
Autumn Precipitation Sq.	0.002***	0.001	0.001	0.001
Spring Precipitation	-0.334**	0.148	-0.505*	0.282
Spring Precipitation Sq.	0.004**	0.002	0.006*	0.003
Soil: Arenosols	-1.177***	0.357	-0.716	0.662
Soil: Luvisols	-0.721**	0.336	0.215	0.635
Soil: Durisols	-0.931***	0.252	-0.183	0.459
Purchase of Water	-0.317	0.306	-0.675	0.564
Free State	-1.805	1.127	-1.108	2.067
Limpopo	-2.843**	1.120	-2.208	2.195
Mpumalanga	-2.810**	1.256	-2.282	2.489
North West	-2.688**	1.170	-1.135	2.192
Northern Cape	-1.124	1.253	-1.313	2.290
Constant	-70.43***	24.46	-62.36	47.62
R2	0.1849		0.2856	
Observations	221		221	

*Note: Table 3.5 is a regression of net revenues of wildlife only firm on climate, soil (only soil variables which are significant have been presented here), and regional dummies on some farm specific variables. The reference province is Eastern Cape while *** p<0.01, ** p<0.05, * p<0.1*

The results here are significantly different from the earlier findings. It emerges that summer temperature has a U-shape relationship with net revenues. This generally implies that summer temperatures are beneficial to wildlife ranchers. The turning point is at 25.23℃ which is lower than the maximum average temperature but higher than the mean temperature of 21.58℃. In the earlier results of the whole sample, summer temperature had a hill-shape relationship with net revenues. This could be because the effects of temperature on the revenues were driven up by the presence of livestock. The linear term on the autumn temperature coefficient is positive and significant, an indication that extended summer conditions are generally beneficial to the farms.

There is also differences in terms of precipitation. Summer and winter precipitations have a hill-shaped relationship with net revenues of ranches with only wildlife on them. This implies that rainfalls result into a decline in net revenues of the farms. The turning point is at 160 mm for summer rainfall. Most wildlife ranches and conservancies are established around the national parks. Ranches that practice ecotourism sometimes share patronage with national parks. A common scenario is that during summer when the roads in national parks are flooded, it is normal to find many tourists spending time in the game reserves. While this initially increases revenue inflows, rains beyond 160 mm later reverses the gains in revenues. This is because increasing summer rains raises the cost of maintenance of roads and machineries such as vehicles. Costs also increase because viewing of animals become more difficult due to bushy vegetation and the ability of animals to move deeper into the bushes. It takes more effort in terms of fuel to track these animals. During winter, temperatures and rainfall are at their lowest. Increasing winter rains are beneficial as it cuts down on the cost incurred by farms to supply water as would have been the case with lower rains. There is also less cost incurred in repairs of roads during winter period.

From the results of the whole sample and the results of ranches with only wildlife, the relationship between climate variables and the two groups of farm are different. At this point, one would conclude that the hypothesis that wildlife only ranches and mixed ranches are the same cannot hold. It is clear that climate change affects the revenues of wildlife ranchers with only wildlife and those with both wildlife and livestock differently. Having established the climate-wildlife relationship, the next section proceeds to explore the regression of climate variables and mixed ranches. Mixed ranches represent 50.6% of the sample, but since the interest is to evaluate the impact of climate change, it is important to compare the results of

mixed ranches with wildlife and cattle. The regression results of mixed ranches with cattle and wildlife are presented in table 3.6:

Table 3.6: Ricardian regression with specialized wildlife only farms and mixed wildlife/cattle

VARIABLES	Specialized Wildlife	Std. error	(Wildlife and Cattle)	Std. error
Summer Temperature	-14.23***	(5.179)	8.246***	(2.857)
Summer Temperature Sq.	0.282***	(0.092)	-0.172***	(0.047)
Winter Temperature	0.427	(1.705)	1.254	(1.239)
Winter Temperature Sq.	-0.003	(0.036)	-0.040	(0.027)
Autumn Temperature	22.56***	(5.203)	-17.79***	(3.194)
Autumn Temperature sq.	-0.443***	(0.096)	0.346***	(0.058)
Spring Temperature	-1.781	(3.370)	0.703	(2.030)
Spring Temperature sq.	0.024	(0.062)	0.005	(0.037)
Summer Precipitation	0.320***	(0.092)	-0.173**	(0.070)
Summer Precipitation sq.	-0.001***	(0.001)	0.001*	(0.0001)
Winter Precipitation	0.286	(0.229)	0.380***	(0.130)
Winter Precipitation sq.	-0.004	(0.003)	-0.005***	(0.002)
Autumn Precipitation	-0.403***	(0.117)	0.266***	(0.093)
Autumn Precipitation sq.	0.002***	(0.001)	-0.001**	(0.0005)
Spring Precipitation	-0.334**	(0.148)	-0.101	(0.066)
Spring Precipitation sq.	0.004**	(0.001)	-0.001	(0.001)
Soil: Fluvisols	-0.070	(0.393)	-0.165	(0.183)
Soil: Ferralsols	-0.0370	(0.308)	0.0201	(0.156)
Soil: Lixisols	-0.310	(0.433)	-0.781***	(0.212)
Soil: Arenosols	-1.177***	(0.357)	0.452**	(0.212)
Soil: Luvisols	-0.721**	(0.336)	0.188	(0.218)
Soil: Leptosols	0.337	(0.352)	-0.511**	(0.228)
Soil: Durisols	-0.931***	(0.252)	-0.620***	(0.154)
Purchase of Water	-0.317	(0.306)	0.660***	(0.173)
Free State	-1.805	(1.127)	-0.355	(0.610)
Limpopo	-2.843**	(1.120)		
Mpumalanga	-2.810**	(1.256)	0.844*	(0.459)
North West	-2.688**	(1.170)	0.0479	(0.444)
Northern Cape	-1.124	(1.253)	-1.185*	(0.632)
Constant	-70.43***	(24.46)	111.2***	(19.85)
R2	0.1849		0.1935	
Observations	**221**		**133**	

*Note: the table illustrates a regression of mixed ranches (which have livestock and wildlife) alongside wildlife only. Statistical significance levels are at *** p<0.01, ** p<0.05, * p<0.1 and Reference Province is Eastern Cape*

The results of the mixed ranches are similar to those of the whole sample and the results found in some of the earlier studies involving livestock farming (Seo & Mendelsohn, 2008b; Aronson, et al., 2009). In terms of the effects of climate change on the mixed farms, in a study by Aronson et al., (2009), they found that temperature has a damaging effect on animal production in South Africa. An explanation for this could be the choice of portfolio of primary animal on the farm. That is, which animal generates the most revenue for the farm? It can be deduced from the results of the mixed ranches that cattle is the primary animal while wildlife on the same farm act as secondary animals. Therefore, most mixed ranches are dominated by livestock. It is possible that wildlife on these farms are at the introductory or growth stage of the enterprise.

3.5.1 Marginal effects of climate change on wildlife ranching.

The marginal effects on the value of wildlife ranching depend on both the linear and squared coefficients. In order to provide an easier interpretation of climate sensitivity, marginal effects were calculated. Table 3.7 presents the results using the entire sample of ranches and the sub categories of ranches.

Table 3.7: Absolute Marginal Effects of Temperature and Precipitation (ZAR/ha)

Province	Summer Temp	Winter Temp	Autumn Temp	Spring Temp	Summer Rainfall	Winter Rainfall	Autumn Rainfall	Spring Rainfall
All Farms								
Eastern Cape	8561	1543	-7677	-2421	455	740	-665	-42
Free State	3679	961	-3242	-983	151	522	-243	-162
Limpopo	10987	-1175	-8036	-2454	367	1904	-703	-153
Mpumalanga	1749	175	-1604	-459	31	259	-94	9
North West	2912	233	-2355	-706	108	477	-190	-33
Northern Cape	5471	1148	-4185	-1419	335	873	-444	-107
Wildlife Only Farms								
Wildlife Only	12022	-88	-9389	-2875	438	1876	-790	-126

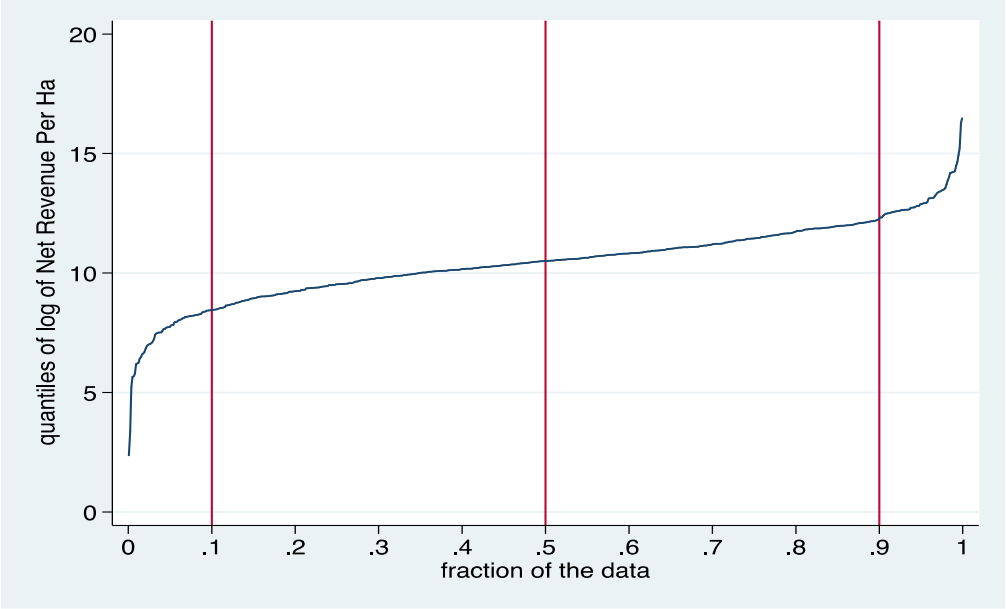
Note: marginal effects of climate change are presented in Rand/ha. These are average marginal effects per ha for each province

Across all the provinces, wildlife ranches seem to generate the most revenues in summer. When the conditions in any given season prolongs, however, the revenues get drained down. Temperature and precipitation have different marginal effects across seasons and regions. Summer temperature together with summer precipitation result in a higher positive farm revenues. However, it should be noted that extended summer period results into substantial losses which almost wipes out the summer gains. For example the average net revenue per hectare of land in the Eastern Cape Province reduces to R494. This can be explained by increased costs of infrastructure maintenance especially those farms practicing eco-tourism or hunting and breeding. Though winter also results into fairly higher returns, again extended winter (spring) results in losses which also reduce the gains from winter. It is noted that on average wildlife ranching almost certainly generates positive income per hectare of land annually. Farms that keep only wildlife generates the most revenue per hectare of land. According to the sample, across regions, ranches in the Northern Cape Province generate a higher annual net profit per hectare of land. The Northern Cape Province is known to have a number of national parks and conservation areas with tremendous growth potential in value added game-farming. This is closely followed by the Limpopo Province which is the province with the highest number of wildlife activities.

3.5.2 Effects of climate change on small and large wildlife ranches

One of the reasons why a quantile regression was proposed in this chapter is because it is able to address the distribution issues in the sample. The study therefore investigates whether ranches are affected differently by climate due to differences in the value of farms. There are a number of activities a single ranch could undertake. Some ranches specialize in one or a number of such activities. The hypothesis is that since ranchers have different value adding activities, ranches that have more value adding activities are likely to have more revenues compared to a farm that has fewer activities. It is, therefore, possible that a number of farms may have higher revenues which could influence the result of the regression due to the effects of outliers in the distribution. In sum, the median Ricardian is used in this study as it takes into consideration the effects of the outliers and distribution entirely. Using Nick Cox's qplot, we illustrate the empirical cumulative distribution frequency (CDF) of log of net revenue per hectare. The CDF appears reasonably symmetric (Figure 3.5).

Figure 3.5: Nick Cox's qplot



The quantile regression is run for all the farms across the quantiles to establish what differences occur on the effects of climate change on revenue when the value of the farm is taken into consideration. In order to capture these differences, we take the five quantiles at (τ=0.10, τ=0.25, τ=0.50, τ=0.75 and τ=0.90). Table 3.8 shows the results. From the results, what can be deduced is that high value ranches are affected differently by climate change when compared to low value ranches. In most of these cases, the effects are not significant. Take, for example winter precipitation, at τ=0.25 and τ=0.75 what can be seen is that winter precipitation is beneficial to both small and larger ranches, but it is significantly more beneficial to ranches on the higher quantiles considering that the quadratic term of higher quantile ranches are larger, than those of lower quantile ranches. Indeed, during winter, farms in the higher quantiles are likely to spend more resources in supplementing water if there is severe drought. But if winter rains are more, larger farms are likely to save more and this results into more profit to such farms. It is also important to note that the hypothesis that climate change affects revenues of all wildlife farms in the same way was rejected. It has been shown that wildlife farms which are larger in size in terms of revenues are affected differently by climate change as shown in table 3.8.

Table 3. 8: South African Ricardian Quantile Regression

	(τ =0.1)	**(τ =0.25)**	**(τ =0.5)**	**(τ =0.75)**	**(τ =0.9)**
VARIABLES	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Summer Temperature	-1.938	-2.385	3.116	-1.120	10.19
	(4.431)	(3.666)	(3.308)	(3.719)	(6.932)
Summer Temperature Sq.	0.020	0.010	-0.072	0.001	-0.185
	(0.077)	(0.063)	(0.057)	(0.065)	(0.120)
Winter Temperature	-0.0142	-0.398	-0.197	-1.430	1.274
	(1.311)	(1.242)	(0.994)	(1.129)	(2.029)
Winter Temperature Sq.	-0.012	-0.007	0.009	0.037	-0.035
	(0.030)	(0.028)	(0.023)	(0.026)	(0.048)
Summer Precipitation	0.0581	-0.0650	-0.143**	-0.120*	-0.0306
	(0.101)	(0.070)	(0.060)	(0.067)	(0.132)
Summer Precipitation Sq.	-0.001**	-0.0002	0.001*	0.0003	-0.0001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
Winter Precipitation	0.0853	-0.347**	-0.225*	-0.437***	-0.105
	(0.237)	(0.156)	(0.134)	(0.152)	(0.267)

Winter Precipitation Sq.	-0.007**	0.004**	0.002	0.0056***	0.0004
	(0.003)	(0.002)	(0.002)	(0.002)	(0.003)
Autumn Precipitation	-0.272**	-0.0263	0.212**	0.124	-0.009
	(0.135)	(0.108)	(0.0925)	(0.104)	(0.199)
Autumn Precipitation Sq.	0.003***	0.001	-0.001	-0.0001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Soil: Fluvisols	0.772**	0.432	-0.192	-0.089	-0.093
	(0.377)	(0.279)	(0.231)	(0.262)	(0.451)
Soil: Arenosols	-0.571*	-0.633**	-0.208	0.255	0.570
	(0.326)	(0.284)	(0.235)	(0.265)	(0.536)
Soil: Leptosols	-0.812*	-0.286	-0.363	-0.605*	0.541
	(0.479)	(0.362)	(0.306)	(0.348)	(0.554)
Soil: Durisols	0.573*	-0.169	0.146	-0.0343	-0.367
	(0.316)	(0.244)	(0.208)	(0.226)	(0.427)
Eastern Cape	1.117	2.151***	1.489**	2.246***	-0.0430
	(0.954)	(0.786)	(0.671)	(0.752)	(1.275)
Free State	0.089	1.732**	0.862	1.769***	-0.276
	(0.825)	(0.702)	(0.578)	(0.639)	(1.103)
Mpumalanga	1.769***	2.009***	0.729	1.247*	1.383
	(0.608)	(0.658)	(0.567)	(0.645)	(1.059)
North West	0.441	1.720***	1.194***	1.468***	0.032
	(0.528)	(0.493)	(0.410)	(0.436)	(0.827)
Northern Cape	2.000**	2.300***	0.900	1.430**	0.126
	(0.917)	(0.732)	(0.630)	(0.709)	(1.251)
Constant	50.60**	27.64	23.23	0.797	14.99
	(20.46)	(18.39)	(15.63)	(17.60)	(30.16)
R2	0.025	0.0741	0.015	0.0815	0.011
Observations	**716**	**716**	**716**	**716**	**716**

*Reference Province ==Limpopo Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1*

At various stages of this analysis, regional fixed effects were controlled for by introducing regional dummies. Other control variables introduced included different soil types and other farm specific variables. Here the intention was to capture regional fixed effect and farms heterogeneity. In summary, in regions where the soil is predominantly luvisols, arenosols or durisols the revenues from wildlife are likely to be affected negatively. Arenosols and

luvisols are fairly well drained and such regions may be more favourable to alternative land uses such as dairy cattle, crop production or horticulture farming. Wildlife use in such areas may therefore be counter-productive. Mixed ranches seem to benefit more in areas where arenosols type of soil exist, since the soil are well drained. Given that dairy cattle are known to perform better in these soil conditions, it can be assumed that mixed ranches are performing well because the primary animal is livestock while wildlife has been introduced as a secondary source of income. Ranches with wildlife perform better in areas with leptosols that are rocky with limited soils or poorly drained. In mixed ranches where water is purchased, the revenues are significantly better than those that do not purchase water. However, in the case of wildlife only ranches, this effect in neither significant nor positive.

In the case of regional dummies, the reference region is the Eastern Cape Province (table 3.5). The negative coefficient term in the Limpopo, Mpumalanga and the North West suggest that revenues of the farms in these provinces are affected more by climate change when compared to the Eastern Cape Province. The impact of climate change in these regions, as can be seen from the coefficients, suggests that the magnitude is relatively severe in Limpopo Province. This can be explained by the fact that about 50 per cent of wildlife ranching activities are in that region.

One of the key issue the study hypothesized is that the effect of climate change on the revenues of wildlife ranchers is the same as the impact of climate change on the revenues of livestock farmers. It has however been proved that climate change affect wildlife ranchers differently and wildlife ranchers respond different to climate change either through the various types of mixed ranching or by increasing the input use on their farms to derive the maximum benefit.

3.5.3 Simulations: Future effects of climate change on wildlife ranching revenues.

This section examines change in net revenue across regions and the type of ranches in South Africa. Three Atmospheric-Oceanic Global Circulation (AOGCM) climate scenarios are used. These include the Coupled General Circulation Model (CGCM), the Parallel Circulation Model (PCM) and the Hadley Centre Coupled (HadCM3) model (Benhin, 2006; Kurukulasuriya et al., 2008b) The predicted change in temperature and precipitation for South Africa is presented in table 3.9.

Table 3.9: Temperature and rainfall prediction for South Africa using AOGCM

	CGCM2 2050	CGCM2 2100	HadCM3 2050	HadCM3 2100	PCM 2050	PCM 2100
Change in Temperature (^{0}c)	3.6	9	3.9	9.6	2.3	5.6
Change in Precipitation (%)	-4	-8	-8	-15	-2	-4

Note: These are predicted values by which temperature and precipitation will change. The values are adopted from Benhin, (2006:86) for the studies carried out for South Africa's agricultural sector.

In order to estimate the impact of climate change using the above predictions, the coefficients from the estimated regression (3) are used to measure the consequences of the future climate scenarios. According to Passel et al., (2012), this is done by first calculating what the regression model predicts the current farmland value to be, then what the model predicts future farmland value will be given the predicted climate scenarios. These calculations take into consideration the predicted changes in rainfall and temperature at each location. Using the projections of the future climate scenarios given by *Benhin, (2006:86),* all the current rainfall and temperature values are projected for 2050 and 2100 for the three circulation models. After that, a simulation of future revenues is undertaken for each of the three models. A percentage change in revenue is calculated by taking the difference between the revenues in the future climate scenario from the current revenue. The results of the analysis are presented in table 3.10.

Table 3.10: Predicted climate change effects on the revenues (million rands)

	Current Farm Value	**CGCM2**		**PCM**		**HaDCM3**	
		2050	**2100**	**2050**	**2100**	**2050**	**2100**
Total	3980	3670	3400	3610	3460	3570	3400
		(-8)	(-15)	(-9)	(-13)	(-10)	(-15)
Eastern Cape Province	1700	1510	1230	1520	1390	1530	1230
		(-11)	(-28)	(-10.6)	(-18)	(-10)	(-28)
Free State Province	410.5	371.7	402.5	359.8	395.4	350.1	402.5
		(-9)	(-2)	(-12)	(-4)	(-15)	(-2)
Limpopo Province	760	663.2	732.1	625.7	673.8	611.7	732.1
		(-13)	(-4)	(-18)	(-11)	(-20)	(-4)
Mpumalanga Province	248.2	201.5	185	192.6	172	189.7	185
		(-19)	(-25)	(22)	(-31)	(-24)	(-25)
North West Province	258.3	249.5	217.2	262.1	218.4	256.8	217.2

		(-3)	(-16)	(+1.5)	(-15)	(-0.5)	(-16)
Northern Cape Province	606	682.4	632.3	642.2	613.6	636.1	612
		(+13)	(+4)	(+6)	(+1.2)	(+5)	(+1)
Wildlife Only ranches	1120	1000	965.9	968.5	965.9	952.3	1010
		(-11)	(-14)	(-13.5)	(-14)	(-15)	(-10)
Mixed Wildlife and cattle Ranch	876.5	811.6	745.7	798.3	745.7	759.8	736.5
		(-7)	(-15)	(-9)	(-15)	(-13)	(-16)

Note: The three GCMs have been used to simulate the effects of climate change across provinces for ease of interpretation. Percentage changes are in the parentheses.

The model predicts that the current value of land under wildlife based on the 2007 data is about R3, 980 Million. This value is likely to reduce by 15 per cent by the year 2100 due to the impact of climate change. The greatest reduction in net revenues from ranching would be experienced in the Eastern Cape Province where according to the HADCM3 Model, is expected to lose up to 28 per cent of its net current value. In the medium term (2050) however the Mpumalanga Province is expected to realize the highest loss in net revenues followed by the Limpopo Province. However, the model predicts that in the medium term, the Northern Cape Province would experience increased net benefits from wildlife ranching. The gains would nevertheless be modest. In terms of revenues from specialized wildlife and mixed ranches, the current net value is R1, 120 million and R877 million respectively. These values are expected to decline by 11 per cent and 7 per cent for wildlife and mixed ranches respectively in the medium term. Wildlife revenues from mixed ranches and ranches with only wildlife will decline by between 7% and 16% over the current values of R1, 120 million and R877 million from wildlife and mixed ranches respectively. In the long run, the effects of climate would be less severe from ranches with only wildlife on them. Wildlife ranches would be more resilient in the long run and there would be a likelihood of more farmers transiting to wildlife ranching.

3.6 Conclusion and policy implications

This chapter investigated the effects of climate change on the net revenue of wildlife ranching using the log-linear median estimation approach. The model reveals that change in climate conditions will affect both wildlife ranches and mixed ranches in the medium to long run.

The impact of climate change is measured by first running a regression for the whole sample. The study controlled for different soil types, farm characteristics and regional fixed effects. The results suggest that summer temperatures are beneficial to ranches with only wildlife,

while damaging to mixed ranches. Winter temperatures are more beneficial to mixed ranches, but more detrimental to ranches with only wildlife. Summer rains are more beneficial to mixed ranches and damaging to wildlife ranches. In the case of winter rains, it is damaging to both ranches. These condition can be explained by two factors. The first is the biophysical benefits associated with increasing temperature and precipitation, which characterizes forage availability (Post & Stenseth, 1999). Availability of forage and water mitigate expenses associated with provision of these mitigating resources. The Second factor is that ranch-based activities such as tourism, hunting among others, though practiced throughout the year have their peak season during summer. Ranches and reserves that are linked to national parks such as the Kruger National Park benefit most during summer since the road conditions and infrastructure in the reserves are much better when compared to national parks. Situations have arisen in the past where national parks are closed due to excessive rains in summer. Increasing temperature eventually put stress on wildlife, livestock and tourists. Wildlife move deeper in search of sheds making viewing more difficult and time consuming. Colder winter is also know to affect animals through cold stress or snow cover on forage access (Coughenour & Singer, 1996). The greater the variation in rainfall, the greater the proportion of time the population spends below carrying capacity, (Biggs, 2003). Since more rains and vegetation characterize summer, warm summer and winter could prolong visitations to private reserves by tourists that subsequently generate more revenues and at the same time reduce the cost of interventions.

Wildlife and mixed ranches respond differently to climate change. In the case of mixed ranches, the effects of summer and temperature is consistent with earlier studies on livestock especially commercial beef animals, (Seo & Mendelsohn, 2008a). This could be explained by the choice of species of livestock. Beef cattle is more sensitive to high temperatures when compared to sheep and goats which are less sensitive. The policies governing wildlife is different from policies governing livestock. Mixed ranches are at liberty to switch from one variety of livestock to another in response to climate change. In wildlife ranching, it may take more time to adjust to climate change as opposed to mixed ranches that are able to switch the species of livestock they keep. It is also known that warming may reduce the number of beef cattle to keep while increasing the number of small animals such as sheep and goats (Seo & Mendelsohn, 2008a).

The study has used three AOGCM models to predict the effects of climate change on wildlife ranching. The models indicate that revenues will steadily decrease over time in the medium term to long term across all regions except the Northern Cape Province which may experience a moderate increase in profits. Interestingly, while revenue will decrease over time, revenues from wildlife will stabilize in the long run as mixed ranches experience a sharper decline in revenues. This can be explained by the desire of more mixed ranches to transit to wildlife ranches as climate changes over time. It is also noted that wildlife are able to adapt faster to emerging climate conditions when compared to livestock. Warming would force a reduction in cattle because pasture and the general ecosystem would be transformed significantly.

The growth in wildlife use on private land is driven in parts by climate change effects on agriculture and the perception that wildlife and wildlife revenues are more resilient to climate change than crops and livestock. From the results of this analysis, a number of policy implications can be drawn. To begin with, the sector policies should be reconfigured to address emerging issues of climate change in wildlife conservation. Climate issues should be mainstreamed into existing polices in wildlife utilization by targeting mitigation and adaptation in wildlife ranching. Policies could be designed to provide potential pathways for strengthening adaptation capacities for climate change. This calls for the extension of climate-based incentives to include wildlife utilization on private land, besides crops and livestock.

Climate change will amplify existing stress on water availability in Africa. This will have a knock-on effect on other sectors. It will also interact with non-climate drivers and stressors to exacerbate vulnerability of agricultural and wildlife systems especially in the semi-arid areas. This raises the need to make progress in managing risks to wildlife use in private land from current climate variability and near-term climate change. It is necessary that policies are designed to increase flexibility in livelihood options which serve to strengthen coping strategies in wildlife sector for near-term risks from climate vulnerability. There is also the need to initiate governance systems for adoption and responding to climate change. This can include institutional framework to effectively co-ordinate the range of adaptation initiatives. Since there is a lag in policy formulation and implementation with regards to climate change and wildlife conservation, there is need to Fast track progress on national and

regional/provincial policies and strategies of adaptation into sector planning which involves complete integration and harmonization of agriculture and wildlife policies.

CHAPTER FOUR: AGRICULTURE AND ADAPTATION TO CLIMATE CHANGE: THE ROLE OF WILDLIFE RANCHING IN SOUTH AFRICA[27]

Abstract

In this chapter, we explore the role of wildlife in adaptation to climate change especially in areas predominantly used for livestock production in South Africa. Using a sample of 1071 wildlife and livestock farms we estimate a multinomial choice model of various adaptation options including and in particular livestock and wildlife farming choices. The results indicate that mixed livestock- wildlife farms are less vulnerable to climate change when compared to specialized livestock or wildlife farms. However, net farm revenues per hectare are higher for specialized wildlife ranches when compared to mixed wildlife-livestock ranches or livestock ranches. The results further show that increase in temperature will influence most livestock farmers to change land use from livestock to wildlife ranching. At farm level, land size and social networks are also likely to play a bigger role in land use change. Using climate models, we establish that livestock farmers in the Eastern Cape Province of South Africa will be most affected by climate change and will subsequently change land use. The main policy implication of the results of this chapter is that there is urgent need to mainstream climate change policies on mitigation and adaptation in agriculture to embrace wildlife ranching.

[27] Note: An extract of this chapter has been disseminated as ERSA working paper No.579.

4.1 Introduction

This chapter is motivated by the compelling evidence in the literature on the emerging role of wildlife ranching in the agriculture space. Evidence asserts that wildlife ranching is increasingly becoming an important land use option in South Africa, especially those areas considered marginal. In the arid and semi-arid areas of Africa, some of the most common land uses are in pastoralism or, in some cases, commercial livestock ranching. Agricultural activities in these areas, especially beef production, are known to be highly vulnerable to the severe effects of climate change (Seo et al., 2008). However, a major limitation is that appropriate adaptation and mitigation options are either few or far apart.

In order to adapt to climate change, both commercial farmers and communities have used temporary coping mechanisms or financial solutions to mitigate adverse effects of climate change(Wiid & Ziervogel, 2012). Some farmers have nonetheless managed to alter use of land for example, by moving away from bigger animals such as cattle to smaller stock such as sheep or goats, as a way of adapting to weather variability and climate change (Seo et al., 2008). In other regions, commercial farmers and communities are moving land away from livestock use to wildlife utilization especially wildlife ranching, wildlife farming or wildlife conservancies. These regions are predominantly in Southern and Eastern Africa.

Several factors such as loss of political power by the white dominated farming sector, the stop of subsidies to farmers, deregulation of agriculture sector and climate change have been attributed to the rise of wildlife ranching in South Africa (Van der Merwe 2004; ABSA, 2003). The role of climate change, however, is the least discussed in the literature especially where the private sector contribution is involved.

The emerging wildlife-based land use in areas traditionally considered arable or grazing land which is replacing agriculture livelihood land-based strategies is a new trend that less empirical investigation has examined. The influence of wildlife ranching as one of the adaptation options may be more expansive than currently thought. There is a dearth of literature linking the growth of wildlife ranching to climate change especially in crop and livestock production. Therefore, accurate quantification of the role played by wildlife as alternative land use is important.

Against this background, linking wildlife utilization to livestock production in the marginal areas as an opportunity for wildlife conservation as well as economic outcomes is important.

In most studies on climate change and agriculture in Africa, the focus has been on livestock and crops and not much attention has been given to the role of wildlife ranching. This is despite the existing evidence suggesting that livestock activities are highly correlated with the performance of wildlife ranching under different climate conditions. For instance, Kreuter and Workman (1997) point out that land used for cattle farming are known to be suitable for wildlife. Langholz and Kerley (2006) in a study on the assessment of eco-tourism based private game reserves in South Africa observe that land previously dominated by livestock farming (beef and dairy) and small stock farming (Merino sheep and angora goats) are being converted for wildlife use. In this chapter, we examine the role of wildlife ranching as an adaptation option for crops and livestock in the marginal areas.

This study adds to the existing literature on agriculture and climate change. The results of this chapter build on to the previous chapter. In particular, we expand land use options in the marginal areas to include wildlife besides livestock and mixed farms. We then estimate the conditional probability of choosing wildlife ranching given various exogenous factors.

We follow three arguments as we explore these questions on adaptation;

1. First, it is argued that contrary to findings of earlier studies which cited limited adaptation options in marginal areas, wildlife ranching could play an important role in adaptation. Besides, the contribution of the over 9,000 wildlife ranches to the agriculture sector, it is also estimated that land transition from livestock to wildlife use is growing at a rate of 2-2.5%[28] in South Africa. This means that omission of wildlife from earlier studies may have biased results or overestimated the effects of climate change especially those in Southern Africa region.
2. It is further argued that determinants of land use change in agriculture strongly correlate with those that derive private sector wildlife utilization. This implies that factors that derived adaptation choices among farmers in agriculture could as well influence land use decisions on wildlife land use.
3. Finally, the performance of integrated wildlife-livestock farms is likely to

[28] This figure has grown to over 5% annually as of 2010 (Dry, 2010).

outweigh mixed livestock farms. Seo (2010) shows that integrated farms perform better than crop or livestock only farms. This study extends this literature on resilience of integrated farms by comparing integrated wildlife-livestock farms to integrated livestock farms.

Given these arguments, the study uses data on commercial agriculture to first evaluate the determinants of land use change especially from livestock to wildlife ranching. Secondly, it looks at farmers' decisions on land use choices when wildlife is added to the menu of choices. Lastly, the study evaluates how vulnerable each of the three options are to climate change.

In South Africa, commercial farms are declining at a high rate. In the last census for commercial farming done in 2007, there were only 39,966 farms. This is a reduction of 12.8 per cent of the number of commercial farming units that were there in 2002 and more than 31.1 per cent reduction when compared to the number of commercial farm units in 1993 (Stats SA, 2010).

Having said this, looking at wildlife conservation in the national parks and reserves, the threat of climate change on species is also real. More species of wildlife in the protected area networks are exposed to extinction due to climate change (Erasmus et al., 2002; Wiedmann, 2009). Erasmus et al., (2002) find that up to 66 per cent of the 179 species in their study on Kruger National Park will be lost due to climate change. Wiedmann (2009) predicts that between 15-35 per cent of species in their sample would be at risk of extinction. Expansion of public protected areas to protect more wildlife is considered almost impossible due to the cost involved. Therefore, the few remaining options for conservation are outside the protected areas such as ex-situ conservation options (IPCC, 2013) or wildlife ranches and conservancies (Von Maltitz et al., 2006).

The prevailing situation in land utilization in the marginal areas render wildlife an important option worth exploring. The number of farmers currently engaging in wildlife utilization are estimated to have increased to more than 9,000[29] with about 4000 of them practicing some

[29] A number of studies have quoted different figures. NAMC (2006) and Stats SA, (2010) notes that livestock and crops farms declined by 31% between 1993 and 2007. But just about the same period (1993-2005), wildlife ranches increased more than twofold from 3,357 ranches with exemption permits to 6,330 ranches covering over 14.8 million ha of land. The current figures show that wildlife ranches with exception certificates are 6,734

form of integrated wildlife-livestock land use (Langholz & Kerley, 2006; Dry, 2010; Child et al., 2012). This chapter builds on the vast literature on climate change and agriculture especially adaptation to climate change in crops and livestock(Erasmus et al., 2002; Seo et al., 2008). It extends this literature by considering the role played by wildlife in countries (particularly in Southern African countries) where private sector-led wildlife utilization has been legalized and practiced side by side with agriculture. Even though wildlife ranching is assumed to be practiced by rich large-scale commercial farmers in the Southern African region, there are indications of emerging small-scale and communities.[30]

At the moment lack of clear understanding of the linkage between livestock and wildlife in terms of climate change and adaptation in the marginal areas raises the question of whether the current adaptation strategies in these marginal areas fully represent all options available to commercial farmers in such agro-ecological zones. Consequently, it also raises the question of whether policies and the management practices currently adopted are for the benefit of both wildlife and livestock. The complexity of wildlife-livestock environment is seen in the lack of synergy and policy lags[31] in wildlife management in South Africa which fall under various government agencies with competing interests (Child et al., 2012). The majority of wildlife ranchers though advocate that certain aspects of wildlife ranching should be considered an agricultural activity (Dry, 2010).

The remainder of this chapter is organized as follow. In section 4.2, we review the literature on land use decisions and adaptation in agriculture and wildlife conservation; Section 4.3 begins with a review of the theoretical framework on land use change, which helps us develop an econometric specification of the model. This is followed by description of the data. The results are presented in section 4.4 followed by discussions and conclusion in section 4.5.

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while another 2,245 farms are considered open farms because they do not have exemption permits (Taylor et al., 2015).

[30] Some rural communities continue to approach conservation agencies and government for aid to establish small game reserves so that they can also benefit from wildlife production, to get involved in wildlife land use (Tomlinson, Hearne & Alexander, 2002).

[31] Currently, the Department of Agriculture in the Limpopo Provincial Government is in the process of formulating a Game Farming Strategy. This implies that until recently certain aspects of wildlife ranching has been operating in a policy vacuum.

4.2 Literature review

4.2.1 Introduction

In climate change studies, adaptation is defined as actions that people and firm take in response to climate change to reduce damages and increase benefits (IPCC, 2007). The theory of adaptation stresses three broad concepts: efficient adaptations, private adaptations and public adaptations. Efficient adaptations are actions that make actors better off (Mendelsohn & Williams, 2004). Private adaptations involve actions that only benefit one person (the actor); it always tends to be efficient because it is in the interest of the actor to make changes. Public adaptation involves many beneficiaries. The market will tend to have trouble making efficient public adaptation for example, protecting endangered species because the cost of coordination across multiple beneficiaries is large, especially if the beneficiaries are heterogeneous (Mendelsohn, 2006). Therefore, farmers switching from livestock and crops to mix or wildlife ranching is an indication of adaptive actions.

This chapter grounds livestock and wildlife land use transition in the land rent theory by Von Thunen et al., (1966) and Ricardo (1822). The theory is founded on the micro-economic theorization tradition (Briassoulis, 2000). According to land rent theory, any parcel of land given its attributes and location will be used in the way that earns the highest rent (Lambin & Meyfroidt, 2010). Land use change or conversion is therefore driven by choices made by land managers among alternative rents. Briassoulis (2002) observe that the determinants or drivers of land use transition or change are always not clear and frequently certain drivers are emphasized over some others. Drivers of land use change can be classified into two categories: biophysical and socio-economic drivers. Biophysical drivers include characteristics and processes of the natural environment such as weather and climate variation, topology and soil type among others. Socio-economic drivers include demographic, social, political, economic and institution factors.

4.2.2 Wildlife, livestock and climate change interface in South Africa

Wildlife ranching sub-sector in South Africa has grown in magnitude and diversity over the last two decades. According to ABSA (2003), the sub-sector is ranked sixth biggest in the agriculture sector with an annual turnover of over R 7.7 billion as of 2008. The wildlife sub-sector covers more than 20 million (16.8 per cent) hectares of land, which is a quarter of 84 million grazing land in South Africa. The sector also holds 2.5 million wildlife which is four

time more than those held under the public protected areas (Dry, 2010). Equally, of the total land area in South Africa, only 17 per cent is arable with over 87 per cent marginal land.

Over the past decades, the number of commercial farms practicing crop and livestock production has declined by over 31 per cent between 1993 and 2007. One of the biggest challenge has been associated with climate change since much of the production activities in agriculture has been rain-based. South Africa, however, is one of the most water stressed countries in Africa. Thus, livestock production is facing an uncertain future in South Africa. Seo and Mendelsohn (2008) find that with a warming of +2.5℃ over the current climate the areas for beef production in South Africa will shrink dramatically and almost entirely disappear with over +5℃ temperature increase over the current level.

The effects of climate change have also extended to biodiversity conservation especially wildlife conservation in the public protected areas. One would expect that the effects of climate change could as well extend to wildlife utilization in the private sector. There is need to bring out the linkage between wildlife utilization and livestock production in the marginal areas due to the possible opportunities as well as risks associated with this linkage in terms of wildlife conservation, economic contribution and social impacts.

The accelerated transition from livestock to wildlife has been attributed to many factors. Underlying some of these explanations is that it was a strategic move by white commercial farmers to preserve their land from restitution claims (Zulu, 2015). This was because these farmers had lost their political power to influence policies in post-apartheid era. Farm subsidies to agriculture sector had also been removed and at the same time, the sector underwent deregulation (ABSA, 2003). This affected productivity and profitability of agriculture, but also raised prospects in wildlife ranching which was considered less labor intensive (Langholz & Kerley, 2006; Carruthers, 2008a).

Some of these issues cited appear to dampen the role played by other factors such as climate change in influencing a shift in land use. Even though a number of studies mention climate change as one of the possible reason why farmers were moving to wildlife ranching, it is only in Van der Merwe et al (2004) who note that transfer of land from traditional agriculture and domestic stock to nature-based wildlife pursuit is likely accelerated by climate change.

Although the decline in crops and animal farms could be explained by the consolidation

process where successful farmers bought off the struggling farms, existing evidence suggests strongly that climate change had a severe impact on agriculture especially crops and livestock (Gbetibouo & Hassan, 2005; Seo & Mendelsohn, 2008). What stands out in the literature is that not much effort has gone into evaluating the role of wildlife ranching in climate change and adaptation even when it is obvious that climate change could have played as a bigger role comparable to other factors mentioned.

The linkage between climate change, wildlife ranching and livestock production can be traced as far back as the 1940s. Carruthers (2008) notes that the 1940s had been very dry, but by the 1950s there were farmers in the arid and semi-arid areas of South Africa who noticed that the springbok on their land had not been as badly affected by the dry years as had the livestock and subsequently began to harvest them. Similar development was noticed in other parts of South Africa. As a result some farmers began keeping one or two species of wildlife in their land in semi-natural states. The interest in game ranching was further fueled by the fact that during the 1960s drought in South Africa depressed the beef prices; this made game ranching attractive.

Looking at how the growth of mixed ranching took shape over this period, it confirms that adaptation was partly the cause of the growth of game ranching. Cloete et al., (2007) conducted a study on why farmers were switching from livestock to wildlife in the Northern Cape Province and concluded that it took many years to breakeven. In addition, the switch also involved enormous expenses and unforeseen difficulties. Farmers could have opted for mixed ranching as a way of generating income to sustain farming activities during bad weather. As van der Waal and Dekker (2000) observe, the number of mixed game ranches were on the decline during the 1990s with many of them switching to game only.

While it is possible that commercial farmers may have anticipated the fall of apartheid regime and the subsequent loss of political dominance, it is hard to lay claim that the farmers anticipated the land reform process and had prior knowledge that land with wildlife would not be affected by restitution claim, and hence transitioned from livestock and crops to wildlife. It is more plausible to hypothesize that mixed ranches emerged out of the need to adapt to climate change. With deteriorating conditions in livestock-based land use, most of these farmers switched to game ranching. Those who held onto mixed ranching could be explained by the seasonality in wildlife-based production which still contributed to the

dominance of mixed ranching (Smith & Wilson, 2002; Carruthers, 2008a) or due to the disenchantment of farmers with livestock farming as a main driver on their farms (Smith & Wilson, 2002).

4.2.3 Determinants of land use change

In order to evaluate the role played by wildlife in adaptation, it was important to understand the different conditions under which livestock and wildlife farmers operate in terms of land utilization. Livestock farmers are known to use financial capabilities to overcome the effects of climate change in the short run. However, in some cases, farmers have changed the composition of their stock of animal species they keep by moving away from larger stock to small stocks which are perceived to be more tolerant to climate factors. In other cases, some farmers have practiced mixed livestock farming where small stock have been mixed with larger stock. As such, it is necessary to first investigate if the factors that influence change of land use within the livestock sub-sector could also play a role in changing land use from livestock to wildlife.

In the literature, several factors are known to influence land use change decisions and adaptation in agriculture. These factors, as mentioned earlier, are classified as biophysical and socioeconomic factors. Biophysical factors (sometimes referred to as ecological factors) such as soil and climate type can limit the type of crop or livestock that a farmer can have on his or her field hence reduce the ability of a farmer to adopt some strategies, (Kurukulasuriya, Mendelsohn & others, 2008). Most common types of soil in the marginal areas of South Africa are largely characterized as arenosols, fluvisols, ferralsols, lixisols, leptosols, durisols and luvisols among others. Areas considered favorable for livestock production are known to have relatively poor soils, erratic rains or generally marginal, (Rubel & Kottek, 2010). Agro-ecologists use land evaluation techniques to determine the potential land uses for a location based on the biophysical characteristics of the location, (Fischer et al., 2005).

Economic factors (for example farmers' access to capital or assets) are known to influence the ability of farmers to adapt to climate change. Financial capabilities mean that farmers are able to invest in new technology (Cooper, Hart & Baldock, 2009). Farmers with finances are therefore able to move to alternative land use, such as wildlife, because they are in a position to invest in capital assets. Farmers with diverse sources of income may be better placed to adapt because they mitigate the risks of climate change by earning income from different

sources (Adger et al., 2009). Similar trends are witnessed in livestock-wildlife land use shifts. Most farmers transit to wildlife ranching after they have practiced mixed ranching for some time to ensure a seamless transition with a steady cash flow. Other studies have suggested that farms with larger parcels of land are also likely to adopt new strategies (Erenstein & Laxmi, 2008). Finally, social factors (for example, farmers who have strong social networks) are more likely to try alternative farming activities due to social pressure which is backed by strategic information on both biophysical and business related issues, (Matuschke & Qaim, 2009).

Besides the general consensus that farmers' perception about climate change often influence their response to land use and adaptive decision in a shifting climate (Wiid & Ziervogel, 2012), other known factors that drive adaptation choices among farmers in agriculture include internal factors such as farmers' managerial preferences, entrepreneurial drive or peer opinion (Bryant et al., 2000; Smit & Wandel, 2006). External factors, such as regional dynamics, political and cultural institutions, social networks and availability of resources, also play a role (Adger et al., 2003; Adger, Kelly & Ninh, 2012). In a climate impacted environment, however, what underline choice is largely influenced by farmer's perception about climate variability (Bryant et al., 2000; Wiid & Ziervogel, 2012).

Farmers who have transited from livestock to wildlife may be better placed to provide knowledge on both non-climate and climate related factors which could motivate adaptation responses including land use change. The economic and agronomic estimated results of recent studies on climate change and livestock in South Africa may be confounded by the large presence of wildlife ranches which has not been considered in these studies. Therefore, the current debate may turn out to paint a false picture on the available adaptation options for commercial and small-scale farmers in these regions. For example, in a climate-impacted scenario, available adaptation option for large-scale beef farmers may be in sheep rearing (Seo et al., 2008). If, however, beef farmers reallocate to wildlife ranching, it is likely that the current estimates based on the Ricardian approach for beef in the Southern African region is biased.

In South Africa, studies on climate change and livestock show worrying results given that farmers experiencing water challenges may reach their financial adaptive limits in livestock if climate change remains severe (Bomhard et al., 2005). Earlier predictions by Seo and

Mendelsohn (2008b) indicate that a +2. 5℃ to + 5℃ temperature increase over the current levels is likely to wipe out cattle or beef farms and shrink drastically sheep farms in Southern Africa region. Farmers who are vulnerable to climate change have undertaken various adjustments to able to adapt. For example, small and large scale farmers have moved production from one form of cropping to more drought resistant varieties or shifted from cattle or beef production to sheep farming in dry areas or goats and chickens in wet areas (Seo & Mendelsohn, 2007). In other areas in Africa, farmers have tried joint production of crop and livestock or moved to forestry (Seo, 2010b). There are also cases where farmers have moved from crop production to livestock production or mixing different species of livestock, (Kabubo-Mariara, 2009). Not much, however, has been done to evaluate performance of those farmers who have chosen wildlife land use as alternative way of adapting.

As Vedwan and Rhoades (2001) observe, farmers are best placed to know how climate fluctuations impact on farming practices. However, farmers may underestimate their ability to respond because of how they perceive environmental risks in terms of personal control over global and regional external environment stresses (Gardner & Stern, 1996).

Wildlife utilization on private land comes at a time when there is an important on-going debate about how agriculture and biodiversity should be integrated (Green et al., 2005). In this emerging literature, the discussion is on whether agricultural policies should encourage land sparing or wildlife-friendly farming (Fischer et al., 2008). Wildlife friendly farming assumes that human activities and nature can coexist in a socio-ecological system (Berkes, 2004). Hence, the interactions between nature and agriculture are of great interest both conservation (Tscharntke et al., 2012).

The importance of wildlife ranching as a better alternative to ex-situ conservation is emphasized in the latest IPCC Fifth Assessment Report (AR5). Von Maltitz et al., (2006) also observes that conservation through expansion of public reserves in the face of climate change will be more expensive, while ex-situ option could be considered as the last option. What would be more cost- effective would be contractual reserves (Matrix management) on private land. This is because the range-land management is already biodiversity-friendly for many species. It is considered potentially cheaper because the economic incentives have already led landowners in these areas to use their land for non-agricultural activities, such as ecotourism

and wildlife ranching, since they provide better returns.

Of particular interest is the role of incorporating wildlife ranching practices in livestock production as a means of climate change adaptation. Kreuter and Workman (1997) explored the impact of integrating cattle with wildlife ranching and Child et al., (2012) looked at the economics of private sector wildlife conservation. In both case, these two studies did not exclusively model adaptation in wildlife ranching. Many studies consider change in farming behavior such as switching species of livestock as adaptive, but it is important to consider the outcome of such behavior to understand how well farmers are able to adapt to changes in climate. By considering the outcome of the decision making, it is possible that certain coping strategies could be shown to be non-beneficial or maladaptive (Barnett & ONeill, 2010).

While the current debate on land use change from livestock may have been gobbled by issues related to political and social transformation in post-apartheid South Africa, there is every reason to hypothesize that the changes witnessed in agriculture-wildlife space could be economically motivated. From this perceptive, climate change is a key factor that influences farmers' adaptation decisions.

Existing empirical economic literature on adaptation states that, if farmers do not make timely adjustments to climate change, there would be high adjustment costs as farmers move from one equilibrium to the next. There are three empirical strategies to modeling adaptation choices in livestock farming (Seo & Mendelsohn, 2007); one can model the primary animal, the portfolio of animals or the demand for each species. A primary animal model is defined as a single animal that earns the most revenue on the farm (Mendelsohn & Dinar, 2009). The approach ignores secondary species; the assumption is that the primary animal dominates the revenues of the farm. The advantage of this approach is that there is a single choice and it is exclusive. The portfolio approach to modeling adaptation treats combination of animals as a choice. The last approach to modeling adaptation is through a system of demand functions (Seo & Mendelsohn, 2007). The farmer can select whether to choose each animal independently from other choices. Because the choices in the model are not mutually exclusive, the totals do not have to add up to one.

In this chapter, a portfolio approach is used. The portfolio approach can reflect how farmers diversify their choices to cope with climate variation. It captures the full complexity of farm choices, but as the number of species increase the number of potential combinations increases

(Mendelsohn & Dinar, 2009). Given that in this study it was not possible to either identify the primary animal or the type of species the farmers keep, the use of portfolio approach to modeling adaptation was preferred because it was easier to categorize animals into small stock which comprised of goats, sheep or pigs and large stock (cattle). It was also possible to classify wildlife as a single portfolio. Farmers start by diversifying the species of livestock they keep; they then incorporate a few species of wildlife. The portfolio of livestock remains the primary source of farm revenue, but overtime, a transition occurs and eventually wildlife becomes the primary source of income with livestock as secondary.

4.3 Research methodology

4.3.1 Introduction

The study is motivated by three specific questions. i) What are the determinants of land use change in the marginal areas? ii) How vulnerable are wildlife ranches to climate change when compared to mix or livestock ranches? iii) What is the future trend in land use especially in the marginal areas?

4.3.2 The theory

Farmers are expected to optimize their well-being by allocating or converting land to alternative uses that maximize their utility. Therefore, a profit maximization model[32] is adopted in this study. A farmer chooses a type or combination of farming practice that generates the highest profits. This is consistent with the land rent theory (Briassoulis, 2000). Profit maximization models have been used in literature to explore optimal farm plans (Van Ittersum, Rabbinge & van Latesteijn, 1998). In agriculture, especially small-scale or subsistence farming, profit maximization models are criticized on the basis that the assumption that farmers maximize profits may not necessarily be true (Barnett & ONeill, 2010; Rufino, Reidsma & Nillesen, 2011). Commercial ranching is, however, based on the assumption that a farmer's main objective is to maximize profit and, therefore, land use management happens in pursuit of profits besides other possible objectives. The preference of a given land use option is assumed to be influenced by a set of factors such biophysical, economic or social. We look at landowner's problem in a climate-impacted scenario to involve decision on either to continue with livestock ranching or transit to wildlife ranching.

We assume a profit maximizing landowner with a parcel of land of size *S* that has multiple which can include livestock and wildlife denoted by *l* and *w* respectively at all points in time such that $l_i + w_i = S_l$. Therefore, the landowner has to choose at each point in time how much of land is put to either use to maximize the present discounted value of benefits less the cost of conversion. That is.

$$max_{\ alw} \int_{t=0}^{\infty} \left\{ \sum_{w=0}^{W} R_w S_w e^{-rt} - \sum_{l=0}^{L} \sum_{w=0}^{W} C_{lw}(a_{lw}) e^{-rt} \right\} dt \quad (1)$$

[32] This model is based on the land rent theory. According to Briassoulis (2000), the traditional statistical base model for land use change model was $LUT_i = a + \beta_1 X_1 + \beta_2 X_2 + \cdots \ldots \ldots \ldots \ldots + \beta_n X_n + \varepsilon$. Where LUT is the land occupied by land use type i and $X_1 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots X_n$ are predictors (soil types, climate factors among others). ε is the error term of the statistical model.

s.t.

$$\dot{S}_l = (a_{wl} - a_{lw}) \qquad (2)$$

$$\sum a_{lw} \leq S_l \qquad (3)$$

$$a_{lw} \geq 0 \qquad (4)$$

Where[33]*;*

L And W; are livestock and wildlife land use respectively.

S_l - Stock of land on use L

a_{lw} – number of ha of land converted from use L to W at a point in time.

R_w/R_l – Net benefits from an ha of land in use W or land use L

$C_{lw}\ (a)$ - The total cost of converting a ha of land from use L to$W$.

The optimal solution for current value Hamiltonian with shadow prices is such that if the marginal conversion costs are constant, the condition for conversion from use L to W becomes:

$$\frac{R_w}{r} - C'_{lw}(a_{lw}) > \frac{R_l}{r} \qquad (5)$$

The decision rule is that conversion from use l to w is optimal if the expected present discounted value of an infinite stream of net returns to use w less conversion cost is greater than the present discounted value of net returns from use l. That means that the farmer chooses the use with the highest return which maximizes his/her utility.

4.3.3 Empirical strategy

In order to address the research questions, in the first stage, we have grouped the farmers into two categories; livestock farmers and wildlife farmers.

[33] *Note: Biophysical factors such as precipitation, soil and temperature variations are allowed to influence conversion costs*

From the previous theoretical formulation, a landowner with a stock of land and facing land use choices of either livestock or wildlife has a profit function:

$$\pi_i = max(R_w - rC_{lw}) \qquad (6)$$

π_i is the profit that accrues to firm *i*. Using the general random utility expression, we can represent the expected profit when landowner moves from a given land use allocation for example livestock to wildlife as:

$$U_{lw} = R_w - rC_{lw} = \beta_i V_{ilw} + \varepsilon_{ilw} \qquad (7)$$

Where U_{lw} is the utility a farmer whose land in use *l* gets by changing land to use *w*, V_{ilw} a vector of observed variables β_i, is the parameters and ε_{ilw}, is the random error term of the equation.

Our first interest is in the probability of land use change at certain locations relatives to all options. The hypothesis is that the factors that drive land use choices within the livestock sector could as well drive land use change decisions from livestock to wildlife. Therefore, there is need for a dichotomous specification of the regression. The statistical model developed is a discrete probit model of two choices: convert location *i* into wildlife use or not. Clearly the preference for the location cannot be observed: therefore, analysis of this dependent variable requires a binary response model. We derive this from the underlying latent variable model:

$$y^* = \beta_0 + x\beta_1 + \varepsilon$$

And

$$y = 1[y^* > 0] \qquad (8)$$

y^* is the latent variable; x denotes the set of explanatory variables and ε is the error term and $1[\,y\,* > 0]$ which defines the boundary outcome. The error term is assumed to have a standard normal distribution characteristic of a probit model (Cameron & Trivedi, 2010). A probit model is preferred because given the normality assumption; several specification problems are more easily analyzed (Baum, 2006).

Having determined that factors responsible for land use choices in livestock sector could as well determine choices of land use in the wildlife-livestock sphere, we now compare the choice of farming system that includes wildlife and integrated wildlife-livestock farms to those that only practice livestock farming. The outcome of the choice a farmer makes is assumed to be one that has the highest net revenue. Therefore, conditional on the type of farming choice made, we are able to estimate the net revenue of the farm chosen.

The basic model is given by:

$$Y_1 = X_1\beta_i + \varepsilon_1 \quad (9)$$

$$Y^*_s = Z_s\gamma_s + \eta_s \quad (10)$$

Where Y_1 refers to the net revenue per ha associated with specific farming choice (livestock, wildlife or mixed wildlife-livestock). Y^*_s, is a discrete choice variable indicating the categories of different farm choices. X_1 and Z_s are explanatory variables that include biophysical factors, economic and social factors. ε_1 is the disturbance term that satisfies the normal assumptions E(ε_1/X)=0 and V(ε_1/X,Z)= σ^2. When we use the normal OLS to estimate the revenue equation, each revenue equation is run separately. But there are problems of unobserved characteristics which affect both the choice of the ranching type and the revenues generated. This implies that the error terms ε_1 and η_s will be correlated and the estimated $\beta_i$will be inconsistent. In order to correct for such inconsistency, bias correction methods such as Heckman's (1979) two-stage selection model is normally used for the multinomial case. We follow Dubin and McFadden (1984) and Dubin and Rivers (1989) for the selection bias correction in the multinomial. This selection bias correction approach has been extended by Bourguignon, Fournier and Gurgand (2007) who offer an alternative approach that take into consideration the correlation between the disturbance term from each of the revenue equation and the disturbance term from each of the multinomial logit equation. In their model, they assume a linear association between ε_1 and η_s , $\varepsilon_1 = \sigma_i \sum \rho_s \eta_s * + \omega_i$. The residual term is orthogonal to all η_s*: The bias corrected net-revenue equation becomes:

$$Y_1 = X_1\beta_1 + \sigma_1\left[\rho_1 m(P_1) + \sum \rho_s \frac{P_s}{(P_s - 1)} + m(P_s)\right] + v_1 \quad (11)$$

Where P_s is the probability that a category s is chosen and $v_1 = \eta_1 + \log P_1$. Estimates of $\sigma_1$in the above equation are consistent. The second term on the right equation corrects for the selection bias. In this study, this term explains the interactions between livestock, mixed

wildlife-livestock farms or wildlife only farms. The number of bias correction terms in the equation is equal to the number of multinomial logit choices. The Bourguignon, Fournier and Gurgand (2007) methodology allows us to identify not only the direction of the bias related to the choice of system but also which choices between any two alternative systems the bias stems from. The model is further preferred because it is flexible incase non-linear specification is present and the independence of irrelevant alternatives (IIA) is violated (Dimova & Gang, 2007).

4.3.4 Data

This study uses three different datasets. The first dataset is data on commercial agriculture in South Africa. It comes from the 2007 census for commercial agriculture (Stats SA, 2010). This data contains production and financial activities of all commercial farmers in South Africa. Since the study is interested in livestock and wildlife activities, the focus is therefore on those two sub sectors of agriculture. It should be noted, however, that reporting on wildlife utilization is yet to be fully captured during the census period. We uniquely identify 716 farms with wildlife ranching across six of the nine provinces. Another point to take note is that the last census for commercial agriculture in South Africa was done in 2007. The data used in this study is thus the most current data available. The data from the six provinces represents over 80 per cent of farming activities in South Africa. Farm level data allows for categorization of farms into mixed ranches, wildlife only ranches and livestock ranches. We draw a sample of 355 livestock farms with similar characteristics to mixed ranches, but only that they do not have wildlife on them. In total, a sample of 1071 farms is drawn. These include 355(33%) of farms that practice livestock farming, 495(46%) farms that practice mixed farming and 221(21%) farms that practice wildlife ranching.

The second dataset is for climate[34] variables. This data is obtained from the Climate System Analysis Group[35]. The climate variables used include temperature and precipitation. Temperature is measured in degree Celsius for monthly averages while precipitation is measured in millimeters.

The soil data for the districts have been obtained from the Food and Agriculture Organization. A similar data set has been used for studies on climate change and agriculture in South Africa (Gbetibouo & Hassan, 2005). Both climate and soil variables have been clustered at the district municipality level using the geographical information systems.

The dependent variables will include the discrete and mutually exclusive categories of ranches and the net farm revenues from wildlife and livestock ranching. There are three sets of independent variables; the first is the biophysical variables which includes temperature, precipitation and soil variables; the second is the economic variables which are represented

[34] The average mean temperature and precipitation has been taken for a period of over 30 years

[35] downloaded from http://cip.csag.uct.ac.za/webclient2/datasets/africa-merged-cmip5/ on 26/08/2014

by access to assets[36], land size and farm turnover, the last is social factors which is represented by social networking through memberships and affiliations to relevant groups. We have also controlled for regional fixed effects.

[36] There are farms that had infrastructure on them especially cattle sheds that were later modified into accommodation for ecotourism. Other farms had office spaces used for cattle management that were also converted. The asset variable is a discrete variable that captures farms with such infrastructure on them.

4.3.5 Descriptive statistics of farm variables

Descriptive statistics for the farm variables are outlined in table 4.1:

Table 4.1: Descriptive statistics for wildlife and livestock ranches

Variable	Livestock Ranching		Mixed Ranching		Wildlife Ranching	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Log Net Revenue/ha	12.84	1.29	12.68	1.49	11.84	1.66
Land Size	8961.93	71222	6438.22	35043.33	2838.25	9620.1
log of Land size	7.8	1.12	7.64	1.26	6.59	1.57
Water Purchase	0.131	0.34	0.12	0.33	0.08	0.27
Assets	0.77	0.42	0.84	0.36	0.74	0.44
Membership	0.51	0.50	0.62	0.49	0.42	0.49
Farm turnover	0.029	0.17	0.06	0.23	0.035	0.18
Soil: Fluvisols	0.30	0.46	0.56	0.5	0.43	0.49
Soil: Ferralsols	0.26	0.44	0.26	0.44	0.55	0.5
Soil: Lixisols	0.81	0.39	0.75	0.43	0.93	0.25
Soil: Arenosols	0.53	0.50	0.49	0.50	0.66	0.47
Soil: Luvisols	0.62	0.49	0.72	0.45	0.44	0.5
Soil: Leptosols	0.78	0.41	0.95	0.20	0.93	0.24
Soil: Durisols	0.65	0.48	0.81	0.39	0.70	0.46
Observations	**355 (33%)**		**495(46%)**		**221(21%)**	

Notes: This table presents summary statics for summary statistics for dependent variables and continuous variables in the sample. For each variable we have the overall mean, standard deviation, minimum and maximum as well as the number of observations.

Table 4.1 provides an overview of the descriptive statistics of the key variables used in this chapter of the study. In the three categories of farms, livestock ranches represent those ranches that have a combination of larger animals (cattle) and smaller animals (sheep and

goat). Therefore, the sample of livestock farms used here is one where only farmers who practice mixed livestock species farming are considered. The mixed ranches on the other hand represent ranchers who have both large and small animals in addition to wildlife. This means that mixed ranches are different from the category of livestock farmers simply because they keep wildlife over and above livestock. The final category is that of wildlife ranches, these are ranches that only have wildlife on them.

From table 4.1, it is evident across the three categories of farms that the net revenue from livestock and mixed ranches are on average higher than those from wildlife ranches. This seems counterintuitive given that it is known that revenues per hectare of land used by wildlife is higher (Kreuter & Workman, 1997; Dry, 2010). Having said that, over 88 per cent of farms in our sample are classified under income category 3 or 4 (these categories have been defined in footnotes in chapter 3). This implies that they are mostly small scale farms when compared to some larger mixed ranches or livestock only ranches[37].

The land sizes for livestock farms are on average higher when compared to mixed ranches. As earlier explained, the livestock category used in this study is composed of livestock farmers who practice mixed livestock ranching. Therefore, we expect that both livestock and mixed ranchers are relatively bigger than wildlife only ranches. However, a higher number of mixed ranches and wildlife ranches have high turnover at 6 per cent and 3.5 per cent respectively when compared to livestock ranches at 2.9 per cent.

Investment in water is one important indicator of farm access to water to mitigate shortfall, especially during periods of shortages or unreliability of natural sources. Farmers in Africa are known to rely on natural sources for production (Dinar & Mendelsohn 2009). Around 13 per cent of livestock ranchers depend on water they purchase compared to 12 per cent and 8 per cent for mixed ranchers and specialized wildlife ranchers respectively. This implies that livestock farmers are more likely to rely on the water they purchase than mixed and wildlife ranches.

Social factors is another important determinant of land use conversion or change. Subscription to a network was used to proxy for farmers' relationship with social networking.

[37] A small game ranch with economic carrying capacity has an equivalent of 150 Large Stock Unit (LSU) (ABSA 2003).

Both livestock and wildlife farmers join or are affiliated to social networks for several reasons, but what is the most important is that farmers' actions are sometimes influenced by these membership organizations. Social networks provide an important avenue for information and bargaining power. Ranches therefore join different bodies for some of these reasons. The difference in enrollment in these bodies among both livestock and wildlife vary among farmers. Around 50 per cent and 42 per cent of livestock and wildlife ranches respectively are in networks. In contrast, up to 62 per cent of mixed ranches are affiliated to these networks. This could be due to farmers subscribing to one or more networks especially the mixed ranchers.

Table 4.2: Descriptive statistics for climate variables

	Wildlife ranches			**Mixed Ranches**			**Livestock ranches**		
	Min	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**
Summer Temperature	15.9	22.6	29.2	13.8	21	28.3	13.9	21.1	28.31
Winter Temperature	4.9	13.3	21.7	3.5	11.4	19.4	2.7	10.9	19.3
Summer Rainfall (mm/month)	-	84.8	-	-	74	-	-	78.6	-
Winter Rainfall (mm/month)	-	36.5	-	-	41.9	-	-	41.7	-

Notes: This table presents summary statistics for climate variables. For each variable we have the overall mean, standard deviation, minimum and maximum. This is presented for each ranching type. Temperature is measured in ^0C while rainfall is measured in mm /month

In table 4.2, the climate variables (average monthly temperature and rainfall) are presented for summer and winter. Monthly rainfall has been measured in millimeters, while temperature has been measured in degree Celsius. Only mean rainfall is presented for the two seasons. Temperature has been captured for the minimum, mean and maximum temperatures. In terms of location of ranches based on climatic conditions, most wildlife ranches are located in areas which are comparatively hotter in both summer and winter when compared to livestock and mixed ranches. On average, temperatures in these areas are above 22.6 ℃ and can go as high as over 29.2℃. A comparison of the three farming options in terms of climate variable suggests that location of wildlife ranches highly correlates with climate conditions. There is, however, not much difference in precipitation during summer, though areas predominantly

occupied by wildlife seem to be areas where less winter rainfall occur.

While ranches are found across the entire regions of South Africa, a significantly higher number of wildlife and livestock ranches are located in areas where the dominant soil types are characterized by Leptosols and Lixisols. Mixed ranches are in areas where soil is characterized by Leptosols and Durisols: livestock are also in areas with large amount of Lixisols and Leptosols. According to WRB (2014), Lixisols are under savannah or open woodland vegetation. Such areas are often used for low volume grazing. Leptosols soil is unattractive soil for arable cropping with limited potential for tree crop production or extensive grazing. Durisols can only be used for extensive grazing. Finally, Luvisols with a good internal drainage are potentially suitable for a wide range of agricultural uses because of their moderate stage of weathering and high base saturation. Much of the Leptosols and Lixisols are found in the Limpopo province. Some part of the Eastern Cape Province has Arenosols, plenty of Leptosols and Luvisols. The Northern Cape has Lixisols and aerosols, Leptosols can be found in large areas in parts of Mpumalanga Province we find Leptosols is found in large number.

A one-way analysis of variance (ANOVA) was carried to see whether the means of variables used are different in the three independent categories of ranching. Taking the case of net revenue per ha, we established that there was a statistically significant difference between the groups as determined by one-way ANOVA (F (20.05), p = 0.000). A Tukey post-hoc test revealed that net revenue per ha were higher statistically in the three categories. Similar results for land size and asset availability were obtained.

Though the ANOVA test for asset variable was statistically significant, a Tukey post-hoc test revealed that the difference in means was not statistically different between specialized wildlife ranches and livestock ranches. The test confirms that the significance was due to differences in mixed ranches and wildlife ranches. Similarly, the test reveals that the means difference in purchase of water is not significant.

4.4 Empirical results

In this section, a probit model is use to determine factors that influence land use change. The results of the binary probit model used to evaluate determinants of land use change is reported in table 4.3.

Table 4.3: Predicted Probability of Land Use Change

VARIABLES	Predicted prob.	Std. Err.
Land size	0.056***	0.020
Assets (Not including land).	0.254***	0.050
Membership/Affiliation	0.254***	0.044
Annual Temperature	0.969***	0.242
Annual Temperature sq.	-0.017***	0.005
Annual Precipitation	0.043***	0.011
Annual Precipitation sq.	0.001***	0.0001
Farm turnover	-0.314***	0.105
Soil: Arenosols	0.039	0.063
Soil: Luvisols	-0.221***	0.061
Soil: Leptosols	0.400***	0.086
Eastern Cape	0.329***	0.096
Free State	-0.401***	0.099
Limpopo	0.666***	0.130
Mpumalanga	0.006	0.134
North West	-0.409***	0.104
Constant	-16.63***	2.973
Observations	1071	

*Note: The table reports coefficients of the probit data estimators. The dependent variable is binary obtained by dichotomizing farms into wildlife and livestock farms. Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. All predictors at their mean value and the Northern Cape is the reference province*

Factors know to influence land use change are classified as biophysical (for example, the type of soil and climatic conditions faced by the ranchers); economic factors (includes asset; this is the value of investment in physical assets, land size and farm turnover); social factors (this includes social networks for example membership or affiliations to associations proxied for by payment of membership fees). Unobserved regional heterogeneity is controlled for by introducing regional dummy variables.

Earlier, it was shown that wildlife and livestock ranching are carried out in areas where soil is generally poor and the temperatures comparatively high with equally lower rainfalls. In the probit results, what emerges is that leptosols has a positive and significant coefficient. Soils characterized by leptosols is known to be unattractive for cropping and extensive grazing, (IUSS Working Group WRB, 2014). This implies that areas predominantly characterized with leptosols have increased probability of practicing wildlife ranching as such soils decrease crop use (Seo, 2010b). For the case of climate conditions, the probability of a livestock rancher changing land use increases rapidly with increasing temperatures. The non-linear term is hill-shaped. This means that the probability of changing land-use increases rapidly with increasing temperatures since climate has a damaging effect on livestock production. It also emerges that as annual rains increase, livestock ranchers would prefer to change land use to wildlife ranching.

The size of land available to a farmer and access to capital assets such as investment in buildings are known to influence the decisions of a rancher on land use. The influence of these two factors on land use change has also been looked at. The size of land is known to motivate private landowners into considering a number of conservation behavior (Lambert et al., 2007). The probit results shows that the size of land increases the probability of a livestock rancher moving to wildlife farming. However, it also emerges that livestock farms with higher turnovers are less likely to change from livestock to wildlife ranching. A possible reason for changes in land use can be attributed to lower returns or productivity of livestock production. Ranches with assets have a higher probability of moving to wildlife ranching. Cases of ranches transforming old farm houses into lodges for ecotourism in South Africa have been reported.

The role of social networking is very important to land use decision making since being in a

social network increases access to production information, market information or collective bargaining power. The use of land and trend in land use in the neighborhood play a role in influencing land use change. The results show that association with social and professional networks increase the probability of a rancher moving to wildlife ranching. This is consistent with earlier narratives in literature and the requirement that in some instances, practitioners join professional bodies for ease of self-regulation or regulation by the state.

We also controlled for regional dummies. The Northern Cape Province was the reference province. The study reveals that holding other factors constant in the current climate scenario, ranches in the Limpopo and the Eastern Cape provinces are more likely to prefer wildlife to livestock when compared to the Northern Cape Province. This is because much of the land conditions in Limpopo province makes it more favorable for wildlife and livestock. The Eastern Cape Province has the highest number of cattle, sheep and goat farms contributing over 24 per cent, 29 per cent and 38 per cent of total national cattle, sheep and goat numbers, respectively (DAFF, 2014). The Limpopo Province has half the total number of wildlife ranches and wild animals outside the protected areas. Individual farms in the Free State and the North West are less likely to prefer wildlife ranching when compared to the Northern Cape Province. This is expected because the two provinces (North West and Free State) are largely arable with the Free State contributing 32 per cent of total arable land followed by the North West with 17 per cent of the total arable land in South Africa (Benhin, 2008). In areas such as the Eastern Cape, the farmers are likely to move to wildlife farming as the area generally receive poor rains. In addition, the farmers are more commercial oriented with 14 per cent of them undertaking commercial livestock farming (13 per cent of all commercial farmers come from Eastern Cape Province). Current climate makes farmers in Limpopo to be almost twice more likely to move to wildlife ranching when compared to ranchers in a province such as the Eastern Cape.

4.4.1 The role of wildlife in adaptation: a multinomial logit approach

There is potential land use change in the future because of climate change and this will alter the way farmers utilize their land (Seo, 2010a). This study empirically explored whether wildlife related ranches are less vulnerable to climate change when compared to livestock ranches. This can also be compared to the narrative in the literature which postulates that wildlife is more resilient to weather variability and, as such, wildlife revenues perform better when compared to livestock in the marginal areas.

The analysis progressed in two stages: in the first stage, we used a multinomial logit is used to model determinants of ranching choice. It should be noted that this step is an extension of the previous section. In this part, the choices have been expanded to include mixed ranches besides wildlife and livestock. This step not only provides insight into the determinants of choice of ranching systems under the three options of ranching, but also generates selection bias correction terms for the second stage where the conditional revenue equation is evaluated for the type of ranch chosen after correcting for the selection bias using the Bourguignon, Fournier and Gurgand (2007) approach. Previous challenges associated with identification of adaptation responses are known to be prone to omitted viable bias (Wang, Huang & Yang, 2014). Before proceeding to analyze the choices, in the next section we undertake diagnostic tests.

4.4.2 Diagnostic tests

First, the analysis began with diagnostic tests to establish if the choice of the model of analysis best suits the research questions. According to Long and Freese (2006), these tests included, testing that all the coefficients associated with an independent variable are simultaneously equal to zero, that is, testing that a variable has no effect; the next test is to test for whether the independent variables differentiate between two outcomes (that is to determine if two outcomes can be combined) and the final test is the test for the assumption of the independence of irrelevant alternatives.

Wald test for independent variables

In this test, most of the variables used in the study are significant at between 1 per cent and 5 per cent. For the two soil variables which are not statistically significant, but potentially important in our model, a further test using joint Wald test is carried out to see whether the two variables are statistically significant as a set. This is done so as to decipher whether to retain or drop them. Looking at the Wald test results for set 1 (table 4.4) it is found that even as a set, the two variables are still not significant and can therefore be dropped from the model.

Table 4.4: Wald test for independent variable

Variable	Chi2	D.f 2	P>chi
log of Land Size	86.2	2	0.000
Membership	59.40	2	0.000
Assets (excluding land)	6.248	2	0.044
Annual Temperature	22.9	2	0.000
Annual Temperature squared	25.46	2	0.000
Annual Rainfall	42.92	2	0.000
Annual Rainfall Squared	15.68	2	0.000
Soil: Fluvisols	14.42	2	0.001
Soil: Lixisols	33.92	2	0.000
Soil: Arenosols	1.85	2	0.396
Soil: Luvisols	5.23	2	0.073
Soil: Leptosols	2.32	2	0.314
Soil: Durisols	7.29	2	0.026
Constant	17.97	2	0.000
Set 1	4.42	4	0.351

Note: The variables are all the independent variables used in this analysis. HO: All coefficients associated with given variable (s) are zero.

Test for whether the categories of the dependent variables can be combined

A test is carried out to determine whether it may have been necessary to combine some categories if the dependent variables jointly do not differentiate between the two categories (meaning that nothing predicts that they are different).

The test results in table 4.5 reveal that the categories are independent and cannot therefore be collapsed.

Table 4.5: Test on whether the categories of the dependent variables can be combined

Categories tested	**chi2**	**D.f.**	**P>chi2**
Wildlife-Mixed wildlife-livestock	195.897	14	0.000
Wildlife only-Livestock only	280.220	14	0.000
Mixed Wildlife & livestock -Livestock	148.165	14	0.000

Note: D.F. is the degree of freedom; Ho: All coefficients except intercepts associated with given pair of outcomes are 0 (i.e., categories can be collapsed).

Test for Independence of Irrelevant Alternatives (IIA)

Even though the choice of model used in this study could allow for estimation of the conditional net revenue even when the IIA is violated (Bourguignon, Fournier & Gurgand, 2007; Dimova & Gang, 2007), a test for IIA is carried out nonetheless using the Small-Hsiao approach. The results are outlined in table 4.6.

Table 4.6: Test for independence of irrelevant alternatives

Ranch Type	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
Wildlife only Cons.	-0.578	0.070	-8.25	0.000	-0.716	-0.441
Livestock Cons.	-0.435	0.069	-6.49	0.000	-0.566	-0.304

Note: In table 4.6, the constants of wildlife only firms, Wildlife-livestock and livestock only farms are tested. Mixed Wildlife-livestock is the base outcome.

The results imply that the IIA is not violated; the odds for each specific pair of outcome do not depend on other outcomes available. We have not carried out a suest-based Hausman test though we are aware the Hausman and Small- Hsiao tests may give inconclusive or sometimes contradictory results (Long & Freese, 2006). However, as indicated earlier, we have chosen Bourguignon, Fournier and Gurgand (2007) approach as our choice of model because whether IIA holds or not it does not affect the results. The results of multinomial logit choice model are presented in table 4.7.

Table 4.7: Results of the multinomial logit choice model.

Variable	Wildlife Ranches	odds ratio	Mixed Ranches	odds ratio
Membership	-0.160	0.852	0.216	1.241
	(0.223)	(0.19)	(0.162)	(0.201)
Asset (Not including land).	-0.100	0.905	0.457**	1.580**
	(0.260)	(0.235)	(0.202)	(0.32)
Annual Mean Temperature	-4.592***	0.010***	-4.083***	0.017***
	(1.169)	(0.012)	(0.978)	(0.017)
Annual Mean Temperature Squared	0.147***	1.158***	0.124***	1.132***
	(0.034)	(0.039)	(0.029)	(0.033)
Annual Mean Precipitation	0.321***	1.379***	0.194***	1.214***
	(0.045)	(0.062)	(0.035)	(0.043)
Annual Mean Precipitation Squared	-0.002***	0.998***	-0.002***	0.998***
	(0.001)	(0.001)	(0.000)	(0.000)
Soil: Fluvisols	0.829***	2.291***	0.730***	2.074***
	(0.304)	(0.696)	(0.220)	(0.456)
Soil: Ferralsols	-0.295	0.744	0.270	1.309
	(0.495)	(0.368)	(0.444)	(0.581)
Soil: Lixisols	1.943***	6.981***	1.084***	2.957***
	(0.375)	(2.615)	(0.234)	(0.693)
Soil: Luvisols	-0.483	0.617	0.327	1.387
	(0.322)	(0.199)	(0.232)	(0.322)
Soil: Durisols	-0.925**	0.397**	-0.401	0.67
	(0.369)	(0.146)	(0.343)	(0.23)
Large Farm	0.283	1.327	0.726*	2.067*
	(0.509)	(0.675)	(0.379)	(0.784)
Constant	25.81***	1.619e+11***	27.40***	7.940e+11***
	(9.894)	1.60E+12	(8.002)	6.35E+12

*Note: The multinomial logit choice model gives the choice spectrum a rancher has conditional on the various climate, soil and farm specific variables. The base category is livestock ranches: All predictors at their mean value and standard errors are in parentheses *** p<0.01, ** p<0.05, * p<0.1*

4.4.3 Discussion of the results

As earlier indicated, there are several variables that influence choice of a ranching method. These factors included biophysical, economic and social factors. The probability of a farmer choosing one of the three available ranching options given the current climate conditions was estimated. The reference category was livestock ranching. From the results, the odds of selecting mixed ranches increase with the farm's turnovers. Wildlife or mixed farms with larger turnovers are 2.067 odds of choosing mixed ranches when compared to livestock ranches. Wildlife ranching is known to require a lot of investment. It is only possible that farms generating high profits given higher sales turnover are able to shift land use from livestock to wildlife or mixed ranching. Equally important is assets, we see that farms with assets are 58 per cent more likely to choose mixed ranching as opposed to livestock ranches.

Looking at the role of temperature and precipitation in the selection of farming options, temperature for example increases the probability of a farmer choosing either mixed ranches or specialized wildlife ranches. In the linear term of temperature, the odds ratio initially shows that the odds of choosing specialized wildlife farms reduce by 99 per cent. The quadratic term, however, show that the odds reduce but after the turning point, they are eventually positive (15.8 per cent odds of choosing wildlife over livestock). Conversely, the odds of the linear term for precipitation suggests that the probability of choosing either specialized wildlife or mixed ranches increases by 37.9 per cent and 21.4 per cent respectively. The quadratic term suggests that this probability increases at a decreasing rate and eventually the probability of choosing either mixed ranching or specialized wildlife ranching reduce by 0.01 per cent in both cases. It can also be noted that the probability of selecting wildlife farming decreases in cases where durisols is the most common soil type while the probability of choosing wildlife ranching increases where soil is more characterized with lixisols. The results generally support the findings of the probit model.

4.4.4 Vulnerability of various ranching systems to climate change

One of the empirical questions is; which of the three types of ranching is more vulnerable to climate change? The vulnerability of each of the three ranching categories can be determined by calculating the change in the marginal effect on the probability of choosing a specific system of ranching when climate variable is perturbed by a small change in temperature or precipitation (Seo, 2010a). The probability of choosing each ranching method given it is less vulnerable is calculated by determining the magnitude of change if the system is perturbed by

1℃ increase in temperature and a 1 per cent decrease in precipitation. The results are presented in table 4.8. A 1℃ increase in temperature over the current levels will increase the probability of choosing either wildlife ranching or mixed wildlife ranching, but significantly reduce the probability of choosing livestock ranching. The results also show that the choice of mixed ranching will be higher than those of specialized ranching. Equally, the probability of choosing wildlife ranching or mixed ranching is likely to increase if precipitation reduce by 1 per cent over the current rates. However, in the case of livestock choice, the probability of choosing livestock is likely to decrease with even with a decline in precipitation. It can be concluded that given an incremental change in temperature and a decrease in rainfall, farmers are more likely to prefer mixed ranching to either wildlife or livestock farming.

Table 4.8: Marginal effects on the probability of each system (%)

	Wildlife Only (%)	Mixed Ranches (%)	Livestock (%)
Baseline Probability	13.06	59.16	27.78
Temperature (1^0C) increase	1.24	3.92	-5.15
Precipitation (1%) decrease	0.03	0.07	-0.07

Note: The table shows the marginal change on the probably of choosing a ranching system given a small change in temperature or precipitation over the current levels.

4.4.5 *Estimation of conditional net revenue of wildlife ranches*

The question that follows then is which of the three options yields more revenues given that it is chosen. In the forgoing discussion, it can be concluded that mixed ranches are less vulnerable, but this does not mean that they earn the most revenues. If a rancher has chosen one of the three ranching options, the rancher can maximize net revenues by choosing the appropriate level of inputs and outputs. After accounting for selection bias of individual farmers into the three categories, we can estimate the conditional revenue equation for each option. The selection bias coefficient represented by M0-M2, are the BFG equivalents for the Mill's ratio. The terms show the interactions among the three systems of ranching discussed.

Table 4.9: Conditional net revenue estimation

Variable	Wildlife	Std. Err.	Mixed Ranches	Std. Err.	Livestock	Std. Err.
Summer: Temperature	0.816	(1.103)	0.714	(0.625)	2.039***	(0.769)
Summer: Temperature squared	-0.013	(0.019)	-0.015	(0.011)	-0.037***	(0.013)
Winter: Temperature	0.173	(0.428)	-0.492	(0.335)	1.013*	(0.529)
Winter: Temperature squared	-0.011	(0.012)	0.018*	(0.011)	-0.007	(0.014)
Summer: Precipitation	0.080***	(0.019)	0.084***	(0.015)	0.081***	(0.021)
Summer: Precipitation squared	0.007	(0.005)	0.011**	(0.004)	-0.021***	(0.007)
Winter: Precipitation	0.088	(0.091)	-0.05	(0.032)	-0.093**	(0.045)
Winter: precipitation Squared	0.002	(0.002)	0.001	(0.001)	0.002**	(0.001)
Soil: Lixisols	-2.399***	(0.896)	1.623***	(0.46)	1.791***	(0.58)
Soil: Luvisols	-0.34	(0.474)	0.206	(0.477)	-0.339	(0.542)
Soil: Durisols	0.142	(0.142)	0.266**	(0.123)	-0.303	(0.246)
Large Farms	3.349***	(0.79)	3.575***	(0.97)	3.559***	(0.799)
_m1 (wildlife-only Ranches)			10.04***	(2.425)	14.53***	(2.069)
_m2 (mixed Ranches)	-4.820***	(1.191)			3.352	(2.048)
_m3 (livestock-only Ranches)	-6.039**	(2.957)	-4.822*	(2.837)		
rho0	0.237**	(0.116)	1.407***	(0.27)	1.716***	(0.116)
rho1	-0.933***	(0.237)	-0.016	(0.05)	0.396	(0.244)
rho2	-1.169***	(0.429)	-0.676*	(0.377)	0.023	(0.08)
Constant	-15.64	(17.0)	-0.099	(7.584)	-27.32***	(10.32)

*Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1: All predictors at their mean value. The figures in brackets are standard errors. _M1, _M2, and_M3, are the BFG equivalents for the Mill's ratio, related to wildlife, mixed ranches and livestock ranches respectively.*

In table 4.9, the results of the conditional net revenue estimation have been presented. The results indicate that the net revenues of livestock ranches are sensitive to both summer and winter temperatures, as indicated by the hill-shape relationship between the net revenues and temperature variables. However, an increase in winter precipitation seems to be beneficial to the revenues of livestock farmers. The revenues of mixed ranches perform better in areas where the soils are predominantly durisols or lixisols, while the revenues of livestock perform better in areas which have lixisols.

The selection bias correction coefficient of wildlife farms is positive and significant in the choice of both mixed ranching and livestock ranching. Essentially this shows interaction or relationship between these farms. More specifically, it implies that holding other factors constant, on average farmers practicing mixed ranching or livestock ranching were more likely to make higher profits if they were to choose specialized wildlife ranching. The implication of this is that farmers who chose wildlife ranching on average make higher profits. On the contrary, if ranchers currently practicing specialized wildlife ranching were to choose either mixed ranching or livestock ranching, then the negative selection bias correction term suggests lower profits than the current levels. Mixed ranches are also likely to make lower profits by choosing livestock ranching under the current climate conditions.

The conditional net revenue analysis results support the multinomial choice results. Even though mixed ranches are less vulnerable with a small perturbation when compared to wildlife ranching, the conditional net revenue results suggest that wildlife ranches are likely to be more profitable in the current climate scenario when compared to mixed ranches.

4.4.6 Projected land use change in the marginal areas

The distribution and choice of farming systems across South Africa as a consequence of climate change is likely to adjust more so in the marginal areas. So far the adaptive changes made by crops and livestock farmers reflect these adjustments to climate change given the prevailing climatic conditions. However, recognizing that livestock ranchers in the marginal areas may consider wildlife if the current climate conditions were to change as predicted by various models, there would be further adjustments[38] in which case more farmers currently practicing livestock or mixed farming would consider wildlife use. In this section, the

[38] We acknowledge that for political and economic factors may also play a role in pushing or pulling farmers into or out of ranching.

probability of changing land use is measured using different climate scenarios. This is done by taking the difference in the probability of choosing land use before and after climate change for each climate scenario. Projections with climate scenarios use three Atmospheric-Oceanic Global Circulation (AOGCM) climate scenarios. These include CSIRO2, the Parallel Circulation Model (PCM) and the Hadley Centre Coupled (HadCM3) model. These models have been used in the literature for South Africa (Benhin, 2006). The predicted change in choice of land use as temperature and precipitation for South Africa change is as follows.

Table 4.10: % increase in the probability of land use change

		CGCM2 2050	CGCM2 2100	PCM 2050	PCM 2100	HadCM3 2050	HadCM3 2100
Mixed Ranches-Wildlife	Temperature	6	16.5	4	9.5	18.5	17.5
	Precipitation	3.1	6.1	8	15.5	7.2	12.2
Livestock Ranches-Wildlife	Temperature	28.2	69.7	18.1	43.7	37.5	74.2
	Precipitation	9	19	5	10	22	35
Livestock Ranching - Mixed Ranching	Temperature	6.25	15.61	3.99	9.71	16.65	16.7
	Precipitation	0.7	1.2	0.3	0.6	1.15	2.3

Note: These are percentage changes. The table captures a change from mixed ranching and livestock ranching to wildlife ranching under the three different climate scenarios projected for 2050 and 2100.

As can be seen across the different models, as climate warms, there will be significant adjustments across farms, especially livestock farms. All of the three AOGCMs predict that the probability of livestock ranches moving will increase substantially by up to 74 per cent in some cases. By 2050, livestock farmers are likely to move away from livestock ranching into wildlife ranching. The reduction in precipitation is also likely to influence the probability of livestock ranchers moving to wildlife ranching. We also note the probability of livestock ranchers moving to mixed ranching as climate changes. The probability of livestock ranchers moving to mixed ranchers increases with warming. The increment in probability to move is however not as high with rainfall. Thus, it appears that in the medium term, livestock and mixed ranches may use financial solutions to temporarily cope with climate change instead of moving to alternative land use. Eventually, however, moving to wildlife ranching may turn

out to be an alternative option that many mixed ranchers and livestock farmers could consider taking to help adapt to climate change.

In the following section land use change across three regions known in South Africa to have the highest number of wildlife ranches (Limpopo Province and Northern Cape Province) and those known to have the highest number of commercial livestock farms (Eastern Cape Province) are examined. The objective is to see how farmers in these provinces are likely to respond to climate change in terms of livestock to wildlife and mixed ranching to wildlife land use transition.

Table 4.11a: Regional impact of climate change on land use decision (2050)

Province		CGCM2 2050		PCM 2050		HadCM3 2050	
		Mixed	Livestock	Mixed	Livestock	Mixed	Livestock
Eastern Cape	Temperature	7.2	12.5	4.5	8	2.5	16.5
	Precipitation	4.4	5.4	2.5	3	23.5	24.5
Limpopo	Temperature	3	8.5	4	11	9.1	16
	Precipitation	2.4	3.4	1.4	1.9	14.8	15.8
Northern Cape	Temperature	7.4	12	4.9	8	7.1	6
	Precipitation	3.3	5.2	1.7	2.9	20.4	24.4

Note: The predicted probability of land use transition from livestock and mixed ranches into wildlife as climate change for 2050.

Table 4.12b: Regional impact of climate change on land use decision (2100)

Province		CGCM2 2100		PCM 2100		HadCM3 2100	
		Mixed	Livestock	Mixed	Livestock	Mixed	Livestock
Eastern Cape	Temperature	14.1	26	9.5	18	14.7	28
	Precipitation	9.4	11.4	5.2	6.4	15.8	19.1
Limpopo	Temperature	6.7	17	9	23	14.1	36
	Precipitation	5.2	7.3	2.9	4.2	8.6	11.5
Northern Cape	Temperature	15.1	26.4	10.8	18	16.8	27.8
	Precipitation	6.9	11	3.5	6.2	13.3	18.1

Note: The predicted probability of land use transition from livestock and mixed ranches into wildlife as climate change for 2050.

Regional climate interactive term suggests that warming will increase the probability of both livestock and mixed ranches moving to wildlife ranching. For example, in the Eastern Cape Province, the probability of livestock ranches moving to wildlife ranching increases by 28 per cent according to the HadCM3 model for 2100. What can also be noticed is that the probability increases marginally with precipitation. In the medium term, ranches in the Eastern Cape and the Northern Cape are more likely to move to wildlife ranching than those in the Limpopo Province. Even though one would expect most changes to be in Limpopo, this is not the case because a high number of farms in Limpopo are already practicing wildlife ranching.

4.5 Conclusion and policy implications

Climate change will continue to threaten conservation and agriculture, especially commercial livestock farming. This chapter set out to establish if factors responsible for land use conversion or change in crops and livestock could be the same factors that drive land use change from livestock to mixed ranching or wildlife ranching. This is because livestock and wildlife activities are known to correlate in the marginal areas. We then moved on to evaluate how vulnerable wildlife ranches were to climate change when compared to alternative land use, especially livestock farms and mixed ranches. Finally, we looked at the current land use

and future land use trend to determine what contribution wildlife ranches would make in a changing climate. Overtime, farmers have changed land use from livestock ranching to wildlife mainly due to climatic and non-climate factors. However, much of the current discourse suggest that land use change from livestock to wildlife has more to do with the politics of land restitution claims in post-apartheid South Africa.

The land use changes being observed among farmers and which the study has been able to corroborate confirms that factors responsible for land use change in other agricultural sectors could as well influence land use change to wildlife ranching. In essence, this means that farmers moving land away from livestock to wildlife ranching could be doing so in an attempt to adapt to climate change.

While wildlife ranching has not been subject to agriculture and climate change studies as yet, the results of this study lend themselves for a comparison with earlier findings by Seo et al., (2008). Using South African beef cattle, they find that with warming of +2.5℃over the current climate, the areas for beef cattle will shrink dramatically and almost entirely disappear with warming of over +5℃. There will also be widespread reduction of sheep in South Africa, a trend that is already being witnessed. We show that with a warming of around+9.6℃, the probability of livestock farmers moving to wildlife ranching would have increased by 74 per cent. Seo (2010a) finds integrated crop and livestock farms to be more resilient to climate change than crops or livestock only farms. This study also finds mixed livestock-wildlife ranches to be less vulnerable to climate change when compared to mix livestock only farms.

The question is whether institutional framework of managing agriculture sector is growing at the same pace as the wildlife ranching sector. The model has predicted that the probability of more farmers moving into wildlife utilization in the marginal areas is going to increase as the temperature warms up. Areas such as the Eastern Cape Province have the highest number of livestock farms and play a very important role in food security in terms of beef production. However, it is also in these areas where the greatest adjustment is likely to take place as beef cattle farmers move to alternative land use. Therefore, there is need to focus attention on sustainable growth for both wildlife and livestock in the marginal areas. This is because a number of farmers may not be resource endowed to independently take up wildlife ranching, but willing to move land to alternative use either through joint ventures or to sell off land to

resource endowed commercial farmers who could use such land for wildlife farming.

While previous studies have predicted that large livestock farms will be hurt most by warming, the analysis in this chapter reveal that wildlife land use will provide an alternative option for land use. Linking wildlife and agriculture provides a sustainable land use option in the marginal areas which could be good for conservation. All the AOGM models predict that land use change will accelerate.

In order to address the problem of climate change in agriculture, it will be necessary to incorporate wildlife as alternative land use option. Wildlife ranching directly competes with other land based options such crop and livestock. Legal and institutional frameworks in South Africa recognize wildlife ranching as one of the subsectors in agriculture. There is urgent need to reconfigure climate change policies on mitigation and adaptation in agriculture to embrace wildlife ranching.

Given multiple uncertainties in crops, livestock or wildlife use in the face of climate change, resilience will depend on successful adaptation. Options for pro-poor resilience in livelihoods include policies on improved social protection, better water and land governance and tenure security over land vital assets to avoid conflict, enhanced water storage and encourage greater involvement of communities in use of wildlife resources.

There is need to design development and adaptation policies and initiatives that adopt a longer term view and consider the multi-stressor context to avoid maladaptation or outcome that may serve short term goals but with some future cost to society. The short term nature of policy and other interventions especially if they favor short term objectives over resilience and human security may themselves act as stressors. The political context can also undermine autonomous adaptation and lead to maladaptation in wildlife utilization on private land.

CHAPTER FIVE: SUMMARY OF FINDINGS, CONCLUSION, POLICY IMPLICATIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

5.1 Summary of findings

This thesis examined the economics of climate change and wildlife utilization on private land using South Africa as a case study. The growth of wildlife ranching can play an important role in rural development and conservation of biodiversity. Several challenges threaten the growth in wildlife use on private land that may in turn impede its contributions. The most pressing issue is lack of adequate information about i) the effects of wildlife ranching on the welfare outcomes (especially poverty) of communities living around the ranches. Lack of information about the contribution of wildlife ranching affects the perception of people on the value of wildlife ranching and this reduces the support of wildlife utilization on private land ii) the sustainability of wildlife ranching as alternative land use option in the face of current and future climate scenarios and iii) the role of wildlife in climate change adaption. Therefore, the thesis contributes to the broad research agenda of wildlife conservation outside the protected areas especially on private land by analyzing the issues highlighted above in three substantive chapters.

In the following section, we summarizes the empirical findings of this thesis. In chapter two, we evaluated the impact of private wildlife ranches on human welfare using the Eastern Cape Province as a case study. Chapter two described the causal mechanism effects of wildlife ranches on poverty through infrastructure, employment and displacement. These are some of the known mechanisms through which protected areas contribute to poverty reduction (Ferraro & Hanauer, 2014b). Most ranches in this study were established after 1996 but before 2001. The time frame was picked to allow for impact evaluation because ranches that were established after 2001 may not have grown to a level where they could be held accountable to the changes realized in the communities. In chapter three, we looked at the economics of climate change and wildlife utilization on private land, focusing on the impact of climate change on various aspects of wildlife ranching in South Africa. In chapter four, we

introduced wildlife ranching into the agriculture and climate change adaptation and evaluated the influence of wildlife ranching as an alternative land-use choice.

The findings in the second chapter which analyzed the impact of wildlife ranches on the welfare outcomes of communities living around the ranches show that establishment of wildlife ranches over the years especially between 1996-2011 led to increased poverty levels within the communities living around by about 2.7%. We decomposed the average treatment effect into mechanism average treatment effect on the treated (MATT) and net average treatment effect on the treated (NATT). Our finding is that growth of wildlife ranching led to loss of employment and displacement of people. We also found that access to infrastructure improved in the communities living around the ranches by about 12.83%. Even after taking areas with up to 50% coverage of wildlife ranches, similar results were still obtained though the lower the coverage, the higher the level of poverty. It was only in areas with above 50% coverage of wildlife ranches that poverty levels went down due to rising employment and better infrastructure. Even though the results indicate that communities around the ranches got poorer, the estimated NATT shows that other factors may have played a bigger role and not wildlife. For example, wildlife ranches are established in rural areas where the communities are generally poor and lack access to markets and infrastructure. These factors could have exacerbated poverty.

In extending the analysis, we estimated the effects of the state protected areas on the communities living adjacent to them. This was meant to provide a basis for comparing the welfare effects of state protected areas and the private wildlife areas. The results revealed that poverty levels in the state protected areas had gone down albeit marginally by about 0.005% over the same period. In tandem with private wildlife areas, the total poverty value was decomposed. It turned out that there was a marginal increase in access to employment over the period. However, low access to infrastructure and displacement were experienced around the state protected areas. One possible explanation for the difference in poverty levels within the two rival communities is the existing benefit sharing framework. Since most communities living around the state protected national parks and reserves have a long history with these conservation areas, there has been modalities of sharing out the benefits and involving the communities in the management of the parks. This is not the case with private wildlife areas.

In chapter three, the analysis was built on the theory of land use rent in rural communities where commercial farming also takes place. One of the challenges faced by the agriculture

sector is climate change. The chapter used the Ricardian model to evaluate the impact of climate change on wildlife ranching. The model was modified to allow for variations in wildlife revenues due to the multiplicity of farm-based value adding activities on wildlife ranches. As such, the median Ricardian model was able to address the effects of outliers in the data together with other distributional issues. Climate change has increased the cost of production in crops and livestock and most farmers in the marginal areas have considered wildlife a viable land use option. Whether or not wildlife revenues are more resilient to climate change remained untested. On the basis of this, the study sought to shed light on the sustainability of wildlife ranching as alternative land use option in the present and future climate scenarios.

Overall, the results demonstrate that there is a non-linear relationship between wildlife revenues and climate variables. Summer temperature has a u-shape relationship with revenues, which implies that rising temperature during summer is more beneficial to farmers with wildlife. The relationship between summer precipitation is hill-shape. Rising summer precipitation is detrimental to the revenues of the farms. The quantile regression results show that at τ=0.25 and τ=0.75 winter precipitation is beneficial to both low value and high value ranches, but it is significantly more beneficial to ranches on the higher quantiles than those on lower quantile ranches. A major observation that can also be made from this analysis is that mixed ranches are ranches which are in transition to wildlife only ranching and that livestock on mixed ranches are indeed the primary revenue earners. This is because the result of mixed ranches bare similarities with earlier studies that looked at the effects of climate change on livestock.

Other important findings come from the simulation of the effects of climate change on revenues using the climate models. Revenues of wildlife ranches will decline by up to 28% according to HADCM3 climate model. As climate warms up, the most decline in revenues will be experienced in Eastern Cape Province. In the Northern Cape Province, revenues are likely to increase with a small margin towards 2100. In the long run, the effects of climate change will be less severe on wildlife ranches when compared to mixed ranches.

In chapter four, wildlife ranching was introduced as one of the adaptation choices within the menu of choices among other agricultural activities in the marginal areas. Since adaptation literature has looked at other options in crops and livestock, the question we sought to answer was what happens to the revenue of farmers who have wildlife or practiced mixed ranching

as their preferred adaptation option. In order to carry out this analysis, the first question we asked was whether the determinants of land use change in crops and livestock could have played a role in influencing land use change from livestock to wildlife. It is known that economic, social and biophysical factors play a major role in land use change. These factors were tested for the wildlife case. Next we moved on to establish which one of the three land use options (livestock, wildlife or mixed ranching) in the marginal area was less vulnerable to climate change. After this, we estimated the conditional net revenues of the three options. That is, conditional on the choice made by the rancher, which of the three system generated the most revenues? Finally, the chapter used the general circulation climate-based models to determine land use choices in the future as climate changes.

The probit results show that the biophysical factors such as temperature, precipitation and soil quality influence land use choices. Farmers in areas receiving low rains and with poor soil quality were more likely to change land use from livestock to wildlife. It was also established that farmers with large tracks of land and capital outlay were more likely to change land use. However, farmers with higher turnovers in their current livestock activities were less likely to move away from livestock to wildlife. One other important finding is that social networks especially affiliations to associations dealing with either wildlife or livestock played a significant role in influencing farmers to change land use.

We also found that the probability of changing use of land from livestock to wildlife increased with rising temperature and that livestock farms in Limpopo and Mpumalanga were more likely to change to wildlife when compared to farms in the Northern Cape Province. Conversely, farms in the North West and the Free State provinces commercial farmers were less likely to move to wildlife ranching when compared to Northern Cape Province. This is plausible because these provinces are still known to have the highest concentration of crop production activities due to good soil condition and favorable agro-climatic conditions. In terms of vulnerability, livestock farms were found to be more vulnerable to climate change when compared to either wildlife or mixed ranches. A 1^0C increase in temperature resulted into about 5% decline in the revenues of livestock and about 1.2% and about 4% increase in the revenues of wildlife and mixed ranches respectively. Even though mixed ranches were the least vulnerable to climate change, it is wildlife ranches that were found to generate the most revenues when compared to either mix or livestock ranches.

The results of the multinomial choice model indicate that increase in temperature will influence most livestock farmers to change land use from livestock to wildlife ranching. Using climate models, it shows that there will be significant adjustments across farms, especially livestock farms. The probability of livestock ranches moving will increase substantially by up to 74 per cent in some cases. Furthermore, up to 18.5 per cent of current mixed ranches are likely to move to wildlife ranching. It is also noted that most land use change would be experienced in Eastern Cape Province which is also known to have the most livestock production activities.

5.2 Policy implications of the research findings

The results of this study highlight the link between wildlife utilization on private land, welfare outcomes and climate change. The study is intended to benefit wildlife conservation agencies, policy makers, local communities and other practitioners who will be able to acquire relevant theoretical and empirically guided evidence on wildlife utilization. The findings will allow users to further interrogate the growing role wildlife, wildlife management strategies and policies and at the same time identify areas which need further improvement. A number of policy implications can be drawn from the thesis.

Chapter 2: Evaluating the impact of private wildlife ranches on socioeconomic outcomes in the Eastern Cape Province of South Africa.

The main policy message in Chapter 2 is that wildlife on private land has the potential to affect the lives of those members of the communities living around the private wildlife areas. The transition from crops and livestock land to wildlife use therefore has serious implications on food security and land reform processes in South Africa. Wildlife ranching can contribute to welfare change especially through the infrastructure mechanism. However, the absence of benefit sharing schemes inhibit wildlife ranching from contributing positively to poverty reduction, given that more jobs are lost due to establishment of wildlife ranching. There is the need to come up with policies that mainstream food security concerns into the growth of wildlife utilization on private land. Equally important, the growth of wildlife sector needs to be integrated with measures that ensure that communities living around the ranches benefit from employment, social development projects and settlement arrangements. This will avoid marginalization of communities and exacerbation of poverty. This implies that reforms in wildlife ranching also needs to empower poor households and communities to actively participate in wildlife conservation outside the protected areas.

Land use change is likely to affect the women, youth and the vulnerable members of the communities whose livelihood is anchored on crops and livestock production. Increasing attention should be directed towards cultural, ethical, and rights considerations by increasing the participation of women, youth and poor and vulnerable people in private sector led wildlife utilization.

There is also an obvious feeling among the black communities that wildlife utilization of private land is skewed towards the interest of the white community. It is important to come up with policies that address constraints to broader wildlife ranching adoption by the black communities by enhancing access to credit and markets, capital, gender oriented wildlife use as well as identifying perverse policy incentives that limit sustainable exploitation of wildlife resources by the black communities. Southern Africa region has a longstanding experience with natural resource management, biodiversity use. Ecosystem-based response for example CBNRM can be harnessed to develop effective and ecological sustainable local adoption strategies to increase the uptake of wildlife utilization by the black communities.

Chapter 3: An economic analysis of climate change and wildlife utilization on private land in South Africa

The growth in wildlife use on private land is driven in parts by climate change effects on agriculture and the perception that wildlife and wildlife revenues are more resilient to climate change than crops and livestock. From the results of this analysis, a number of policy implications can be drawn. To begin with, the sector policies should be reconfigured to address emerging issues of climate change in wildlife conservation. Climate issues should be mainstreamed into existing polices in wildlife utilization by targeting mitigation and adaptation in wildlife ranching. Policies could be designed to provide potential pathways for strengthening adaptation capacities for climate change. This calls for the extension of climate-based incentives to include wildlife utilization on private land, besides crops and livestock.

Climate change will amplify existing stress on water availability in Africa. This will have a knock-on effect on other sectors. It will also interact with non-climate drivers and stressors to exacerbate vulnerability of agricultural and wildlife systems especially in the semi-arid areas. This raises the need to make progress in managing risks to wildlife use in private land from current climate variability and near-term climate change. It is necessary that policies are designed to increase flexibility in livelihood options which serve to strengthen coping

strategies in wildlife sector for near-term risks from climate vulnerability. There is also the need to initiate governance systems for adoption and responding to climate change. This can include institutional framework to effectively co-ordinate the range of adaptation initiatives. Since there is a lag in policy formulation and implementation with regards to climate change and wildlife conservation, there is need to fast track progress on national and regional/provincial policies and strategies mainstreaming of adaptation into sector planning which involves complete integration and harmonization of agriculture and wildlife policies.

Chapter 4: Agriculture and adaptation to climate change: the role of wildlife ranching in South Africa

In order to address the problem of climate change in agriculture, it will be necessary to incorporate wildlife as alternative land use option. Wildlife ranching directly competes with other land based options such crop and livestock. Legal and institutional frameworks in South Africa recognize wildlife ranching as one of the subsectors in agriculture. There is need to reconfigure climate change policies on mitigation and adaptation in agriculture to embrace wildlife ranching.

Given multiple uncertainties in crops, livestock or wildlife use in the face of climate change, resilience will depend on successful adaptation. Options for pro-poor resilience in livelihoods include policies on improved social protection, better water and land governance and tenure security over land vital assets to avoid conflict, enhanced water storage and encourage greater involvement of communities in use of wildlife resources.

There is need to design development and adaptation policies and initiatives that adopt a longer-term view and consider the multi-stressor context to avoid maladaptation or outcome that may serve short term goals but with some future cost to society. The short-term nature of policy and other interventions especially if they favor short term objectives over resilience and human security may themselves act as stressors. The political context can also undermine autonomous adaptation and lead to maladaptation.

The overall message coming out of this thesis is that wildlife in the private areas do not optimally benefit the communities and with climate change affecting agriculture, a move to wildlife ranching may expose the communities and ranchers to further problems. The current scenario in agriculture does not recognize the role of wildlife and there exist several policy bottlenecks that impedes the sustainable growth of wildlife conservation on private land.

5.3 Suggestions for further research

This section, outlines areas that may require further research and highlights some of the challenges or limitations of the study. In this study, we found that wildlife ranching contributed to the exacerbation of poverty through displacement of people and loss of employment. According to Ferraro and Hanauer (2014b), there are several dimensions or mechanisms through which protected areas could contribute to poverty reduction or result in an increase in poverty. Our estimation of MATT as well as the NATT suggest that there could be several other unaccounted for mechanisms or dimensions which affect poverty. The contribution of MATT suggests that only a limited proportion of the total increase in poverty could be explained by loss of employment and displacement in areas where wildlife ranches were established. This study therefore points to the need for further research that could help tease out the causal relationship between welfare outcomes and conservation areas by looking at other alternative mechanisms. One possibility is to compare alternative livelihood mechanisms for example in livestock or crop farming to see how livestock farming interact with welfare outcomes. It would be interesting to see the causal relationship between livestock and welfare outcomes in the marginal areas. There seems to be other mechanisms that contribute more to poverty in these areas than wildlife ranching.

What is also known is that the relationship between wildlife ranches and the communities has not been founded on policies that ensure some form of benefit sharing. Muir, Skowno and Kerley (2011) found that most wildlife ranches did not have a corporate social responsibility (CSR) framework in place. It would be important to evaluate the welfare status of communities around ranches with CSR policy and compare this to those in areas where ranches do not have any CSR. This could be a good basis for determining what form of relationship between communities and wildlife ranches generate mutual benefits to the community. It could also explain the working of CSR as a mechanism for providing socioeconomic support to the communities.

Secondly, it has been established that climate change affect wildlife ranchers. In order to respond to climate change, livestock farmers have been seen to incorporate wildlife with livestock. Such farms have been found to be less vulnerable to climate change. However, it may be necessary to move further and look at decision making in the choice of wildlife varieties or species given climate change. This is because the choices of species may differ for wildlife ranchers who are breeders or hunters or engage in ecotourism. Also, some

ranchers may be inclined to choose herbivores or carnivores under certain climate conditions. Since this study has used a portfolio approach where wildlife revenues were clustered together irrespective of the primary animal or activity, it is possible that the underlying effects of these could bias the results.

The need to balance biodiversity and agriculture has never been greater because of the challenges associated with protected areas networks and the effects of climate change on crops and livestock. Therefore, an important area that may warrant more investigation is the link between wildlife ranching and food security. What would be the best policy mix that could encourage sustainable land utilization especially where the private sector is involved? What are the existing incentives or what additional incentives or enticement could be provided to the landowners in order to ensure proper conservation? Currently, the stewardship programs have been introduced, but most informal conservation areas (where wildlife ranching fall in) may not qualify to benefit. Lastly, another area that could be looked at is the role of land restitution or transformation in South Africa as a driver to land use change. There is no empirical evidence that validates the claim that commercial livestock and crop farmers are switching to wildlife so as to avoid land being returned to the communities or to compensate communities for land lost during apartheid.

It is necessary to keep in mind the limitations of the study. The first limitation is in regard to the Ricardian model. We have assumed that prices are constant over the period, but if prices were to greatly vary, then these results would overestimate the welfare effects of climate change. Secondly, the results show that wildlife land use will be less vulnerable to climate change and wildlife ranchers would earn higher revenues. However, for livestock farmers to make this adaptation choice of wildlife over the current stock, the cost of adjustment may involve high capitation or investments and substantial learning process in order to adapt. These requirements may be out of reach for most commercial livestock farmers or communities. Therefore, our result could overestimate the benefits of wildlife ranching over livestock production. Third, consistent with earlier Ricardian modeling, it is assumed that while forecasting climate change, the only thing that changes is climate (Seo et al., 2008). It is expected, however, that several things may change in the future. Such things could include population, institutional arrangements or technologies (Seo., 2008). These changes could bring about different outcomes unanticipated in this thesis. Finally, it is assumed that that climate change will steadily change the ecosystem over a period of time moving it from a

state favorable for crops to livestock and eventually to wildlife. This may not be entirely true because efforts to step-up mitigation strategies in the future may halt or reverse the loss of land or vegetation quality. Some areas such as the Free State and the North West provinces may, therefore, survive land use transition entirely. Land use change theory also postulates that land use change is not entirely a gradual process. It can also be discrete, a situation commonly found due to socio-economic changes such as change in markets or political policies. This could result into abrupt transitions (Lambin & Meyfroidt, 2010).

In conclusion, determining the role of wildlife ranching in the agriculture-climate change debate is the first step in looking at livestock, crops and wildlife as land use options which individuals with private property rights could choose. Livestock-wildlife land use change is here and factors that drive crop and livestock farms to adapt different land use choices are the same factors which could drive them to wildlife ranching. In order to get the best out of the situation, what may be necessary are policies that ensure that the benefits arising from wildlife ranching accrue to the communities around the ranches as much as those directly involved. Secondly, it is well known that the best opportunity to conserve wildlife is to target land outside the protected areas. In South Africa, the private sector already benefits from the legislative measures that provide consumptive and non-consumptive right to wildlife. It is also known that climate change, inadequate budget provision among other limitations make state-led wildlife conservation a huge challenge. Therefore, it is only logical that a balance is struck between policies that promote private sector led wildlife use for conservation of biodiversity and profits without undue emphasis put on one without the other. Food security is very important, but changing climate will put pressure on productivity. The situation may deteriorate further as more land is converted from crops and livestock production to wildlife without making sound policy provisions that facilitates food security.

Although there is need for further research in the economics of wildlife ranching and agriculture, we have contributed to this literature by establishing what role wildlife ranching plays in the welfare outcomes of the communities. This goes at the heart of protected area networks and community based natural resource use. This thesis forms the first causal study to look at the causal relationship between private sector wildlife use and the community. We have also demonstrated that studies on climate change and agriculture, especially in the Southern African region may have omitted an important subsector in agriculture. As such

they may have overestimated the effects of climate change. This study has shown that wildlife ranching plays an important role in adaptation but is affected by climate change.

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Appendix: A1

Table A1: Balance Results for first-stage Mahalanobis one-to-one Covariate Matching with Replacement

Covariate	**Status**	**Mean Protected**	**Mean Unprotected**	**Difference in Means**	**Normalized Difference**	**Mean eQQ Difference**	**% improved mean Difference**
Proportion of poor people	Unmatched	0.104	0.244	-0.140	0.691	0.144	
	Matched	0.104	0.103	0.001	0.009	0.007	0.993
Grazing Capacity	Unmatched	6.307	11.920	-5.613	0.708	5.583	
	Matched	6.307	5.871	0.436	0.062	0.541	0.922
Infrastructure	Unmatched	0.295	0.250	0.045	0.198	0.105	
	Matched	0.295	0.300	-0.005	0.042	0.005	0.878
Proportion of those employed	Unmatched	0.910	0.678	0.232	0.733	0.236	
	Matched	0.910	0.911	-0.001	0.005	0.008	0.998
Proportion of female	Unmatched	0.492	0.501	-0.009	0.124	0.025	
	Matched	0.492	0.491	0.002	0.041	0.004	0.814
Distance to the nearest service center	Unmatched	30649.67	34612.97	-3963.3	0.173	6238.061	
	Matched	30649.67	30401.17	248.506	0.014	990.154	0.937
Proportion of untransformed land	Unmatched	0.957	0.790	0.166	0.586	0.172	
	Matched	0.957	0.957	-0.001	0.008	0.008	0.995

5.1 Appendix A2: Wildlife utilization in South Africa: Some Facts and Figures[39]

Land Use allocation (Ha)	
Total land area in South Africa	122,320,100
State protected land area	7,500,000
Commercial Wildlife ranches land area	20,500,000
Industry conservation Management	28,000,000
Total Agricultural area	100,600,000
Gross income from major agricultural products for 2008/09 (in Rand)	
Poultry	R 20 billion
Red Meat	R 18 billion
Maize	R 18 billion
Fruit	R 15 billion
Vegetables	R 10 billion
Wildlife Ranching	R 7.7 billion
Number of commercial Ranches	
Exempted	7500+
Mixed	3000
Total	10000+
Estimated Game population in;	
State protected area	625,000
Commercial Wildlife ranches	2,500,000

The table is adopted from a report by Gert Dry (former president of Wildlife Ranching South Africa) from a presentation made to the 7th International Wildlife symposium in Kimberley, South Africa on October 2011.

[39] Data adopted from Gert Dry 2011.