An Economic Analysis of Climate Change and Wildlife Utilization on Private Land: Evidence from Wildlife Ranching in South Africa

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Abstract

Wildlife ranching is emerging as a new frontier for wildlife conservation and alternative land use to agriculture in Southern Africa marginal areas. But wildlife sector also faces climate related challenges. In this study, we investigated the effects of climate change on the revenues of wildlife ranchers in South Africa. This paper applied a median Ricardian modelling on net farm revenues using a sample of 506 wildlife ranches drawn from the latest version (2007) of Census of Commercial Agriculture data for South Africa. In order to predict the impact of climate change in future, the paper used three Atmospheric-Oceanic Global Circulation, which includes CSIRO2, Parallel Circulation Model, and Hadley Centre Coupled model, which have been used for South African agriculture modelling. 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. For example towards 2050, climate change could reduce net revenues from wildlife by up to 28 percent. In certain regions the models predict modest gains on revenues towards 2100. Revenues of specialized wildlife ranches would be more affected in the long run when compared to ranches that practice mixed wildlife and livestock ranching.

Keywords: Wildlife Ranching; Climate change; Ricardian

JEL classification: Q50; Q54; Q57; Q15

1 Introduction

The effect of climate change especially on livestock and crops is shown to be severe in several studies for Africa and around the world. Studies on climate change and agriculture for South Africa have looked at the effects of climate

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change, mitigation and adaptation on agriculture with specific reference to crops and livestock (see for example, Dube et al.,2013; Gbetibouo & Hassan, 2005, for the case of South Africa). On the other hand, across Africa, studies have looked at the effects of climate change on wildlife but on how the ecosystem components and processes influence growth and reproduction of wildlife (Kappelle et al., 1999; Walther et al., 2002) This literature looks at the effects of climate change on individual species of wildlife with emphasis on physiology, distribution as well as shift in range of species (Heller & Zavaleta, 2009) and they also focus on wildlife husbandry decisions within the protected areas (Lovejoy & Hannah, 2005; Musengezi, 2010).

South Africa on average has become hotter and drier in the past 15 years than during the 1970s, (Aronson et al., 2009). Areas initially suitable for crops are now under irrigation or alternative land use such as livestock. Irrigation has increased over time, but so is the cost of production. A number of farmers, both small scale and large commercial farmers have moved to wildlife farming as the net income margins from crop and livestock shrink.

Wildlife ranching provides important avenue for biodiversity conservation in South Africa given that only a third of wildlife is currently protected by the State while the remaining two thirds are in private ranches. It also provides an alternative land use option given limited options livestock farmers especially cattle farms have in the arid and semi-arid areas of South Africa. Around the world, land outside the public protected areas provide the alternative avenue for conservation (Langholz et al., 2000). But for private landowners to look at wildlife ranching as an option, commercial viability of wildlife is vital more so in climate impacted environment. It is evident in South Africa that ranches are sensitivity to factors that negatively impact on their revenue even when most may be pursuing conservation (Cousins et al., 2010).

In the IPCC-AR5, 2013 report, it is observed that given current level of adaptation in wildlife conservation, there is very high risk in the near term (2030-2040) and long term (2080-2100) the global increase of temperature will shift biome distribution and have severe impact on wildlife due to diseases and species extinction. It is noted that going forward very few adaptation options will exist besides migration corridors, protected areas and better management of natural resource. Even if adaptation would be enhanced, a temperature increase of 2°C and 4°C above preindustrial levels would still lead to medium risk. One of the adaptive options proposed by IPCC in the AR 5 report is ex-situ conservation initiatives. Therefore private sector-led wildlife conservation emerges as an avenue for conservation. Its competitive edge would be on how best the institutions balance between conservation objectives and socioeconomic objectives. It has to compete with other land-use options by providing opportunity for wildlife conservation at the same time financial and social development, (Mitchell, 2006).

In this paper, we identify climate change as a potential sources of challenge to farmers' revenues given existing evidence from agriculture and wildlife in protected areas. We therefore take an economic analysis of climate change and wildlife ranching on private land linking the discussion to the existing literature on agriculture in South Africa. Currently there is an intense debate in South Africa between the wildlife ranching sector, the wildlife agencies and the state on policies governing the sector and institutionalization of the sector to better govern its operation sustainably. Not including climate change in this debate raises two issues: first is the role of wildlife in adaptation decision in agriculture husbandries since more livestock ranchers are moving into wildlife ranching in the case of South Africa (Dry 2010a) and second and most important issue is the contribution of wildlife ranching to wildlife conservation and by extension the challenges ranchers face as they strive to balance revenue generation and sustainable wildlife conservation approaches in a climate impacted scenario.

1.1 Motivation of the study

Currently the ongoing debate is on whether wildlife ranching should be considered an agricultural activity given both the production and conservation aspects of the sector. The strong argument however is that just like domestic farming animals, wildlife on private land have to pay their way to stay on private land. There are indications that wildlife like domestic animals face various climate related changes although diverse views exist on their resilience in such scenarios. But unlike wildlife in public protected areas, ranchers with wildlife in enclosed ranches or conservancies 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 vary with climate change. Climate change though currently not mentioned 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 to what extend wildlife ranching sector perform under various climate scenarios since the decision to conserve wildlife on private land is an economic decision which implies that wildlife on private land compete with other land use options. It would also be important to shed light on how livestock ranches that introduce wildlife perform when compared to specialized wildlife ranches.

The objective of this study therefore is to evaluate the effects of climate change on the value of wildlife ranching and determine performance of various wildlife ranching models in a climate-impacted scenario. This evidence can form the basis for mainstreaming the discussions of climate change in wildlife conservation at the same time understanding the contribution of wildlife ranching in the climate change and agriculture debate.

The hypothesis is that while wildlife ranching provides an alternative land use option, on its own wildlife ranching sector equally suffers from climate change related aspects. The effects of climate change on wildlife ranching is also likely to differ across ranches given that different ranches practice value adding activities and therefore high value ranches are likely to respond differently when compared to low value ranches. There is need to reflect on and address potential adverse effects of climate change on wildlife if wildlife ranching is to be considered a sustainable land use option and if substantial welfare loss in the sector is to be avoided and conservation gains consolidated.

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. South Africa has up to 14,000 game ranches with 10,000 practicing specialized wildlife ranching while more than 4,000 are mixed ranches, (Child et al., 2012). Currently some 28 million (16.8 per cent of agricultural land) hectares of marginal, semi desert agricultural land have been converted into sustainable land use option through ranching with wildlife ranching protecting up to 73 per cent of wild animals in South Africa, [Dry 2010a]. The remainder of this paper is organized as follows; in section 2 we analyze literature on climate change and wildlife conservation with reference to the linkage between agriculture and wildlife ranching. In section 3 we introduce the median Ricardian model and its application in modeling effects of climate change on agriculture. Data analysis followed by empirical results are presented in section 4 before discussions and conclusion is done in section 5.

2 Literature Review

2.1 Introduction

For a long time, wildlife ranching activities were carried out in marginal areas of South Africa that are highly susceptible to effects of climate change. However wildlife ranching is now practiced even in areas which were traditionally crop or livestock farms and are beyond the marginal areas. 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. Besides the legislative changes that gave consumptive and non-consumptive rights to ranchers of wildlife, deregulation of the agricultural sector 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.

The major strand of literature on climate change and wildlife conservation is on the impact of climate on ecosystems and processes (Kappelle et al., 1999; Walther et al., 2002). For example, (Christensen et al., 2004) uses a simulation model to investigate a coupled system of plants and grazers under different climate conditions. They determine that grassland were likely to undergo transition to shrub-lands if the density of grazers were maintained. Other studies have used bioclimatic envelope models, which use current species distribution to predict future distribution as a function of climate (Hannah et al., 2007). Finally, mathematical models have also been used with integrated demographic and climate data to determine climate change appropriate harvest or stocking schedules (Garcia & Holmes, 2005). In these studies, the underlying observation is that models to evaluate the effects of climate change on species distribution, phenology and range shifts of species targeting species in the protected public areas and private ranches exist. But there are also cited limitations of these models and one such critique is from Scott & Lemieux, 2007; Chambers, Hughes, & Weston, 2005; Groves et al, 2002 who all observe that most conservation policies and management plans do not explicitly consider climate change in their design, implementation and reviews. Studies on the effects of climate change on ecosystems components and processes do not incorporate the role of human decision-making processes which ranchers face in making investment decisions on wildlife ranching.

There are two studies on climate change effects on wildlife in the protected areas in South Africa, (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 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. These studies are however not extended to private wildlife utilization and therefore the role of human factor in decision making on profit maximization as well as conservation is not represented.

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 (Gbetibouo & Hassan, 2005; Kabubo-Mariara, 2008; Mendelsohn, Nordhaus, & Shaw, 1994). The economic models such as Ricardian and structural Ricardian are used extensively to study the sensitivity of Africa 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, 2008b). The studies find that in a climate impacted scenario cattle farmers have limited alternatives in other species or in crops. I 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 may bias these results. We investigate whether by incorporating wildlife and livestock farmland performance would change.

One would 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. But the findings of most of these studies are specific to livestock and therefore provides little comparable results, (for example (Seo & 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). But given the perception that wildlife is more tolerant to heat, one would expect commercial livestock ranches to move to wildlife ranching in warmer conditions, but the results indicate that large commercial livestock farmers have limited adaptation options unlike the small 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 Southern African region.

There is reference in literature that wildlife is more resistant or resilient to marginal climate when compared to livestock under the same conditions. This position is supported by the literature on effects of climate change on ecosystems and their processes. However, 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) that though wildlife systems may have ecological advantages over modern livestock production systems, these may be difficult to quantify in complex dry land ecosystems, but they are trump by economic and political processes. On the other hand (Kreuter & Workman, 1997) in a study on cattle, wildlife and mixed ranching in central Zimbabwe found out that in areas with abundant wildlife, 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 in semi-arid savannas wildlife ranching is more profitable than cattle ranching. 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 study 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 policy should encourage land sparing or land sharing or wildlife friendly farming (Fischer et al., 2008; Green et al.,2005). 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, but it would be in the best interest of biodiversity conservation and agriculture if wildlife friendly farming were otherwise promoted even if through provision of subsidies to farmers to provide more non-cultivated land as wildlife habitat around the world (Norris, Ngambi, Lekalakala, & Nesamvuni, 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 further 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, game breeding and 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.

In South Africa, more than 73 percent of wildlife is under wildlife ranching. South Africa has witnessed an increased land use change from livestock to wildlife ranching while in certain cases a number of ranchers in South Africa have been sharing land between livestock and wildlife. While previous studies on climate change have investigated the impact of climate change and adaptation behavior in crop and livestock (Seo & Mendelsohn, 2008b), remarkably there has been little research to understand the vulnerability of wildlife ranching to climate change. Even in cases of land sharing behavior between wildlife and livestock, it is not clear whether such mixed ranches perform differently from livestock farms or specialized wildlife ranches in these climate conditions.

2.2 A review of Seasonal weather variations and their influence on wildlife Ranching[1] activities

In this section, the variations in temperature and rainfall across the four seasons namely summer, winter, autumn and spring for South Africa and how they relate to biophysical conditions of wildlife and wildlife revenues is summarized. Summer begins in October-March. It is the beginning of rainy seasons, but dry and humid if rains delay therefore it can be very hot if rains are late. Temperatures during summer can rise from between 16-36^0 C (mostly in January). It is the period during which most 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 case is severe in National parks sometimes leading to closure of parks due to bad road conditions. The arrivals of tourists to private reserves and game farms mostly increase with rains. Ranches incur less cost on supplementation of water and feeds since these are abundant as summer rains increase. Autumn begins in April and there is noticeable temperature drop to 13-29^{0}C. 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^{0}C. 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 are rising during the day. Good game viewing at waterholes and along the river lines. Temperatures are 10-28^{0}C. 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.

[1] Mostly those ranches that deal with ecotourism

3 Methodology

3.1 Introduction

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

In this study we use Median Ricardian approach recently 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: first is because of the need to address the influence of the outliers in our key independent variable. Wildlife ranching as earlier stated encompasses a number of on-farm value adding activities that significantly raise the value of the ranches. Such onsite activities include hospitality and ecotourism, game meat processing, packaging and export and game breeding of disease free wild animals for sale and 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 such activities generating high revenues to have undue influence on the regression results. Second, relaxing the assumption of the error term allows us to acknowledge ranches heterogeneity and consider the possibility that estimated slope parameters vary at different quantiles of the conditional net farm value distribution.

3.2 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.

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

P is the market value of each farm activity (including hunting, sale of meat and live animal, ecotourism among others), Q_i is the value of output priced at P of activities at ranch i, X_i is a vector of inputs for each ranching activity at the ranch i, H is a vector of input prices, Z is a vector of exogenous variables and δ is the discount rate. This Ricardian assumption is quite important because it allows us to neatly set aside biophysical processes and focus more on the rancher's decisions based on economic environment. The assumption made is that the decision the rancher makes on the species to keep and their numbers is reflected in the outcome of present value of net revenues.

The rancher chooses the output 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:

$$V_i = f(Z) \tag{2}$$

We group the exogenous variables into climate variables (temperature (T) and rainfall(R)); geographical variables (G); soil variables (S) and social-economic variables.

3.3 Estimation Strategy

The following quantile regression model is therefore estimated:

$$Q1nV_1,(\tau\backslash T,,.D) = \alpha(\tau)+\beta(\tau)T+\gamma(\tau)T^2+\beta(\tau)R+\gamma(\tau)R^2+\eta(\tau)S+\upsilon_i \tag{3}$$

Where R and T are vectors of rainfall and temperature respectively and υ_i is a random error term. We also control for the regional fixed effects by introducing regional dummies. The expected marginal impact of seasonal temperature (T_i) or rainfall (R_i) on net revenue per hectare is given by:

$$\frac{\delta V_i}{\delta R_i} = (\beta_{T,i}(\tau) + 2\gamma_{T,i}(\tau)T_i) \tag{4a}$$

The marginal impact may differ over quantiles and temperature marginal consequently vary depending on both the underlying net revenue and climate. The marginal effects of precipitation can be calculated as;

$$\frac{\delta V_i}{\delta R_i} = (\beta_{R,i}(\tau) + 2\gamma_{R,i}(\tau)R_1) \tag{4b}$$

The impact of climate change on the value of net wildlife revenue per hectare in ranch i is calculated by comparing the estimated value of wildlife revenues under the new temperature and precipitation (T_1, Y_1) to the estimated value under the present climate $(T_0 Y_0)$:

$$\Delta Y_i = \sum\nolimits_{i=1}^{n} [Qv_i(\tau)(T_1,R_1) - Qv_i(\tau)(T_0,R_0)] \tag{5}$$

Where Qv_i is given by

$$Qv_i = \exp(\alpha(\tau) + \beta(\tau)T + \gamma(\tau)T^2 + \beta(\tau)R + \gamma(\tau)R^2 + \eta(\tau)S + \theta(\tau)G_r + \phi(\tau)D_i) \tag{6}$$

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

3.4 Data and Description of dependent and explanatory variables

This study combines three different datasets; first a sample of wildlife and livestock data drawn from latest commercial census for agriculture for South Africa (StatsSA 2010) carried out in 2007; while data on climate[2] variables is obtained from Climate System Analysis Group. Soil data for the districts have been obtained from the Food and Agriculture Organization. A sample of 506 wildlife ranches from across six provinces were studied. The sample contains 377 (74.5 per cent) mixed ranches and 129 (25.5 per cent) specialized wildlife ranches. The mixed ranches can further be divided into three distinct categories depending on species of livestock ranched alongside wildlife by the same rancher. This includes 101 mixed ranches with wildlife and cattle only; 47 ranches with wildlife and small animals and 229 wildlife, cattle and small animals'[3] ranches.

The key variables for this study are the net revenues/ha of land, climate variables, which include precipitation and temperature and soil data. The key variables are defined as follow;

a) **Net revenue per hectare**

The dependent variable (V) is measured as wildlife or wildlife and livestock *(in case of mixed ranches)* net revenue per hectare of land. Net revenue is gross wildlife or wildlife and livestock revenue less total cost of production. As Seo and Mendelsohn (2006) observe, it is ideal to examine cases where farmers jointly maximize the combined profits from different forms of farming activities. The cost element is mainly total variable costs.

b) **Climate variables: temperature and precipitation**

The long-term maximum, mean and minimum temperatures and precipitation for municipal districts from the six provinces are presented for the four seasons (summer, winter, spring and autumn).

c) **Soils**

FAO defines 26 major soil categories out of which about ten are found in South Africa Benhin (2006). For the purpose of this study we use seven of the ten major soil categories in South Africa, which are found in the regions of the study.

First the sample is divided into four farming categories which include specialized wildlife ranches, mixed wildlife and cattle ranches; wildlife and small animals and finally wildlife, cattle and small animals. On average, wildlife, cattle and small animals' farms generate more net revenues when compared to other farms. And as it would be expected, the larger the size of the farm the more varieties of animals one had in the farm. In order to shed more light on

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

[3]Small animals includes sheep and goats

the distribution of farm revenues, we draw out the distribution of revenue of all farm types as shown in figure 1;

The distribution of specialized wildlife farms show a normal distribution with a thick tail and a wide spread. However, there is a distinctive distribution of net revenues of mixed ranches with both wildlife and cattle. The kinked tail shows that a proportion of farmers earn very high income on average while the left tail suggests that a number of ranches earn very low income. There seems to be no difference in the distribution between wildlife and small animals and wildlife, cattle and small animals, but the kink on the latter suggests that these farms are more efficient or at least generate more revenues than the former.

An ANOVA test has been carried out to see if the means of the net revenues for the four farms are different. We conclude that the difference are statistically different and using the post Turkey test, the difference in means is largely between wildlife and small animals when compared with specialized wildlife farms and for the case of wildlife, cattle and small animals when compared with specialized farms. Lastly there is also a significant difference between wildlife and cattle farms when compared with wildlife, cattle and small animals' farms.

3.5 Contribution of wildlife revenue to net farm revenues

In figure 1, we plotted the kernel densities of the log of net revenues for the four farms. But in order to determine the contribution wildlife makes to the farm net revenues, we disaggregate income and expenditure of each farming type to establish how much of income is generated by wildlife or livestock. This is compared with how much spent on both wildlife and cattle. Figure 2 shows that most revenues in mixed ranches are generated by wildlife related activities.

As one would expect, specialized wildlife farms depend less on water from either stream flow or water purchased during drier seasons. However, about 19% of mixed farms with wildlife, cattle and small animals depend on stream flows. It is also less surprising that mixed farms with cattle depend more on water purchases than farms with wildlife only or mixed farms with small animals such as goats and sheep, which are known to better, perform in marginal areas.

Mixed farms with wildlife, cattle and small animals rely more (82%) on membership to associations dealing with wildlife or cattle when compared to other farms such as specialized wildlife farm (41.9%).

One other test we have carried out is on whether the differences in means of the attributes are statistically significant when income groups[4] are considered. We conclude that the difference between net revenue per ha and land size of farms from the four income groups are statistically significant.

Specialized wildlife ranches are largely found in areas where soil is Lixisols and Leptosols. In the same areas, mixed wildlife and cattle ranches are also found. However, mixed ranches with wildlife and small animals are found across

[4] 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)

all soil types. Lastly, mixed ranches with wildlife, cattle and small animals are mainly found in areas with Luvisols, Leptosols and Durisols. These soils are known to be of poor quality.

Generally farms specializing in wildlife ranching are located in areas with higher temperature when compared to other farms. Either, specialized farms are located in areas with higher rainfalls when compared to other farms.

4 Empirical Results

4.1 Introduction

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 response by farmers to local climate since it takes into account the costs of different alternatives. For example if the rancher decides to incorporate any type of livestock ranching with wildlife as climate warms, the Ricardian model assumes that the rancher will pay the cost associated with the wildlife introduced given that the rancher has considered the costs of alternative adaptation options in livestock species such as a move to smaller animals as climate warms up. If it turns out that the introduced wildlife activities fails to be productive, the cost of this learning process is not included in the Ricardian model (See (Kurukulasuriya et al., 2008). Therefore we do not have to explicitly model adaptation at this point because it is implied in this approach.

The regression therefore controls for the climate variables, regional differences and introduces dummies for ranches which purchase water, have membership to wildlife bodies and insurance of stock. These factors are known to influence revenue because ranches that buy water are expected to either generate more revenues or less returns due to higher costs of doing business. Equally, ranches that are a member of an association are assumed to attract more revenues due to social networking.

In the first model (Table 4), net farm revenue for all farms is regressed on all variables except regional dummies. The variables include climate variables, soil and farm specific dummies. Since the study uses median regression, we also present an alternative OLS model for robustness check.

The results in table 4 shows that temperature and precipitation have a large and significant effect on the net revenues in wildlife ranching. Summer temperatures are known to rise up to 36^0 C in areas where livestock and wildlife ranching is practiced. As temperature rises, the net revenues increase at a decreasing rate during summer as the quadratic summer coefficient suggests a hill-shape relationship between summer temperature and net revenues. The turning point which is determined by dividing the linear coefficient with twice the quadratic coefficient shows that the turning point is at 27.49^0 C. On average the maximum temperature is 28.64^0 C, therefore warmer summer temperatures are generally harmful. The autumn temperature confirms that extended summer temperatures are detrimental to farm revenues. The results are therefore consistent with earlier studies where (Seo & Mendelsohn, 2008b) found that for the case of beef cattle and sheep, summer temperatures have a damaging effect on the value of land.

The results of summer precipitation however suggests that net farm revenues decreasing with increasing precipitation, but as suggested by the quadratic term, the relationship between the revenues and precipitation is U-shape with the turning point at 176.24mm of summer rains. The average summer rainfall is about 203.04mm, therefore increasing precipitation is beneficial to net revenues. We also find winter precipitation to be significant and U-shaped with a turning point at 99.68mm.

The effects of summer rains and temperatures on net revenue can be summarized as follows; from the production point, summer rains provide the right opportunity for animals to thrive since more food and water is easily available. Summer migratory birds are also known to occupy these ranches during this time. However, in terms of revenue generation, increased rains reduce the cost incurred to provide water and other interventions, but increase the cost of road repairs and maintenance.

At this stage, we investigate further to determine how specialized wildlife ranches perform under the same climate scenario because our results above can be influenced by the number of mixed farms. Due to this, we cannot tell at this stage whether inclusion of wildlife improves revenues of ranchers who incorporate wildlife and livestock. We cannot also exclusively draw out the possible effects of climate change on wildlife ranching. In order for us to do this, we split our sample at this point into two and run separate regressions for specialized wildlife farms and mixed farms. Table 5 is the results of specialized wildlife farms.

When wildlife only ranches are analysed separately, it turns out that initially summer temperature that is humid and dry results into a decline in net revenues. But a look at the quadratic term of summer temperature shows that farm revenues are positively related. The U-Shape relationship suggests that summer temperatures are eventually beneficial to the farms revenues holding other factors constant. The turning point is at 25.32^0C which is lower than the maximum average temperature but high than the mean temperature of 21.58^0C. The linear term of autumn temperature suggests that extended summer temperatures are indeed beneficial to the farms value.

Summer rains are beneficial to net farm revenues, but more rains eventually damage revenues as can be seen by the hill-shape relationship more so when rains go beyond 135.59mm during summer. This increase in revenues results from inflows of tourists from the national parks to the reserve due to poor state if roads in the parks. However, increasing summer rains raises the cost of maintenance on roads and machineries such as vehicles. Cost also increase because viewing of animals become more difficult due to busy vegetation and ability of animals to move deeper into the bushes. It takes more effort in terms of fuel to track these animals. What is also interesting is that while one would expect farms that intervene by purchasing water to realize better revenues, on the contrary purchase of water reduces farm's revenues. 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. There is also less cost incurred in repairs of roads.

In order to investigate the source of variation in the results of specialized wildlife ranches and the regression of the whole sample, we compared these results to a regression of mixed ranches. For this purpose we use mixed ranches that keep both wildlife and cattle. In our sample, they represent 20% of the total sample and therefore form a good basis for comparison. We regress and compare the results of wildlife only ranches with mixed cattle-wildlife ranches. Table 6 provides the results.

At this point what is clear is that the result of mixed ranches are reflective of what other studies found on the effects of climate change in livestock case, (Aronson et al., 2009; Seo & Mendelsohn, 2008) For example in a study by Aronson et al., 2009, they find that temperature has a damaging effect on animal production in South Africa. This has resulted into animal farmers making use of irrigation to offset declines in rainfall. In our result of mixed wildlife and cattle ranches, the same trends are witnessed, but we see a different performance in revenues when compared to specialized wildlife ranches.

For example, the effects of summer temperature on wildlife ranching exhibits a damaging effect on mixed ranches while it is more beneficial for specialized wildlife ranches. Looking at the turning point, summer temperature become beneficial to ranchers at 25.32^0 C while for the case of mixed ranches, summer temperature as low as 23.97^0C is detrimental to net farm revenues. An indication that specialized wildlife ranches are on average able to perform better in the current climate holding other factors constant. Summer rains as high as 168.29mm (turning point) is required for mixed ranches to become beneficial. On the contrary, specialized wildlife ranches require just about 135.59mm for the revenues to suffer during summer. Prolonged summer precipitations are more beneficial to mixed ranches compared to specialized wildlife ranches. This should be expected, because when we compare the benefits of a farm purchasing water, it is more beneficial to mixed ranches than wildlife ranches. We can see from this that inclusion of cattle does affect wildlife revenues. These results are quite revealing at this point; mixed farms are farms on transition from livestock to wildlife.

4.2 Ricardian quantile Regression

One of the reasons we proposed to use quantile regression is because it is able to address the distribution issues. The study therefore investigated whether ranches are affected differently by climate due to differences in the value of farms. The hypothesis was that since ranchers have different value adding activities, ranches that have more value adding activities, have more revenues compared to a farm that has fewer activities. It is on this premise that the study used median Ricardian so that the effects of the outliers are taken into consideration and the entirely distribution is also study. 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).

We therefore run a regression of all farms across quantiles to see how climate change affects the value of farms across the quantiles. 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 7 shows the results. What the study finds is that high value ranches are affected differently by climate when compared to low value ranches. In most of these cases the effects are not significant, but take for example winter precipitation, at τ=0.25 and τ=0.75 we see that winter precipitation is beneficial to both small and larger ranches, but it is significantly more beneficial to high value ranches considering that the quadratic term of high value ranches are large than those of smaller ranches. In deed during winter, high value farms are likely to spend more in providing water, therefore more winter rains can reduce this cost.

At various stages of this analysis, we have controlled for regional dummies, soil types and other farm specific dummies such as purchase of water. Here the intention was to capture regional fixed effect and farms heterogeneity. In regions where the soil is predominantly Luvisols, Arenosols or Durisols, 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 use such as dairy cattle or crop production. As can be shown, mixed ranches seem to benefit more in areas where Arenosols type of soil exist, since the soil are well drained. Specialized wildlife ranches 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 is effect in neither significant nor positive. In the case of regional dummies, our reference region is Eastern Cape Province. The negative coefficient term in Limpopo, Mpumalanga and North West suggest that revenues of these farms are more affected when compared to Eastern province. The impact of climate in these regions as can be seen from the coefficients suggests that the magnitude is relatively severe in Limpopo which could be explained by the fact that about 50% of wildlife ranching activities are in that region.

4.3 Marginal effects Analysis

The marginal effects on the value of wildlife ranching depend on both the linear and squared coefficient. In order to provide an easier interpretation of climate sensitivity, marginal effects were calculated. Table 8 presents the results using the entire sample of ranches and the sub categories of ranches.

In terms of marginal effects per hectare of land, temperature and precipitation have different marginal effects across seasons and regions. Summer temperature together with summer precipitation results into 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, even though summer temperature and rains results into over R12,022 gains for specialized wildlife farms, this gains are significantly reduces during autumn. This could be explained by increasing cost of infrastructure maintenance especially those farms practicing eco-tourism. Though winter also results into fairly higher returns, again extended winter (spring) results into losses which also reduce the gains from winter. What is noted however that on average wildlife is 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 our sample, across regions, ranches in Northern Cape Province generate a higher annual net profit per hectare of land, Northern Cape is known to have a wealth of National parks and conservation areas with tremendous growth in value added game-farming. This is closely followed by Limpopo province.

4.4 Projections with Climate Scenarios

In this section, the study examined change in net revenue across regions and ranch-types in South Africa. Three Atmospheric-Oceanic Global Circulation (AOGCM) climate scenarios are used. This includes CSIRO2, Parallel Circulation Model (PCM) and Hadley Centre Coupled (HadCM3) model which have been used in literature for South African (Benhin, 2008; Kurukulasuriya et al., 2008) The predicted change in temperature and precipitation for South Africa is presented in table 9;

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 predict the current farmland value, then what the model predict future farmland value will be given the new climate scenarios. These calculations take into consideration the predicted changes in rainfall and temperature at each location. The results of the analysis are outlined in table 10;

The model predicts that the current value of land under wildlife based on the sample used is about R3980 Million. This value is likely to reduce by 15% by the year 2100 due to impact of climate change. The greatest reduction in net revenues from ranching would be experienced in Eastern province where according to the HADCM3 Model is expected to lose up to 28% of its net current value. In the medium term (2050) however Mpumalanga province is expected to realize the highest lost in net revenues followed by Limpopo. However, the model predicts that in the medium term, Northern Province would experience increased net benefits from wildlife. The model nonetheless predicts that in the long term these gains would be modest. In terms of revenues from specialized wildlife and mixed ranches, the current net value is R1120 Million and R877 Million respectively. These values are expected to decline by 11% and 7% for wildlife and mixed ranches respectively in the medium term. It seems wildlife ranches would be more affected in the long run when compared to mixed ranches. (This could mean that mixed ranches embody some form of resilience).

5 Discussion and Conclusion

In this paper, using log-linear median estimation approach we investigated the effects of climate change on the net revenue of wildlife ranching by extending the Ricardian model. The model reveal that climate factors will affect both specialized wildlife ranches and mixed ranches in the medium to long run.

5.1 Climate change and Wildlife ranching- all ranches

We measured the impact of climate change by first running a model for all farms in our sample. The study controlled for different soil types, farm characteristics and regional fixed effects. The summer and winter temperatures initially increases revenues before eventually resulting into decline in revenue at the turning point. This can be explained by two factors: First is the biophysical benefit 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. Second, ranch-based activities such as tourism, hunting among others are largely practiced during the high season, which is apparently during summer. Ranches and reserves which are linked to National Parks such as Kruger National Park benefit most during summer since the road conditions and infrastructure in the reserves are much better. 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. On the other hand, cold 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 at the same time reduce the cost of interventions.

5.2 Climate Change and specialized wildlife farms

The results of wildlife only farms give a different perspective, as expected, summer temperature results in more revenues. Rising temperatures and moderate summer precipitation are more beneficial to ranching revenues. However, increasing winter temperatures and precipitation have damaging effects on wildlife revenues due to increasing cost of maintenance.

5.3 Wildlife and Livestock Compared

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, 2008b). This could be explained by the choice of species of livestock which indicate that 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 on livestock, mixed ranches are at liberty to switch from one variety of livestock to another in response to climate change. Specialized wildlife ranches may take a longer time to adjust to climate change as opposed to mixed ranches which 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, 2008b). However, the results also indicate that mixed ranches are ranches that are in transition to specialized wildlife ranches.

5.4 Climate change simulations

The study has used three AOGCM models to predict the effects of climate change on wildlife ranching. From the models, revenues will steadily decrease over time in the medium term to long term across all regions apart from Northern Cape Province. The interesting result is that while revenue will decrease over time, revenues from wildlife sources will stabilize in the long run as mixed ranches experience declining revenues. This could be explained by the desire of more ranches to transit to specialized 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.

5.5 Areas for further Research

It is imperative to evaluate factors that influence ranchers to apply their land to wildlife or livestock in the current climate scenario. If wildlife is to be consider a land use option for adaptation, it is important to understand whether choices currently made by farmers who transit from livestock to wildlife are adaptive or maladaptive choices. Another area for further research is to evaluate the role of government incentives in mitigating and promoting sustainable wildlife conservation through wildlife ranching. As (Western et al., 1989) observed, areas outside national parks constitutes the only opportunity to expand and protect wildlife. Equally, whether or not monetary benefits accrue to private individuals, the government has a role to play in non-consumptive value of wildlife in private ranchers since wildlife is still considered a public resource. Finally, there are a number of limitations that needs to be bore in mind about the study; first is that cross sectional studies are vulnerable to omitted variables bias, therefore the results may be sensitive to other controls not currently included. Second, the analysis did not take into consideration changes in prices and the technological changes that may occur in the future which is consistent with earlier Ricardian studies.

5.6 Contributions of the study

Attempts to describe, understand and predict the effects of climate change are important in identifying practical and sustainable strategies that could help reduce or ameliorate anticipated negative effects of climate change. Establishing the nature and extent of climate change on wildlife ranching provide sector with information necessary for them to consider sustainable ways of adapting to climate change. The study therefore makes contribution in the following areas; in this study, we have been able to show that beyond the biophysical channels identified in literature, climate change affects wildlife revenues directly across seasons. Previous studies on climate change and agriculture especially in South African did not consider the role of wildlife ranching as land use option or as possibly being affected by climate change besides being able to play a mitigating role in a climate impacted agricultural environment. There has been a strong debate in South Africa on whether or not wildlife ranching should be considered an agricultural activity and the proponents of this debate are for wildlife to be considered an agricultural activity. The findings of this study also corroborates earlier studies on livestock (Seo & Mendelsohn, 2008a; Sungno Niggol Seo, 2006) it however shows that most mixed ranchers especially commercial cattle ranchers are likely to consider wildlife as an alternative land use option where policies permit. The study further addresses itself to the literature on resilience of wildlife over livestock; the finding corroborates that by (Kreuter & Workman, 1997), the revenues of wildlife may not necessarily be resilient. Finally, the use a median Ricardian has allowed us to fit a model that could explore the effects of climate on various ranches of different values.

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Table 1: Summary of descriptive statistics

Variable	Specialized Wildlife	Wildlife and Cattle	Wildlife and Small animals	Wildlife, cattle and small animals
Log of Net rev	11.48	11.76	12.22	12.40
	(1.72)	(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	**129**	**101**	**47**	**229**

Note: standard deviations is in the parenthesis

Table 2: Descriptive statistics for Soil types

Variable	Specialized Wildlife	Wildlife and Cattle	Wildlife and small animals	Wildlife, cattle and small animals
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	**129**	**101**	**47**	**229**

Note: standard deviations is in the parenthesis

Table 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	-

Table 4: Ricardian Regression for South Africa Wildlife Ranching - All Ranches

VARIABLES	Median Regression	Se	OLS Regression	Se
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
Observations	506		506	
R-squared			0.114	

Note: *** p<0.01, ** p<0.05, * p<0.1

Table 5: Ricardian Regression for Wildlife only Ranches

VARIABLES	Median Regression	Se	OLS Regression	Se
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
Observations	129		129	

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$ and Reference Province is Eastern Cape

Table 6: Ricardian Regression with specialized Wildlife only farms and Mixed Wildlife/Cattle

VARIABLES	**Specialized Wildlife**	se	(Wildlife and Cattle)	se
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)
Observations	**129**		**101**	

Table 7: South African Ricardian quantile Regressions

VARIABLES	(τ =0.1) Model 1	(τ =0.25) Model 2	(τ =0.5) Model 3	(τ =0.75) Model 4	(τ =0.9) 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)
Observations	506	506	506	506	506

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

Table 8: Absolute Marginal Effects Temperature and Precipitation (ZAR/ha)

	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

Table 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

Table 10: Predicted climate change Ranching Systems (Million Rands)

Province/Farm Type	Current Farm Value	CGCM2		PCM		HaDCM3	
		2050	2100	2050	2100	2050	2100
Total	3980	3670 (-8)	3400 (-15)	3610 (-9)	3460 (-13)	3570 (-10)	3400 (-15)
Eastern Province	1700	1510 (-11)	1230 (-28)	1520 (-10.6)	1390 (-18)	1530 (-10)	1230 (-28)
Free State Province	410.5	371.7 (-9)	402.5 (-2)	359.8 (-12)	395.4 (-4)	350.1 (-15)	402.5 (-2)
Limpopo Province	760	663.2 (-13)	732.1 (-4)	625.7 (-18)	673.8 (-11)	611.7 (-20)	732.1 (-4)
Mpumalanga Province	248.2	201.5 (-19)	185 (-25)	192.6 (22)	172 (-31)	189.7 (-24)	185 (-25)
North West Province	258.3	249.5 (-3)	217.2 (-16)	262.1 (+1.5)	218.4 (-15)	256.8 (-0.5)	217.2 (-16)
Northern Province	606	682.4 (+13)	632.3 (+4)	642.2 (+6)	613.6 (+1.2)	636.1 (+5)	612 (+1)
Wildlife Only ranches	1120	1000 (-11)	965.9 (-14)	968.5 (-13.5)	965.9 (-14)	952.3 (-15)	1010 (-10)
Mixed Wildlife and cattle Ranch	876.5	811.6 (-7)	745.7 (-15)	798.3 (-9)	745.7 (-15)	759.8 (-13)	736.5 (-16)

Figure 1: Kernel Densities of log of Net revenue per ha for different farms

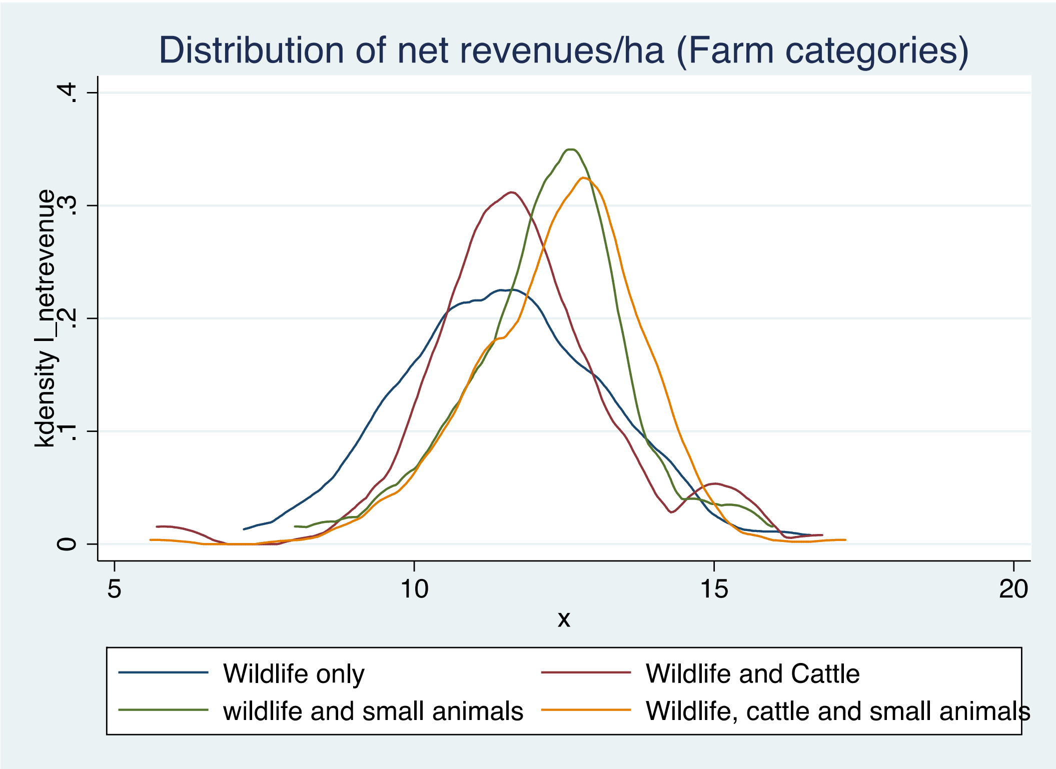

Figure 2: Contribution of wildlife revenue to total ranching revenue (Million Rands)

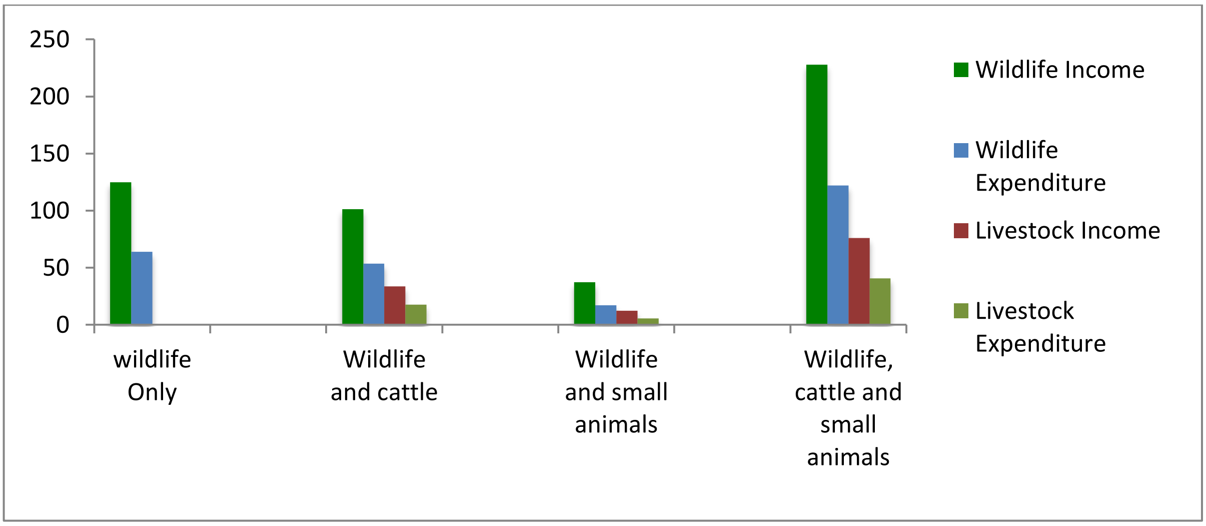

Figure 3: Nick Cox's *qplot*