

The economic impact of climate change on commercial agriculture in Namibia

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December 2009

In collaboration with Namibia Nature Foundation

This paper is based on the Dissertation submitted for MSc. Environmental Economics, University of York by Louise Helen Brown, September 2009, entitled "The effects of climate change on revenues to commercial agriculture and tourism enterprises in Namibia"

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Acknowledgements

I would like to thank my supervisor, Jim Smart, for his support, advice and valuable suggestions throughout the course of my dissertation. I am grateful to Colin McClean for his guidance in obtaining and using the climate data, and Jon Barnes for advice on the methods and comments on a draft of the questionnaire. I would like to thank Chris Brown for presenting the project proposal for this study to a meeting of the Namibia Agricultural Union, for comments on a draft of the questionnaire and for general advice, ideas and discussions. I would also like to thank the Namibia Nature Foundation for supporting the distribution of the questionnaires.

I am grateful to the following people and organisations in Namibia who assisted in the provision of data: Ministry of Agriculture, Water and Forestry, who provided the GIS map of commercial farms; John Mendelsohn of Research and Information Services of Namibia, who provided the Atlas of Namibia data; Elsabe Steenkamp and Annatjie du Preez of the Namibia Agricultural Union, who assisted in the distribution of the questionnaires; Kiep Lepen and Suzanne at AGRA Cooperative and Diana van Schalkwyk at Hartlief Corporation who provided data on prices. I would also like to extend a word of thanks to all the land owners who took the time to complete and return the questionnaire, without whom this study would not have been possible.

Summary

Namibia is one of the world's most vulnerable countries to climate change, due to its extreme aridity and dependence on primary industry, combined with a limited adaptive capacity. Approximately 70% of Namibia's 2.1 million people live in rural areas and are directly reliant on subsistence agriculture for their livelihoods. Namibia's climate is predicted to become hotter and drier in the future, with more variability in rainfall. Much of the land that is currently being used for agriculture is barely able to support the people who depend on it, and a reduction in rainfall is likely to make these areas less suitable for agriculture. The loss of agricultural productivity as a result of climate change could have severe economic impacts on farmers and on the Namibian economy.

In this study, a survey of commercial farms in Namibia was conducted, and a multiple regression model was used to identify the main factors that determine farm revenue. The model was applied to predictions of future rainfall in order to estimate revenues for the years 2050 and 2080. Revenue per hectare was found to be lower for livestock production than for trophy hunting. Substantial losses in farm incomes are predicted to result from climate change, with annual revenue per hectare projected to decrease by up to 42% of its current value by 2050, and up to 59% by 2080. Livestock production is identified as particularly vulnerable due to its direct reliance on rainfall. Tourism is identified as being less vulnerable, as it generates higher revenues, and being a service industry, is likely to be less constrained by rainfall and less dependent on primary production. Diversifying farming activities to include wildlife production is recommended, especially in areas that are currently marginal for livestock production. In the most vulnerable regions, a conversion to using wildlife production systems could be a key adaptation that allows farmers to avoid complete loss of production under climate change.

1. Introduction

Over the past 30 years, average global temperatures have risen steadily at a rapid rate of 0.2 degrees Celsius (°C) per decade (Stern, 2007). This rate of temperature increase is predicted to be sustained over the next two decades (Intergovernmental Panel on Climate Change (IPCC), 2007), with severe implications for physical and biological systems and human livelihoods and well-being. Poor countries, particularly those in Africa, are amongst the most vulnerable to the negative effects of climate change (IPCC, 2007). They also have the least capacity to adapt to climate change due to their limited financial resources, skills and technology, and their dependence on climate-sensitive primary sectors (Boko *et al.*, 2007). Namibia is one of the driest countries in sub-Saharan Africa, and is heavily reliant on its primary sectors, with agriculture, mining and fisheries comprising approximately 24% of gross domestic product (GDP) in 2008, and agriculture alone comprising 5.5% of GDP (Central Bureau of Statistics, 2009). Approximately 70% of Namibia's 2.1 million people live in rural areas and are directly reliant on subsistence agriculture for at least part of their livelihoods (Government of Namibia, 2002). It is likely that the poorest people will bear the costs of climate change most directly, as they are reliant on the land and natural resources, and do not have access to capital that would enable them to adapt or avoid the worst effects (Reid *et al.*, 2007).

Namibia's climate is predicted to become hotter and drier in the future, with more variability in rainfall (Reid *et al.* 2007). Much of the land that is currently being used for agriculture is marginal and barely able to support the people who depend on it. Any reduction in rainfall is likely to make these areas unsuitable for agriculture altogether. Several studies have investigated the potential impacts of climate change in Namibia, and have predicted significant detrimental environmental, economic and social impacts (e.g., von Oertzen, 2009; Reid *et al.*, 2007; Midgley *et al.*, 2005; Government of Namibia, 2002). Reid *et al.* (2007) have demonstrated that, in the absence of adaptation, the effects of climate change on agriculture could lead to economic losses of up to 3.5% of GDP per year, and could exacerbate the already high inequality in income distribution. The Ministry of Environment and Tourism (2006) states that "climate change could potentially become one of the most significant and costly issues that affect the national development process in Namibia".

Further analysis and quantification of the impacts of climate change on agricultural systems and tourism is imperative, particularly at the level of the individual land owner. By gaining a better understanding of the changes that are likely to occur, these impacts can be incorporated into land use planning and policy making. Identifying the regions and sectors that are likely to be most vulnerable to climate change will give land owners the opportunity to make informed decisions and adapt or diversify their farming systems so as to avoid unnecessary losses. This study investigates and attempts to quantify the probable economic impacts of climate change on commercial farming and tourism enterprises in Namibia. In addition, it identifies those regions or land uses that are likely to be the most vulnerable to the negative effects of climate change, and makes recommendations as to how land owners can diversify or adapt their farming practises so as to reduce their vulnerability.

1.1 Namibia's circumstances

Namibia is amongst the most arid countries in southern Africa, with a mean annual rainfall that ranges from more than 600 millimetres (mm) in the north-eastern Caprivi region to less than 50mm in the south west and along the west coast, and a high inter-annual variation in rainfall (Mendelsohn *et al.*, 2002). Namibia as a whole loses considerably more water through evaporation than it receives through rain (Mendelsohn *et al.*, 2002). Evaporation rates range from less than 2,400mm per year in the north east and along the coast to more than 3,800mm per year in the south east (Mendelsohn *et al.*, 2002). Namibia relies heavily on groundwater reserves, which currently supply more than 50% of the country's water demand (Government of Namibia, 2002). Lack of water is identified by the Government of Namibia (2002) as the single biggest limitation to Namibia's development.

Namibia's economy is heavily reliant on natural resources, with primary industry comprising 24.4% of GDP in 2008 (Central Bureau of Statistics, 2009) and agriculture and forestry contributing 5.5% of GDP, of which 3.2% derives from livestock farming. Agriculture is the main land use in Namibia, with approximately 64 million hectares (ha), or 78% of the total land area, being used for farming (Mendelsohn, 2006), and approximately 70% of the population practicing subsistence farming (Government of Namibia, 2002). In terms of employment, agriculture is the most important industry in Namibia, employing around 27% of the country's work force and 58% of the workforce in rural areas (Ministry of Labour and Social Welfare, 2004).

Cattle farming for meat production takes place on approximately 38% of Namibia's land, in the northern and central regions, and its productivity, which is generally low compared to that of other countries, is largely determined by rainfall. Large areas are required, with an average stocking rate on commercial farms of 14.8ha to one large stock unit¹ (Mendelsohn, 2006). Small stock farming takes place on about 33% of the land area, in the arid southern regions where there is insufficient grass for cattle farming. Intensive agriculture takes place on less than one percent of Namibia's commercial farmland, and includes the production of maize, wheat, and high value commodities such as dates, olives, grapes, dairy products, pigs, fruit and vegetables.

Production systems involving natural resources, primarily wildlife, are on the increase in Namibia, both on commercial and communal land. Wildlife production is estimated to contribute about two percent to gross national product (GNP), of which 62% comes from wildlife viewing tourism, 19% from trophy hunting and 10% from live game production (Barnes *et al.*, 2009). Part of the value of wildlife to farmers lies in the diversification of risk (Ashley and Barnes, 1996). Tourism is Namibia's fastest growing industry, and an important source of foreign exchange (Mendelsohn *et al.*, 2002). Tourism directly contributed approximately 3.7% to GDP in 2006, and generated 18,800 jobs (World Travel and Tourism Council (WTTC), 2006). The full potential of tourism in Namibia is yet to be realised, especially in the

¹ A large stock unit is approximately equivalent to one cow or six sheep or goats (Mendelsohn, 2006).

communal areas, and the economic contribution of wildlife alone to GNP is projected to triple over the next 30 years (Barnes *et al.*, 2009).

1.2 Climate change

Over the past 30 years, average global temperatures have risen at a rapid rate of about 0.2°C per decade, with a total increase in temperature of about 0.74°C since 1900 (Stern, 2007; IPCC, 2007). Anthropogenic global warming is caused by the emission of greenhouse gases (GHGs), predominantly carbon dioxide (CO₂), which trap heat in the atmosphere, causing a gradual warming of the Earth's surface. Increases in global CO₂ concentrations are largely the result of burning fossil fuels for energy supply, transport and industry, as well as land use changes including deforestation. Global warming is of considerable concern to society because it could have profound impacts on human lives, through changes in water supply, food production, health, availability of land, and ecosystems (Stern, 2007). Climate change is likely to cause changes in the distribution and seasonality of rain, increasing the severity and frequency of droughts and floods. Between 75 and 250 million people in Africa are projected to be exposed to water stress by 2020, and yields from rain-fed agriculture could be reduced by up to 50% in some African countries, reducing food security and exacerbating malnutrition (IPCC, 2007). Developing countries are particularly vulnerable to the negative effects of climate change due to their geographic location (often in areas that are prone to drought, flooding and tropical diseases), low income, and reliance on climate sensitive primary sectors such as agriculture and fisheries (Stern, 2007; Reid *et al.*, 2007). Ironically, it is these countries that have contributed least to the problem of global warming.

1.3 Climate change in Namibia

Several studies have attempted to predict and quantify the major changes in climate systems that can be expected in Namibia over the next few decades as a result of global warming. Government of Namibia (2002) reports projected temperature increases of 2 to 6°C by 2100 for the central highland region around Windhoek. This is consistent with historical temperature observations from the weather station in Windhoek, which records an average temperature increase of 0.023°C per year between 1950 and 2000. Several other studies have projected significant increases in temperatures for southern Africa, with increases in the range of about 1 to 4°C by 2050 and 1.5 to 7°C by 2080 (Ruosteenoja *et al.*, 2003).

Future rainfall predictions are less consistent, with different climate models revealing different projections. Government of Namibia (2002) reports inconsistent predictions for future rainfall patterns, ranging from an increase in annual rainfall of around 30mm to decreases of up to 200mm, with the greatest changes projected for the central inland areas. A study by Ruosteenoja *et al.* (2003) found that mean rainfall predictions for southern Africa range from an increase of more than 10% to a decrease in excess of 45% of current rainfall by 2050. Predictions for 2080 range from an increase of more than 10% to a decrease of more than 60% of current rainfall. Midgley *et al.* (2005) project declines in rainfall throughout Namibia for 2050 and 2080, with severe reductions in rainfall in the north west and central

regions, and particularly in the highlands around Windhoek. Rainfall is also predicted to become more variable (Government of Namibia, 2002), with an increase in the frequency and intensity of extreme events such as droughts (Reid *et al.*, 2007; Stern, 2007).

The predicted climate changes could lead to substantial changes in ecosystem structure and function. Midgley *et al.* (2005) predict a reduction in vegetation cover for many parts of Namibia as well as a shift in the distribution of major vegetation types, with an expansion of the most arid biomes (Desert and Nama Karoo) of 20% by 2050 and 43% by 2080 and a reduction in Tree and Shrub Savanna. In addition, these authors suggest that Namibia's biodiversity is highly vulnerable to climate change, and predict that 30 to 40% of Namibia's plant species could become critically endangered or extinct by 2080.

1.4 Effects of climate change on agriculture and tourism

Namibia's extreme aridity combined with its dependence on agriculture make the country acutely vulnerable to the effects of climate change. Crop yields and livestock production rates are low compared to those of other countries, and large areas of land are required to provide sufficient grazing for livestock production (Mendelsohn, 2006). Reid *et al.* (2007) estimate that losses in agricultural productivity as a result of climate change could amount to losses of 1.5 to 3.5% of GDP per year. The commercial production of livestock, which is an important sector of Namibia's economy, is underpinned by the productivity of rangelands, which is largely determined by rainfall (Mendelsohn, 2006; Midgley *et al.*, 2005). The numbers of cattle, sheep and goats on commercial farms have declined substantially over the past 20 to 30 years, probably due to decreasing returns from livestock farming, poor rainfall and increasing bush encroachment (Mendelsohn *et al.*, 2002). The reductions in vegetation cover predicted by Midgley *et al.* (2005) would have severe implications for agricultural output, as they imply less vegetation available for grazing and browsing livestock and wildlife. Livestock production rates in Namibia are already low and highly sensitive to climatic conditions, with livestock numbers declining drastically during times of drought (Government of Namibia, 2002). Much of the land that is currently used for agriculture is already marginal and barely productive enough to support current agricultural practices (Reid *et al.*, 2007). The reduction in carrying capacity resulting from increasing temperatures and decreasing rainfall is likely to reduce revenues to land owners and could result in agriculture becoming non-viable in the more arid areas (Reid *et al.*, 2007).

The expansion of the Nama Karoo biome combined with the reduction in rangeland productivity predicted by Midgley *et al.* (2005) is likely to induce a shift from livestock production to natural resources production, especially the use of wildlife for tourism and trophy hunting. Indigenous wildlife species are adapted to the arid conditions in Namibia, and are generally better able to withstand periods of drought than are livestock species. However, indigenous biodiversity is not immune to the effects of climate change. Up to 40% of mammals in national parks in sub-Saharan Africa may be endangered by 2080 (Boko *et al.*, 2007), and Namibia's biodiversity is threatened by extensive range shifts for many mammals (Reid *et al.*, 2007) and loss of many plant species (Midgley *et al.*, 2005). Tourism relies on the integrity of natural ecosystems, and could therefore be sensitive to climate change if it impacts on biodiversity (Midgley *et al.*, 2005).

1.5 Objectives and methodology of this study

1.5.1 Objectives

The aim of this study is to investigate and quantify the probable economic impacts of climate change on commercial farming enterprises in Namibia, and to identify those regions or land uses that are likely to be the most vulnerable to the negative effects of climate change. The results of this study provide the following key outcomes:

1. Identify the key explanatory variables that determine revenue per hectare to commercial farms across Namibia, using a multiple regression model.
2. Estimate farming revenues for the years 2050 and 2080 by applying predictions of future climate to the regression model.
3. Identify those areas of Namibia where current commercial farming practices are likely to become economically non-viable under the predicted climatic changes.
4. Identify the farming activities that are particularly vulnerable to the effects of climate change.
5. Discuss potential adaptations that may allow land owners to avoid or mitigate the effects of climate change.

1.5.2 Methodology

The study uses a multiple linear regression model to identify the main determinants of revenue to commercial land owners across Namibia. Revenue per hectare of land was measured indirectly², by applying average market prices of livestock and wildlife (meat, animal products and live animals) to data on sales. Data on farm sales were collected by means of a questionnaire (included in Appendix 1, with the covering letter in Appendix 2) which was sent out to a large number of commercial farmers in Namibia, with the assistance of the Namibia Agricultural Union (NAU). Wildlife, livestock and trophy hunting prices were obtained from various sources³.

² The questionnaire focused on sales rather than asking directly for data on revenues because it was believed that most respondents would be unwilling to provide confidential financial information.

³ Livestock meat prices were taken from the Meat Board of Namibia (2008), and prices of livestock sold for stud breeding were provided by the Stud Services division of AGRA Cooperative in Namibia. Prices of game meat were provided by D. Van Schalkwyk, a researcher at Hartlief Corporation. Prices of live game sold at auction were obtained from the Game Auction division of AGRA Cooperative and from the African Wildlife Services (2009). Average trophy fees and average daily hunting rates were calculated based on prices quoted on the websites of several trophy hunting establishments. Data on occupancy rates were taken from the Namibia Tourism Board (2008).

Each respondent who returned the questionnaire was identified on a global information systems (GIS) map of all surveyed farms in Namibia, acquired from the Ministry of Agriculture, Water and Forestry. Climatic, geographic and vegetation variables were obtained for each farm, using GIS maps of each variable which were overlaid onto the map of farms.

A model was estimated that related the revenue per hectare of land to several climatic, geographic and land use variables that were expected to have an influence on farm revenue. Revenue per hectare was used instead of total revenue in order to control for differences in farm size. The explanatory variables that were included were the following⁴:

- Average annual rainfall
- Average temperature
- Inter-annual variability in rainfall
- Region
- Biome (Nama Karoo or Savanna)
- Carrying capacity
- Green vegetation biomass
- Distance to Windhoek
- Distance to the nearest main road
- Main land use

The farming land uses that are considered in this study can be divided into two main categories: livestock production, which includes farming of cattle, sheep or goats for meat, pelts or stud breeding; and wildlife production for meat, live sale, or trophy hunting tourism. Commercial crop farming is not considered as it is practiced on less than one percent of Namibia's commercial farmland (Mendelsohn 2006), and would complicate the analysis. Respondents that gain some proportion of their revenue from crop farming were, however, included in the analysis, and total revenue estimated based on data provided for other land uses. Every factor listed above was initially included in the model, but was removed if it was not found to have a significant effect on revenue. The final model included only the variables that were found to have a statistically significant influence over revenue.

⁴ Geographic and vegetation variables (region, biome, carrying capacity, green vegetation biomass, and distance variables) as well as inter-annual variability in rainfall were determined using GIS maps obtained from the Atlas of Namibia (Mendelsohn *et al.*, 2002). Climate variables were obtained from the WorldClim online database (WorldClim 2009), which uses climate surfaces generated by Hijmans *et al.* (2005). Land use was given in the questionnaire.

Data on predicted future climate conditions⁵ were applied to the regression model and future revenue per hectare in 2050 and 2080 were estimated. It was assumed that all non-climatic variables in the model remain unchanged between current and future time periods. The change in revenue between current and future time periods as a result of climate change was calculated for each farm, and the average change in revenue was calculated for 2050 and 2080.

⁵ Projections of future climate are most commonly generated using general circulation models, which can simulate changes in regional climate in response to given changes in concentrations of GHGs. Different models give different future climate projections due to the uncertainties in future GHG emissions as well as uncertainties in the sensitivity of physical processes and feedbacks to changes in the climate system (Ruosteenoja et al., 2003). Data on future climate variables were obtained from the WorldClim online database (WorldClim 2009). For this study, future climate projections for the years 2050 and 2080, generated by the Hadley Centre coupled model 3 (HADCM3, Gordon et al., 2000) under the IPCC A2 storyline (Nakicenovik and Swart, 2000) were used.

2. Results and Discussion

2.1 Description of the data

The questionnaire was completed and returned by 60 commercial land owners. Of these, two had to be excluded from the analysis due to insufficient information provided from which to compute revenues. Of the remaining 58 respondents, annual revenue ranged from N\$31/ha to N\$933/ha, with a mean of N\$219/ha and a median of N\$163/ha (Figure 2.1). Seven of Namibia's 13 regions were represented in the sample, incorporating all but one of the regions in which commercial farming occurs (Figure 2.2). A map of the farms included in the analysis is provided in Figure 2.3. Farm size varied from 2,300ha to 64,000ha, with a mean of 9,420ha. Ninety-five percent of respondents practice livestock farming for meat production, and for 72% this generates more than half their total revenue. Forty percent offer trophy hunting tourism, but only 10% generate more than half of their total revenue from this land use. Sixteen percent generate some proportion of their revenue from farming activities other than livestock or wildlife production – including charcoal, maize, vegetables, olives and hay production. Only three percent of respondents gain more than 50% of their total revenue from these sources. Fifteen percent of respondents have diverse sources of farming revenue, gaining less than 50% from each activity.

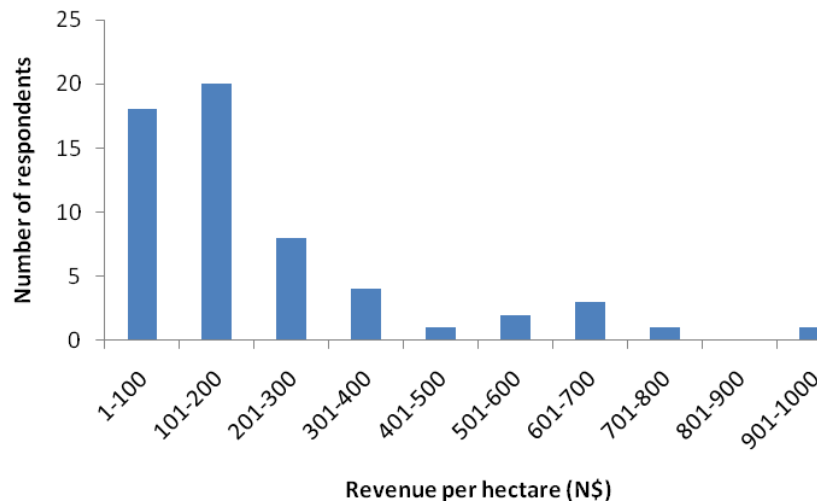


Figure 2.1: Frequency distribution of revenue per hectare.

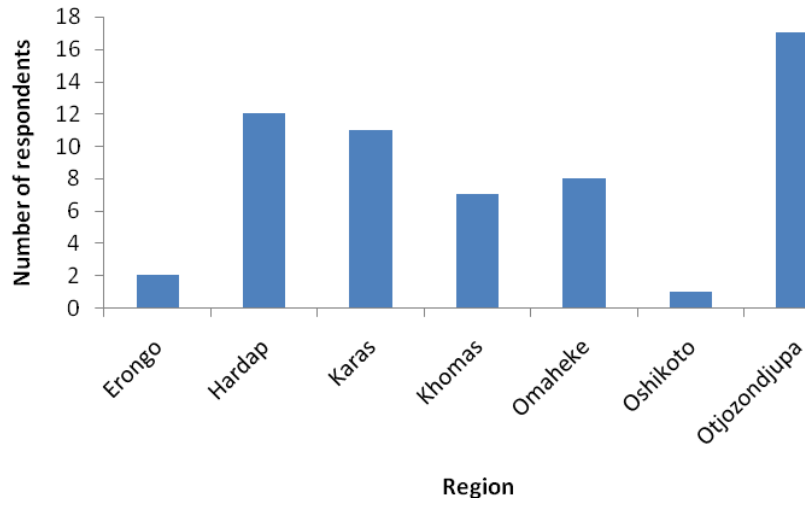


Figure 2.2: Regional distribution of respondents.

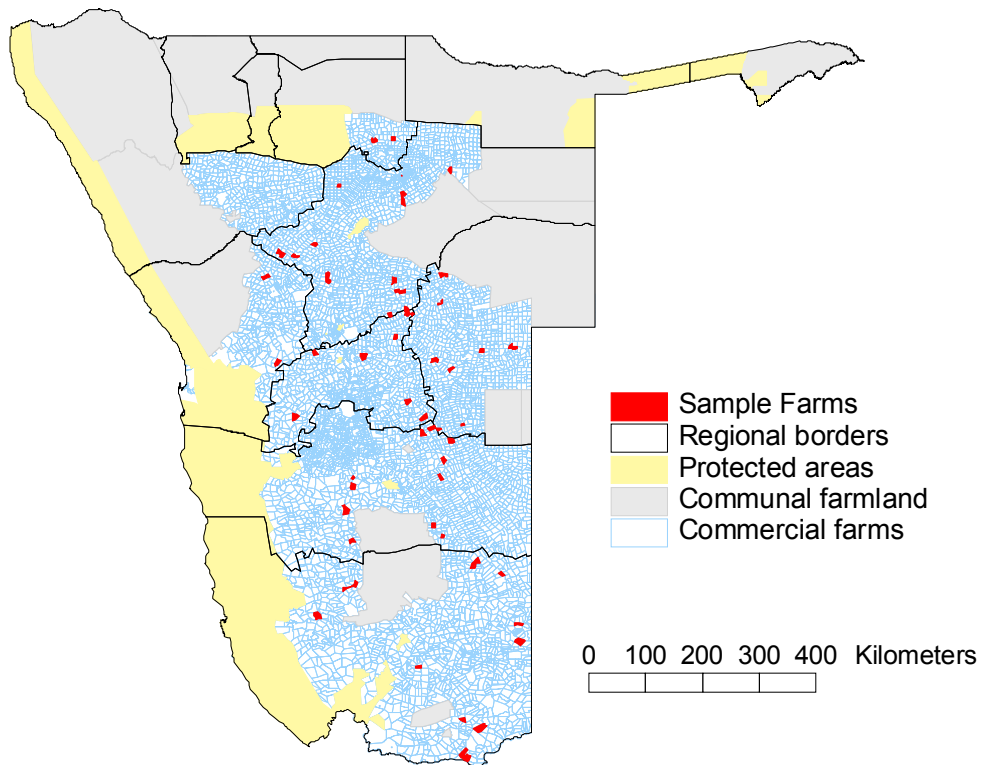


Figure 2.4: Sample of farms included in the analysis, as a subset of all the commercial farms in Namibia.

2.2 Results of the multiple regression model

The multiple regression model identified three factors as being the main determinants of revenue. These factors are rainfall, region and land use. Rainfall was found to have a strong positive effect on revenue, with a one percent decrease in mean annual rainfall resulting in a 1.36% decrease in revenue per hectare, other factors being equal.

The Khomas region was found to have the highest revenues, other factors being equal, with revenue per hectare in the southern Karas, Hardap and Erongo regions being 40% lower than that of the Khomas region, in the Omaheke region being 60% lower than that of the Khomas region, and in the northern regions of Oshikoto and Otjozondjupa being 63% lower than that of the Khomas region (Figure 2.4). This is largely attributable to the proximity of farms in the Khomas region to Windhoek, which provides the main local market for livestock and livestock products, and an important point of departure for exports. Moreover, Windhoek is the first destination for the majority of tourists to Namibia (Ministry of Environment and Tourism, 2004), and has the main international airport, so farms in the Khomas region that offer trophy hunting or wildlife-viewing tourism are strategically located to attract visitors as they enter or leave the country.

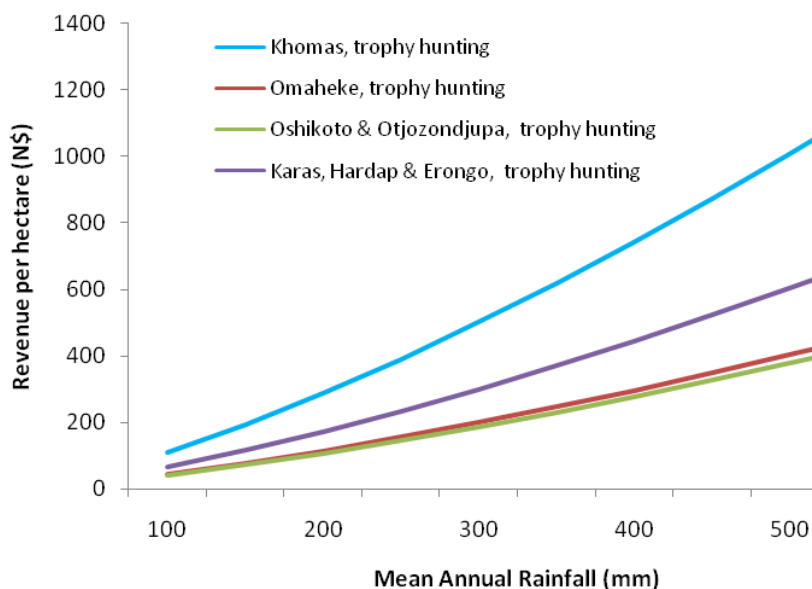


Figure 2.4: The effect of rainfall on revenue per hectare for different regions, under trophy hunting land use.

An activity was recorded as being the main land use if it generated 50% or more of total revenue. The main land uses reported by the sample of land owners in this study were livestock farming for meat

production and trophy hunting. Trophy hunting was found to generate higher revenue than livestock farming, other factors being equal, with revenue per hectare on farms with livestock for meat production as the main land use being 42% lower than that of farms with trophy hunting as the main land use. This corroborates the findings of several studies that have found higher economic returns to wildlife based production systems than to livestock farming for several parts of Namibia (MacGregor *et al.* (unpublished); Barnes and Humavindu, 2003; Figure 2.5).

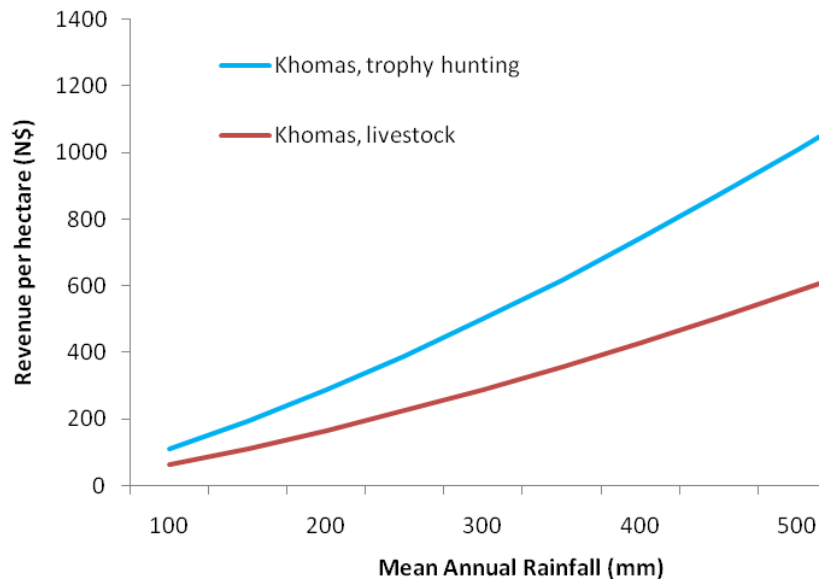


Figure 2.5: The effect of rainfall on revenue per hectare for livestock production and trophy hunting in the Khomas region.

Another way of looking at the above results is to note that the effect of rainfall on revenue is different for different regions and different land uses, such that an additional millimetre of rainfall is used more productively to generate revenue for a trophy hunting establishment in the Khomas region than for a livestock farming establishment in another region. This is not an unreasonable finding. The Government of Namibia (2004) emphasises the importance of using Namibia’s scarce water resources in the most efficient way possible. The value added to every cubic metre of water used in agricultural production is approximately N\$7, while the value added to the same volume of water used for tourism is about N\$574 (Government of Namibia, 2004). Thus, the productivity of rainfall is higher for trophy hunting than for livestock farming because each millimetre is used more efficiently in generating revenue.

The fact that trophy hunting was found to generate higher revenues per hectare than livestock production at all levels of rainfall suggests an economic inefficiency in land use, since the majority of farmers engage in livestock production. This implies that farmers could experience substantial gains in

revenue by diversifying their farming activities to include tourism. The potential for tourism depends on a number of factors such as scenic landscapes, abundance of wildlife, and geographic location, and is therefore not the same everywhere (Mendelsohn *et al.*, 2002, Barnes and Humavindu, 2003). Land owners in some locations would thus have more to gain by diversifying into tourism related land uses than would others. However, tourism is an expanding industry which still operates well below its full potential (WTTC, 2006), and is more sustainable than agriculture over the long term due to its efficient water use and low impact of the environment (Krugman, 2009), particularly when managed in large open systems.

The other factors that were considered (temperature, inter-annual variation in rainfall, distance from Windhoek, distance from the nearest main road, biome, green vegetation biomass, and carrying capacity) were dropped from the model as they were not found to be important determinants of revenue. This does not necessarily mean that these factors have no effect on revenue, but rather that they were not found to have a statistically significant effect when included along with the three most significant variables. In some cases, this is probably because many of the variables, such as variation in rainfall, biome and carrying capacity, are closely related to rainfall, while the variable distance to Windhoek is correlated with region.

2.3 Climate change effects

The projections of future rainfall generated by the model used in this study (see footnote 5) show significant declines in rainfall by 2050 and 2080 for Namibia compared to current conditions. This is illustrated in Figures 2.6, 2.7 and 2.8, which show current rainfall and predicted rainfall in 2050 and 2080 respectively. The sample of farms included in this study is also shown, in order to illustrate how they will be affected by these changes. For the farms under consideration, the model predicts decreases of up to 33% of current rainfall by 2050 and up to 48% by 2080, with the largest reductions occurring in the central region. Slight increases in rainfall are predicted for a farm in Luderitz district, in the south west coastal area. Most of the farms in the Karas, Hardap and Erongo regions currently fall into the rainfall range of 111 - 234mm/year, with some receiving up to 271mm/year. By 2080, most of these farms will receive less than 153mm/year. In the Khomas region, current rainfall ranges from 196 to 478mm/year. By 2080, this range shifts to 111 - 271mm/year. Most of the farms in the Omaheke region currently receive between 308 and 478mm/year, which is expected to fall to 154 - 307mm/year by 2080. Farms in the Otjizondjupa and Oshikoto regions currently receive between 390 and 569mm/year. This range will decline to between 235 and 433mm/year by 2080.

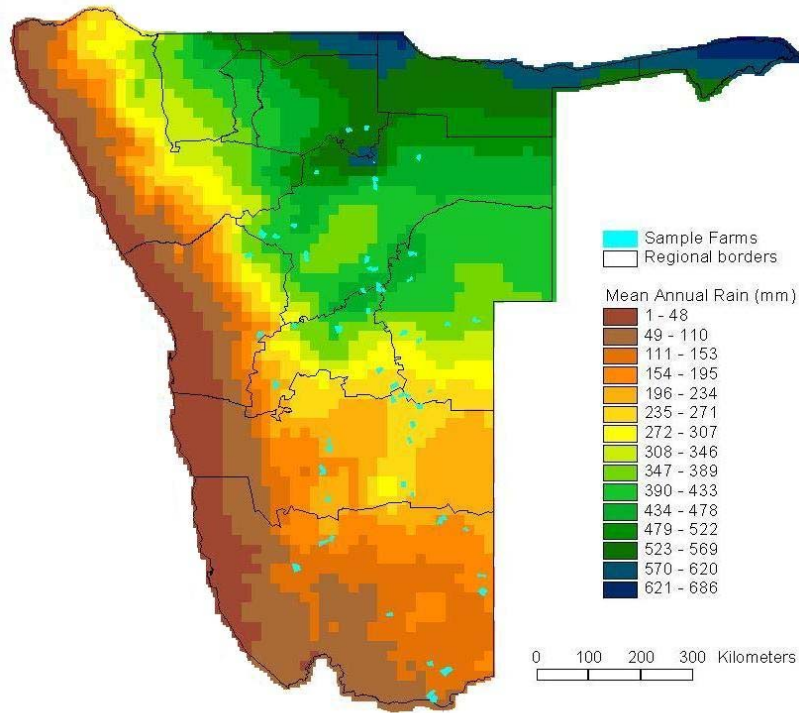


Figure 2.6: Current mean annual rainfall across Namibia.

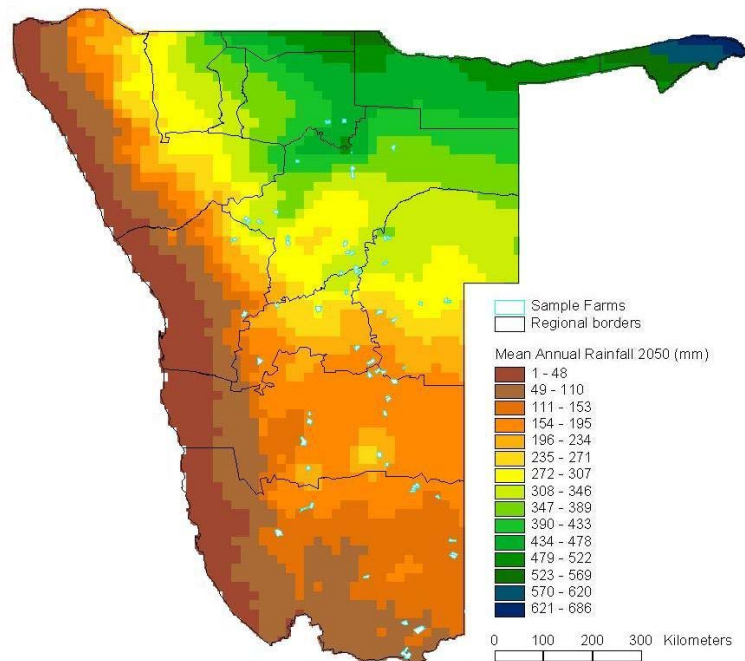


Figure 2.7: Mean annual rainfall across Namibia by 2050, according to predictions generated by the model adopted in this study.

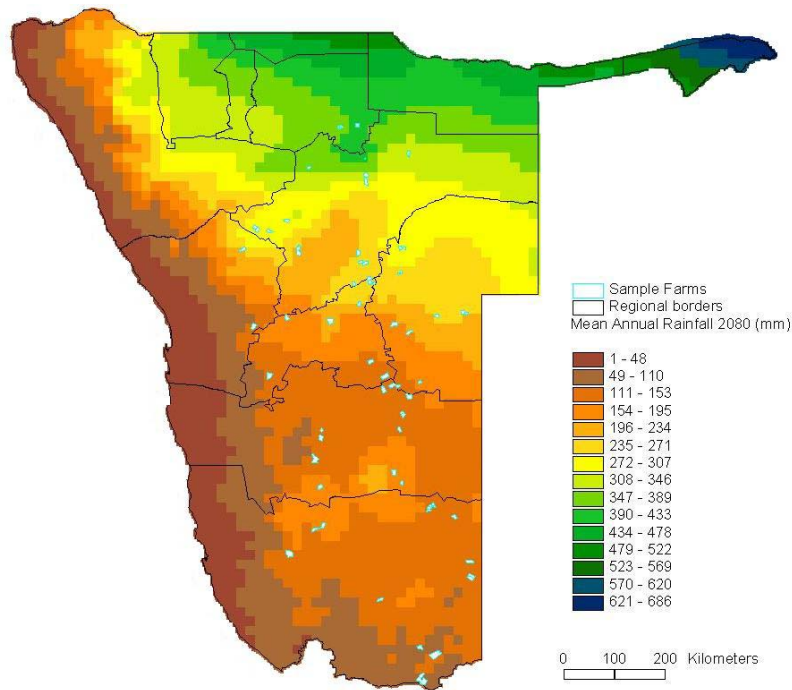


Figure 2.8: Mean annual rainfall across Namibia by 2080, according to predictions generated by the model adopted in this study.

The projections of future mean temperature generated by the model used in this study show significant increases in temperature by 2050 and 2080 for Namibia compared to current conditions. For the farms considered, the predicted increases in temperature range between 0.4 to 3.7°C by 2050 and between 0.8 to 5°C by 2080, with the greatest increases occurring in the east, and the smallest along the west coast.

2.4 Climate change effects on farm revenues

Since temperature was not found to have a significant effect on revenue per hectare, the calculated impacts of climate change on revenue per hectare consider only the projected changes in rainfall. However, it is important to note that the indirect effects of an increase in temperature, such as lower humidity, increased evaporation and lower soil moisture, are not taken into account in the model but are likely to have a compounding effect on water availability to farmers.

By applying the above climate change predictions to the model, substantial declines in revenue were forecasted for the majority of farms in this study. Revenue per hectare is projected to decrease by up to 42% of its current value by 2050, and up to 59% by 2080, with the largest reductions occurring in the

central region. The average predicted change in revenue across the sample of farms is a loss of 28% of current revenue by 2050 and a loss of 42% by 2080. A slight increase in revenue per hectare of 9% is predicted for one farm in the Luderitz district, which will see increasing rainfall. Revenue per hectare in the current and future time periods is illustrated in Figure 2.9.

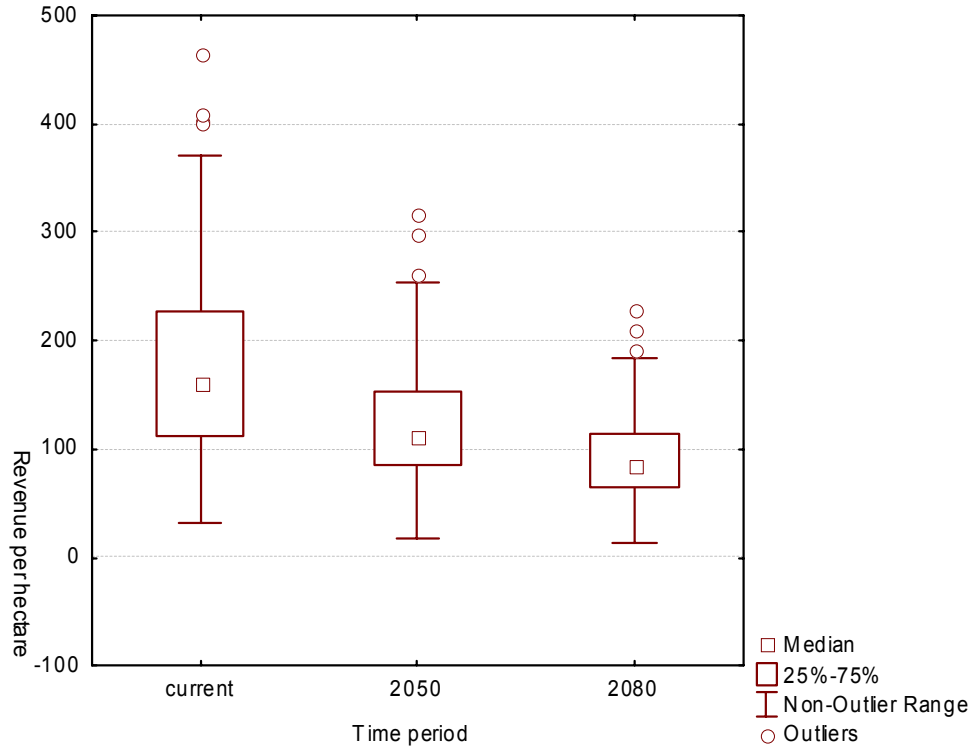


Figure 2.9: Revenue per hectare currently, and that predicted for 2050 and 2080 for the sample of farms.

The consequences of losses in revenue on this scale are alarming. The mean revenue for farms included in this study is N\$218/ha, and the mean area is 9,420ha. This amounts to an average loss of about N\$575,000 per farm by 2050 and about N\$860,000 per farm by 2080. Such large reductions in income will be devastating to farmers. If losses of this scale are experienced by all commercial land owners in Namibia, of which there are approximately 4,200 (Conroy and Kwala, 2006), the losses to the economy resulting from climate change effects on commercial farming would be in the region of several billion Namibian dollars per year by 2080. Of course, this study has made a number of simplifying assumptions, one of which is that land use remains constant over time, and is based on values for revenue per hectare that are computed using current prices, therefore failing to take into account changes in prices of agricultural output that will inevitably occur over time. In addition, it should be noted that the climate change predictions discussed here are those of a single general circulation model for one scenario of future development, and may differ from the results produced by other models and assuming a different development pathway.

2.5 Threshold effects

Another important factor to consider is whether the proportional effect of rainfall on agricultural productivity is really the same at all levels of rainfall. The results of this study suggest that a one percent reduction in rainfall would result in a 1.36% reduction in revenue per hectare, all other factors being equal. However, this does not take into account threshold effects that may occur if a farming system is currently operating at the lowest limit of rainfall at which production can be sustained. According to Mendelsohn (2006), cattle farming takes place in regions with a mean annual rainfall of between 150mm and 550mm, with only nomadic pastoralism being viable at the lower end of this rainfall range, and small-stock farming is practised in regions with mean rainfall of 100 to 250mm/year. The climate predictions generated by the model used in this study suggest that rainfall will decline to below 154mm/year in large parts of the Khomas and Omaheke regions by 2080, and to below 196mm/year in large parts of the Otjozondjupa region. Cattle farming, which is currently the dominant land use in these regions (Mendelsohn, 2006), will become non-viable under the projected rainfall conditions for large areas in these regions. Mean rainfall is predicted to decline to less than 111mm/year over much of the Karas and Hardap regions, and to less than 49mm/year in the far south and west. The loss of grass cover that will result from these decreases will render much of these regions unsuitable for small stock farming, which is currently the dominant agricultural activity (Mendelsohn, 2006).

The productivity of livestock farming systems in Namibia generally is strongly constrained by rainfall, with stocking rates increasing in years of good rainfall and decreasing in years of drought (Mendelsohn, 2006). As a result, revenue generated per hectare of land used for livestock farming depends directly on rainfall. This is probably not the case for trophy hunting and wildlife viewing tourism, where revenues depend on the number of tourists and not directly on the number of animals that the land can support. Wildlife are better adapted to arid conditions, and trophy hunting only removes a small percentage of the wildlife population (about one percent of the national wildlife stock; Brown, 2005). The revenue per hectare to wildlife production systems is therefore probably not directly constrained by rainfall. If this is the case, then a reduction in rainfall would be expected to have less effect on a trophy hunting enterprise than on a livestock production enterprise, other things being equal.

3. Conclusion

3.1 Key outcomes and recommendations

The above discussion highlights a number of important outcomes. Revenue per hectare was found to be lower for livestock production than for trophy hunting. The marginal productivity of rainfall in generating revenue is higher for trophy hunting than for livestock production. Livestock production is constrained by rainfall, and in many parts of Namibia, farming systems are currently operating under rainfall conditions that are at or near the threshold of viability. Any reduction in rainfall in these regions is likely to make current farming practices unsustainable. Climate change is likely to cause significant reductions in rainfall, leading to substantial losses in revenue to farms that remain productive. The central region of Namibia is particularly vulnerable to climate change, as the largest rainfall reductions are predicted for this region. Large areas of the Karas and Hardap regions are also very vulnerable, as rainfall is predicted to fall below the threshold at which small-stock farming can occur. In addition, the southern parts of the Omaheke and Otjozondjupa regions are at risk, as rainfall is predicted to fall below the threshold at which cattle farming is viable. Livestock farming is probably more vulnerable to the effects of climate change than trophy hunting, as its productivity is strongly constrained by rainfall.

Climate change will exacerbate water scarcity, and it is therefore imperative that land owners adapt to climate change by adopting farming practices that use water more efficiently. While efforts to use water more efficiently by farming with arid-adapted livestock species (such as Sanga cattle) may be effective as short-term adaptations, larger scale changes in land use will be required in order to adapt to the impacts of climate change over the long term. A key land use change is a switch to farming with indigenous species which are better adapted to arid conditions. The combined effect of considerable declines in rainfall predicted for most of Namibia and the lower productivity of rainfall in generating revenue under livestock production than trophy hunting suggests that farmers could benefit from diversifying their farming activities to include trophy hunting or wildlife viewing tourism. In areas that are currently marginal for livestock production, a switch to using wildlife production systems could be a key adaptation that allows farmers to avoid complete loss of production under climate change. Barnes and Humavindu (2003) note that livestock values will fall in the long term due to the increasing cost of producing the same unit of output, while the value of wildlife will increase.

The Government of Namibia (2004) highlights the need to “capitalize on Namibia’s comparative advantages and provide suitable incentives to use our natural resources in the most appropriate and efficient way possible”. Wildlife production systems provide a more efficient use of water, a scarce resource that is identified as being the key constraint to Namibia’s development, than does livestock farming. Moreover, tourism is on the increase in Namibia, and has the potential to generate significant revenues and create considerably more employment than does agriculture.

3.2 Areas for further research

This analysis has provided some insight into the effects of climate change on revenues to commercial land owners in Namibia. There is, however, much scope for further research on the topic. This study focused on commercial land used for agriculture, with only a small number of respondents gaining most of their revenue from trophy hunting and other tourism related land uses. It would be instructive to conduct a separate regression model for tourism establishments in order to identify the main determinants of revenue for tourism enterprises, and to see whether these differ from the factors affecting revenue to livestock production. This was not possible in this study due to the small number of respondents who practice trophy hunting.

In addition, a study that incorporates other land uses, such as crop production, would provide a broader understanding of how climate change will affect land owners across Namibia. Crop farming is amongst the most vulnerable land uses to climate change due to its dependence on rainfall. This study did not consider commercial farming on communal land, or subsistence farming, due to the challenges involved in trying to estimate revenue per hectare on land that is not individually owned and managed. However, it would be of particular interest to include communal and subsistence farming revenues in future studies, as subsistence farmers are generally poor, and likely to be highly vulnerable to the effects of climate change.

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Appendix 1: Questionnaire sent to commercial farms

QUESTIONNAIRE

**SURVEY OF COMMERCIAL FARMS IN NAMIBIA: POTENTIAL IMPACT OF CLIMATE CHANGE ON
PROFITABILITY**

All information will be treated in strict confidence

Please return the completed questionnaire to Louise Brown by e-mail (louisehelenbrown@gmail.com
or lhb502@york.ac.uk) or fax to the Namibia Nature Foundation at 061 248344 by no later than **17th**
August.

PART A: BASIC INFORMATION

Owner's details

Name:	
Address:	
e-mail address:	
Telephone:	

Farm/ Company details

Farm/ Company Name:	
Size of farm (ha or km ²):	
Region:	
District:	
Average long-term rainfall (mm)	

Farming activity:

Which of the following activities do you run on your farm (please answer with yes or no), and approximately what percentage of your farming income comes from each activity?

Activities	Yes / No	Percentage of income (%)
Cattle farming for meat production		
Cattle farming for stud		
Sheep/goat farming for meat production		
Karakul sheep farming		
Game farming for meat production		
Game farming for live sale		
Trophy hunting		
Other (please specify)		

PART B: SALES

Approximately how many of the following livestock do you sell per year, for meat or for stud?

Livestock		For meat	For stud
Cattle	Cows		
	Heifers		
	Steers/oxen		
	Weaners		
	Bulls		
Sheep	Lambs		
	Sheep		
Goats			
Other (please specify)			

Approximately how many of the following livestock products do you sell per year?

Karakul pelts:	
Other (please specify)	

Approximately how many of the following game species do you sell per year, for meat, as live animals and as trophies?

Game species	No. sold for meat	No. sold live	No. sold as trophies
Gemsbok			
Springbok			
Kudu			
Red Hartebeest			
Eland			
Zebra			
Ostrich			
Other (please specify)			

PART C: BUILDINGS, VEHICLES, STAFF, STOCK

Buildings

How many of the following do you have on your property?

Managers' Houses	
Staff houses	
Number of staff accommodated:	
Offices/Storerooms	
Sheds for housing livestock	
Other (please specify)	

Vehicles

Approximately how many of the following vehicles do you have on your property?

Trucks/tractors/heavy vehicles	
4x4s/light vehicles	
Quad bikes/ motorbikes	

Wildlife

Which of the following wildlife species occur on your property, and approximately how many do you have?

Wildlife species	Approximate numbers
Leopard	
Cheetah	
Hyena (brown/spotted)	
Giraffe	
Kudu	
Gemsbok	
Springbok	
Eland	
Wildebeest (blue / black)	
Red Hartebeest	
Zebra (Hartmann's/ Burchell's)	
Klipspringer	
Ostrich	
Other (please specify)	

Livestock

Approximately how many of the following animals do you have?

Livestock	Approximate number
Horses/donkeys/mules	
Cattle	
Sheep	
Goats	

How many boreholes do you have on your property that are functioning and in use? _____

Staff

Approximately how many staff do you employ full-time in the following categories?

Unskilled staff (farm labourers, cleaners, etc)	
Semi-skilled or skilled staff (mechanics, tractor drivers, etc)	
Managers	

NOTES (optional)

Please use this space to make any notes that you feel are relevant or necessary to better explain your responses, or if you have any further information you wish to convey to the researcher.

PART D: CLIMATE CHANGE EFFECTS (optional)

Do you feel that climate change could affect the profitability of your farming business in the future?

If yes, in what way?	
Have you noticed any changes already, and if so what are they?	
Do you have any plans or suggestions as to how climate change effects may be avoided or mitigated?	

PART E: FINANCIAL INFORMATION (optional)

If you are willing to provide a brief outline of your main costs and revenues, it would be of great value for this assessment. This as well as all other information will be treated with strict confidentiality. Please give an outline of your main costs and revenues, and indicate how important each is as a percentage of overall costs or revenues.

Costs

Item/category	Approximate % of total costs

Revenues

Item/category	Approximate % of total revenue

Thank you very much for your assistance.

Appendix 2: Covering letter to accompany questionnaire to commercial farms

Environment Department
University of York
Heslington, YO10 5DD
York, UK
E-mail: louisehelenbrown@gmail.com
Alternative e-mail: lhb502@york.ac.uk
Local Fax: 061 248344
28 July 2009

To: Owners/Managers of Commercial Farms in Namibia

Dear Sir/Madam,

Potential impacts of climate change on profitability of commercial farming in Namibia

I am a Namibian student, currently doing my Masters in Environmental Economics at the University of York, in the UK. I am doing my dissertation on a priority issue identified by the Namibia Nature Foundation as potentially having a significant impact on the country's productivity - the effects of climate change on the profitability of commercial farming activities in Namibia. As part of my research, I am sending out questionnaires to commercial land owners across Namibia to find out what types of farming activities they operate, what livestock and wildlife they have, the scale of their enterprise in terms of capital investment and staff employed, and whether they feel that climate change is a threat to the profitability of their business. My objective is to gather data from a survey of a large number of commercial farms from all over the country, and to combine this with data on climate, soil and vegetation type, in order to determine which farming activities are most profitable for various regions and which parts of the country are likely to be the most vulnerable to the negative effects of climate change (such as increasing temperature and decreasing rainfall). As a longer-term goal, I hope that my research will contribute to sustainable economic growth in Namibia by identifying the regions or districts that are likely to be badly affected by climate change, and coming up with some suggestions as to how commercial land-owners in these areas could protect themselves against the worst of these effects.

Attached is a questionnaire, which I have tried to design in such a way that it should be fairly simple to answer from memory, and should take up as little of your time as possible. Approximate numbers and figures are fine; I am not asking you to look up exact numbers. Parts A, B and C should be fairly straightforward, but if there are some questions that are not expressed in a convenient format, or to which you feel that your responses need further explanation, there is a section for notes at the end of Part D, in which you can add any comments or explanations that you wish. The main focus of this questionnaire is Parts A, B and C, so if you are short of time, you can just answer these three sections. In Part D (optional), I ask for your views on how climate change will affect your business. In part E (optional), I ask you to give an indication of your main costs and revenues, and how important each is as an approximate percentage of the total. Please note, I am not asking you to provide N\$ information, but rather the percentages, and any information you give will be treated with confidentiality. This section is entirely optional.

Please send the completed questionnaires to me, preferably by e-mail to either of the addresses above. Alternatively, you can fax them to the Namibia Nature Foundation (061 248344) in Namibia. I would appreciate it if you could send your response as soon as possible, and not later than **17th August 2009**. If you have any questions or uncertainties, please do not hesitate to contact me at either of the e-mail addresses above.

I will send a copy of the results of this work to each person that returns this questionnaire. I would like to thank you very much for completing and returning this questionnaire, your contribution to this assessment is hugely appreciated.

Best Regards,

Louise Helen Brown