International Institute for Environment and Development

Environmental Economics Programme

Discussion Paper 07-02

The economic impact of climate change in Namibia

How climate change will affect the contribution of Namibia's natural resources to its economy

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International Institute for Environment and Development (IIED)

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Executive sumary

Introduction

Climate change is likely to exacerbate the dry conditions already experienced in Southern Africa. And when rainfall does come, it is likely to be in bursts of greater intensity leading to erosion and flood damage. But these predictions gain little policy traction in Southern African countries. Research in Namibia suggests that over 20 years, annual loses to the Namibian economy could be up to 6 per cent of GDP due to the impact that climate change will have on its natural resources alone. This will affect the poor most, with resulting constraints on employment opportunities and declining wages, especially for unskilled labour. Namibia must take steps to ensure that all its policies and activities are 'climate proofed' and that it has a strategy to deal with displaced farmers and farmworkers. The need to mainstream climate change into policies and planning is clear, and it is the responsibility of industrialised nations, who have largely created the problem of climate change, to help Namibia and other vulnerable countries cope with climate change impacts and plan for a climate constrained future.

Vulnerability to climate change

It is becoming widely acknowledged that poor nations will suffer most from the effects of climate change. This vulnerability stems partly from their geographic location in areas such as drought-prone sub-Saharan Africa or flood-prone Bangladesh. Their capacity to cope with climate change is also lower than that of wealthier nations because of limited financial resources, skills and technologies and high levels of poverty. And they are heavily reliant on climate-sensitive sectors such as agriculture and fishing. Namibia is very dependent on natural resources: some estimate that up to 30 per cent of its GDP is reliant on the environment.[1]

Ironically, it is also these poor nations who have contributed least to the problem of climate change. Data covering 1950 to 2000 from the Climate Analysis Indicators Tool, developed by the Washington DC-based World Resources Institute, indicates that African countries contributed 4.6 per cent of cumulative global carbon emissions during that period.[2] Today their share of emissions is even lower, amounting to just 3.5 per cent of the total.[3] Namibia was in fact estimated to be a net sink for carbon dioxide in 1994 due to the large uptake of CO_2 by trees. Namibia contributed less than 0.05 per cent to global CO_2 equivalent emissions in 1994, even when this carbon sink is excluded from calculations.[4]

Increasingly, countries are recognising the need to assess the likely impact of climate change on their desired development pathways, and take steps to ensure all policies and activities are 'climate-proofed'. While climate change clearly must be mainstreamed into policies and planning, knowing how this will happen is less clear.

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[1] Lange, G-M. (2003) National Wealth, Natural Capital and Sustainable Development in Namibia. DEA research discussion paper 56 Ministry of Environment and Tourism. Windhoek, Namibia.
[2] World Resources Institute (2006). Climate Analysis Indicators Tool (CAIT) Version 3.0. WRI, Washington DC.
[3] MacGregor, J. (2006) Ecological Space and a Low-carbon Future: Crafting space for equitable economic development in Africa. Fresh Insights no. 8, DFID/IIED/NRI.
[4] Midgley, G. *et al*. (2005) *Assessment of Potential Climate Change Impacts on Namibia's Floristic Diversity, Ecosystem Structure and Function*. South African National Botanical Institute, Cape Town.

The forecast for Namibia

Temperatures in Namibia have been increasing at three times the global mean temperature increases reported for the 20th century. The temperature rise predicted for 2100 ranges from 2 to 6°C. Particularly in the central regions, lower rainfall is expected, while overall rainfall is projected to become even more variable than it is now. Even if rainfall changes little from today's levels, rises in temperature will boost evaporation rates, leading to severe water shortages. Poor rural pastoralist and dryland populations will be affected most. The frequency and intensity of extreme events such as droughts are likely to increase.

There may be less plant cover and productivity on grassland and savanna in response to relatively scant rainfall and more evaporation. Grassy savanna may also become less dominant as desertification occurs in some areas, and shrubs and trees benefit from higher levels of CO_2 in others. Impacts on the marine environment are uncertain, but scenarios range from dramatic ecosystem responses that reduce their overall productivity to more intense coastal upwelling - the wind-driven movement of cooler, nutrient-rich water to the ocean surface - which would increase productivity.

Quantifying the impacts

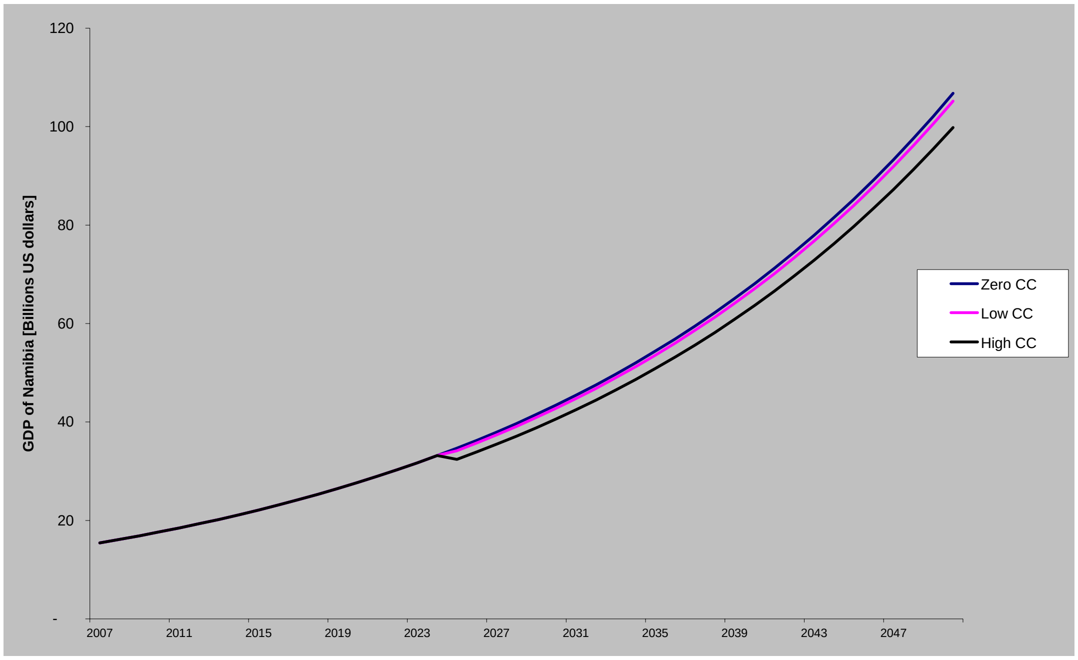
Namibia's advanced Natural Resource Accounts (NRA) helps to evaluate the contribution of the environment to national wealth by developing so-called 'satellite' accounts for natural assets such as fish, forests, wildlife, water and minerals. Data from the NRA can be fed into the conventional national economic accounts. This capability potentially allows for sound sustainable development planning that includes natural resources as well as man-made or owned assets - a clear advantage for policymakers in economies such as Namibia's, which is so dependent on natural resources.

In NRA, natural assets are valued in two ways. First, the values of the total natural resource stocks are measured. These are treated as capital assets in the stock or asset account. Second, their annual contribution to national income in terms of direct use values is measured in the production or flow account. Changes in the capital stock from year to year are also reflected in the national income.

Data from the NRA was fed into a computable general equilibrium (CGE) model, which uses actual economic data to determine how economies respond to policy or other changes. This revealed that under a best-case scenario, agricultural impacts would be partly offset by improved water distribution, there would be no impact on fisheries and the overall GDP would fall by only about 1 per cent. Under a worst-case scenario, large-scale shifts in climate zones would reduce agricultural and fishing outputs, and the overall GDP would fall by almost 6 per cent over 20 years. However, this estimate constitutes only a fraction of possible climate change impacts because it considers only two economic sectors - agriculture and fisheries - and ignores impacts such as those on health, infrastructure and energy that relate less to natural resources and that other country studies have shown to be significant.

Namibian natural resource experts have further worked to quantify, as much as possible, the economic impacts of climate change on Namibia's natural resource base. Estimates of how climate change will affect various sectors, and subsequent translation into economic impacts, can only be best guesses. Expert estimates suggest, however, that over 20 years, annual loses to the Namibian economy could be between 1 and 6 per cent of GDP - that is, between £35 million and £100 million - if no action is taken to adapt to climate change.

Projected Namibian GDP under three climate change impact scenarios, 2007-2050:



Who will be hit hardest?

Combining data from the NRA with Namibia's Social Accounting Matrix (SAM) provides the chance to see who will be hit hardest by the impacts of climate change on the environment. The SAM is a database that provides information on activities in different economic sectors and helps identify the poverty status of different groups. Evidence from low-income countries around the world suggests that the people likely to be most affected by climate change are the poorest and most vulnerable. And in Namibia, results show that climate change impacts will hit the poor hardest, with employment opportunities constrained and a substantial decline in wages, especially for unskilled labour.

Even under the best-case scenarios generated by the CGE model, subsistence farming will fall sharply. In the worst-case scenario for agriculture, labour intensive livestock farming is hit hard, and while high-value irrigated crop production could thrive, employment creation in this area would be minimal. Thus, even under the best-case scenario, a quarter of the population will need to find new livelihoods. Displaced rural populations are likely to move to cities, which could cause incomes for unskilled labour to fall by 12 to 24 per cent in order to absorb the new workers. Income distribution in Namibia is already one of the most uneven in the world and this inequality is likely to increase. What this will do to social cohesion, if no counteracting policies are put in place, can only be imagined.

1 Introduction

1.1 Background to this study

The fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC) makes it clear that even if the Kyoto Protocol is fully implemented, the impacts of climate change will start being felt within the next two decades. Indeed, some impacts are already being felt. The first countries likely to be affected most by climate change are the poor countries who will be struck by more climate change impacts and have less capacity to adapt to them. This is despite the fact that they have contributed little to the problem of global warming. The IPCC recognises Africa as a whole to be "one of the most vulnerable continents to climate variability and change because of multiple stresses and low adaptive capacity" (IPCC 2007). Besides this, many African countries are heavily dependent on climate sensitive sectors, such as rain-fed agriculture. Issues like food scarcity and inequitable land distribution make the African continent particularly vulnerable. In addition, development challenges like high population growth rates, high prevalence of diseases such as HIV/AIDS and malaria, growing poverty, inadequate technological development and insufficient institutional and legal frameworks to cope with environmental degradation all make it even harder for Africa to cope with additional challenges like climate change (Sokona *et al*. 2001).

Reducing the impacts of climate change on poor countries requires action now, both at the level of reducing greenhouse gas emissions and helping those countries that are particularly vulnerable to climate change to adapt to its impacts. This, however, requires domestic political will, and whilst ministerial rhetoric is often strong, translation into action is usually piecemeal. Predictions of temperature and precipitation changes for vulnerable regions seem to gain little policy traction when it comes to domestic development policies. This is not because of a shortage of scientific consensus on the realities of climate change. A more probable explanation for the lack of political action is the fact that the multilateral climate change process is complicated and slow, and relies on reaching consensus through negotiation. Policymakers also fear that serious action on climate change will be a domestic 'vote loser', and see climate change as a problem they hope can be avoided within their political lifetime.

One way to tackle these challenges and raise climate change concerns further up the agenda for policymakers is to try to put an economic value on the environmental impacts from climate change. This can both strengthen the argument for early action, and provide evidence to convince the electorates that the lifestyle changes required will actually be of long-term benefit to them and their children. The Stern Review on the Economics of Climate Change, led by the UK Government but global in scope, demonstrated both these arguments to great effect (Stern 2006). Even though some specific assumptions and estimates in the Stern Review have been subject to criticism from other climate economists (see for example Dasgupta 2006; Nordhaus 2006; Tol 2006; Sterner and Persson 2007 and Weitzman 2007), the mainstream economics of climate policy seem to support the fact that on a global level, the estimated costs of starting to reduce emissions today is lower than the expected damages that might otherwise occur[5] (Nordhaus and Yang 1996; Nordhaus and Boyer 1999; Tol 2002; Mendelsohn *et al*. 2000; Yohe *et al*. 2007 and Nordhaus 2006). The Stern Review, for

[5] Even if most serious economic assessment studies generally recommend a lower initial rate of emission reductions followed by a more gradual increase in the rate of reduction over time than the Stern Review does, the main policy recommendation - that it is time to act - remains.

example, suggests that "[t]he costs of stabilising the climate are significant but manageable; delay would be dangerous and much more costly" (Stern 2006).

Even though there is still uncertainty over the magnitude of costs and benefits of reducing emissions on a global scale, there is a general consensus among climate economists that poor countries will be most negatively affected by climate change. Figures that provide a clear message on what climate change impacts can be expected will also be powerful motivators for policymakers in developing countries to start considering climate change as a part of their national development policies; some investments in adaptation today might curtail future climate change costs.

This study is a first attempt to provide some economic indicators of how climate change will affect Namibia – one of the most vulnerable countries in sub-Saharan Africa. The study aims to assess the likely economic values of some of the most important environmental as well as socio-economic impacts of climate change in Namibia, and also to capture how some of the most important impacts might affect the overall structure of the economy. In this analysis we focus on climate change impacts on natural resources, leaving out other possible impacts like for example human health and sea level rise.

The National Resource Accounts (NRA) developed in Namibia provide information on the contribution of a number of natural resources to GDP and make Namibia particularly interesting for this kind of study. In Namibia, NRA methods have been widely used to develop satellite accounts for natural assets like livestock (Lange *et al*. 1998), fish (Lange and Motinga 1997; Lange 2005), forests (Barnes *et al.* 2005), wildlife (Barnes *et al*. 2004), water (Lange 1998), energy (Stage and Fleermuys 2001) and minerals (Lange and Motinga 1997; Lange 2003). However, due to poor information about likely climate change impacts on specific natural resources, the main focus of this study is the impacts on production in the agricultural sector (the agricultural livestock, crop and subsistence production sectors) together with the tourism and the fishing sectors, which are all important sectors in the Namibian economy. In general, there seem to be more consensus about what the economic impacts of climate change will be in the agricultural sectors than in other sectors of the economy. In vulnerable sectors, changes in productivity caused by climate change will directly affect the value these sectors add to national income and also the livelihoods of the people who depend on these sectors.

These direct effects on production and livelihoods, however, might have indirect effects on other economic sectors, with changes in prices on inputs and outputs within the directly affected sectors following the changes in production. In economic terms, these additional impacts on the economy are referred to as *general equilibrium effects*. In order to give some idea of the likely magnitude of the general equilibrium effects of production changes in the agricultural and fishing sectors, a Computable General Equilibrium (CGE) model is used. The primary data input for the CGE model is a Social Accounting Matrix (SAM) for Namibia from 2002 (Lange *et al*. 2004). The SAM is a database that provides information on the economic activity in different sectors and can be used to examine policy impacts on income distribution between different socio-economic groups. Using the SAM makes it possible to say something about not only the likely environmental impacts, but also the likely distributional impacts throughout the sectors of the economy from climate change.

1.2 Outline and methodology of this study

The first step in this preliminary analysis is to collect existing information about likely climate change impacts on Namibian ecosystems. This is partly done through a literature review of earlier research conducted in the area. Information is sparse for Namibia, so information on impacts on Southern African ecosystems is also sometimes considered.

Namibian natural resource experts added depth and experience to this review, primarily at a roundtable discussion held in Windhoek in February 2007. The theme of this roundtable discussion was “climate change, natural resources and economic growth in Namibia” and a list of the participants of the meeting can be found in Appendix 1. Presentations were prepared by Namibian experts on three key topics: climate change predictions (Midgley 2007); wildlife (Brown 2007); and water (Zeidler et al. 2007). The meeting aimed to quantify, as much as possible, the economic impacts of climate change on Namibia’s natural resource base. Information provided from the meeting is included for discussion throughout our analysis. It should be emphasised that because it is impossible to say with certainty what climate change impacts will be, let alone how they will impact Namibian natural resources and the economy, estimates of how climate change will affect various sectors, and subsequent translation into economic impacts can only be best guesses. However, the experts attending this meeting were, in many cases, best placed to make these guesses in the Namibian context.

The next step of analysis is to identify the economic values accruing to society from the affected natural resources, and to try to quantify predicted changes in these natural resources under climate change. This is done by gathering existing information on NRA and other available data on evaluation of natural resources. The sectors analysed (by means of both use values and non use values) are agriculture, fishing, forests, tourism. The preliminary impact values in this study provide information on the potential magnitude of damages in the absence of any adaptation measures. For example, although increased aridity may reduce livestock stocking rates, it might facilitate a shift towards indigenous biodiversity production systems that could ultimately be more productive. In other words, the impact values described here can be seen as worst-case estimates if climate change is not considered in national development policies. If adaptation measures are taken, these impacts could be reduced. Although adaptation measures could also be costly, these preliminary ‘business as usual’ damage costs suggest where priority actions could be worth taking.

Scenarios described here also exclude possible impacts from what is known as ‘response measures’ in climate change negotiations. For example, a reduction in international flights due to airline taxes could affect the Namibian economy, which relies heavily on tourism. There are already fears in South Africa that moves by European supermarkets to sell ‘low carbon footprint’ food products will reduce South African exports of foods like apples. Alternatively, the bush encroachment expected as a result of CO_2 fertilisation could provide Namibia with a source of revenue from the sale of carbon sequestration if monetised. Such issues have not been considered in this study as they are too hard to predict.

The last step of our analysis contains an example of the likely general equilibrium effects of a production change within the agricultural and fishing sectors. The agricultural sector is the sector where there seem to be most consensus about what the likely climate change impacts will be. In the fishing sector there is more uncertainty, but as this sector contributes significantly to Namibia’s GDP, a few different possible scenarios are analysed in order to get an idea of likely general equilibrium effects. Economies that are highly dependent on their natural resource base will demonstrate the highest economy-wide effects if production changes in their natural resource sectors. A CGE model of the Namibian economy is used in order to capture these potential economy-wide effects. The sectoral structure of the model also facilitates an analysis of the distributional aspects of likely climate change impacts on agricultural production.

2 The economics of climate change

The global nature of climate change makes an economic analysis more complex than for any other local or regional environmental pollution problem. In addition, the fact that the impacts of climate change will not necessarily be felt immediately, but rather some time in the future, complicates the analysis. Economic analysis of a problem with such a long time horizon will be highly dependent on what assumptions are made about the preferences of future generations. This study is neither global nor dynamic in scope, which means that we avoid some of the problems with an economic analysis. Our aim is to quantify, on a national level, the likely climate change impacts on a natural resource based economy like Namibia.

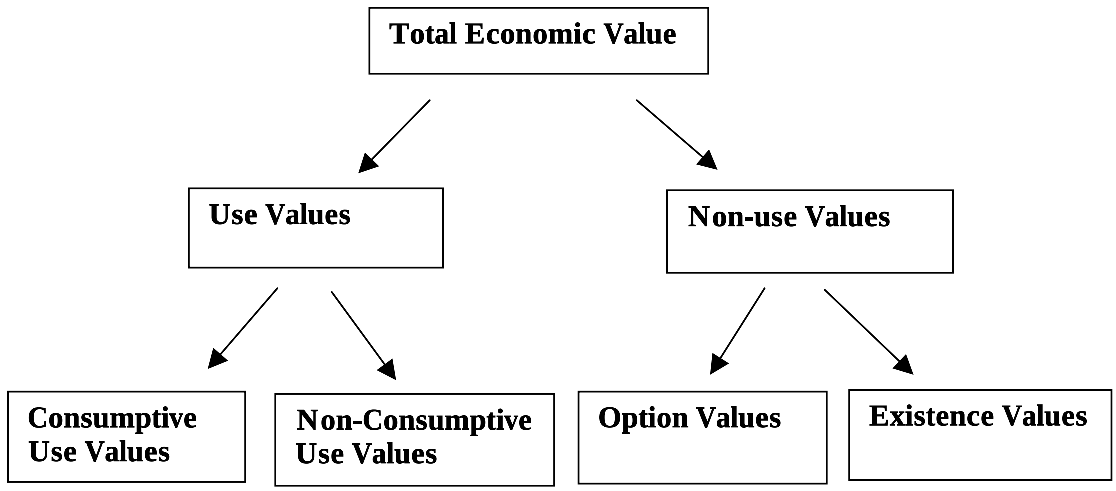
2.1 Economic values of natural resources and ecosystems

Even if our analysis is not global or dynamic in scope, it does not mean that no difficulties remain. A careful economic analysis of climate change requires that all kinds of economic values associated with affected environmental systems are addressed. Natural systems provide goods and services that have value for society. In addition, certain attributes of an ecosystem, for example biodiversity, can be valuable because local people and/or people living further away value the fact that certain species exist. Values associated with the functioning of ecosystems can be divided into *use values* as well as *non-use values*, where the first type concerns the direct use of a natural resource and the second type refers to the *option value* for future use or even the *existence value* of just knowing that a resource exists. Use values can be further divided into *consumptive* and *non-consumptive* values. Consumptive use values could, for example, be the value of harvesting a resource such as timber, fish or trophy hunting tourism activities, or the value of production from agricultural land use. Non-consumptive use values are obtained without directly affecting the natural resource. They include recreation and wildlife viewing tourism activities. These values are summarised in figure 1 below.

Within both the use and non-use categories, some values are hard to capture because markets for these ecosystem attributes do not exist. An example of a non-marketed use value could be the collection of firewood from forests. This activity can be very important for the livelihoods of rural households, but such values are typically not included in traditional national accounts. Non-use values are almost always non-marketed values, like for example the value people place on the conservation of an endangered species.

To assess the total value of a natural resource or an ecosystem, all the values described above should be recognised. This is not an easy task, and as a result, most current economic studies considering climate change impacts are partial studies that concentrate on a specific area, such as agricultural impacts, and focus on the impacts that are reflected in the national accounts (impacts for which market values exist).

Figure 1. Economic values of natural resources



2.2 The economics of climate change impacts: poverty implications

The economic literature on climate change impacts has not always agreed upon the likely welfare impacts of climate change, even when it includes non-market values. However, most of these studies have been concerned only with agricultural impacts in industrialised countries, especially in the USA and Canada (for example, Weber and Hauer 2003; Deschenes and Greenstone 2007; Mendelsohn and Reinsborough 2007). In global studies, there is general agreement that poor countries, particularly those in Africa (Reid 2005; Simms and Reid 2005) will suffer the most from climate change impacts. Economic impact assessment studies at a global level generally conclude that the global benefits of acting today outweigh the global future costs of uncontrolled emissions, particularly because of the high damage estimates for the poor parts of the world (Nordhaus 1994; Nordhaus and Yang 1999; Tol 2002; Mendelsohn *et al*. 2000; Nordhaus 2006 and Stern 2006). Developing countries are often more directly dependent on their natural resource base, implying that climate sensitive sectors in these countries make significant contributions to national GDPs. Winters *et al*. (1998) focus on the economic and welfare impacts of climate change due to changes in agricultural production in different parts of the developing world. The study suggests that Africa in particular, due to low substitution possibilities between imported and domestic foods, will most likely experience significant income losses and a drop in consumption of the low-income households as a result of climate change. Mendelsohn *et al.* (2006) examine the distributional impact of climate change on rich and poor countries and predict that poor countries will be most vulnerable due to their location. Although these studies are insightful, they do not necessarily predict what will happen to particular poor communities within a country. But there are many reasons to believe that poor people in a country will bear much of the burden; they have less access to capital, making it harder for them to adapt to climate change or purchase their way out of reductions in crop productivity by buying food. Many poor people also live in vulnerable locations, such as floodplains and coastal areas, and they often lack access to the social safety nets, which protect wealthier individuals in times of need.

3 Economic impact analysis in Namibia

Namibia is highly dependent on its natural resource base. It has many pressing development challenges and already struggles to provide for its population with current levels of environmental degradation. More environmental impacts could further impede development. Although there is currently no specific policy that addresses climate change in Namibia, there are a wide range of policies and programmes concerning natural resource management and sustainable environmental development under current climatic conditions. Much work has been done on developing natural resource accounts (NRA) for resources like livestock, fish, forests, wildlife, water, energy and minerals, as an extension to the traditional national accounts. In traditional national accounting systems the economic impacts from natural resources that are included are usually not explicitly tied to their natural resource inputs. Consequently, the manner in which the impacts are included does not help policymakers to make fully informed decisions. For example, in traditional national accounts, although private owned fish resources usually are correctly accounted for, the production value of harvesting fish in the wild is included only as a positive figure while the decline in the stock of wild fish is not accounted for. The extension of the traditional national accounting system to include natural resource accounts (which includes stocks and flows for the natural resources) has been useful for policymaking in Namibia. It also makes Namibia a good country in which to investigate the likely economic impacts of climate change; the existing NRA should make it easier to assess economic values (including some of the non-marketed values mentioned above) of some of the changes in natural resource stocks that might follow from climate change.

This study is a first attempt to identify the economic impacts of climate change in Namibia. It should only be considered as a first step in this regard, but it is hoped that the ideas and work presented here will encourage further studies along these lines. The results of this and similar work could guide decisions about priority adaptation measures required to reduce the future costs of climate change, and precipitate political action in this regard.

3.1 Namibia's vulnerability to climate change

Namibia is one of the driest countries in sub-Saharan Africa, and is highly dependent on climate sensitive sectors. Primary sectors, consisting of natural resource based production like agriculture, fisheries and mining account for about 30 per cent of the total GDP (Lange 2003). Income distribution in Namibia is unusually inequitable (with an estimated Gini coefficient of 0.71 (UNDP, 2006), Namibia may have the most inequitable income distribution in the world) and over half of the population depends on subsistence agriculture. Namibia is therefore potentially one of the most vulnerable countries to climate change.

Although there is currently no specific climate change policy in Namibia, the need to consider climate change impacts as a part of the national development policy framework has been recognised. As a Party to the United Nations Framework Convention on Climate Change, Namibia is obliged to prepare and present an Initial National Communication on the status of climate change as well as corrective actions to reduce predicted effects within the country. As part of this work, a climate change country study was produced in 1998 (Tarr 1998; Du Plessis 1998; Blackie 1998). In the Initial National Communication, seven vulnerable sectors were identified: water resources, marine resources, agriculture, biodiversity ecosystems (tourism), coastal zones, health and energy (Government of Namibia 2002). This report concludes that "[a]s an arid, agriculturally marginal country with a low economic growth flexibility, and a high dependence on natural resource based industries, including subsistence agriculture and tourism, Namibia currently has limited capacity to adapt to climate change impacts. Namibia is therefore considered to be among the highly vulnerable African countries with regard to climate change."

3.2 Climate change predictions for Southern Africa and Namibia in particular

3.2.1 Temperature changes

Long-term temperature records from weather stations in Namibia and the northern Cape show a mean decadal temperature increase of 0.2ºC. This is roughly three times the global mean temperature increase reported for the 20th century (Midgley *et al*. 2005). When it comes to predictions, the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2001) states that climate change scenarios indicate a future warming of 0.2 to 0.5 °C per decade across Africa. This warming is greatest over the interior of semi-arid margins of the Sahara and central Southern Africa. A more recent Global Circulation Model suggests that by the 2070-2099 period, maximum warming in Southern Africa is expected to be up to 7°C (Ruosteenoja *et al*. 2003). However, Hudson and Jones (2002) show that regional climate models for Southern Africa give slightly different results due to their improved ability to predict climate variability. They predict a 3.7°C increase in summer mean surface air temperature and a 4°C increase in winter by the 2080s. In Namibia itself, predictions for temperature increases by 2100 range from 2 to 6°C (Government of Namibia 2002). Temperature increases are lower in the coastal regions than the inland regions (Midgley *et al*. 2005; Government of Namibia 2002).

3.2.2 Changes in precipitation

Precipitation projections are generally less consistent, but most simulations in Southern Africa indicate reduced precipitation in the next 100 years and most models project that by 2050 the interior of Southern Africa will experience significant decreases during the growing season (IPCC 2001). The Southern African monsoon is projected to weaken during the 2000-2049 period, precipitation is expected to decrease, and by the 2080s, a drying over much of the western subtropical region (which includes northern Namibia) due to fewer rainy days and less intense rainfall is predicted (Hudson and Jones 2002; Hulme *et al*. 2001; IPCC 2001; Ruosteenoja *et al*. 2003). Kigotho (2005) adds that climate change induced warming of the Indian Ocean is likely to lead to persistent droughts in Southern Africa in the coming years, and the monsoon winds that bring seasonal rain to sub-Saharan African could be 10-20 per cent drier than 1950-2000 averages.

Within Namibia, rainfall reductions are expected to be greatest in the northwest and central regions. Particularly strong reductions are expected in the central areas around Windhoek and surrounding highlands (Midgley *et al*. 2005). Projections range from small increases of less than 30mm per year to severe decreases of 200mm per year compared to current averages (Government of Namibia 2002). Both rainfall and temperature in Namibia are sensitive to the El Niño-Southern Oscillation (ENSO) effect, and rainfall is below average during El Niño conditions. Rainfall in the future is projected to become even more variable than at present (Government of Namibia 2002).

3.2.3 Changes in evaporation

In Africa, water supplies from rivers, lakes and rainfall are already threatened by unsustainable use, and climate change could impose additional pressures on water availability. Global warming is predicted to reduce soil moisture in sub-humid zones and reduce runoff. De Wit and Stankiewicz (2006) calculate that decreases in perennial drainage will significantly affect present surface water access across 25 per cent of Africa by the end of this century. Arnell (1999) shows that the greatest reduction in runoff by the year 2050 will be in Southern Africa. He further suggests that the percentage of years with runoff below the current drought runoff is likely to increase by about 30 per cent across much of Southern Africa by the 2050s (Arnell 2004).

In Namibia, even if rainfall changes little from present levels, the water balance is expected to become drier because of an increase in evaporation rates due to temperature increases. An increase in evaporation of about 5 per cent is expected per degree of warming (Government of Namibia 2002). With rainfall decreases as well, however, Namibia is likely to face severe water shortages. The country's poor rural population, particularly pastoralists and drylands populations, will be affected most.

3.2.4 Extreme events

The frequency and intensity of extreme events, such as floods and droughts, has increased in Africa over the past few years. This has caused major disruptions to the economies of many African countries, thus exacerbating continental vulnerability (Washington *et al*. 2004; AMCEN/UNEP 2002). For example, the 2003/4 drought cost the Namibian Government N$275 million in provision of emergency relief. Extreme events are predicted to increase in many desert regions in Southern Africa (Scholes and Biggs 2004). In Namibia, there is also some evidence to suggest that coastal fisheries may be more impacted by extreme events than more gradual climatic changes (Neville Sweijd, personal communication 2007).

3.3 Climate change impacts on Namibian ecosystems

Despite its aridity, Namibia is home to remarkable biodiversity. More than 4,500 plant species have been recorded, almost 700 of which are endemic and a further 275 of which are Namib Desert endemics shared with southern Angola (Maggs *et al*. 1998). The four main Namibian biomes are ephemeral therophyte-dominated desert, succulent shrub-dominated succulent karoo, grass and shrub-dominated nama karoo, and tree and grass-dominated savanna (Midgley *et al*. 2005). Savannas occupy up to 84 per cent of Namibia (Government of Namibia 2002). Because Namibia-specific information is sparse, some information on climate change impacts on Southern African ecosystems more generally is also presented.

3.3.1 Succulent karoo

The succulent karoo biome would be threatened by a shift in rainfall seasonality (Desanker 2003), and by 2085, McClean *et al*. (2005) predict that it will have lost much of its climatic suitability for many species. The Government of Namibia (2002) states that the succulent karoo biome "is regarded as under high risk of ecosystem boundary shifts and local extinctions under climate change scenarios. It is a diverse and unique biome occurring in an area of winter rainfall, and hence is vulnerable to changes in the seasonality of rainfall projected by some of the climate change models."

3.3.2 Grassland and savanna

Some African savanna tree species seem sensitive to seasonal air temperatures (Chidumayo 2001). However, most models look at whole ecosystem responses and little work has been done on the responses of individual plant species to climate change.

Although the distributions and productivity of savanna species in Namibia might change, they may be less affected by climate change as they have wider distributions than species characterising other biomes (Government of Namibia 2002). However, drought is known to significantly affect savanna and grassland ecosystems. Woodward and Lomas (2004) predict reductions in plant cover and productivity in the Southern African savanna in response to drying trends. Desanker *et al*. (1997) add that increases in drying of the savanna biome in the next century will be compounded by other pressures such as conversion to agriculture. Climate change is also likely to alter the frequency, intensity, seasonality and extent of vegetation fires needed to maintain some Southern African grasslands and miombo woodlands (IPCC 2001).

Dixon *et al*. (2003) suggest that South African savanna and nama-karoo biomes will advance at the expense of the grasslands. Midgley *et al*. (2005) also suggest that Namibia's dominant vegetation type, grassy savanna, will lose its dominance to desert and arid shrubland vegetation types. They predict that vegetation cover will be reduced along with net primary productivity throughout much of Namibia by 2050. In models where savanna converts to grassland, four out of five savanna systems showed a 10 per cent rainfall reduction, suggesting the presence of positive feedback from climate change (Hoffmann and Jackson 2000).

Other models show that the tree-grass balance in savannas may shift towards trees due to rising atmospheric CO_2 concentrations, and the resulting reduced ability of grasses to suppress rapidly growing tree saplings in grass fires (Bond and Midgley 2000; Bond *et al*. 2003; Midgley *et al*. 1999). This kind of ecosystem switch would have major implications for grazing and browsing animals and their predators. Midgley *et al*. (2005) predict that elevated CO_2 levels will further reduce the dominance of grassy savanna by 2080. Resultant bush encroachment could be particularly problematic in north-eastern Namibia. However, they point out that there is considerable uncertainty relating to the impact of CO_2 fertilisation (Midgley *et al*. 2005).

Climate change is predicted to reduce population success amongst African arid savanna raptor species (Wichmann *et al*. 2003). Similarly, Erasmus *et al*. (2002) predict 4-98 per cent reductions in species ranges for almost 80 per cent of the 179 modelled species in South Africa, including many savanna species. Climate change could alter the range of many African antelope species (Hulme 1996). Population declines of three ungulate species in Kruger National Park, South Africa, suggest that reduced summer rainfall, possibly related to regional warming, is likely to result in their local extinction if warming continues, especially as boundary fencing inhibits their migration (Ogutu and Owen-Smith 2003). In the Lengwe and Nyika National Parks in Malawi, climate change could induce a decline of nyala *(Tragelaphus*) and zebra *(Equiferus*), which could not adapt to climate induced habitat changes (Dixon *et al*. 2003). In Namibia, increased aridification associated with climate change is likely to cause three mammalian extinctions at a national level, range declines from ten species (such as lechwe and giraffe) and range increases for two arid adapted species: the gemsbok and springbok (Brown 2007).

Large herds of migratory ungulates are common in Southern Africa. Major migratory systems occur in the Serengeti in Tanzania, and in the Masai-Mara in Kenya. Reduced migratory systems persist in the Kalahari in Botswana, South Africa and Namibia, and in Etosha in Namibia. Migrations are typically regular events with mammals moving between dry and wet season grazing areas. There is currently no indication that the broad pattern of seasonality is likely to change in the Serengeti or the Kalahari, although climate change could alter rainfall amounts and the intensity of seasonality by about 15 per cent in either direction (Hulme 1996). This is well within the range of existing variability, so existing migratory systems seem likely to persist if land-use pressures permit them to.

3.3.3 Deserts

The combination of spatial and temporal changes in patterns of temperature, rainfall, solar radiation and wind along with increased land use pressure in Southern Africa may lead to expansion of desert areas due to increased desertification (Millennium Ecosystem Assessment 2005). This is a critical threat to sustainable resource management in arid, semi-arid and dry sub-humid regions of Africa. Desertification will cause conversion of perennial grasslands to savannas dominated by annual grasses. Such changes have already occurred in the Kalahari Gemsbok National Park in South Africa, where Landsat imagery shows increases in exposed soil surface (Palmer and van Rooyen, 1998). Thomas *et al*. (2005) expect that drying, increased wind speeds and temperature increases due to climate change will reduce vegetation cover and cause the reactivation (where sand becomes significantly exposed and moves) of Southern African desert dune systems as early as 2039. Even under a medium emissions scenario, significant dune dynamism is predicted for parts of the northern dunefields (which include those in Namibia), which are currently heavily vegetated (Thomas *et al*. 2005). Midgley *et al*. (2005) also predict the expansion of desert and arid land vegetation at the expense of grassland and savanna in Namibia.

Arid and semi-arid systems are very sensitive to precipitation changes because of the important role that soil moisture plays in determining ecosystem processes and plant diversity (Leemans and Kleidon 2002; Nicholson 2002; Schwinning and Sala 2004). Warming is likely to favour more mobile species and eliminate more rare, isolated or sedentary species (Dukes and Mooney 1999; Hardy 2003). More summer droughts could also favour shrub species with deep roots (Schwinning and Sala 2004).

However, there are uncertainties surrounding the effects of greater CO_2 concentrations on arid ecosystems. Desert regions may be more sensitive to CO_2-induced climate change than models predict (Lioubimtseva and Adams 2004), and desert shrubs in Southern Africa may benefit from higher CO_2 concentrations (Bond and Archibald 2003). Midgley *et al*. (2005) believe that desertification in Namibia will proceed, but at a slower pace than some models predict due to the effects of CO_2 fertilisation.

Deserts and semi-arid areas are sometimes classified as ‘pulse-reserve’ systems in which a ‘pulse’ - such as an extremely wet period - triggers fast active growth of dormant seeds, plants and animals (Ogle and Reynolds 2004; Schwinning and Sala 2004). Climate change could well enhance these episodic patterns due to greater variation in climate extremes and more extreme climate events (Smith *et al*. 2000; Scholes and Biggs 2004). The episodic nature of arid and semi-arid systems means that they are more prone to desertification (Holmgren *et al*. 2001; Leemans and Kleidon 2002; Nicholson 2002). Evidence from the Kalahari suggests that desertification occurs faster during periods of extreme events, for instance in drought years when demand for ecosystem goods and services exceeds supply (Dube and Pickup 2001).

3.3.4 Marine environment

The upwelling of the cold, nutrient-rich Benguela current drives the highly productive marine ecosystem off the west coast of Namibia. This upwelling is caused by the interaction of southeasterly winds with the north-flowing current and the topography of the seabed. When upwelling is suppressed by northerly or easterly winds, oxygen-poor water can accumulate near the seabed and suffocate marine life. Such events may be connected to climate change related phenomena such as ENSO. Future changes in the distribution and intensity of winds could therefore affect the fisheries sector (Government of Namibia 2002). It is also possible that observed reductions in pilchard stocks since 1993 could be partially explained by warmer seas (Ministry of Fisheries and Marine Resources 2002).

It is impossible to say with certainty what impacts climate change has on Namibian fisheries at this stage. This is because no studies have looked directly at climate change impacts, and the effects of fishing are likely to be far more important than shifting environmental conditions. Links between environmental variability and fisheries dynamics are also poorly understood and large environmental anomalies or extreme events, such as the 'Benguela Niño', have negative impacts which far outweigh other incremental changes in the system. Despite this, it is clear that changes have occurred and it is uncertain whether they can be attributed entirely to fishing impacts (Neville Sweijd, personal communication 2007). Roux (2003) describes four possible scenarios that could result from climate change:

1. Reduction in coastal upwelling intensity along the Namibian coast through a slackening of the South Atlantic trade wind circulation. This would probably lead to dramatic ecosystem responses, which would reduce the productivity of the ecosystem as a whole. The species that characterise the Benguela system could suffer major reductions in stock size and distribution. Some will be at a greater risk of extinction, which might in turn negatively impact endangered local seabird species such as the African penguin. This scenario may cause the Angola-Benguela Front to shift to the south, thus reducing the extent of the Benguela system.
2. Increase in average summer wind stress and coastal upwelling intensity. Enrichment and potential primary production are likely to be enhanced, which could benefit some pelagic species (possibly anchovy) and their predators. The ecosystem as a whole might benefit through increased productivity and possibly a new regime shift. On the other hand, if the change in wind stress is to intense, increased turbulence and offshore advection might become detrimental to spawning success of pelagic fish.
3. The frequency and severity of Benguela Niño events is increased. This will greatly increase system variability and will cause an overall decrease in average productivity. Species at risk of large-scale population fluctuations and particularly pelagic species will be most directly affected.
4. Low amplitude gradual affects, which is possibly the best-case scenario, but probably also the least probable (because climate change effects are expected to be quite rapid and large). Gradual affects would probably lead to a succession of rapid regime shifts between semi-stable states. These regime shifts would affect primarily the dominant pelagic species, which would, in turn, induce large changes in the entire system.

4 Likely impacts on the different economic values of ecosystems

Having described the likely impacts of climate change on ecosystems, natural resources and biodiversity in Namibia, this section identifies the possible impacts on the economic values, divided into use and non-use values, that society obtains from these natural systems and attributes. Sectors like coastal zones, human health, infrastructure and energy are not included in this study due to a lack of information on these sectors and the chosen focus on natural resources, but it is important to note that this does not mean there could not be severe impacts within those sectors as well. It should also be noted that we do not analyse climate change impacts on the water sector. The Government of Namibia (2002) states that even without climate change, Namibia faces absolute water scarcity by 2020, and "the additional stress on the Namibian water sector due to climate change would be severe." Water is a major constraint for development in Namibia, and as water availability will affect all economic sectors, this is also how water impacts have been included in this analysis. Amongst the sectors studied, the main impacts of climate change are likely to be felt through changes in production in the agricultural sector. Impacts in other sectors are associated with more uncertainty.

4.1 Use values

4.1.1 Agriculture

Africa is heavily reliant on rain-fed agriculture, with over 70 per cent of the population living by farming, and 40 per cent of all exports being agricultural products (WRI 1996). Plus, agriculture presents opportunities for economic growth and industrial upgrading. Yet, the sector's importance is apparently waning, evidenced by its receiving a declining proportion of public spending (OPM, 2007), potentially reducing overall system flexibility in the face of external changes. There is wide consensus that climate change, through increased extremes, will worsen food security in Africa (IPCC 2007). Specifically, forecasted increases in the frequency and severity of drought are likely to exacerbate desertification. Further, declines in rainfall and increased desertification have already led to decreases in soil fertility and agricultural, livestock, forest, and rangeland production. Ultimately, such impacts lead to socioeconomic and political instability (IPCC 2001).

Agricultural output from Namibia is extremely sensitive to climatic conditions (Government of Namibia 2002), and with over two-thirds of Namibians practicing subsistence cropping and pastoralism, mostly on communally owned land. Less than 10 per cent of land is used for cropping, whilst nearly 75 per cent is used for grazing (Government of Namibia 2002). In total, agricultural activities contribute about 5 per cent to GDP. Both subsistence cropping in the form of millet, on which most rural households in the north of Namibia depend, and commercial cropping in the form of maize, are likely to be negatively impacted by climate change (Government of Namibia 2002). Much land used for agricultural purposes is already marginal, and changes in rainfall variability (for example with rain coming in deluges and then long dry spells) as well as quantity could mean agriculture will no longer be viable in these areas.

4.1.2 Livestock production

The Namibian economy depends heavily on extensive ranching activities, both commercial and communal/subsistence, which are underpinned by the productivity of grassland, savanna and shrub-dominated ecosystems (Midgley *et al*. 2005). Reactivation of the Southern African desert dune systems due to climate change could mean that vegetation for grazing will become scarce, which could be disastrous for pastoral farmers (Thomas *et al*. 2005). "Reductions in vegetation cover, increases in proportion of bare ground, and overall reductions in [Net Primary Productivity] all point to reduced potential of vegetation to support rangeland activities, be they on a commercial or subsistence model" (Midgley *et al*. 2005). In Nama Karoo, for example, a 20 per cent reduction in mean annual rainfall will lead to an average carrying capacity loss of about 2 kg per hectare, which is a loss of meat production of N$18/ha (Brown 2007).

Effective management of subsistence rangelands will be important as many species will need to be able to track suitable habitats in response to climate change (Von Maltitz *et al.* 2007). Semi-arid areas of the Sahel, the Kalahari, and the Karoo have historically supported nomadic societies that respond to annual and seasonal variation in rainfall by migrating. These nomadic pastoral systems are good at coping with fluctuating and extreme climate, provided they can move and such systems are supported (Hesse and MacGregor, 2006; Hesse and Cotula, 2006; Thomas and Twyman 2004; Desanker 2003). Fence removal, the restoration of open landscapes and support for creative collaborative management systems (e.g. park-neighbour co-management, neighbouring landowners forming companies with full land ownership of farms changed to part ownership (via shares) in larger areas of land) will help landowners cope with the increases in drought and rainfall variability expected with climate change (Brown 2007).

The Centre for Environmental Economics and Policy in Africa (CEEPA) at the University of Pretoria has conducted a series of studies on climate change affects crop and livestock production in different African countries. Using a ricardian cross-sectional analysis[6], the results illustrate impacts without any adaptation measures. Specifically, large farms with livestock production will be more vulnerable to climate change than small farms. The reason for this might be that large farms depend more on beef cattle, which are not well suited to warm temperatures, while on small farms, small stock species which can tolerate higher temperatures can be more easily substituted. However, whether the net revenues for livestock production depend on projected precipitation rates. If precipitation rates are predicted to decrease in an area, which is the most likely scenario for Namibia, net revenues of livestock will increase. There are, according to this study, three possible explanations for this. First, farmers shift to livestock as rainfall decreases. Second, grassland shifts to forests as rain increases. Third, increases in precipitation increase the incidence of certain diseases (Niggol Seo *et al*. 2006).

In Namibia, with the projected risk of even more dryness, livestock could increasingly substitute for crops, although the suitability of this substitution is likely only on very small tracts of land. Other studies also recognise the fact that vegetation changes due to desertification may not necessarily result in changes in productivity. For example, switching from cattle ranching to game farming or from meat production to wool production may not

[6] This method is based on the assumption that farm net revenue reflect net productivity. The Ricardian model is a reduced form model that examines how several exogenous variables, for example prices of inputs and outputs, soil quality and climatic variables, affect farm value.

reduce income (Ash *et al.* 2002). The Government of Namibia also states that greater aridity would likely be associated with a shift towards smaller stock and game farming.

Discussion at the February roundtable suggested that losses in livestock farming (large and small stock) could be significant. In the Nama Karoo region, carrying capacity will drop from 15kg/hectare by an estimated 15 per cent – losses of 2–3 kg/hectare – as small stock [such as caracal, sheep and goats] experience range shifts, affecting the poorest people who will get a lot poorer as they could lose all their stock. Significantly, many small farm units will no longer be viable. Losses from livestock are also predicted for central savanna and woodland areas, and the northern central areas as carrying capacity of the land is reduced. Although nationally livestock production is expected to suffer under climate change, discussion at the February roundtable suggested that potential to use indigenous biodiversity in the Nama Karoo and central savanna and woodland areas could increase.

4.1.3 Crop production

Another CEEPA study found dryland crop production to be significantly more climate sensitive than irrigated crop production (Kurukulasuriya *et al*. 2006). This study emphasises that the magnitude of the impacts on production depend on whether the country is already hot and dry. Further temperature increases and precipitation reductions in hot dry countries will have large impacts on farm incomes. This study does not capture carbon fertilisation effects or effects on prices and wages, which might occur if the impacts are large enough. Carbon fertilisation is a particularly hotly debated topic when it comes to impacts on crop production. For example, in a South African study of the climate change impacts on maize production, an overall total value of lost production of R681 million without the carbon fertilisation effect was estimated, compared with a loss of only R46 million when the fertilisation effect was included (Du Toit *et al*. 2000).

Discussion at the February roundtable suggested that in the Nama Karoo region in the south of Namibia, potential for irrigation could increase both in terms of the quantity of land that would be available and its quality. For example, more grapes could be grown along the Orange River. The economic gains from this would be significant. However, the increased potential of irrigation in this region is due to already planned irrigation projects, and might in the context of climate change be seen as an adaptation measure rather than an impact. It should be recognised that the predicted losses in precipitation rates due to climate change will probably not improve the potential of extended irrigation, but rather reduce the potential benefits from the projects. Likewise, despite the added problems of more invasive species, there would be great potential for high-value agricultural activities, such as the growth of Mediterranean crops. In the central savanna and woodland areas, the February roundtable predicted an increase in the proportion of high-value irrigation, but predicted climate change impacts were negative: participants consider that dryland crop farming would cease entirely and that there would be a loss of profitability (and viability) of smaller farms. Invasive species, such as prosopis, would increase, and reduced amounts of groundwater would mean that there would be less land available for irrigation.

In the agrosilvipastoral zones in the north-central agropastoral region, the February roundtable predicted that dryland crop production would also suffer considerable losses, but that these losses could be partially offset by greater incentives for use of perennial crops and natural resources such as trees. It was thought that there could be increases in irrigated production of high value crops, but the viability of this was questioned. Increases in irrigated subsistence farming and local market production were also predicted. In the north-eastern agropastoral region, the February roundtable predicted a loss of dryland crops (and substitution to mahangu) and a loss of rangeland capacity. Again, these losses would be partially offset by greater potential for irrigation (if commercially viable) and subsistence use.

In summary, the preliminary production impacts in the agricultural sectors divided into our four different geographical regions that were agreed upon at the February roundtable discussion are summarised in Table 1.

Table 1. Likely impacts of climate change on agricultural production

Sector	Nama Karoo	Savannah and woodland (central areas)	North-eastern Agropastoral region	North/Central Agropastoral region
Livestock	-100%	-35%	-10%	-15% to -30%
Small stock	-15% to -50%			
Irrigated crops	20%	-15% to +0%	20%	15%
Dryland cropping		-100%	-20%	-50%

Overall, predicted losses were greater than gains, except in the Nama Karoo region where the potential for irrigation would increase. Agricultural production is the sector where consensus exists over the likely direction of climate change induced impact, although the magnitude remains uncertain.

In summary, it is clear that dryland subsistence cropping is sensitive to reduced rainfall and higher temperatures, and will probably be the sector to shrink the most, even disappear in some of the central areas. Although there are studies suggesting that livestock could be a good substitute to crop production when the land becomes dryer, there was consensus at the February roundtable discussion of falls in livestock and small stock production in all regions in Namibia. The only agricultural sector that could experience an increase in production would be the irrigated high-value crop production, largely in the south, using the Orange River for irrigation. In other regions, the viability of increased irrigation was questioned at the February roundtable discussion meeting.

4.1.4 Fishing

Natural resources such as fish stocks can generate so-called resource rents, profits over and above the normal rate of return on invested capital, if managed properly. These rents can be appropriated by government through licensing fees and other resource-specific taxes, and if designed properly such taxes should not distort economic incentives (unlike most other taxes). Most countries with fish stocks are guilty of poor management, so that these potential resource rents are completely lost: in fact, many fisheries are subsidised by governments rather than subjected to extra taxes, which encourage overfishing and further depletion of the fish stocks. However, Namibian fishing policy has been one of the most successful in the world in terms of avoiding this trap. Fishing is subject to some of the highest taxes in the country, but these additional fishing levies are sufficiently well designed that the fishing sector remains highly profitable.

Namibia’s fishery is one of the richest in the world. Yet, before independence in 1990, Namibia had little control over its lucrative offshore fisheries, which operated as an open access resource, with non-Namibian vessels fishing heavily and depleting stocks considerably. After independence, the Government of Namibia has been successful in managing the resource and fish stocks have mostly stabilised (Lange and Motinga 1997;

Lange 2003). The main species caught are hake, horse mackerel and pilchard; pilchard is the most valuable of the three, but the pilchard stock collapsed in the 1960s due to overfishing and has never recovered fully. Fisheries now constitute almost 5 per cent of Namibia's GDP, and in addition to this fish processing (which is heavily dependent on domestically caught fish) accounts for a further 2 per cent.

One of the first applications of NRA in Namibia (Lange and Motinga 1997) assessed the state of the fishing sector and concluded that the Government captured approximately one-third of the overall rents from the fish stock. A later, more sophisticated study (Lange 2003) supported these findings and concluded that the overall value of the fish stocks had increased by over 50 per cent since independence.

Even if Namibia's fishing policy after independence has been successful compared to that of most other countries, good resource management might not be enough to maintain a sustainable fisheries sector if climatic change affects the lucrative marine ecosystem at the west coast of Namibia. Some theoretical models suggest that climate change could result in increased wind speeds (due to increased pressure differentials), which would cause increased upwellings, resulting in eutrophication and reduced productivity of Namibian fisheries due to higher turbulence and costlier transport. Others contend that the system would become more productive under certain conditions. But high productivity is not always a blessing as it can cause hydrogen sulphide eruptions (and other related biochemical phenomena), which can adversely affect the system (Neville Sweijd, personal communication 2007).

The best-case scenario is that climate change will increase the productivity of the Benguela ecosystem. This could occur if the recovery of certain fisheries were promoted by a shift in the ecosystem dynamics and environmental conditions which have seen the system depressed since the mid-1990s. It is possible that the system could be revived and we would see, for example, a recovery in the pelagic stocks in the northern Benguela (off Namibia and Angola). Other scenarios, such as the increased oxygenation of the system, might also have unforeseen advantageous effects which could bring new opportunities to the Namibian coast (Neville Sweijd, personal communication 2007).

Other scenarios are worse. It is possible that changes in the physical parameters (such as acidification and temperature) that affect the life cycles of key fish species or influence environmental forcing (such as upwelling) would have a detrimental effect on productivity and survival in the Benguela. This would further challenge resources that are already under pressure and could affect important elements of the system like gobies and mesopelagic fish which are important food sources for commercially exploited fish. The other worst-case scenario is that the frequency, intensity and duration of extreme events could increase. If this happened then the system would not have the capacity to recover – at least in economic timeframes (Neville Sweijd, personal communication 2007). The four possible climate change scenarios described by Roux (2003) earlier would each have different effects on the Namibian fisheries:

1. Reduction in coastal upwelling intensity would probably have disastrous effects on established fisheries. Valuable commercial stocks are likely to undergo major irreversible stock reduction while the total productivity of the system, and therefore the potential yield, declines. The demersal hake fishery would likely be the most affected fishery, which will result in a large reduction of the contribution of the fisheries sector to the national revenue from exports.

2. Increase in average summer winds could lead to both positive and negative effects on the established fisheries depending on the scale of the change. Significantly, it might put the ecosystem at risk of ‘regime shift’ and it is difficult to predict which species would dominate under the new environmental regime and if it will be a commercially valuable one.
3. Increased frequency and severity of Benguela Niño events would result in rapid population fluctuations for some stocks, lowering productivity, reducing safe levels of exploitation and increasing the risk of collapse.
4. Low-amplitude gradual affects would impact the pelagic fisheries (both positively and negatively) most. The associated industry already experiences recurrent crisis periods, but this would compound this uncertainty.

Namibia also has small inshore fisheries, primarily in the north-eastern Caprivi region. These fisheries contribute little to Namibia’s economy, but support a large subsistence-based population. The February roundtable estimated significant losses from this sector resulting from damage to the wetlands.

4.1.5 Forests

Preliminary forest accounts have been compiled for Namibia in 2004 (Barnes *et al* 2005). As there are no true forests in Namibia, forest resources are in this study defined as all woody plants which occur in the woodlands and the shrublands (savanna) in the country. The forest accounts deal exclusively with natural forest resources, as there are almost no planted forests in Namibia.

Most of the forest products examined in this study are consumed directly by the households collecting them, rather than traded, and are therefore not included in the traditional national accounts and hence not in the traditional GDP measure. However, according to this study, forest use makes a direct contribution to Namibia’s national income of N$ 1 billion, which is equivalent to about 3 per cent of the official GDP. The direct use values of forests, which have been estimated here, come from harvesting of fuel wood and poles for construction of houses and fences (mostly consumed by rural households) and the consumption of other forest products like plant products for craft production, food, medicine and cosmetics. The results of this study imply that forest use, by contributing up to 3 per cent to national income, might be more important for the economy than previously believed.

The areas of Namibia with broadleaf woodlands are likely to experience no particular losses due to climate change. Indeed discussion at the February roundtable thought that the potential to use forest products here could increase. In the north-central and north-eastern regions it was also thought that potential sale of forest products could increase, but this is likely to be as an adaptation to climate change rather than an increased opportunity in its own right. However, in the latter zone, potential benefits from climate change might be offset by increases in tree damage (and hence timber resources) from fire and elephants.

4.1.6 Tourism

Tourism is a key economic activity in Africa, particularly wildlife and coastal tourism. But the impacts of climate change on wildlife and coastal areas in Africa are uncertain. It is argued that climate change induced droughts and floods might have caused the outbreaks of canine distemper virus that have devastated lion populations in East Africa in recent years (Kissui and Packer 2004). Midgley *et al*. (2005) state that in Namibia, climate change and associated aridification could threaten the lucrative tourism sector. Indeed, the contribution of nature-based tourism (including landscape, game viewing and trophy hunting) is estimated to be 75 per cent of Namibia's total tourism sector (Humavindu and Barnes 2003). The Government of Namibia (2002) asserts that since tourism relies solely on Namibia's natural resources base, any impacts to biodiversity and natural ecosystems will impact on tourism. Protected areas and reserves are a key component of Namibian tourism. But for Southern Africa, between one-quarter and one-third of current reserves could experience a major dominant biome shift if pre-industrial CO_2 concentrations double (Hulme 1996). Greater species diversity occurs outside than inside protected areas so protected areas alone are unlikely to be able to adequately conserve biodiversity. Land outside protected areas therefore needs careful management (Von Maltitz *et al*. 2007).

The tourism industry makes up 2.3 per cent of the Namibia's entire economy (Suich 2002). Industry output growth rates of 14 per cent between 1991 and 1996 outstrip other sectors, and tourism is considered to harbour significant potential for growth and development (Suich 2002; Turpie *et al*. 2004). The main reasons visitors give for coming to Namibia are nature and landscape touring and game viewing (Turpie *et al*. 2004). These are both examples of *non-consumptive use values* in the tourism sector. According to the study by Turpie *et al*. (2004), the direct non-consumptive use value of protected area tourism ranges from N$ 546 to N$ 1103 million in gross value-added. Further, indirect values, derived from the demand generated in the rest of the economy by the tourism industry are also estimated by means of a SAM multiplier analysis. Adding the indirect values, the total economy-wide effect from tourism expenditure ranges from N$ 1013 to N$ 2022 million, which is equal to 3.1 per cent to 6.3 per cent of GDP.

Another important source of tourism income in Namibia, and an example of a *consumptive use value*, is trophy hunting, which constitutes to about 14 per cent of the total tourism sector. Humavindu and Barnes (2003) estimate the consumptive economic use value of trophy hunting to be N$ 134 million in gross output, and N$ 63 million in gross value added (the value of production of goods and services minus intermediate inputs like raw materials).

There are no available studies of likely climate change impacts on tourism in Namibia. In order to derive likely impacts, more specific information about tourism supply and demand is required, with no comprehensive studies existing on this in Namibia.

According to a preliminary study on the economic impacts of climate change in South Africa, likely impacts on tourism activities could be divided into three main kinds: a change in supply due to loss of habitat, change in supply and demand due to loss of biodiversity, and change in demand due to increases in temperature, humidity and malaria. Many visitors to Namibia value its biodiversity and desert landscapes, but it is difficult to know how sensitive tourism demand would be to, for example, an expansion of deserts. It is very difficult to estimate the importance of, for example, biodiversity to tourism value, as tourism demand is a function of many different features of the chosen destination.

In areas of Namibia with higher rainfall and high soil fertility, exotic species (i.e. farming systems) generally provide more income than indigenous biodiversity production systems. But in arid zones the markets generally support indigenous biodiversity production systems. In the Nama Karas biome, the economic rates of return for communal livestock, freehold livestock and tourism are 5.5 per cent, 9.8 per cent and 12.9 per cent respectively (Brown 2007). But policy failures and market distortions often prevent potential benefits materialising by driving down the value of indigenous species and subsidising exotic species, even when indigenous species provide greater benefits. Data show that natural resources (wildlife and tourism) out-perform farming by a factor of two or more. Trophy hunting (coupled with high-end tourism) is the most lucrative of natural resource uses. If policy failures and market distortions can be addressed, it might be that climate change impacts on tourism will not be as significant as in other sectors, as switches to indigenous production systems on land that can no longer support agriculture and exotic livestock species could increase productivity (Brown, 2007).

Table 2. Generalised impact of Climate Change on Production systems

Activity	Impact of Climate Change on Production System
Ecotourism	Small: arid zones - scenery and wilderness values
Trophy hunting	Small to medium: fewer species in some areas, cost of supplementary feeding
Live sale	Medium to high: particularly for high value species, because of lower productivity and cost of feeding
Meat production	Medium to high: lower carrying capacity

Source: Chris Brown, presentation at roundtable discussion 2007.

Discussion at the February roundtable suggested that tourism potential in the Nama Karoo region could increase if the areas in which tourism can operate increase in size. In central savanna and woodland areas and northern central areas, increases in tourism (including cultural tourism) and natural resource use could be facilitated by climate change, even though wildlife carrying capacity might decrease. In the north-eastern region, improved potential for transfrontier conservation areas could occur, along with increased tourism revenue, greater incentives for elephant management and conservation and the ensuing sale of ivory and skins. However, increases in human wildlife conflict and damage to floodplain wildlife and grazing resources could also occur in this zone. Some preliminary estimates from the meeting are summarised in Table 3.

Table 3. Potential for tourism expansion as a substitute for climate sensitive sectors

	Nama Karoo	Savannah and woodland (central areas)	North-eastern Agropastoral region	North/Central Agropastoral region
Tourism potential	20%	20%	20%	15% - 20%

In summary, whilst land use changes to tourism as a result of climate change might benefit the sector, it is a fact that the Namibian tourism sector is highly dependent on natural resources, so there should be concerns that any climate change impacts on biodiversity and natural ecosystems might significantly affect tourism. Tourism is dependent on many external factors that cannot be addressed in a single-country analysis – including global incomes, regional stability and competition. Moreover, past growth rates in the tourism sector during the last decade are no guarantee of future growth. The Government of Namibia recognises the need for conservation of biodiversity and ecological complexity as a priority (Government of Namibia 2002).

4.2 Non-use values

Non-use values are often derived from the conservation of resources that can either be valuable for future use (option value) or even for just knowing that a specific area or species is being protected (existence value). These values are often hard to estimate as they generally cannot be derived through the observation of agents' behaviour concerning consumption or production, which is the normal way to derive use values of goods and natural resources. Instead, direct methods, like contingent valuation, are used to derive people's willingness to pay (WTP) for conservation of resources.

4.2.1 Option values

Option values can be derived from the value of future use of an area or species that is being protected. An example of a Namibian study capturing an option value is a contingent valuation study of the WTP for recreational fishing in Namibia. Although this survey, used for assessing the economic value of the recreational line fishery, was not specifically designed to collect information on non-use values, it provides some indication of option and existence values. Anglers were willing to contribute some N$ 1 million per annum to a coastal conservation trust fund. However, it is not possible to know how much of this value is associated with possible future use of the fishery in isolation because to some extent this also could reflect the existence value of conservation. However, the anglers' statements indicate that there is a non-use value associated with the recreational fishing sector (Barnes *et al*. 2005).

4.2.2 Existence values

Existence values are values that cannot be captured either by current or future use of a resource. In a review about conducted WTP studies of nature based tourism and conservation in Namibia, it is stated that in general, visitors are willing to pay far more for these activities (through entrance fees and support to conservation funds) than they currently do pay (Humavindu 2002). However, only a few of the WTP studies are designed to capture the existence value for conservation.

A study by Barnes *et al*. (1997) captures an existence value by differentiating between WTP for conservation funds (existence value) and WTP for wildlife viewing (use value). The average WTP, among the 72 per cent of surveyed visitors that were willing to pay for conservation, was found to be N$ 144 per person. The WTP among all visitors was N$ 104. This would add up to a total existence value of N$ 28.7 million for all tourists visiting Namibia.

Although conservation of areas or species is often associated with tourists' WTP, this need not always be the case. An interesting example of a study where residents', rather than tourists', willingness to pay is analysed can be found in a South African contingent valuation study of existence values. This study was conducted in order to estimate the WTP among residents in the Western Cape for conservation of different biomes. Some 76 per cent of all respondents were willing to pay for conservation. The overall mean willingness to pay was R 211 per year. The total WTP was R 224 million per year, which on a national level might imply an existence value of R 1.5 billion per year (Turpie 2003).

In Namibia, the values captured by contingent valuation studies of tourists' WTP for conservation probably only represent a fraction of total international WTP for protection of Namibia's biodiversity. For example, non-users, i.e. non-visitors to Namibia, might also have a positive WTP for conservation of areas and species. As Namibia has a large strain of the African elephant, it is interesting here to mention a study about the WTP by Swedes for the preservation of the African elephant. In a paper by Vredin-Johansson (1999) the overall mean WTP for preservation of the African elephant was found to be SEK 238 annually and the median WTP was found to be SEK 100 (Vredin-Johansson 1999). The mean value in Swedish currency corresponds to a value of about $ 258 (based on the exchange rate at 14 November 2007). Although this study only focuses on elephants, it implies that many African species could be of significant value to people, even though they have never visited, or have any plans to visit, the place where the species in question live.

In the Nama Karoo biome in the south of Namibia, the February roundtable estimated non-use values to experience particularly significant losses as a result of climate change.

There are currently no reliable studies of estimations of total non-use values that could be used for assessing climate change impacts. However, it is important to note that these values could be significant. This implies that if climate change will lead to losses in biodiversity, non-use economic values of these losses can be significant.

5 Evaluation of the impacts on national income level

As the purpose of our study is to assess the likely impacts of climate change on the national income in Namibia, in this section, we try to add the sectoral and regional impacts discussed at the February roundtable meeting together into some rough estimates of likely impacts on a national level. This section combines analysis and findings from a literature review, expert interviews and the February roundtable.

5.1 Agriculture

On a national level, the agricultural sector can be divided into a commercial cereal production sector, a commercial sector for other crops, a commercial livestock production sector and a traditional sector, containing mainly subsistence crop and other food production for personal consumption. This is how the agricultural sector is described in the SAM database which we will use in a later section of analysis, which is the reason why we focus on the likely national impacts within each of these agricultural sectors.

From the discussion in the previous section a compelling pattern of likely production changes can be traced out. In the commercial crop production sector, some planned irrigation projects are already underway, which means that a future increase of the irrigated crop production sector should be expected. However, while this might expand, it would probably not be profitable to invest in irrigation to expand cereal production. Taking the predicted impacts of climate change into account, the viability of expanding crop irrigation in areas other than the Nama Karoo region (where the Orange River provides the water for irrigation) is questionable, because there is likely to be less groundwater available for recharge and irrigation. A best-case scenario for the irrigated crop production sector under climate change would therefore be a smaller increase in production than would otherwise occur. The commercial cereal production sector is likely to suffer losses even in a best-case climate change scenario, as the viability of irrigation expansion is questionable for these crops. Concerning the livestock production sector, there is general agreement that carrying capacity will be reduced because of climate change. A best-case scenario would probably imply a small reduction, while in a worst-case scenario there would be a greater decrease in the production of livestock. On balance, we estimate a loss of between 20 and 50 per cent in productivity in this sector.

The traditional agricultural sector, including subsistence dryland cropping, is the sector that is predicted to suffer the most from climate change. This is of particular concern to poorer sections of Namibia's population, who depend on dryland cropping for their livelihoods and subsistence. In some regions, dryland cropping is even predicted to disappear entirely. Therefore, in a worst-case scenario, there could be a substantial decrease in production in this sector at a national level, and even in a best-case scenario, a significant decrease should be expected. We assume the reductions could be in the range of 40 to 80 per cent of production at a national level.

It is important to note that these are estimates. However, although the magnitude of the likely impacts on agriculture can be debated, there is relative certainty over the direction of impact.

5.2 Fishing

The fishing sector is seen as a potential future growth sector in Namibia, very much dependent on sustainable management – and of course climatic conditions. However, in general the likely climate change effects are more uncertain in the fishing industry than in the agricultural sector. The best-case scenario implies an increase in the productivity of the Benguela ecosystem possibly followed by a recovery in the pelagic stocks in the northern Benguela. However, there is a risk that higher productivity will have adverse effects on the marine ecosystem, thereby offsetting some of the possible benefits from such a scenario. There are several possible climate change scenarios for the fishing sector which predict stock reductions followed by potential yield declines. For example, a reduction in coastal upwelling intensity would probably have disastrous effects especially on the demersal hake fishery, which is the dominant species within the commercial fisheries in Namibia. There is also a risk that the frequency and severity of Benguela Niño events will increase. This could have severe consequences on the fisheries in terms of rapid population fluctuations that might lower productivity and increase the risk of collapse. There are more climate change scenarios predicting a reduction in productivity than there are positive scenarios for the fishing sector. Even though the impacts could be anywhere in a range from an increased productivity to a significant decrease in the fish stock available for fishing, it might be argued that the negative impacts are slightly more likely than the positive impacts predicted by only one of the scenarios. Hence, here we analyse what a reduction of up to 50 per cent in the fish stock available for fishing would imply for the economy.

5.3 Forests and tourism

According to the February roundtable meeting, Namibia's woodlands are predicted to experience no particular changes as a result of climate change.

There is a strong belief in Namibia that the tourism sector has potential to expand as a substitute to production in climate sensitive sectors. Without any specific studies on tourism demand it is hard to predict how tourism would be affected by climate change, but there is reason to be cautious about tourism potential as there is a risk that at least some areas will probably be less suitable for tourism if the land becomes drier. The fact that tourists are currently visiting the deserts along the west coast does not mean that they would also like to visit other desert-like areas in other parts of the country in the future. Our preliminary estimates of losses within the agricultural and fishing industry can give some idea of what the actual growth in the tourism sector would have to be to offset these losses. However, due to a lack if information on impacts, we do not estimate any effects on GDP in the tourism sector.

5.4 Non-use values

Even though there are some estimates on tourists' WTP for conservation funds in Namibia, there is too much uncertainty about the likely effects of climate change on specific species to derive monetary quantifications of this. However, as the non-use values of conservation are often large, any climate change effects on the quality and/or quantity of wildlife will be of significant economic value.

5.5 Total impact on the economy

The total GDP for the year 2002, which is the year for the SAM database that we will use in the next section of the paper, was N$ 33 000 million (Central Bureau of Statistics 2007). By recognising the natural resources current contribution to GDP, together with the expected changes due to climate change, some preliminary monetary measures can be stated in terms of lost GDP per year. These are summarised by sector in table 6 below.

Table 4. Possible Climate change effects on GDP per sector

Values	Current contribution to GDP	Changes expected due to climate change	Affect on GDP, millions N$ per year	Confidence in range of change
Use values				
- Cereal production	0,5%	*Decrease (10 - 20%)*	- 16 to - 32	*Low to Medium*
- Crop production	1,0%	*Decrease (10 - 20%)*	- 32 to - 65	*Low to Medium*
- Livestock production	4,0%	*Decrease (20 - 50%)*	- 264 to - 660	*Medium*
- Traditional agriculture	1,5%	*Decrease (40 - 80%)*	- 197 to - 395	*Medium to high*
- Fishing	6,0%	*Increase (30%)/decrease (50 %)*	0 to - 990	*Low*
- Tourism	2-3%	*Increase/Decrease*	-	*Low*
- Forests	+ *	*Unchanged*	0	*Low*
Non-use value	+ *	*Decrease*	-	*Low*
Total value			- 509 to - 2 142	

** not included in the traditional national accounts*

The monetary values of lost GDP due to likely climate change effects on use values within natural resource sectors could, according to these preliminary estimates, be somewhere between N$ 500 million and N$ 2000 million per year. The agricultural use values range from a loss of 1.5 per cent of GDP in the best case to 3.5 per cent in the worst case. Adding the more uncertain negative effect on fisheries, the worst-case total use values would constitute up to as much as 6.5 per cent of total GDP.

6 Possible general equilibrium effects: examples from a CGE model of the Namibian economy

As well as analysing total direct GDP impacts, our aim is also to evaluate the likely economy-wide, and especially the distributional, effects of climate change. In vulnerable sectors, changes in productivity caused by climate change will not only directly affect the value these sectors add to national income but also the livelihoods of the people (and their dependents) who depend on these sectors. Furthermore, the direct effects on production, might also have indirect effects on other economic sectors that sell goods to the directly affected sectors (or buy goods from them) or to the people who depend on these sectors for their income.

In order to give some idea of the likely magnitude of these general equilibrium effects of production changes in the agricultural and fishing sectors, a social accounting matrix (SAM)[7] of the Namibian economy is used to build a computable general equilibrium (CGE) model.[8] This kind of macroeconomic model has been widely used for policy analysis in both developed and developing countries during the last two decades. CGE models are used to analyse the economy-wide and distributional welfare effects of economic policies, and examples of CGE applications can be found in many different areas, such as fiscal reforms (for example Perry *et al*. 2001), international trade (for example Martin and Winters 1996; Harrison *et al*. 1997) and environmental regulation (for example Bovenberg and Goulder 1996; Goulder 2002).

To be able to use the CGE model to analyse the effects that climate change has on natural resources, these resources should be explicitly modelled as components of production in the different economic sectors. Climate change simulations then require information on how these natural resources will be affected by climate change. Due to a lack of reliable information about climate change impacts on many resources, for example wildlife tourism and forests, we have chosen to include only the agricultural and the fishing sectors in this CGE analysis. These simulations can serve as examples of what the economy-wide effects of likely (although still uncertain) production changes in the agricultural and fishing sectors due to climate change might be.

6.1 The CGE model and data

The International Food Policy Research Institute (IFPRI) has developed a generic CGE model for developing country analysis. In this study, we use an adjusted version of this model. Full documentation for the original model is given in Löfgren *et al*. (2002).

The primary database on which the CGE model is built is the preliminary SAM for Namibia from 2002 (full documentation is given in Lange *et al*. 2004).[9] The SAM divides the economy into 26 sectors of production, five factors of production and six households groups, according to their main source of income. The sectors of production include three commercial

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[7] The SAM is a database that provides information on the economic activity in different sectors during one year.
[8] The standard CGE model is written as a set of simultaneous equations, explaining all of the payments recorded in the SAM by defining the behaviour of the different actors.
[9] Technically, the SAM is a square matrix in which each account is represented by a row and a column where the incomes of an account appear along its row and its expenditures along its column. The economy is disaggregated into factors, activities (production), commodities and institutions. The sum of each row (total revenue) must equal the sum of each column (total expenditure) in the SAM.

agricultural sectors (commercial crop production, commercial cereal production, and commercial livestock production), one traditional subsistence agriculture sector, one fishing sector, three processing sectors that depend on these sectors for important inputs (meat processing, grain milling and fish processing) as well as a number of other primary, secondary and tertiary production sectors. The factors of production included in the SAM are unskilled labour, skilled labour, mixed income in the commercial agricultural sectors (i.e. income to farm owners, generated by own labour, capital, as well as a land rent component), mixed income in the traditional agricultural sector (analogous to that in the commercial sectors, but with a negligible capital component) and capital. The household groups are: 1) Urban - wage and salaries in cash; 2) Urban - business activities including farming; 3) Urban - pensions, cash remittances and other sources of income; 4) Rural - wage and salary; 5) Rural - business activities and commercial farming; and 6) Rural - subsistence farming, pensions, cash remittances and other sources of income. Although the households are not divided by income deciles in the SAM, the poorest household groups are the rural households that derive their income from wages and salaries and other rural households including mainly subsistence agriculture. Therefore, it is possible to say something about the effects of climate change on income distribution by studying the real income changes for the poorest household groups.

Some necessary small changes in the SAM have been made for the traditional agricultural sector. In the original SAM, the traditional agricultural sector produces an "own" commodity called "traditional commodity", which can be described as "food for own consumption"; this is largely crop production. This sector will be heavily affected by climate change even in the optimistic scenarios described above, and it is likely that food produced for own consumption will have to be supplemented by purchases of food produced elsewhere. We have therefore redefined the "traditional commodity" and assumed that the traditional sector produces crops that are replaceable either by crops produced elsewhere in the country or by imported crops.

Some adjustments have also been made to the distribution of factor income in the traditional agricultural sector and in the fish production sector in the SAM. In the traditional agricultural sector, the mixed income category includes land rents and income generated by labour supplied by those informally employed in the sector. By recognising the approximate number of informal workers in the subsistence agricultural sector (Angula and Sherbourne 2003) together with an estimate of the mean informal wage (see Humavindu 2007), a part of the total mixed income in the traditional sector can be transformed into factor income for unskilled workers. For the purposes of this study, this small adjustment represents a good way of modelling the factor income distribution in the traditional agricultural sector. In order to study the effects on changes in the available fish stock, fish needs to be included as a factor of production in the fishing sector. In the SAM, this is done by making use of the resource rent (as factor income distributed to different households etc.) developed through the NRA methods for fish (Lange 2005). In addition to these revisions, a number of the smaller manufacturing and service sectors have been aggregated in order to make the model easier to solve numerically.

In the CGE model, most assumptions follow the standard setup in the generic IFPRI model. However, in order to capture the effects of climate change on the natural resource based sectors, the resource component in these sectors is modelled explicitly. Thus, in the fishing sector, fish is included directly as a factor of production in the fishing sector's production function. In the commercial agricultural sectors, as there is no available estimate of resource rent for land that can be included in the SAM, the CGE model is extended by including a factor productivity parameter for the mixed income category (which also includes land) in the agricultural sector production function. Climate change impacts on the agricultural sector can thus be modelled through a change in the productivity of the mixed income factor of production.

Apart from the SAM, some additional data are needed to calibrate the model. These include mainly elasticities.[10] As there are no available empirical estimates of elasticities in Namibia, these are all taken from a CGE model of the South African economy developed by Thurlow and Seventer (2002). This is motivated by the fact that the structure of the Namibian economy is similar to the South African economy. When it comes to trade elasticities for agricultural goods and for fish, the South African estimations are relatively low, implying low substitutability between imports/exports and the demand/supply of domestically produced goods. There are reasons to believe that the elasticities could be higher for Namibia, as the country has a free trade agreement with South Africa, which produces both agricultural products and fish products and there is little domestic consumption of fish in Namibia. The substitutability between Namibian and South African products should be high. In CGE models for many other African countries, for example Zimbabwe (Bautista and Thomas 2000) and Kenya (Kiringai *et al.* 2006), larger estimates of elasticities are used. A sensitivity analysis has been conducted concerning the importance of the size of the trade elasticities. This analysis shows that whether we apply the South African estimates or the higher estimates for the trade elasticities for Namibia, the results remain largely similar; there are no changes in directions of the results, and only minor effects in the magnitude of changes. The changes in GDP, especially in the traditional agricultural sector, are higher when the low South African trade elasticities are used. However, as we think that higher elasticities are more realistic for Namibia, these are chosen for the simulations.

6.2 Simulations and scenarios

For the agricultural sectors, preliminary climate change simulations can be carried out using the preliminary changes in the productivity levels that are likely to emerge due to climate change. The simulations include two different ranges of changes within the agricultural sector, one best-case and one worst-case scenario. These production changes are modelled as shocks on the factor productivity of land used in the agricultural sectors. The results from such simulations will show how much the likely production changes will affect the national GDP and the distribution of income in the Namibian economy.

In addition to the agricultural sector, the fishing sector is also included in our climate change simulations. As the fish rent can be described as the direct contribution from the fish resource to the economy, by changing the fish stock available for fishing we will be able to track what such a change would mean for the national economy and for income distribution in Namibia. Due to high uncertainty we limit the analysis to only one possible fish scenario; it does not make sense to predict different ranges of fish stock changes when we do not have any idea of what range is most likely. As we are interested in what the predicted losses in stocks might imply for the Namibian economy, a simulation of a reduction in the total fish stock of 50 per cent is analysed. This should be seen as a worst-case scenario for the fishing sector following climate change but although highly uncertain, it gives some idea of what the distributional effects from a significant fish stock change might be.

[10] These include trade elasticities, substitution elasticities between factors of production, substitution elasticities between factors and intermediates, aggregator elasticities and expenditure elasticities

In total, six different preliminary scenarios have been worked out and then used for simulations in our CGE model. These scenarios are shown in table 5 below.

Table 5. Scenarios

Scenarios	Crop production	Cereal production	Livestock production	Traditional agriculture	Fish stock change
Scenario 0 - no climate change	+20%				
Scenario 1 - best case agriculture	+10%	-10%	-20%	-40%	
Scenario 2 - worst case agriculture	*no change*	-20%	-50%	-80%	
Scenario 3 - fall in fish stock	+20%				-50%
Scenario 4 - combined 1 and 3	+10%	-10%	-20%	-40%	-50%
Scenario 5 - combined 2 and 3	*no change*	-20%	-50%	-80%	-50%

In *Scenario 0*, a 20 per cent increase of the mixed income factor productivity of irrigated crop production is assumed. This first scenario ignores likely climate change impacts and includes an expected increase of the production in the irrigated crop sector due to an extension of irrigation in different areas.

Including climate change, two different scenarios are analysed for the agricultural sector, where the first can be considered a best-case scenario and the second a worst-case scenario. In *Scenario 1*, a productivity loss of 20 per cent is assumed for farms used for livestock production, together with a 10 per cent productivity loss for cereal farms, an increase in 10 per cent in productivity for crop farms (assuming that the benefits of increased irrigation are partly offset by climate change impacts) and a reduction in subsistence agricultural productivity of 40 per cent. *Scenario 2* predicts a reduction in livestock farm productivity of 50 per cent, a loss of 20 per cent of the productivity in irrigated cereal farms, no change in productivity for irrigated farms (the effects of increased irrigation are assumed to be completely offset by climate change) and a reduction in subsistence agricultural productivity of 80 per cent. *Scenario 3* is a scenario where only the fish stock is negatively affected by climate change. Leaving the agricultural sector unaffected means that the commercial crop productivity increases due to improved irrigation, as in scenario 0. Finally, the effects of combinations of the different effects in the agricultural sector and the fishing sector are analysed. *Scenario 4* is a combination of the agricultural best-case and the fish scenario, while *Scenario 5* is a combination of the worst-case agricultural scenario together with the fishing climate scenario.

6.2.1 Simulation results

In this section, the scenarios described above are analysed in terms of total effect on GDP and on income distribution across enterprises and households within the country. The results are presented in Table 6.

Table 6. Simulation results

		Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
GDP (market prices), total % change		0,1	-1,1	-3,1	-2,4	-3,2	-5,8
GDP (factor cost), total % change		0,1	-1,0	-2,6	-2,0	-3,2	-4,8
Current activity share, % of total GDP at factor cost		**% change in activity share of total GDP at factor cost**					
- Cereal production	**0,5**	0,0	-8,4	-17,0	0,9	-7,6	-16,3
- Other crop production	**1,0**	19,2	10,2	1,3	22,3	12,9	3,7
- Livestock production	**4,0**	0,0	-19,0	-48,4	1,2	-18,0	-47,9
- Traditional agriculture	**1,5**	0,0	-33,5	-74,6	4,7	-30,7	-73,8
- Fish production	**5,5**	-0,1	0,4	1,0	-45,2	-45,0	-44,8
- Fish processing	**2,0**	0,0	0,1	0,4	-43,5	-43,4	-43,3
- Mining	**15,0**	-0,1	0,5	1,6	2,3	2,8	3,8
- Meat processing	**0,5**	0,0	-6,7	-33,7	0,9	-4,6	-32,7
- Grain milling	**1,5**	0,0	-0,1	-0,5	0,1	0,0	-0,4
- Manufacture of beverages	**3,5**	0,0	0,1	0,2	0,9	1,0	1,1
- Other industry	**7,5**	-0,1	0,4	1,1	1,8	2,2	3,0
- Construction	**2,0**	0,0	0,2	0,5	0,8	1,0	1,3
- Water supply	**1,0**	0,1	-0,4	-0,9	0,9	0,4	0,0
- Electricity supply	**2,0**	0,1	-0,1	-0,4	1,4	1,2	1,0
- Private services	**31,5**	0,0	0,3	0,7	1,8	2,1	2,7
- Government services	**21,0**	0,0	0,0	0,0	0,1	0,1	0,0
- TOTAL	**100**	0,1	-1,0	-2,6	-2,0	-3,2	-4,8
% change in income from base year for different household groups, by current main source of income							
- Urban,wage and salary		0,3	-1,1	-3,8	-10,0	-11,3	-13,7
- Urban,agr and business		0,7	-1,4	-6,8	6,9	4,5	-3,2
- Urban other		0,3	-1,4	-4,6	-9,9	-11,5	-14,5
- Rural, wage and salary		0,3	-1,1	-3,8	-10,0	-11,3	-13,8
- Rural, agr and business		0,8	-1,7	-8,3	10,1	7,2	-2,2
- Rural other		0,0	-4,9	-12,2	-8,0	-13,1	-26,9

The total effects on GDP, presented as percentages from base level, are negative for all climate change scenarios, while positive for scenario 0, where commercial crop production is supposed to increase due to irrigation expansion with any climate change impacts being ignored. For all climate scenarios, the total GDP is reduced by between 1.1 per cent, for the best-case agricultural scenario, and 5.8 per cent in the combined agricultural and fishing worst-case scenarios. These figures provide an example of what climate change impacts could mean for the national economy. As we are working in a static rather than a dynamic model setting, these figures should be interpreted as costs of climate change *per year*, given that the predicted climate change impacts on production have been felt. Of course these impacts are not going to be felt overnight, and one could therefore argue that the structure of the economy will gradually change during the actual time period before the impacts are likely to be fully realised. Consequently, it is important to note that these simulations can only serve as rough guidelines of the economy-wide importance of the agricultural and fishing sectors. These simulations give an indication of what would happen to the economy if no adaptation takes place (other than the planned expansion of the irrigation network) and no other adjustments take place in the meantime.

The impacts on GDP in the CGE analysis differ slightly from the impact analysis on different sectors in the previous section. This is because the CGE model captures not only the direct, but also the general equilibrium effects in the economy following production changes in the directly affected sectors. Considering only the agricultural impacts, the economic losses are now between 1.1 per cent and 2.6 per cent of GDP, compared to 1.5 per cent and 3.5 per cent of GDP in the previous section where general equilibrium effects were not considered. The indirect effects on other sectors in the economy are shown in the table above.

The losses in GDP due to the productivity effects in the agricultural and fishing sectors are not quite as large as the initial changes in land productivity or reductions in the fish stock. This is partly because of the fact that agriculture and fishing will use labour and capital more intensively in order to offset some of the effects of the loss in productivity of the natural resource base. However, the main reason is that the decline in agriculture, and the subsequent loss in employment, pushes down wages and makes it possible for other sectors to expand, offsetting part of the overall loss in production. This is explained further later. When the fish stock is negatively affected, all sectors except fish and fish processing increase their production. However, these small general equilibrium effects are not enough to offset the significant production losses within the directly affected sectors.

In our model, the only real adaptation measure considered in the simulations is an expansion of the irrigated high value crop production, which is already under way in Namibia. The results indicate that this adaptation measure will not be enough to offset the predicted negative impacts on the agricultural sector. However, it is important to note that only limited substitution options (and one single adaptation measure) are considered in the model. For example, if the tourism sector, which could grow substantially in the future, is shown to be less sensitive to climate change than other sectors, the future GDP growth might not be as threatened.

Turning to the impacts on income distribution, the results show that in the worst-case scenario, all households become worse off, but the impacts are highly unevenly distributed. It is clear that the poorest households will lose relatively more of their income than the richer households. The main reason for this is that when production decreases in the agriculture and fishing sectors, there will be a loss of employment for unskilled workers in these sectors. These workers will need to find employment in other sectors, pushing down the wages for unskilled labour in these sectors, and the households that rely on these wages will experience substantial losses of income (this also means that the household categories in the table show the current main source of income, rather than the anticipated main source: since many workers will need to move from rural areas into the cities, they will switch categories from “rural wage earners” and “rural other” to “urban wage earners”). In the agricultural scenarios, the factor category mixed income will become less productive, implying a lower rate of rent for the households relying on this factor income. The impacts on income distribution differ between the agricultural and the fishing scenarios. In scenarios 1 and 2, the negative production shocks on the agricultural sectors affect the income for the households within “rural agriculture and business” and “rural other” most negatively. In scenario 3, the household groups “urban agriculture and business” and “rural agriculture and business” are positively affected from the negative shock on the fish production; lower wages lead to higher profits, which increases income for those households that are capital owners.

The households that are most vulnerable to a decrease in the fish production are “urban and rural wage and salary” and “urban and rural other”. A combination of production shocks on agriculture and fishing will increase income for enterprises and reduce income for all households. The urban and rural households that have their own businesses will lose relatively less income compared to the households that work in businesses or on farms, or are involved in subsistence agriculture. As Namibia already has one of the worlds’ most unequal income distributions, the Government should therefore be aware of the fact that climate change could further increase inequality. It is clear that the poorest household group, “rural other”, which includes subsistence farmers, is likely to be the most negatively affected household group from climate change, while the relatively richer households groups, “urban and rural agriculture and business”, will be the least negatively affected groups.

Again, these results can only serve as rough guidelines and examples of how the economy might be affected by climate change, and they should be seen as worst-case figures. However, it must also be kept in mind that the examples included in the CGE model only constitute a fraction of possible climate change impacts. First, we have only considered the direct use values of the production in two economic sectors, leaving possible non-use values out of the analysis. Secondly, impacts such as health and sea level rise, which have been estimated to be significant in other country studies (Spalding-Fecher and Moodley 2002); Dasgupta *et al*. 2007), are completely left out of this natural resource based analysis.

7 Conclusions

This study is a first attempt to provide some economic indicators of how climate change will affect Namibia. We have discussed the likely economic values of some of the most important environmental as well as socio-economic impacts of climate change in Namibia and we have made a first attempt to put monetary values in relation to total GDP on some of the impacts.

Our analysis focuses on impacts on natural resources, thereby disregarding other possible impacts such as, for example, health effects and the impacts of rising sea levels. The agricultural sector in Namibia is where there seems to be most agreement on what the likely climate change effects will be, while impacts in the fishing, tourism and forest sectors are more uncertain.

Agriculture and fishing both constitute important economic sectors in the Namibian economy (approximately 5 per cent of GDP each), and therefore it is particularly interesting to analyse what the likely effects on GDP as well as income distribution would be if production in these sectors were severely affected by climate change.

Our results show that the climate change impacts on the total GDP could range between losses of N$ 500 and 1000 million if only the agricultural impacts are considered. These figures correspond to about 1.5 per cent and 3.5 per cent of GDP. If production losses within the fishing industry are included, the total losses could be up to N$ 2,000 million in a worst-case scenario, implying 6.5 per cent of the total GDP.

Taking general equilibrium effects into account by the use of a CGE model of the Namibian economy, the losses are shown to be slightly lower than before, ranging between 1.1 per cent and 2.6 per cent if only the agricultural impacts are considered, and up to 5.8 per cent in the worst-case scenario when fishing impacts are included . The reason for the slightly lower figures in the CGE model is that people who lose their livelihoods due to the decline in agriculture and fishing will, sooner or later, find employment elsewhere, leading to increased production in the sectors where they begin to work. However, two important points should be noted in this regard. The first point is that this expansion in other sectors only offsets a small part of the overall losses to the national economy. The second point is that this new employment causes a substantial decline in wages, especially for unskilled labour.

The only adaptation measure considered in our simulations is the currently planned expansion of irrigated high value crop production. Our results indicate that even in the more optimistic scenarios, this measure will not be enough to offset the likely negative climate change effects on other parts of agricultural production.

As well as analysing the total GDP impacts, our aim was also to evaluate the likely distributional effects from climate change. As the traditional agricultural sector is predicted to suffer the most from climate change, it is not surprising that the rural households within subsistence agriculture will be most negatively affected. In fact, it is clear that the income distribution will be even more unequal following the impacts of climate change. In the combined worst-case scenario for agriculture and fishing, the urban and rural households who own capital within agriculture and business will be least affected, while poorer household groups will be significantly negatively affected. Although people who are dislocated by climate change could find new employment elsewhere, this comes at a social cost; Namibian income distribution, already one of the most (if not *the* most) inequitable in the world, will become even more inequitable. What this will do to social cohesion, if no counteracting policies are put in place, can only be imagined.

The results of this study imply that climate change impacts in a natural-resource based economy are unlikely to be negligible, and the results might serve as guidelines for future policy directions, making sure that a worst-case scenario will not occur.

References

AMCEN/UNEP (2002) *Africa environment outlook. Past, present and future perspectives*. Earthprint, Hertfordshire.

Angula, M. and R. Sherbourne (2003) Agricultural Employment in Namibia: Not the Engine of Wage Employment Growth. *Briefing paper* 16, Institute for Public Policy Research, Windhoek, Namibia.

Arnell, N. W. (1999) 'Climate change and global water resources' *Global Environmental Change* 9: S31-S50.

Arnell, N. W. (2004) 'Climate change and global water resources: SRES emissions and socio-economic scenarios' *Global Environmental Change* 14: 31–52.

Ash, A. J., D. M. S. Smith and N. Abel (2002) 'Land degradation and secondary production in semi-arid and grazing systems: What is the evidence?' In J. F. Reynolds and D. M. Stafford-Smith (eds) *Global Desertification. Do Humans Cause Deserts?* Dahlem University Press, Berlin, Germany.

Barnes, JI, Nhuleipo, O, Muteyauli, PI and MacGregor, J. (2005). Preliminary asset and flow accounts for forest resources in Namibia. DEA Research Discussion Paper no. 70, Ministry of Environment and Tourism, Windhoek, Namibia.

Barnes, J.I, G-M. Lange, O. Nhuleipo, P. Muteyauli, T. Katoma, H. Amapolo, P. Lindeque and P. Erb (2004) Preliminary valuation of the wildlife stocks in Namibia: wildlife asset accounts. Available at http://www.columbia.edu/~gl2134.

Barnes, J.I., C. Schier and G. van Roy (1997) Tourists' willingness to pay for wildlife viewing and wildlife conservation in Namibia. DEA Research Discussion paper no. 15. Ministry of Environment and Tourism, Windhoek, Namibia.

Bautista, R.M. and M. Thomas (2000) Macroeconomic and Agricultural Reforms in Zimbabwe: Policy Complementarities Toward Equitable Growth. Trade and Macroeconomics Division, International Food Policy Research Institute, Washington DC.

Blackie, R. (1998) Emission scenarios and mitigation options for Namibia: A preliminary overview. Mitigation study for the Namibian climate change study – Economic scenarios, emission scenarios and mitigation options. Volume 3. Prepared for the Desert Research Foundation of Namibia as part of the Namibia Country Study on Climate Change.

Bond, W. J. and S. Archibald (2003) 'Confronting complexity: fire policy choices in South African savanna parks' *International Journal of Wildland Fire* 12: 381-389.

Bond, W. J. and G. F. Midgley (2000) 'A proposed CO_2-controlled mechanism of woody plant invasion in grasslands and savannas' *Global Change Biology* 6(8): 865-869.

Bond, W. J., G. F. Midgley and F. I. Woodward (2003) The importance of low atmospheric CO_2 and fire in promoting the spread of grasslands and savannas. *Global Change Biology* 9(7): 973-982.

Bovenberg, A.L. and L.H. Goulder (1996) Optimal Environmental Taxation in the Presence of Other Taxes: General- Equilibrium Analysess, American Economic Review 86(4): 985-1000.

Brown, C. (2007). Presentation at 'Roundtable on climate change, natural resources and economic growth in Namibia', 6 February, Windhoek, Namibia.

Central Bureau of Statistics (2007) Preliminary National Accounts 2006, Central Bureau of Statistics, National Planning Commission, Windhoek, Namibia.

Chidumayo, E. N. (2001) 'Climate and phenology of savanna vegetation in southern Africa' *Journal Of Vegetation Science* 12(3): 347-354.

Dasgupta, P. (2006) *Comments on the Stern Review's Economics of Climate Change* Department of Economics, Cambridge University Available at http://www.econ.cam.ac.uk/faculty/dasgupta/STERN.pdf.

Dasgupta, S., B. Laplante, C. Meisner, D. Wheeler and J. Yan (2007) The impact of sea level rise on developing countries: a comparative analysis. *World Bank Policy Research Working Papers* Available at http://www-wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/2007/02/09/000016406_20070209161430/Rendered/PDF/wps4136.pdf.

Desanker, P. (2003) *Impact of Climate on life in Africa*. WWF, Godalming. Available at http://www.wwf.org.uk/filelibrary/pdf/africa_climate.pdf.

Desanker, P. V., P. G. H. Frost, C. O. Justice and R. J. Scholes (eds) (1997) *The Miombo Network: Framework for a Terrestrial Transect Study of Land-Use and Land-Cover Change in the Miombo Ecosystems of Central Africa*. International Geosphere-Biosphere Programme (IGBP), Stockholm, Sweden.

Deschenes, O. and M. Greenstone (2007) The Economic Impacts of Climate Change: Evidence from Agricultural Output and Random Fluctuations in Weather. *American Economic Review* 97(1): 354-85.

De Wit, M. and J. Stankiewicz (2006) 'Changes in surface water supply across Africa with predicted climate change' *Science Express*. 2 March 2006.

Dixon, R. K., J. Smith and S. Guill (2003) 'Life on the edge: vulnerability and adaptation of African ecosystems to global climate change' *Mitigation and Adaptation Strategies for Global Change* 8(2): 93-113.

Dube, O. P. and G. Pickup (2001) 'Effects of rainfall variability and communal and semi-commercial grazing on land cover in southern Africa rangelands' *Climate Research* 17: 195-208.

Dukes, J. S. and H. Mooney (1999) Does global change increase the success of biological invaders? *Trends in Ecology and Evolution* 14: 135-139.

Du Plessis, P. (1999) Republic of Namibia: First Greenhouse Gas Inventory. A report on sources and sinks of greenhouse gases in Namibia in 1994. Volume 1. Prepared for the Desert Research Foundation of Namibia (DRFN) as part of the Namibia Country Study on Climate Change.

Du Toit, A., M. Prinsloo, W. Durand and G. A. Kiker (2000) Vulnerability of maize production to climate change and adaptation assessment in South Africa. Contribution to the Vulnerability and Adaptation project of the South African Country Study on Climate Change Department of Environmental Affairs and Tourism, Pretoria Available at http://www.sanbi.org/countrystudy/Agriculture%20Report.pdf .

Erasmus, B. F. N., A. S. Van Jaarsveld, S. L. Chown, M. Kshatriya and K. J. Wessels (2002) 'Vulnerability of South African animal taxa to climate change' *Global Change Biology* 8(7): 679.

Goulder, L., ed. (2002). Environmental Policy Making in Economies With Prior Tax Distortions, Edward Elgar, Northampton MA.

Government of Namibia (2002) *Initial National Communication to the United Framework Convention on Climate Change*. July 2002. Available at http://unfccc.int/resource/docs/natc/namnc1.pdf.

Hannah, L., G. F. Midgley, T. Lovejoy, W. J. Bond, M. Bush, J. C. Lovett, D. Scott and F. I. Woodward (2002) 'Conservation of biodiversity in a changing climate' *Conservation Biology* 16(1): 264-268.

Hardy, J. T. (2003) *Climate Change. Causes, Effects and Solutions*. John Wiley and Sons Ltd., San Francisco.

Harrison, G.W., T.F. Rutherford and D.G. Tarr (1997). Quantifying the Uruguay Round *Economic Journal* 107: 1405-1430.

Hesse, C. and J. MacGregor (2006). Pastoralism: drylands' invisible asset? Developing a framework for assessing the value of pastoralism in East Africa. Drylands Issue Paper 142, International Institute for Environment and Development (IIED), London. http://www.iied.org/pubs/pdf/full/12534IIED.pdf.

Hesse, C. and L. Cotula (2006). Climate change and pastoralists: Investing in people to respond to adversity. Sustainable Development Opinion Paper, International Institute for Environment and Development (IIED), London. http://www.iied.org/pubs/pdf/full/11059IIED.pdf.

Hill, J. K., C. D. Thomas, and B. Huntley (1999) 'Climate and habitat availability determine 20th century changes in a butterfly's range margin' *Proceedings of the Royal Society of London Series B - Biological Science* 266: 1197-1206.

Hoffmann, W. A. and R. B. Jackson (2000) 'Vegetation-climate feedbacks in the conversion of tropical savanna to grassland. *Journal of Climate* 13(9): 1593-1602.

Holmgren, M., M. Scheffer, E. Ezcurra, J. R. Gutierrez and G. M. J. Mohren (2001) El Niño effects on the dynamics of terrestrial ecosystems. *Trends in Ecology and Evolution* 16(2): 89-94.

Hudson, D. A. and R. G. Jones (2002) *Regional climate model simulations of present day and future climates of Southern Africa*. Hadley Centre, Bracknell, Technical Note 39.

Hughes, L. (2000) 'Biological consequences of global warming: is the signal already apparent?' *Trends In Ecology and Evolution* 15(2): 56-61.

Hulme, M. (1996) *Climate Change and Southern Africa: An Exploration of Some Potential Impacts and Implications in the SADC Region*. Climatic Research Unit, University of East Anglia, Norwich, United Kingdom.

Hulme, M., R. M. Doherty, T. Ngara, M. G. New and D. Lister (2001) 'African climate change: 1900-2100' *Climate Research* 17: 145-168.

Humavindu, M.N. (2007) Estimating National Economic Parameters for Namibia. In *Essays on Public Finance and Environmental Economics in Namibia.* Ph.Lic. thesis, Umeå Economic Studies no 705, Department of Economics, Umeå University, Sweden.

Humavindu, M.N. (2002) Economics without markets: Policy inferences from nature-based tourism studies in Namibia *DEA Research Discussion Paper* 49 Ministry of Environment and Tourism, Windhoek, Namibia.

Humavindu, M.N. and Barnes, I. J. (2003) Trophy Hunting in the Namibian Economy: An Assessment. *South African Journal of Wildlife Research* 33(2): 65-70.

IPCC (2001) *Impacts, Adaptation, and Vulnerability*. Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.

IPCC (2007) *Climate Change 2007: Impacts, Adaptation and Vulnerability. Summary for Policymakers*. Working Group II Contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report.

Jarvinen, A. (1994) 'Global warming and egg size of birds' *Ecography* 17(1): 108-110.

Kappelle, M., M. M. I. Van Vuuren and P. Baas (1999) 'Effects of climate change on biodiversity: a review and identification of key research issues' *Biodiversity and Conservation* 8: 1383-1397.

Kigotho, W. (2005) 'Decades of drought predicted for Southern Africa' *Science and Development Network* www.SciDev.Net 2 June 2005.

Kiringai, J., J. Thurlow, and B. Wanjala, (2006) "Beyond Recovery: A More Equitable Growth Strategy for Kenya", Kenya Institute for Public Policy Research and Analysis, Nairobi, and International Food Policy Research Institute, Washington, D.C.

Kissui, B. M. and C. Packer (2004) ‘Top-down population regulation of a top predator: lions in the Ngorongoro Crater’ *Proceedings of the Royal Society of London B* (2004) 271: 1867–1874.

Kurukulasuriya, P. and R. Mendelsohn (2006) A Ricardian analysis of the impact of climate change on African cropland. *CEEPA discussion paper number 8*. Centre for Environmental Economics and Policy in Africa, University of Pretoria.

Kurukulasuriya, P**.,** R. Mendelsohn, R. Hassan, J. Benhin, T. Deressa, M. Diop, H. Mohamed Eid, K. Y. Fosu, G. Gbetibouo, S. Jain, A. Mahamadou, R. Mano, J. Kabubo-Mariara, S. El-Marsafawy, E.Molua, S. Ouda, I. Séne, D. Maddison, S. N. Seo and A. Dinar (2006) Will African Agriculture Survive Climate Change? *The World Bank Economic review* 20(3): 367-388.

Lange, G-M. (2005) Economic value of fish stock and the natural wealth of Namibia. In U. R. Sumaila (Ed) *Namibias fisheries: ecological, economic and social aspects* University of Chicago Press, pp. 187-203.

Lange, G-M. (2003) National Wealth, Natural Capital and Sustainable Development in Namibia. *DEA research discussion paper* 56 Ministry of Environment and Tourism, Windhoek, Namibia.

Lange, G-M. (1998) An approach to sustainable water management in Southern Africa using natural resource accounts: the experience in Namibia, *Ecological Economics* 26; 299–311.

Lange, G-M. and D. Motinga (1997) The Contribution of Resource Rents from Minerals and Fisheries to Sustainable Economic Development in Namibia. *DEA research discussion paper* 19 Ministry of Environment and Tourism, Windhoek, Namibia.

Lange, G-M., K. Schade, J. Ashipala and N. Haimbodi (2004) *A Social Accounting Matrix for Namibia, 2002 - a Tool for Analysing Economic Growth, Income Distribution and Poverty*. NEPRU working paper 97 The Namibian Economic Policy Research Unit, Windhoek, Namibia.

Lange, G-M., J. I. Barnes and D. Motinga (1998) Cattle Numbers, Biomass, Productivity, and Land Degradation in the Commercial Farming Sector of Namibia. *Development Southern Africa* 15(4): 555-572.

Leemans, R. and A. Kleidon (2002) ‘Regional and global assessment of the dimensions of desertification’ In J. F. Reynolds and D. M. Stafford-Smith (eds) *Global Desertification. Do Humans Cause Deserts?* Dahlem University Press, Berlin, Germany, pp. 215-232.

Leemans, R. and A. van Vliet (2004) *Extreme weather: does nature keep up?* WWF/Wageningen University, the Netherlands.

Leemans, R., and A. Kleidon (2002) ‘Regional and global assessment of the dimensions of desertification’. In J. F. Reynolds and D. M. Stafford-Smith (eds) *Global desertification. Do humans cause deserts?* Dahlem University Press, Berlin, Germany, pp. 215-232.

Lioubimtseva, E., and J. M. Adams (2004) Possible implications of increased carbon dioxide levels and climate change for desert ecosystems. *Environmental Management* 33(Supplement 1): S388-S404.

Löfgren, H., R. Lee Harris and S. Robinson (2002) A Standard Computable General Equilibrium (CGE) Model in GAMS. International Food Policy Research Institute (IFPRI), Washington D.C.

Maddison, D. (2006), Further Comments on the Stern Review. Department of Economics, Birmingham University Available at http://www.economics.bham.ac.uk/maddison/Stern%20Comments.pdf.

Maggs, G. L., P. Craven, H. H. Kolberg (1998) 'Plant species richness, endemism, and genetic resources in Namibia' *Biodiversity and Conservation* 7: 435-446.

Martin, W. and L.A. Winters (eds.) (1996) The Uruguay Round and the Developing Economies, New York: Cambridge University Press.

McClean, C. J., J. C. Lovett, W. Küper, L. Hannah, J. H. Sommer, W. Barthlott, M. Termansen, G. F. Smith, S. Tokumine and J. R. D. Taplin (2005) 'African plant diversity and climate change' *Annals of the Missouri Botanical Garden* 92(2): 139-152.

Mendelsohn, R. O. (2006), A Critique of the Stern Report, *Regulation*, 29, (4), 42-46.

Mendelsohn, R. O. and M. Reinsborough (2007) A Ricardian Analysis of US and Canadian Farmland. *Climatic Change* 81(1): 9-17.

Mendelsohn, R. O., M.E. Schlesinger and L. J. Williams (2000) Comparing Impacts across Climate Models, *Integrated Assessment* 1: 37-48.

Mendelsohn, R., A. Dinar and L. Williams (2006) The distributional impact of climate change on rich and poor countries. *Environment and Development Economics* 11: 159-178.

Midgley, G. 2007. Presentation at 'Roundtable on climate change, natural resources and economic growth in Namibia', 6 February, Windhoek, Namibia.

Midgley, G. F., W. J. Bond, S. J. E. Wand and R. Roberts (1999) Will Gullivers travel? Potential causes of changes in savanna tree success due to rising atmospheric CO_2. In S. Ringrose and R. Chanda (eds) *Towards Sustainable Management in the Kalahari Region - Some Essential Background and Critical Issues*.University of Botswana, Gaberone, Botswana.

Midgley, G., G. Hughes, W. Thuiller, G. Drew and W. Foden (2005) *Assessment of Potential Climate Change Impacts on Namibia's Floristic Diversity, Ecosystem Structure and Function*. South African National Botanical Institute, Cape Town.

Millennium Ecosystem Assessment (2005) *Ecosystems and Human Well-being - Desertification synthesis*. Island Press, Washington D.C.

Ministry of Fisheries and Marine Resources (2002) *Management recommendations for pilchard based on the biological state of the stock*. Report for the Marine Resources Advisory Council. Directorate of Resource Management Report no 2/2002.

Nicholson, S. E. (2002) 'What are the key components of climate as a driver of desertification?' In J. F. Reynolds and D. M. Stafford-Smith (eds) *Global desertification. Do humans cause deserts?* Dahlem University Press, Berlin, Germany, pp. 41-57.

Njaya, F. and C. Howard (2006) 'Climate and African fisheries' *Tiempo* 59: 13-15.

Nordhaus, W. D. (2006) Geography and Macroeconomics: New Data and New Findings, *Proceedings of the National Academy of Sciences* Available at http://www.pnas.org/cgi/content/abstract/103/10/3510.

Nordhaus, W. D. (2006) The Stern Review on the Economics of Climate Change Available at http://nordhaus.econ.yale.edu/SternReviewD2.pdf.

Nordhaus, W. D. and J. Boyer (1999) Roll the Dice Again: Economic Models of Global Warming, Yale University Available at http://www.econ.yale.edu/~nordhaus/homepage/web%20pref%20102599.PDF.

Nordhaus, W. D. and Z. Yang (1996) RICE: A Regional Dynamic General Equilibrium Model of Optimal Climate Change Policy *American Economic Review* 86(4): 741-765.

Ogle, K. and J. F. Reynolds (2004) Plant responses to precipitation in desert ecosystems: integrating functional types, pulses, thresholds, and delays. *Oecologia* 141: 282-294.

Ogutu, J. O. and N. Owen-Smith (2003) 'ENSO, rainfall and temperature influences on extreme population declines among African savanna ungulates' *Ecology Letters* 6(5): 412-419.

OPM (2007). The decline in public spending to agriculture – does it matter? OPM Briefing Notes 2007-02, Oxford Policy Management, Oxford, 4pp. www.opml.co.uk.

Palmer, A. R. and A. F. van Rooyen (1998) 'Detecting vegetation change in the southern Kalahari using LandsatTM data'. *Journal of Arid Environments* 39: 143-153.

Parmesan C. and G. Yohe (2003) 'A globally coherent fingerprint of climate change impacts across natural systems' *Nature* 421: 37-42.

Perry, G., J. Whalley and G. McMahon (eds.) (2001). Fiscal Reform and Structural Change in Developing Countries, New-York: Palgrave-Macmillan.

Reid, H. (2005) 'Africa: a crucible for climate change and poverty' in T. Bigg and D. Satterthwaite (eds) (2005) *How to Make Poverty History: the Central Role of Local Organisations in meeting the MDGs*. IIED, London. pp 157-175.

Reid, H. (2006) 'Climatic change and biodiversity in Europe' *Conservation and Society* 4(1): 84-101.

Riddell, P.J., Westlake, M. and J. Burke (2006). Demand for products of irrigated agriculture in sub-Saharan Africa. FAO Water Reports no. 31, Food And Agriculture Organization of the United Nations, Rome. ftp://ftp.fao.org/agl/aglw/docs/wr31e.pdf.

Root T. L., J. T. Price, K. R. Hall, S. H. Schneider, C. Rosenzweig and J. A. Pounds (2003) 'Fingerprints of global warming on wild animals and plants' *Nature* 421: 57-60.

Roux, J-P (2003) 'Risks'. Chapter 8 in F. Molloy and T. Reinikainen (eds) *Namibia's Marine Environment*. 162pp. Directorate of Environmental Affairs, Ministry pf Environment and Tourism.

Ruosteenoja, K., T. R. Carter, K. Jylhä and H. Tuomenvirt (2003) *Future climate in world regions: an intercomparison of model-based projections for the new IPCC emissions scenarios*. Finnish Environment Institute, Helsinki, no. 644.

Scholes, R. J. and R. Biggs (eds) (2004) *Ecosystems Services in Southern Africa: A Regional Assessment*. CSIRO, Pretoria.

Schwinning, S., and O. E. Sala (2004) Hierarchy of responses to resource pulses in arid and semi-arid ecosystems. *Oecologia* 141: 211-220.

Secretariat of the CBD (2003) *Interlinkages Between Biological Diversity and Climate Change: Advice on the Integration of Biodiversity Considerations into the Implementation of the United Nations Framework Convention on Climate Change and Its Kyoto Protocol*. CBD Technical series no. 10. Secretariat of the CBD, Montreal, Canada.

Seo, S. N. and R. Mendelsohn (2006) Climate change impacts on animal husbandry in Africa: a Ricardian analysis. *CEEPA discussion paper number 9* Centre for Environmental Economics and Policy in Africa, University of Pretoria.

Simms, A. and H. Reid (2005) *Africa – Up in smoke?* The second report from the Working Group on Climate Change and Development. New Economics Foundation, London.

Smith, S. D., T. E. Huxman, S. F. Zitzer, T. N. Charlet, D. C. Housman, J. S. Coleman, L. K. Fenstermaker, J. R. Seemann and R. S. Nowak (2000) Elevated CO_2 increases productivity and invasive species success in an arid ecosystem. *Nature* 408: 79-82.

Sokona, Y. and F. Denton (2001) 'Climate change impacts: can Africa cope with the challenges?' *Climate Policy* 1: 117– 123.

Spalding-Fecher, R. and S. Moodley (2002) Economic Valuation of Increased Malaria Due to Climate Change: A South African Case Study. *South African Journal of Economic and Management Sciences*, N.S. 5(2): 395-412.

Stage, J. and Fleermuys, F. (2001) Energy use in the Namibian economy from 1995 to 1998 *Development Southern Africa* 18 (4): 423 – 441.

Stern, N. (2006) Stern Review on the Economics of Climate Change. October 2006. Crown copyright 2006. Available at http://www.hmtreasury.gov.uk/independent_reviews/stern_review_economics_climate_change/sternreview_index.cfm.

Sterner, T. and U.M. Persson (2007) An even Sterner Review – Introducing Relative Prices into the Discounting Debate *work in progress* Available at http://www.hgu.gu.se/files/nationalekonomi/personal/thomas%20sterner/b88.pdf.

Suich, H. (2002) Development of preliminary tourism satellite accounts for Namibia. *Development Southern Africa* 19(1): 105-121.

Tarr, J. (1998) An overview of Namibia's vulnerability to climate change. Volume 2. Prepared for the Desert Research Foundation of Namibia as part of the Namibia Country Study on Climate Change.

Thomas, C. D., A. Cameron, R. E. Green, M. Bakkenes, L. J. Beaumont, Y. C. Collingham, B. F. Erasmus, M. F. De Siqueira, A. Grainger, L. Hannah, L. Hughes, B. Huntley, A. S. Van Jaarsveld, G. F. Midgley, L. Miles, M. A. Ortega-Huerta, A. T. Peterson, O. L. Phillips, S. E. Williams (2004) 'Extinction risk from climate change' *Nature* 427: 145-148.

Thomas, D. S. G., M. Knight and G. F. S. Wiggs (2005) 'Remobilization of southern African desert dune systems by twenty-first century global warming' *Nature* 435: 1218-1221.

Thomas, D. and C. Twyman (2004) 'Good or bad rangeland? Hybrid knowledge, science, and local understandings of vegetation dynamics in the Kalahari' *Land Degradation and Development* 15: 215-231.

Thomas, D. and C. Twyman (2005) 'Equity and justice in climate change adaptation amongst natural-resource-dependent societies' *Global Environmental Change* 15: 115-124.

Thurlow, J. (2004) A Dynamic Computable General Equilibrium Model for South Africa: Extending the Static IFPRI Model. *Trade and Industrial Policy Strategies* (TIPS) working paper 1-2004, Johannesburg, South Africa.

Thurlow, J. and D.E. van Seventer (2002) A Standard Computable General Equilibrium Model for South Africa *Trade and Macroeconomics Division discussion paper* 100, International Food Policy Research Institute, Washington D.C.

Tol, R. S. J. (2002) New Estimates of the Damage Costs of Climate Change, Part I: Benchmark Estimates, *Environmental and Resource Economics* 21(1): 47-73.

Tol, R.S.J (2002) New Estimates of the Damage Costs of Climate Change, Part II: Dynamic Estimates, *Environmental and Resource Economics* 21(1): 135-160.

Tol, R. S. J. (2006) The Stern Review of the Economics of Climate Change: A Comment. *Energy and Environment* 17 (6): 977-981.

Turpie, J. (2003) The Existence Value of Biodiversity in South Africa: How Interest, Experience, Knowledge, Income and Perceived Level of Threat Influence Local Willingness to Pay. *Ecological Economics* 46(2): 199-216.

Turpie, J., G-M. Lange, R. Martin, R. Davies and J. Barnes (2004). Economic Analysis and Feasibility Study for Financing Namibia’s Protected Areas. http://www.span.org.na/Economic_Analysis_and_Feasibility_study_for_Financing_Protected_Areas.pdf.

Turpie, J., H. Winkler, R. Spalding-Fecher and G. Midgley (2002) Economic Impacts of Climate Change in South Africa: A Preliminary Analysis of Unmitigated Damage Costs. *Research paper Southern Waters Ecological Research, Consulting, Energy and Development Research Centre*, University of Cape Town.

UNDP (2006). Human Development Report 2006. United Nations Development Programme.

Von Maltitz, G. P., R. J. Scholes, B. Erasmus and A. Letoalo (2007) ‘Adapting conservation strategies to accommodate impacts of climate change’. AIACC Working Paper No.5, AIACC Project , Washington DC.

Vredin-Johansson, M. (1999) Valuing a Peripheral Environmental Amenity. The Swedes’ Willingness to Pay for the Survival of the African Elephant. In *Economics without markets*, Ph.D. thesis, Umeå Economic Studies No. 517, Department of Economics, Umeå University.

Walther, G. R. (2000) ‘Climatic forcing on the dispersal of exotic species’ *Phytocoenologia* 30(3-4): 409-430.

Walther, G. R., E. Post, P. Convey, A. Menzel, C. Parmesan, T. Beebee, J-M. Fromentin, O. Hoegh-Guldberg and F. Bairlain (2002) ‘Ecological responses to recent climate change’ *Nature* 416: 389-395.

Washington, R., M. Harrison and D. Conway (2004) *African climate report*. A report commissioned by the UK Government to review African climate science, policy and options for action.

Weber, M. and G. Hauer (2003) A Regional Analysis of Climate Change Impacts on Canadian Agriculture *Canadian Public Policy* 29(2): 169-180.

Weitzman, M. (2007) “The Stern Review of the Economics of Climate Change”, *Journal of Economic Literature*, 45 (3): 703-724.

Weitzman, M. (2007) The Role of Uncertainty in the Economics of Catastrophic Climate Change Available at http://www.economics.harvard.edu/faculty/Weitzman/papers/Catastrophe.pdf.

Wichmann, M. C., F. Jeltsch, W. R. J. Dean, K. A. Moloney and C. Wissel (2003) ‘Implication of climate change for the persistence of raptors in arid savanna’ *Oikos* 102(1): 186-202.

Winters, P., R. Murgai, E. Sadoulet, A. de Janvry and G. Frisvold (1998) Economic Impacts of Climate Change on Developing Countries. *Environment and Resource Economics* 12:1-24.

Woodward, F. I. and M. R. Lomas (2004) ‘Simulating vegetation processes along the Kalahari transect’ *Global Change Biology* 10(3): 383-392.

World Bank (2000) *Can Africa Claim the 21st Century?* World Bank, Washington D.C.

WRI (1996) *World Resources: a Guide to Global Environment 1996-1997*. World Resources Institute, UNEP, World Bank. Oxford University Press, Oxford.

Yohe, G., R. S. J. Tol and D. Murphy (2007) On Setting Near-term Climate Policy while Dust Begins to Settle: The Legacy of the Stern Review. *Energy and Environment*, forthcoming Available at http://www.fnu.zmaw.de/fileadmin/fnu-files/publication/working papers/sternenergyenvironment2.pdf.

Yom-Tov, Y. (2001) 'Global warming and body mass decline in Israeli passerine birds' *Proceedings of the Royal Society of London Series B-Biological Sciences* 268(1470): 947-952.

Yom-Tov, Y. and S. Yom-Tov (2004) 'Climatic change and body size in two species of Japanese rodents' *Biological Journal of the Linnean Society* 82(2): 263-267.

Zeidler, J., Jones, J. and R. Chunga (2007). Presentation at 'Roundtable on climate change, natural resources and economic growth in Namibia', 6 February, Windhoek, Namibia.

Appendix 1

People present at the roundtable discussion on climate change, natural resources and economic growth held on February 6th 2007 at the Directorate of Environmental Affairs, Windhoek, Namibia.

Name	Institutional affiliation
Phoebe Barnard	South African National Biodiversity Institute
Jon Barnes	Ministry of Environment and Tourism
Chris Brown	Namibia Nature Foundation
Reagan Chunga	Integrated Environmental Consultants Namibia
Titus Endjala	Ministry of Agriculture, Water and Forestry – Department of Water Affairs
Jurgen Hoffman	Agricultural Trade Forum
Jessica Jones	Integrated Environmental Consultants Namibia
Glenn-Marie Lange	Columbia University
James Macgregor	International Institute for Environment and Development
Ben van der Merwe	ENVESCC
Guy Midgley	South African National Biodiversity Institute
Edgar Mowa	Ministry of Environment and Tourism
Peter Muteyauli	Ministry of Environment and Tourism
Olimpio Nhuleipo	Ministry of Environment and Tourism
Detlof von Oertzen	Desert Research Foundation of Namibia
Pierre du Plessis	CRIAA SA-DC
Hannah Reid	International Institute for Environment and Development
Linda Sahlen	Umeå University
Sem Shikongo	Ministry of Environment and Tourism
Juliane Zeidler	Integrated Environmental Consultants Namibia

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The Environmental Economics Programme (EEP,) which forms part of IIED's Sustainable Markets Group, seeks to develop and promote the application of economics to environmental issues in developing countries. This is achieved through research and policy analysis on the role of the environment and natural resources in economic development and poverty alleviation, specifically:

- the impact of economic policies and market liberalisation on natural resource management, pollution and environmental quality;
- the economic value of natural resources and environmental services, and the costs of environmental degradation; and
- policy incentives to internalise environmental values in economic decision-making.

A unifying theme in much of the progamme's work is capacity building through collaborative research. To this end, EEP works with a range of partners around the world, including government and multilateral agencies, private enterprise, academic institutions, research organisations and advocacy groups.

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