PART VIII:

CLIMATE CHANGE

Chapter 21: Review of the Climate Change Situation in Namibia: Projected Trends, Vulnerability and Impacts

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1 Introduction

Climate change is one of the biggest challenges and threats that humanity has ever faced. It has been acknowledged as "one of the greatest challenges of our time" by many organisations including the United Nations. The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods".[1] This definition slightly differs from the definition of the Intergovernmental Panel on Climate Change (IPCC), which refers to climate change as "a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer".[2] The IPCC's definition therefore refers to any change in climate over time, irrespective of the causes, whether due to natural variability or anthropogenic causes.

Climate change has largely resulted from anthropogenic influences on the climate system. In 2014, the IPCC reported that human influence on the climate system is clear, and that recent anthropogenic emissions of greenhouse gases are the highest in history. The IPCC[3] estimated that human activities have caused approximately 1.0°C of global warming above pre-industrial levels, and is likely to reach 1.5°C between 2030 and 2052 if it continues at current rate. These influences have had widespread impacts on human and natural systems. These impacts necessitate global actions to mitigate its causes, adapt to, and cope with the impact thereof. Actions to do the above are being taken through commitments to international instruments such as the United Nations Framework Convention on Climate Change and the Paris Agreement.[4] It has been acknowledged that a certain amount of climate change is apparently unavoidable, regardless of reductions in emissions, thus necessitating adaptation.[5] Human adaptation to a changing environment has been going on for millennia, but the current scenario calls for the need to up-scale and accelerate multi-level and cross-sectoral climate

1 UN (1992).
2 IPCC (2007d).
3 IPCC (2018).
4 UN (2015).
5 IPCC (2007c).

change mitigation strategies and transformational adaptation.[6] Namibia ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1995 as a Non-Annex I Party. Namibia therefore has an obligation to submit information in accordance with Article 4, paragraph 1 of the UNFCCC. Such Reports include the National inventory of anthropogenic greenhouse gas (GHG) emissions by sources and removals by sinks GHGs, National Communications to the Convention, and Biennial Update Reports (BURs). Namibia's Initial National Communication to the Conference of Parties of the UNFCCC was submitted in 2002[7] in accordance with decisions taken at various COPs to the UNFCCC. The Second National Communication was submitted in 2010.[8] The Third National Communication was submitted in 2015[9] while the Fourth National Communication was submitted in 2020.[10] However, with the adoption of the Cancun Agreements at COP16 in 2011 held in Mexico, the reporting by non-Annex I Parties in national communications, including national GHG inventories should also include information on mitigation actions, their effects and support received. Such Parties should also submit Biennial Update Reports (BURs). Thus, Namibia submitted its first BUR in 2014,[11] the second BUR in 2016[12] and the third BUR in 2018.[13] According to the requirements, BURs should contain updates on national GHG inventories, information on mitigation actions, needs and support received and institutional arrangements done by the Party and should be submitted every two years. Namibia also submitted its Intended Nationally Determined Contributions (INDC) in 2015[14] and an updated Nationally Determined Contribution in 2021[15] in readiness for COP26 which was held in November 2021 in Glasgow, Scotland. The Ministry of Environment, Forestry and Tourism (MEFT) through the Directorate of Environmental Affairs (DEA), Division of Multilateral Environmental Agreements, is responsible for overseeing the coordination of climate change issues in Namibia.

Despite its insignificant contributions to greenhouse gas emissions, southern Africa is very susceptible to the impacts of climate change, including sea level rise, increased frequency and intensity of extreme weather events such as floods and droughts. Most of southern Africa is already largely water-stressed, with high frequencies of drought. Climate change is exacerbating this problem, considering that the region's susceptibility in the agricultural sector is rooted in its widespread rain-fed agriculture.[16] The

6 IPCC (2018).
7 GRN (2002d).
8 GRN (2011a).
9 GRN (2015a).
10 GRN (2020).
11 GRN (2014a).
12 GRN (2016c).
13 GRN (2018g).
14 GRN (2015a).
15 GRN (2021a).
16 CEEPA (2006); IPCC (1997); Hulme (1996).

vulnerability of the region's agricultural sector to climate change has been well documented over the last two decades in the respective National Communications to the UNFCCC of several southern African countries. Moreover, scientific modelling suggests that southern Africa will be hit harder by climate change than most regions of the globe, becoming hotter and drier.[17]

In many countries of the southern African region, close to 70% of the population lives in rural areas where their direct dependence on the natural ecosystems with their goods and services is high. The impacts of climate change are more pronounced in these rural communities, who are often poor and marginalised. Their livelihoods are largely dependent on agriculture, a sector which is very sensitive to climate change. Studies have identified several sectors where Namibia is most vulnerable to climate change. These include water resources, fisheries and marine resources, agriculture, biodiversity and ecosystems, coastal zones and systems, health, and energy. Therefore, Namibia has to continue taking measures and actions designed to mitigate climate change and to capacitate communities to cope with and adapt to the effects of climate change.

This Chapter highlights the projected changes in climate in southern Africa, with particular focus on Namibia. The vulnerability of Namibia to climate change and the impacts of climate change on various sectors of the economy and on biodiversity are also reviewed. Some of the measures taken by the Namibian Government and other stakeholders to deal with the challenges of climate change are also summarised.

2 Namibia's Contribution to Greenhouse Gas (GHG) Emissions

Parties to the United Nations Framework Convention on Climate Change (UNFCCC) are categorised into three main groups according to differing commitments. Thus, certain groups of developing countries are recognised as being especially vulnerable to adverse impacts of climate change, including countries with low-lying coastal areas and those prone to desertification and drought. These are classified as non-Annex 1 countries, and most developing countries including Namibia belong to this group. According to the UNFCCC process, the baseline values for greenhouse gas (GHG) emissions for non-Annex 1 countries are pegged at 1994 as the base year. The IPCC Guidelines[18] require that GHG emission estimates should be compiled for the sectors of Energy, Industrial Processes and Product Use (IPPU), Agriculture, Forestry, and Other Land Use (AFOLU) and Waste.

A wealth of scientific literature indicates clear evidence that global climate has changed and will continue to change over the next century, both globally and locally

17 IPCC (2007c and 2018).
18 IPCC (2006).

due to increased GHG concentrations in the atmosphere. These increases are mainly due to human activities, most notably the use of fossil fuels. Africa's contribution to greenhouse gas emissions is insignificant at only 3.8% compared to the largest emitters China (23%), United States of America (19%), and the European Union (13%) of global emissions.[19] Just like many other countries in southern Africa, except South Africa, Namibia's contribution to greenhouse gas emissions is insignificant.[20] Globally, Agriculture, Forestry and Other Land Use (AFOLU) activities accounted for around 13% of CO_2, 44% of methane (CH_4), and 81% of nitrous oxide (N_2O) emissions from human activities during 2007-2016, representing 23% of total net anthropogenic emissions of GHGs.[21]

Namibia neither produces fossil fuels of its own, nor refines any fossil fuels though explorations have been taking place. Currently there are oil and gas explorations in Kavango Region and in southern Namibia by ReconAfrica and Shell, respectively. Therefore, only fossil fuel consumed and combusted in the country was used to estimate emissions in the energy sector under Fuel Combustion Activities.[22] The Namibian economy is not energy-intensive, as it relies primarily on agriculture, fisheries and mining without much secondary processing.[23] A greenhouse gas emissions inventory of Namibia has been performed in 1994[24] and compared and reviewed comprehensively in 2000.[25] Stand-alone GHG Inventory Reports are also available.[26] However, estimates in these and other documents tend to vary somewhat but those given in the Third Biennial Report (BUR3) are the latest and best estimates of emissions in light of available data and information.[27]

Namibia's Fifth National Development Plan (NDP5) aims to expedite the implementation of the country's development strategy, including environmental sustainability. To this end, tackling climate change is high on the country's agenda. The country is committed to complement the international efforts in curbing GHG emissions in accordance with the UNFCCC provisions. Namibia has compiled and submitted GHG inventories in accordance with Article 4.1(a) of the Convention. The country has recorded an increase of 12.1% in emissions from 1994 to 2014.[28] The Agriculture, Forestry and Other Land Use (AFOLU) sector remained the leading emitter throughout this period (91.7% in 1994 to 81.5% in 2014) followed by Energy, which increased from 1,464 Gg CO_2eq (7.8% in 1994) to 3,234 Gg CO_2eq (15.3%) in 2014. Emissions

19 Sy (2015).
20 GRN (2002d); Hartz / Smith (2008).
21 IPCC (2020).
22 GRN (2014a).
23 GRN (2002d).
24 Du Plessis (1999a).
25 Hartz / Smith (2008).
26 GRN (2015c; 2016d; 2018h).
27 GRN (2018g).
28 Ibid.

from the AFOLU sector increased from 17,328 Gg CO_2eq in 1994 to 19,275 Gg CO_2eq in 2012 before declining to 17,271 in 2014 (a 0.3% decrease from the 1994 to 2014). Hence, the main target is to reduce deforestation rate and achieve a decrease in CO_2eq by over 13.5Mt by 2030.[29] The Industrial Processes and Product Use (IPPU) became the third emitter from 2003. Emissions from the IPPU sector increased from 22 Gg CO_2eq in 1994 to 522 Gg CO_2eq in 2014, a very sharp increase accounted for by the commencement of Zinc production in 2003 and cement production in 2011.[30] Emissions from Waste doubled between 1994 and 2014 (from 75 Gg CO_2eq in 1994 to 153 Gg CO_2eq in 2014). Despite the increases in emissions stated above, the country has remained a net sink of GHG over the period 1994 to 2014 whereby removals exceeded emissions. The net removal of CO_2 increased by 26.3% from 1994 to 2014 (increase of 20,484 Gg CO_2eq from 77,770 Gg CO_2eq in 1994 to 98,254 Gg CO_2eq in 2014). Trends in emissions and removals are summarised in the Table below (NB: 1994 is the base year).

Table 1: GHG Emissions by Sector and Removals from 1994 to 2014

YEAR	EMISSIONS (Gg CO_2eq)					REMOVALS (Gg CO_2eq)	
	Energy	IPPU	AFOLU	Waste	TOTAL	AFOLU	Net
1994	1,464	22	17,328	75	18,889	-96,659	-77,770
2000	1,934	25	16,637	88	18,684	-108,067	-89,383
2002	2,163	27	16,073	91	18,353	-112,687	-94,333
2004	2,521	237	15,879	103	18,742	-114,949	-96,208
2006	2,823	255	17,003	112	20,194	-109,119	-88,925
2008	2,752	291	16,256	117	19,416	-114,977	-95,561
2010	2,923	301	17,365	131	20,720	-107,364	-86,644
2012	3,003	515	19,875	149	23,542	-104,485	-80,943
2014	3,234	522	17,271	153	21,180	-119,434	-98,254

Source: Table compiled by the author based on figures from GRN (2018g).

Emissions analysis by respective gases did not change during the period 1994 to 2014. CO_2 has remained the main contributor, followed by CH_4 and N_2O. The share of CO_2 increased while that of CH_4 and N_2O declined between 1994 and 2014. In 2014 the contributions were 63.44% CO_2, 23.98% CH_4 and 12.58% N_2O.[31] Emissions of indirect GHGs (CO, NO_X and Non-methane volatile organic compounds (NMVOC)) and SO_2 showed varied trends: nitrogen oxides (NO_X) decreased from 48.4 Gg in 1994 to 38.2 Gg in 2014; Carbon monoxide (CO) decreased from 2198 Gg in 1994 to 939 Gg

29 GRN (2021a).
30 Ibid.
31 GRN (2018g).

in 2014; NMVOC increased from 15.9 Gg in 1994 to 24.5 Gg in 2014; Sulphur dioxide (SO_2) varied between 1.9 Gg and 4.2 Gg (2.6 in 1994 and 2.7 in 2014).[32]

Namibia aimed for a reduction of 89% of its GHG emissions by 2030 compared to the BAU scenario, meaning that the projected GHG emissions to be avoided in 2030 is of the order of 20000 Gg CO_2eq (inclusive of sequestration in the AFOLU sector) compared to the 'Business as Usual' (BAU) scenario of 24.167 MtCO_2eq.[33] However, this target was recently revised to aim at a reduction of 91%.[34] This revised target has been viewed by some quarters as being ambitious due to the lack of clarity on where the necessary funding would come from.[35] The estimated amount for both adaptation and mitigation is about USD 5.33 billion.[36] With reference to the AFOLU sector, it is important to note that vegetation growth captures CO_2 thereby acting as a sink. The clearing of vegetation has the opposite effect. Namibia has a significant land area that is bush-encroached by species such as *Senegalia mellifera*, *Terminalia sericea*, and *Dichrostachys cinerea*. Bush encroachment largely results from poor rangeland management practices which lead to overgrazing and upsetting the natural balance between woody plants and grasses such that the woody component proliferates. Though agriculturally undesirable, the impact of bush encroachment is highly significant for Namibia's greenhouse gas emissions profile because bush-encroached areas serve as huge sinks for CO_2. It remains to be seen how the on-going de-bushing programmes and commercial charcoal production will impact this profile in future.

3 Climate Trends and Projections

Future trends in climate are predicted using modelling approaches based on past and present patterns. There are several climate models used worldwide to provide the basis for projections of future climate change scenarios, the most used being General Circulation Models (GCMs). The IPCC's Fourth Assessment Report[37] discussed and evaluated these models at length while the IPCC Fifth Assessment Report[38] highlighted the current situation and future trends in global climate. The heterogeneity in the new generation of climate models and an increasing emphasis on estimates of uncertainty in the projections raise questions about how best to evaluate and combine model results in order to improve the reliability of projections.[39] GCMs work on a spatial scale of

32 Ibid.
33 GRN (2015b).
34 GRN (2021a).
35 Odendaal (2021).
36 GRN (2021a).
37 IPCC (2007c).
38 IPCC (2014a).
39 IPCC (2010).

200-300 km, therefore this limits their projections for changes at a local scale.[40] Nevertheless, GCMs remain a fundamental tool used for assessing the patterns in past change and projecting changes in the future.

There is undisputed evidence for climate change at global scale, much of which is attributed to anthropogenic activities. However, understanding how global climate change may manifest itself at the local level is still a challenge.[41] At a global scale, it is widely recognised that there has been a detectable rise in temperature over the last few decades. This rise in temperatures cannot be explained unless human influence is taken into account.[42] In fact, human activities are estimated to have caused about 1.0°C of the recorded global warming above pre-industrial levels and warming likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate.[43] The regional distribution of temperature increases is not uniform; some regions have experienced greater change than others.[44] Globally, the rate of average temperature increase has been quicker during the latter half of the 20th century than before. This increase in the rate of change is expected to continue, potentially resulting in more rapid changes of climate in the future.[45] Surface temperature is projected to rise over the 21st century under all assessed emission scenarios in GCMs.[46] Rising temperatures will result in more frequent heat waves which will last longer, and that extreme precipitation events will become more intense and frequent in many regions of the world. The ocean will continue to warm and acidify, and global mean sea level will rise. In fact, the IPCC warns that continued anthropogenic emissions of GHGs will cause further warming and long-lasting changes in all components of the climate system which would increase the likelihood of severe and irreversible impacts on people and ecosystems.[47]

There is greater variability in global rainfall, therefore changes in rainfall are harder to detect, both spatially and temporally. Changes in global rainfall patterns have been detected in many parts of the globe. In southern Africa, there have been moderate decreases in annual rainfall and there have also been detectable increases in the number of heavy rainfall events. Trends also indicate an increase in the length of the dry season and increases in average rainfall intensity,[48] suggesting a shorter but more intense rainfall season. Other aspects of global change are increases in intensity and spatial extent of droughts since the mid-1970s; increases in the duration of heat waves during the latter half of the 20th century; shrinking of arctic ice caps since 1978; widespread shrinking of glaciers, especially mountain glaciers in the tropics; increase in upper

40 DRFN / CSAG (2010).
41 Ibid.
42 IPCC (2001).
43 IPCC (2018); Singh *et al*. (2018).
44 DRFN / CSAG (2010).
45 Ibid.
46 IPCC (2014a).
47 Ibid.
48 New *et al*. (2002).

ocean heat content; increases in sea level at a rate of 1.8 mm per year between 1961 and 2003, with a faster rate of 3.1 mm per year between 1993 and 2003.[49] The IPCC[50] predicted that by 2100 the global mean sea level rise will continue well beyond 2100, the magnitude and rate of which will depend on future emission pathways.

There are few studies detailing historical climate trends of Namibia. Due to the arid nature of the country, natural variability is extremely high and is complicated by decadal variability. There is evidence that changes in temperatures in Namibia have followed global trends as described above. There has been a tendency for warmer temperatures in the latter half of the 20th century, which is generally 1-1.2°C warmer than at the beginning of that century. Namibia experienced significant increases in temperature over the past century, with greater increases in winter than in summer, and the largest increases of up to 0.5°C were recorded in the northeast.[51] Namibia's average annual temperature has been increasing at a rate of 0.0123°C annually over the period 1901 to 2016.[52] Maximum temperatures have been getting hotter over the past few decades with significant increases in the frequency of days exceeding 35°C and declines in the frequencies of days with temperatures below 5°C, suggesting an overall warming.[53] This magnitude of warming in Namibia is greater than the global mean temperature change,[54] which is worrisome for Namibia. An increase of 1°C generally implies an increase in evaporation of 5%. For a country with already high evaporation rates (reaching more than 2,660 mm per annum in some areas) this has serious negative consequences, as will be discussed in a separate section below.

Meteorological data for 25 years from the Namibia Meteorological Services indicate that there have been consistent increases in daily maximum temperatures at seven stations (Lüderitz, Keetmanshoop, Windhoek, Hosea Kutako International Airport, Sitrusdal, Grootfontein and Okaukuejo).[55] Long-term temperature and rainfall records from 15 weather stations that had data with durations of between 25 and 60 years in Namibia and the Northern Cape (South Africa) have been examined, and 53% of the stations showed significant increases in temperature over their recording period, while none showed a significant decline.[56] Generally, it is predicted that Namibia will become hotter with predicted increases in temperatures of between 1°C and 3.5°C in summer and 1°C to 4°C in winter over the period 2046 to 2065.[57]

Rainfall patterns are a bit difficult to decipher compared to temperatures. The long-term rainfall records for Namibia (1915 to 1997) suggest an overall national mean of

49 IPCC (2007c).
50 IPCC (2018).
51 Spear *et al*. (2018).
52 GRN (2020a).
53 GRN (2011a).
54 Midgley *et al*. (2005).
55 DRFN / CSAG (2010).
56 Midgley *et al*. (2005).
57 GRN (2011a).

272 mm. In the period from 1981 to 1996 only two of the 16 years had rainfall above this mean.[58] The variation in rainfall year-to-year is extremely high (in excess of 30% everywhere in the country, rising to 70% in southern Namibia and 100% in the Namib Desert). DRFN and CSAG[59] reported that there are no obvious trends in rainfall patterns over a 100-year period, between 1901 and 2000 in Namibia. However, there have been significant increases in the length of the dry season and decreases in the number of consecutive wet days in some areas. The onset of the rainy season is delayed in the north and the end of the rains is earlier than before.[60] Recent experiences by local communities combined with meteorological data confirm real changes in climate patterns over the last few decades in Namibia. Delayed on-set of the rainy season and the shortening of the growing season have been reported. Using different climate modelling scenarios, for the winter period, the lower estimates of change suggest a drying in the south and wetting in the north, whilst upper estimates of change suggest a wetting over most of the country except in the far southwest where reduced rainfall is projected.[61] During summer, the lower estimate of change suggests drying over most of the country except for an increase in rainfall over the coastal regions.

There have been unbearably hot summer temperatures and more frequent droughts. Communities in the northern and north-eastern parts of the country have experienced more severe flooding which has caused significant suffering among local communities. A study conducted in Ohangwena reveals that communities reported variability in rainfall patterns characterised by high intensity of rainfall over a shorter period of time, late coming of the rain, quick disappearance of surface water, less cold winters than before and much stronger and hotter summer sun.[62] These trends in rainfall and temperature patterns, observed by communities in northern Namibia, were confirmed through trend analysis[63] of the period 1900 to 2000. Droughts have also become more frequent, with a very devastating drought during 2018/2019 season throughout the whole country. In Africa, dryland areas (such as Namibia) are also expected to become more vulnerable to desertification caused by climate change.[64]

58 GRN (2002d).
59 DRFN / CSAG (2010).
60 Ibid.
61 Ibid.
62 Nunes *et al*. (2010).
63 Mitchell *et al*. (2004) in Midgley *et al*. (2005).
64 CDKN (2019).

4 Potential and Actual Impacts of Climate Change

4.1 Climate Situation and Vulnerability

Arid environments are areas that receive 100 mm to 250 mm of rain per annum, semi-arid environments receive between 250 mm and 500 mm and hyper-arid environments receive less than 100 mm per annum. In Namibia, annual rainfall is low and highly variable between years, ranging from an average of 25 mm in the southwest to 700 mm in the northeast. Thus, the greatest proportion of the Namibian environment is arid to semi-arid. The coefficient of variation of rainfall is also very high, ranging from 25% in the northeast to more than 80% along the coast in the west.[65] Not only does Namibia receive little rain, it also experiences high rates of evaporation due to high solar radiation, low humidity and high diurnal summer temperatures. This makes the arid nature of the country even worse because the availability of water to plants, animals and humans is limited. It is estimated that only about 1% of rainfall ends up replenishing the groundwater aquifers.[66] This makes the Namibian environment 'harsh' for most organisms, including people. This aridness of the country is caused by weather patterns prevailing in regions with oceanic cold currents – the cold Benguela Current that flows north along the west coast – and situated between 20° and 30° North and South, where dry air of the Hadley Cells descends resulting in persistent high pressure off the coastline.

Global climate change has resulted in changes to the normal patterns of weather and climate in Namibia, causing significant stress on various economic sectors of the country. Overall, it is predicted that there will be a 10% decrease in rainfall in the northern and southern regions of Namibia, and a 20% decrease in the central regions by 2050, and that these figures will worsen to 20% and 30% respectively by 2080.[67] The natural conditions described above make Namibia very susceptible to the effects of climate change because it is already a stressed environment. In general, countries in southern Africa are vulnerable to effects of climate change to varying degrees depending on their local conditions. The likelihood that an individual or group of people will be exposed to, and will be adversely affected by new climatic circumstances depends on the characteristics of the individuals or groups of people in terms of their capacity to anticipate, cope with, resist and recover from the impacts of environmental change.[68] The capacity to adapt to climate change varies among countries and socio-economic groups in the sense that those with the least capacity to adapt are generally the most vulnerable. This also depends on the resources available for mitigation and adaptation.

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65 Mendelsohn *et al*. (2002).
66 GRN (2002d).
67 GRN (2010b).
68 Galvin *et al*. (2004).

Africa is, and will continue to be negatively affected by climate change, more so because of the poor socio-economic conditions which exacerbate the vulnerability of the continent's population. This is particularly so because vulnerability to environmental change does not only depend on changes in frequency or duration of climatic conditions but also on the capacity to respond adequately to those changes as stated above.[69] Poverty and prevailing levels of income disparities influence the resource base of households and this determines the resilience of households to deal with impacts of climate change. Africa's capacity to respond is severely hampered by lack of resources. Given the above situation, there is no doubt that climate change will affect the attainment of most of the United Nations Sustainable Development Goals (SDGs). Namibia's situation is not very different from neighbouring southern African countries. If anything, the local environmental conditions make Namibia even more vulnerable to the effects of climate change. Namibia is an upper middle-income country with a per capita GDP of N$ 74 489 in 2017 and among the highest inequalities in the world of 0.59 Gini coefficient[70] with about 17.4% of the population living in poverty.[71] There are considerable income disparities as reflected by the Gini-coefficient stated above. Being a country that is highly dependent on its natural resource base of minerals, fisheries, agriculture and wildlife, coupled with variable rainfall, frequent droughts and heavy reliance on subsistence agriculture, Namibia is highly vulnerable to climate change.

In Namibia, human vulnerability to climate change is mainly driven by social, political, economic and structural factors – factors which have huge influence on their livelihoods.[72] The vulnerability of Namibia to the effects of climate change have also been reviewed by comparing two contrasting Regions, the Zambezi and Karas Regions, in the northeast and south, respectively.[73] These two regions differ in their average climatic conditions and livelihood systems. Zambezi receives higher rainfall than Karas. Livelihood systems in Zambezi are based on subsistence-oriented maize cultivation, which is combined with a small number of goats and cattle for domestic purposes, approximately supporting 12,000 farming households.[74] Livelihoods in Zambezi used to be flexibly organised around seasonal movement of water but nowadays the region is considered vulnerable to flooding of wetlands. In Zambezi natural shocks such as floods for those living in low-lying wetlands, droughts and climate change, livestock diseases and pests are factors that make people vulnerable. In 2009, close to 700,000 people were either directly or indirectly affected by floods in the north

69 Ibid.

70 NSA (2019).

71 Ibid.

72 Some of these factors have discussed by a number of authors, including van Wyk (2015), the EIF (2019) Lendelvo *et al*. (2018) and Spear *et al*. (2018), among others.

73 DRFN / CSAG (2010).

74 Ibid.

and north-eastern parts of Namibia which cost an estimated N$ 1.7 billion (1% of GDP) worth of damages and losses, both public and private.[75] On the other hand, natural conditions and livelihood systems in southern Namibia are very different from Zambezi. Rural production is dominated by raising small stock such as goats and sheep. In the Karas Region, vulnerability is related to loss of employment, disability and sickness (including HIV and AIDS), having many dependents and orphans.[76]

A number of sectors of the Namibian economy were identified as being particularly vulnerable to the effects of climate change, namely agriculture, biodiversity, ecosystems and tourism, coastal zone, human health and well-being, fisheries and marine resources, energy and water resources. These are discussed below.

4.2 Agriculture

Agricultural production is closely linked to climate, especially precipitation and temperature. IPCC[77] reported that climate change has already affected food security due to warming, changing precipitation patterns, and greater frequency of some extreme events such as floods and droughts. The Namibian climate is characterised by semi-arid and hyper-arid conditions and highly variable rainfall (though about 8% of the country is classified as semi-humid or sub-tropical). These conditions alone pose a great challenge to agricultural production in the country. The sector contributed 7.19% to GDP in 2018[78] and supports over 70% of the population.[79] However, the contribution of this sector has declined from 8.58% in 2010 to a lowest of 5.9% in 2015 before the recent slight rise noted above. Much of this can be attributed to the impacts of climate change. Climate change events have mostly manifested themselves in the forms of droughts, floods and heat waves. About 56.7% of Namibians live in rural areas and the main basis for their livelihoods is subsistence agriculture. Farming is an important source of livelihood for the majority of Namibians living in rural areas.[80] It is estimated that 70% of Namibians are directly dependent on agriculture for their daily livelihoods.[81] Some urban dwellers are also full-time, part-time or weekend farmers. Crop production plays an important role in household food security, particularly in the northern parts of the country where pearl millet (mahangu) is a subsistence dry-land crop and a major staple food. However, mahangu harvests have been affected by

75 GRN (2009).
76 DRFN / CSAG (2010).
77 IPCC (2020).
78 Plecher (2020).
79 GRN (2011b:3).
80 Lendelvo *et al*. (2018).
81 Uebelhoer *et al*. (2015).

extensive flooding and poor yields in the last few years,[82] an indication of possible impacts of climate change on crop production. Maize, wheat, rice and other grains and horticultural crops are also produced. Livestock production (especially cattle, goats and sheep) is the driver of the agricultural economy, with meat being a major export of Namibia, particularly to Europe. Less than 10% of the land surface is used for crop production while livestock production takes place on about 75% of the land.[83]

There have been attempts to model the potential impacts of climate change on agricultural production,[84] but such attempts have been constrained by the lack of reliable data (in some cases) as well as the inherent uncertainties within the General Circulation Models (GCMs) themselves when applied to local scales such as farms. A modelling attempt for Rundu, in the Kavango East Region has indicated that the number of days exceeding 34°C during the six hottest months of the year will increase from 67 to 118 between 2046 and 2065.[85] This means that even a hardy crop such as mahangu will struggle to withstand such prolonged dry periods. Models were developed by the Africa Adaptation Project Namibia[86] to determine potential yields and planting windows for the middle of the 21st century for maize and millet production but the models were inconclusive. Current climatic trends suggest a shorter growing season with a late onset of the rains and an early cessation of the rains. This is already being witnessed in some areas with significant negative impacts on agricultural production.

During the 2008/9 season, the Agronomic Board of Namibia commented that "floods and droughts can easily occur simultaneously and even within close geographic proximity, as we have seen for the past few years". [87] They contended that grain production, especially millet surplus production, could seriously be hampered if solutions in terms of crop insurance, production methods, cultivars, alternative crops, and financing schemes are not found. These are not encouraging signs as climate projections indicate that the growing season will start later than usual in the northeast, with onset of rains delayed by about half a day per year (meaning that currently the season starts about 20 days later than during the last century). This indicates early cessation of the growing season and significant negative impacts on the agriculture sector.

The livestock subsector is also currently suffering the effects of climate change and will further be negatively affected. Grazing rangelands are affected by alterations in precipitation regimes, temperature and atmospheric concentrations of CO_2. All these factors affect net above-ground primary productivity (NPP). There is likely going to be shifts in ratios of C3/C4 species of grasslands, changes in evapotranspiration and

82 NAB (2006).
83 GRN (2021a).
84 Dirkx *et al*. (2008).
85 Ibid.
86 UNDP (undated).
87 NAB (2009).

run-off and changes in forage quality. If the quantity and quality of NPP is reduced as predicted, then cattle production will also decline. The 2018/19 season experienced one of the worst climate change-induced droughts in recent times throughout Namibia. There was wide-spread deficit of forage and water resulting in over 88,000 livestock deaths.[88] Changes in climate will lead to alterations in the boundaries between rangelands and other biomes such as deserts and woodlands through shifts in species composition and indirectly through changes in wildfire regimes and opportunistic cultivation. Modelling analysis projected significant changes in vegetation structure and function in several areas of Namibia by 2080, where arid vegetation types will increase in cover by almost 20% by 2050, and up to 43% by 2080 in the absence of CO_2 fertilisation effect.[89]

Heat and water stress on livestock will lead to decreases in feed intake, milk production and rates of reproduction.[90] The 2018 IPCC Special Report[91] paints dire potential consequences a 1.5°C warming would have on agriculture. Fewer areas would be viable for livestock production but this requires more data to be certain. Risks to food security will intensify due changes in crop nutrient content, yield reduction, increase in pests and price escalation. These negative impacts will have major implications for hunger and poverty eradication and overall attainment of the SGDs. Higher average temperatures have been reported to reduce conception rates in cattle, largely due to the positive correlation between high rectal temperatures and lower fertility rates, and partly as a consequence of appetite-suppressing tendencies of heat stress.[92] Changes in climate may affect the distribution of livestock diseases as well as the timing of their outbreaks or their intensity. For vector-borne diseases, the distribution patterns of the vectors may be altered by changes in temperature and rainfall, thus influencing potential distribution of diseases. It is reported that climate appears to be more frequently associated with the seasonal occurrence of non-vector borne diseases than their spatial distribution.[93] The changes that may be necessary in Namibian farming systems to enable adaptation to climate change were discussed by various authors.[94]

4.3 Biodiversity, Ecosystems and Tourism

Despite the harsh arid climatic conditions described above, the Namibian landscape supports remarkable biodiversity, especially its plant and animal species. More than

88 Hartman (2020).
89 Midgley *et al*. (2005).
90 DRFN / CSAG (2010).
91 IPCC (2018)
92 Newsham / Thomas (2009).
93 Ibid.
94 E.g. by Wilhelm (2012); Kuvare *et al*. (2009) and Van Wyk (2015).

4,500 plant taxa have been recorded,[95] almost 700 of which are endemic to the country, and a further 275 of which are Namib Desert endemics shared with southern Angola.[96] The endemism of plant species is concentrated in five centres, namely the Kaokoveld in the northwest, the Otavi highland in the Kalahari basin in the east, the Kavango regions in the northeast, the Auas Mountains on the western edge of the central plateau, and the succulent-rich southern Namib.[97] These landscapes and biodiversity are important tourist attractions for the country. The mammal fauna of Namibia comprises 250 species, representing about 75% of the southern Africa's species richness, of which 14 are endemic.[98] Most of the endemic mammals occur in the Namib Desert, pro-Namib transition zone and the adjoining escarpment. Close to 14% of Namibia is set aside as State protected areas while 86 registered communal conservancies constitute 20.2% of the country's land area. All these areas support amazing landscapes and significant biodiversity which attract a lot of tourists.

However, the natural ecosystems are vulnerable to climate change. Before the 2005 assessment,[99] there had been no previous quantified assessments of vulnerability of plant biodiversity to climate change in Namibia. Projections for warming and drying are harsh for central and western parts of southern Africa, with extreme warming centred on Botswana. Terrestrial areas that are particularly vulnerable to climate change are the western escarpment and the south-western succulent Karoo.[100] A dynamic global vegetation model (DGVM) has been used[101] to explore the effects of climate change on ecosystem structure, function and dominance of plant functional types in Namibian ecosystems. The main plant functional types they analysed were broad categories such as C4 grasses, deciduous trees and C3 herbaceous and shrub types. Elevated CO_2 levels that may result from anthropogenic causes potentially increase the water-use and nutrient-use efficiency of plants that use the C3 photosynthetic pathway,[102] and this will favour woody plants with a high degree of investment in carbon-rich support tissue (such as trees) relative to herbaceous species.[103] Seven vegetation structural classes are defined as occurring in Namibia under the current and future conditions by the DGVM, namely desert, arid shrub land/grassland, grassy savanna, mixed savanna, woody savanna, mixed shrub land/grassland and C3 shrub land/grassland. Projections of impacts on total vegetation cover were monitored through analyses of changes in bare ground and leaf area index (LAI).

95 Barnard (1998).
96 Maggs *et al*. (1998).
97 Maggs *et al*. (1994).
98 Griffin (1998).
99 Midgley *et al*. (2005).
100 GRN (2010b).
101 Midgley *et al*. (2005).
102 Drake *et al*. (1997).
103 Bond / Midgley (2000); Bond *et al*. (2003).

Results of projections of the impacts of climate change on biodiversity indicated a reduction in vegetation cover over the central highlands by 2050, with further reductions to 2080. The greatest absolute cover reductions are projected for the Kaokoveld region in the extreme northwest, and in the Kalahari basin in the southeast, with less significant reductions recorded at higher altitudes in the central highlands. It has also been shown that direct effects of rising atmospheric CO_2 on total cover were not significant and projected changes in LAI were more diverse, indicating significant reductions in areas of highest decrease in vegetation cover as expected.[104] However, such areas are of limited spatial extent, and much of the country is projected to experience LAI changes of between +10% and –10%. There will be an expansion of the two most arid vegetation types, desert and arid shrub land/grassland, mainly at the expense of grassy savanna and mixed savanna vegetation types. The arid vegetation types are projected to increase by almost 20% by 2050, and up to 43% by 2080, in the absence of a CO_2 fertilisation effect, but with CO_2 amelioration, the expansion of desert in 2080 is reduced from 43% to just less than 30%.[105]

The current grassy savanna vegetation of Namibia is projected to decline substantially by 2050, with significant cover and biomass reductions in the central highlands and north-eastern plains, a scenario which will be exacerbated by effects of elevated CO_2 by 2080. The effect of elevated CO_2 is by facilitating the increase of currently relatively scarce C3-dominated vegetation types, woody savanna, mixed grassland, and C3 grassland/shrub land. This means that currently uncommon vegetation types will become widespread in the north-eastern part of the country, suggesting a strong potential for bush encroachment in these regions. In addition, the potential fire frequency is predicted to increase somewhat in the northeast region under the elevated CO_2 scenarios only. The distribution of deciduous trees will also decline in extent – they will suffer a reduction in both biomass and cover throughout their current range, showing a general retreat towards the north-eastern Kalahari. Projections also suggest that NPP will be significantly reduced by between 0.5 and 1 t/ha in the central-northwestern regions and by up to 0.5 t/ha in the north-eastern Kalahari.[106] Overall, the SDGVM projections reveal a significant negative impact of climate change on ecosystem NPP, vegetation structure and cover, and the distribution of dominant plant functional types. These effects are strongest in the central/northwest regions and the northeastern parts.

Impacts of climate change at species level will lead to high species losses, with mean species loss of between 40% and 50% by 2050 and between 50% and 60% by 2080.[107] However, these patterns of species loss and turnover will vary markedly in

104 Midgley *et al*. (2005).
105 Ibid.
106 Ibid.
107 Ibid.

space. There will also be significant changes in plant community composition resulting from these species losses. Changes in habitat composition and structure will result in changes in the faunal complement of these habitats. Species turnover ranges of between 40% and 70% were projected, with much of the change to occur under climate regimes projected for 2050. Projected local extinctions at the pixel scale, assuming that there are no species migrations, are in excess of 80% in the north-eastern and northern Kalahari, dropping to below 20% from the edge of the escarpment into the coastal desert zone.[108] There will be high species turnover in the north-eastern parts of the country, with an overall trend of a reduction in turnover from northeast to west and south-west. The majority of species will suffer declining range size while a minority will experience significant increases in range size. This finding suggests that future climate change may be an advantage to a small subset of species that might be able to capitalise on the novel climatic conditions expected in this country, but that this will depend strongly on their migration capacity.[109] Endemic species will have overall lower susceptibility to climate change (19% and 12% will be classified extinct and critically endangered, respectively by 2080) than non-endemic species. This is largely due to the fact that endemics are both arid-adapted and located in regions of lower projected climate change. The above predicted changes may also be affected by, and have synergistic effects with other processes such as desertification, deforestation and overall land-use changes.

The tourism sector contributes significantly to the Namibia economy, either directly or indirectly. It is the third largest contributor to the country's Gross Domestic Product (GDP) and contributed 20.5% in 2012[110] but declined to 10.2% in 2015 and 10.5% in 2016, with an estimated 11.7% in 2020.[111] However, the corona virus disease (COVID-19) pandemic and associated worldwide lockdowns have hit the tourism sector hard in 2020. In Namibia, an estimated zero tourist arrivals were expected in the country between March and August and possibly for the entire 2020.[112] Government used the Tourism Climate Index (TCI) for the period 2035 to 2065 as a proxy for the suitability of the climate of an area for outdoor tourism activities and showed that Regions which will have high exposure to future climate stressor are Otjozondjupa, Oshana, Oshikoto, Omaheke and Ohangwena while Hardap, Omusati, Kunene, Erongo and Khomas will be least exposed.[113]

The effects of climate change on ecosystems and biodiversity described above will also negatively impact on tourism. Projected declines in vegetation cover in most parts of the country, and significant changes in vegetation structure with associated changes

108 Ibid.
109 Ibid.
110 MET (2016).
111 NTB (2016).
112 Shifeta (2020).
113 GRN (2015a).

in fauna will negatively impact on tourism. Livelihoods of rural communities will be negatively affected since a significant number rely on tourism ventures within communal conservancies. Increasing temperatures due to climate change will increase operational costs associated with the cooling of tourist accommodation facilities. Floods can damage infrastructure and affect accessibility to tourist destinations and facilities and may also lead to increases in incidences of vector-borne diseases.[114] One of the biggest drawcards of Namibia as a tourist destination is the political stability.[115] However, climate change has potential to increase risk of political or other conflict as reported by IPCC.[116] Such a situation will damage the tourism industry if it happens in Namibia.

4.4 Coastal Zone

Worldwide, coastal areas are very important economic zones which provide many goods and services to humanity. About 40% of the world's population lives within 100 km of a coastal area. These human communities who are in close connection with coastal environments are exposed to changes in the ocean and cryosphere. One of the impacts of climate change is a rising sea level due to melting glaciers and ice caps of the Arctic and Antarctica (i.e. widespread shrinking of the cryosphere). The IPCC[117] indicated that globally, the sea level rose at a rate of 1.8 mm per year between 1961 and 2003, with a faster rate of 3.1mm per year between 1993 and 2003. Sea level is projected to rise by between 30 cm and 100 cm by the year 2100, relative to the 1990 level. The rate of rise is projected to be relatively steady, accelerating slightly over time, although storm surges are expected to be the main source of damage to coastal infrastructure. Coasts will be exposed to increasing risks of coastal erosion and by 2080 more millions of people than today will experience floods every year due to sea level rise. The most affected people will be those in low-lying, densely-populated mega deltas of Asia and Africa.[118] The global ocean has warmed since 1970 and it has taken up more than 90% of the excess heat in the climate system, resulting in increases in marine heat-related events.[119] Namibia will not be spared from some of these effects. However, compared to other countries in the region, the Namibian coastline is relatively invulnerable to climate change impacts.[120]

114 Spear *et al*. (2018).
115 GRN (2015a).
116 IPCC (2020).
117 IPCC (2007c).
118 IPCC (2007b).
119 IPCC (2019).
120 Theron / Rossouw (2008).

Namibia's coastline stretches some 1,800 km long and consists of 78% sandy beaches, 16% rocky shores and 4% mixed sandy and rocky shores, with only 2% of the shore backed by lagoons. The coastline is very important for tourism and recreation activities, which contribute significantly to the Namibian economy. Four major towns are situated along the coast, namely Lüderitz, Walvis Bay, Swakopmund and Henties Bay. Walvis Bay is located between one and three metres above sea level, in a semi-sheltered bay surrounded by an erodible coastline. The coastal aquifers which supply water to the town are susceptible to salt intrusion which would be further exacerbated by sea level rise. A sea level rise of 0.3 m, now regarded as virtually certain, will flood significant areas, and a 1m rise would inundate most of the town during high tide.[121] The other three towns, Swakopmund, Henties Bay and Lüderitz, are less vulnerable to rising sea levels due to their relatively safe topographic positions. It was reported that in the near future, most of Namibia's coastal towns would be able to deal with impacts of severe weather conditions but in the long-term they need to carefully plan adaptation strategies to deal with the effects of climate change.[122] Walvis Bay was cited as particularly vulnerable and should safeguard its continued economic activity by properly planning for future effects. The vulnerability of Walvis Bay to rising sea levels was already reported way back,[123] and potential increased coastal erosion, inundation, increased saline intrusion, raised water tables and reduced protection from extreme events have been highlighted. Some of these effects are already being experienced.[124] Overall, coastal areas will experience increased incidence of flooding and inundation. Potential increased storminess due to climate change may increase the difficulty of coastal diamond mining in certain areas of the Namibian coast.[125]

4.5 Energy

There is an intrinsic link between energy and development.[126] This makes the impact of climate change on the energy sector an important one since a number of economic sectors are dependent on various types of energy. The demand for energy is increasing partly due to the increase in human population. Poverty and lack of adaptive capacity and limited coping strategies of most rural communities in Namibia exacerbate the situation. The most dominant energy source in Namibia is imported liquid fuel which accounts for about 63% of total energy consumption (mainly in the transport sector), followed by electricity (17%), coal (5%) and other sources such as solar, wood and

121 GRN (2002d).
122 Consulting Services Africa *et al*. (2009).
123 Hughes *et al*. (1992).
124 Rowswell / Fairhurst (2011).
125 Theron and Rossouw (2008).
126 Bradley-Cook (2008).

wind (15%).[127] While contributing between 8% and 16% to the GDP, the mining sector is also a major consumer of energy. Namibia imports most of its electricity but has limited local generation at the Van Eck coal-fired power station in Windhoek, the Paratus and Anixas diesel power stations at the coast and the Ruacana hydro-electric power station on the Kunene River. Recent droughts have severely reduced electricity generation from the Ruacana plant. Given the projected decline in rainfall and more frequent droughts that are likely to result from climate change, hydro-electric power generation will be severely curtailed. In areas where rainfall is anticipated to increase in the tropical regions of southern Africa including the catchments of the Kunene River in Angola, there may be potential for increased generation of hydro-electricity during some seasons. Energy consumption is projected to increase and high fuel prices will directly affect accessibility of transport, price of goods and services and the cost of living in general.

With plenty of sunshine most of the year, Namibia has great potential to develop solar-powered electricity. This is an option worth serious consideration given the looming energy crisis, not just in Namibia but in the whole southern African sub-region. It has been projected that bush encroachment may increase in some parts of the country as a result of climate change.[128] Encroacher bushes may provide more firewood to local communities, and in urban areas where charcoal is also sold. Charcoal production from encroacher bushes (mainly *Senegalia mellifera*) is on the increase, and some of the charcoal is exported overseas.[129] However, care must be taken not to reduce the carbon sink through excessive de-bushing and at the same time increasing greenhouse gas emissions through biomass burning and charcoal production.

4.6 Human Health and Well-Being

Human health, well-being and livelihoods are strongly dependent upon the state of global ecological and biophysical systems. Climate change is one of the global change factors which have adverse effects on human health. Changes in temperature, precipitation and other factors may lead to short-, medium- and long-term changes in the physical environment, many of which may have direct and/or indirect impacts on human health.[130] This may be through its impacts on aspects such as water quality and availability, nutrition status of humans, and distribution and abundance of vector organisms due to changing temperatures and rainfall patterns. The impact of climate change on human health has increasingly attracted attention after it was highlighted in

127 GRN (2018g).
128 Midgley *et al*. (2005).
129 Namibia Charcoal Association (2018).
130 DRFN (2009).

the IPCC's First[131] and Second[132] Assessment Reports. In its Fourth and Fifth Assessment Reports, the IPCC projected that globally there will be increased malnutrition, diarrhoea, cardio-respiratory and infectious diseases; increased morbidity and mortality from heat waves, floods and droughts, changes in distribution of some vectors and substantial burden on health services.[133] Existing knowledge on the impacts of climate change on health in the SADC region has been reviewed and the review suggested that that there have been no substantial studies assessing the association between climate change and health in the SADC region, and where research has been done it focused only on infectious diseases (particularly malaria).[134] As discussed above, drought negatively impacts food security, particularly in rural populations, at the same it reduces the availability of clean water. Limited food supply during prolonged droughts and the absence of safe drinking water can result in poor nutritional and mental status.[135] Heat waves are likely to increase mortality among the elderly, infants and people whose health is already weak.

Namibia's health system is decentralised to enable it to be responsive to the needs of the population. Thus, the public healthcare system is organised into directorates at the national and regional levels. The Government has invested tremendously in the healthcare system since Independence. Despite this, general life expectancy has not improved, partly because of the HIV/AIDS pandemic.[136] About 15% of the population aged 15 to 49 is living with HIV/AIDS, but the infection level appears to have stabilised, 7% of which are under the age of 15 and 60% are women.[137] The main causes of adult mortality are HIV and AIDS, tuberculosis (TB) and malaria. High incidence of TB is fuelled by the HIV/AIDS epidemic (38% of TB patients are also HIV-positive) and this has reduced life expectancy from 62 years in 1991 to 49 years currently.[138] Recently, the COVID-19 pandemic has also claimed significant numbers of adults. Infant mortality is higher in rural areas and in the wetter north, compared to urban areas and the more arid south, with main causes of death being diarrhoea (42%), malnutrition (40%), malaria (32%) and acute respiratory infections (30%).[139] These causes of death have a strong link to environmental influences, especially climatic factors. For instance, drought decreases the nutritional status of humans and reduces availability of clean water rendering the population vulnerable and susceptible to attacks by various infections.

131 IPCC (1990).
132 IPCC (1995).
133 IPCC (2007c and 2014).
134 Young *et al*. (2010).
135 UNDP (undated).
136 DRFN (2009).
137 GRN (2020a).
138 Ibid.
139 GRN (2002d).

About 60% of the Namibian population lives in areas where malaria is prevalent. These areas are predicted to expand southwards into the central inlands.[140] Such shifts may already be occurring with the warming effects. Namibia aims to eliminate malaria by 2022. However, recent successes in controlling the disease have been punctuated by occasional increases in the disease over the past few years.[141] Increased flood risk also increases the risk of the spread of other serious waterborne diseases such as cholera and bilharzia. This gives an indication of the magnitude of the impacts of changing temperature on the range of the *Anopheles* mosquito, the vector for the malaria parasite. Indeed, it has been reported that rising temperatures are likely going to lead to increased frequency, greater spread and increased transmission rates of vector borne diseases.[142] Sleeping sickness, carried by the tsetse fly (*Glossina morsitans)*, is currently not present in Namibia although the cattle version (nagana) occurs in eastern Zambezi.[143] Both these forms of disease are projected to decrease under future climate projections because of a reduction in habitat availability for the tsetse fly. Government also predicts the possibility of incursion of lymphatic filariasis (elephantiasis), dengue fever and yellow fever from countries to the north with changes in climatic conditions.[144]

Therefore, major impacts of climate change on health will result from decreasing crop yields and food insecurity, increasing water scarcity in some areas, extreme weather events (floods, droughts, heat waves, etc.), and changes in the distribution patterns and abundance of parasites and disease vectors. In the final analysis, the effects of climate change on Namibia will increase the pressure on human health and other health-related aspects of the economy and may lead to an increase in disease burden and poverty in communities.

4.7 Fisheries and Marine Resources

The fisheries sector contributed only 2.8% to GDP in 2014, which is a decline from 4.6% in 2009.[145] Namibia's fisheries sector is largely dependent upon the highly productive marine ecosystem driven by the upwelling of the cold, nutrient-rich Benguela Current in the Benguela Current Large Marine Ecosystem (BCLME) while comparatively limited production is from inland fisheries. The upwelling in the BCLME is caused by the interaction of south-easterly winds with the north-flowing current and the topography of the seabed. Currently there are no reliable scientific projections to

140 UNDP (undated).
141 Jacobson *et al*. (2019).
142 Husain / Chaudhary (2008).
143 GRN (2002d).
144 Ibid.
145 GRN (2018g).

suggest either an increase or a decrease in the Benguela fisheries yield as a result of climate change.[146] 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.[147] Because the BCLME upwelling-driven, it is naturally highly variable and complex, making it difficult to predict long-term climate change-related trends apart from the warming of the surface water at the northern and southern boundaries and the cooling of inshore waters.[148] Recent studies have shown that sea surface temperatures over the northern Benguela region appear to have become persistently warmer since 1993, consistent with global predictions of rising surface water temperature. It is possible that observed reductions in pilchard stocks since 1993 could be partially explained by warmer seas.[149]

Any changes in the distribution and intensity of winds would affect the fisheries sector as it has direct impact on the upwelling dynamics of the Benguela system. Four possible scenarios that could result from climate change have been described.[150] The first is a possible reduction in coastal upwelling intensity through a slackening of the south Atlantic trade wind circulation. This would reduce the productivity of the ecosystem and the species that characterise the Benguela system could suffer major reductions in stock size and distribution. The second would be an increase in average summer wind stress and coastal upwelling intensity which would enhance enrichment and potential primary production. This could benefit some pelagic species and their predators due to increased productivity. However, it has been commented that, contrary to a popular assumption, there is little evidence to suggest that there have been large-scale inter-annual changes in primary production in response to changing wind fields.[151] The third is that the frequency and severity of Benguela Niño events would increase, with a direct risk of large-scale population fluctuations, particularly of pelagic species; the Benguela Niños have the most obvious consequences for marine life in the northern Benguela, and intrusions of warm, nutrient-poor water from southern Angola has affected a wide range of species from small pelagic fish to top predators.[152] These events have led to increased reduction in oxygen in Namibian shelf waters. The distribution of hake, and possibly other demersal species, could be substantially altered as a result, making the fish less available to trawl and long-line fleets. This has serious negative consequences on the economy and livelihoods of fishing communities. The fourth is a possible best-case scenario but probably the least possible where there would be low amplitude gradual affects that would lead to a succession of rapid regime

146 GRN (2002d).
147 Reid *et al*. (2007).
148 Hampton (2012).
149 Ibid; MFMR (2002).
150 Roux (2003).
151 Ibid.
152 Ibid.

shifts between semi-stable states of the system. These regime shifts would affect primarily the dominant pelagic species, which would in turn, induce large changes in the entire system.[153]

4.8 Water Resources

Predictions are that southern Africa will receive 10% to 20% less rainfall by 2050. Such reductions in areas with rainfall regimes of 400-1,000 mm per annum may lead to a drop in perennial surface drainage of 75% and 25%, respectively by 2050.[154] The magnitude of surface water shortage may even be higher in drier areas of Namibia, which actually form the bigger proportion of the country. Even in the absence of climate change, water is an extremely scarce resource in Namibia.[155] The agriculture sector is the major user of water in Namibia, consuming close to 75% of water in the country.[156] Several other sectors such as mining (3.3%), services (2.9%) manufacturing (2.4%) and domestic (12.2%) sectors also have significant demands for water. Any changes that result in a decline in water supply will have serious repercussions on human livelihoods and the economy of the country in general.

Increases in temperature will have a marked increase in evaporation. It is estimated that for every degree of temperature rise, evaporation increases 5%. Therefore, there will be less water available for recharge and storage with increased atmospheric warming. The length of inundation of seasonally flooded terrestrial wetlands will therefore decrease due to increased evaporation. In some instances, this may lead to increased salt content of pans and pools and make them less suitable for human and animal consumption. Increased temperatures will also lead to increases in evaporation from plants, which will mean that plants will pump out more ground water, further depleting underground water. All this will lead to a reduction in the size and productivity of many wetlands,[157] negatively affecting human livelihoods that are critically dependent on these wetlands particularly in the north and north-eastern parts of the country.

It is predicted that rainfall over the Angolan catchments of the Zambezi, Kavango, Cuvelai and Kunene rivers will decrease by 10-20% between 2045 and 2065 leading to a 25% reduction in run-off and drainage into these river systems.[158] Of all the rain that falls in Namibia, less than 1% recharges groundwater and only 2% remains as surface water storage while the rest evaporates.[159] Groundwater recharge is predicted

153 Reid *et al*. (2007).
154 Ibid.
155 Spear *et al*. (2018).
156 GRN (2002d).
157 DRFN / CSAG (2010).
158 GRN (2011a:6).
159 GRN (2002d).

to suffer a reduction of 30-70% across the country.[160] The whole of Namibia experiences a net water deficit, meaning that evaporation exceeds rainfall throughout Namibia, with average water deficit being highest in the southeast (-2,300 mm/year) and lowest in Zambezi (-1,300 mm/year).[161] Recent estimates put these deficits at -4000 mm/year in the south-east and -1600 mm/year in the north-east.[162] Water deficit in southern areas result in most terrestrial wetlands being ephemeral.

An estimated 60% of Namibia's population lives near the major wetlands, with the highest population density along the perennial Kavango River.[163] Most of these communities are largely poor and highly dependent on the river and floodplains for water and other resources. The projections outlined above therefore spell gloomy prospects for these people, who were identified as being extremely vulnerable to environmental change. The above situation will further be worsened by increased demand from a growing population in general - demand for irrigation and demand in urban areas in response to projected heat stress.[164]

5 Compliance, Mitigation and Adaptation to Climate Change: Summary of Selected Actions Taken

The above account has highlighted the vulnerability of Namibia to climate change and the effects this may have on the environment, the economy and human livelihoods. The country is experiencing an increase in frequency and severity of disasters such as floods, droughts and heat waves. The potential losses due to disasters is set to increase as the impacts of climate change continue to unfold.[165] The IPCC warns that many aspects of climate change and associated impacts will continue for centuries, even after anthropogenic emissions of greenhouse gases have been stopped.[166] It is therefore important that the country takes steps to mitigate climate change and capacitate communities to adapt to these effects. Under the UNFCCC and other international instruments, Parties to these conventions and treaties have obligations to introduce measures in order to mitigate further environmental deterioration and to reduce the effects these changes have on humanity and the environment. As a party to the UNFCCC and the Paris Agreement Namibia is obliged to put in place structures, policies and measures that meet the above objectives.

160 Spear *et al*. (2018).
161 DRFN / CSAG (2010).
162 GRN (2021a).
163 Heyns *et al*. (1998).
164 GRN (2015a).
165 GRN (2011c).
166 IPCC (2014a).

Available literature highlights why climate change adaptation and mitigation are critical issues not only for Namibia and southern Africa, but the world over. It is conceded though, that a certain amount of climate change is unavoidable regardless of reductions in greenhouse gas emissions.[167] It must be noted that effects of climate change will act in combination with other drivers of ecosystem degradation, for instance, communities in the region already face high levels of vulnerability and numerous stresses due to poverty, HIV/AIDS, food insecurity, and political instability.[168] Hence measures put in place must take cognisance of these interactive effects and approach them in a holistic manner.

Namibia established the Namibian Climate Change Committee (NCCC) in 2001 with the main function of advising and making recommendations to Government on climate change including how to meet its obligations to the UNFCCC. The NCCC is hosted by the Directorate of Environmental Affairs in the Ministry of Environment, Forestry and Tourism. Its membership is drawn from representatives of various Government ministries, NGOs, parastatals and the private sector. Thereafter, Cabinet approved the first National Policy on Climate Change (NPCC) in 2011[169] and the National Climate Change Strategy and Action Plan (NCCSAP): 2013-2020 in 2014[170] to aid in the implementation of the Policy on Climate Change by setting out the country's direction towards addressing climate change mitigation.

Thus, Namibia has taken several steps in addressing the issue of climate change and other global change challenges. In addition to the formation of the NCCC, other important steps under the obligations of the UNFCCC include (but are not limited to) the following:

- National policies and laws related to global change challenges and environmental management and protection are in place, including the Namibian Constitution, Vision 2030, National Development Plans, Environmental Management Act No. 7 of 2007, various sector policies and Cabinet directives. These policies are discussed in various Chapters of this Book. This includes the development of the National Policy on Climate Change for Namibia, development of the National Climate Change Strategy and Action Plan stated above;
- Initial National Communication to the UNFCCC in 2002;
- Second National Communication to the UNFCCC in 2010;
- Third National Communication to the UNFCCC in 2015;
- Fourth National Communication to the UNFCCC in 2020;
- Intended Nationally Determined Contributions (INDC) to the UNFCCC in 2015;

167 IPCC (2007c).
168 Shackleton *et al*. (2008); Ziervogel *et al*. (2006a).
169 GRN (2011b).
170 GRN (2014b).

- Intended Nationally Determined Contributions (INDC) to the UNFCCC in 2021;
- First Biennial Update Report (BUR1) to the UNFCCC in 2014;
- Second Biennial Update Report (BUR2) to the UNFCCC in 2016;
- Third Biennial Update Report (BUR3) to the UNFCCC in 2018;
- First National GHG Inventory Report (NIR1) in 2015;
- Second National GHG Inventory Report (NIR2) in 2016;
- Third National GHG Inventory Report (NIR3) in 2018;
- Assessment of capacity needs required to implement Article 6 of the UNFCCC was completed in 2005;
- A Directorate of Disaster Risk Management is operational in the Office of the Prime Minister. A National Disaster Risk Management Plan was developed;[171]
- A National Drought Policy and Strategy was developed in 1997;
- Continuous reviews and updates of national circumstances concerning impacts of climate change on various sectors are done;
- A Technology Needs Assessment was conducted in 2005 to identify requisite financial and research needs;
- Local-level activities are on-going for communities to adapt to climate change through improvement of traditional crops and livestock farming in several regions; and enhancing the adaptive capacities of farmers, pastoralists and natural resource managers to climate change in agricultural and pastoral systems in the country; a number of projects have been, and are being implemented across the country;
- Efforts are being made to increase access to climate change information and improved access to alternative resources by local communities, farmers and other stakeholders in the country;
- Namibia has integrated climate change issues in its development plans and has implemented numerous mitigation measures in various economic activities to curb emissions; the mitigation actions are summarised in the various Biennial Update Reports listed above; and
- The Environmental Investment Fund (EIF) was established in 2001 with the objective of mobilising funds to support activities and projects which promote sustainable use and efficient management of natural resources. To-date, the EIF has funded numerous projects on community resilience, capacity building, adaptation, mitigation etc. which have made a significant improvement of community livelihoods.

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6 Concluding Remarks

Climate change continues to be one of the greatest challenges of all time as it is cross-cutting all sectors of the economy. Namibia is very vulnerable to the effects of climate change due to the arid nature of the country, limited capacity to deal with its effects and inadequate technical and financial capacity for adaptation, given that there is a myriad of other challenges (e.g. poverty, HIV and AIDS, malaria, unemployment, and the COVID-19 pandemic) that need to be dealt with in addition to climate change. The evidence of climate change in Namibia are very clear, manifested by more intense flooding, shortening of the growing season, more frequent droughts, rising average summer and winter temperatures, frequent heat waves, among many other effects. These conform to predictions from General Circulation Models (GCMs) that paint a gloomy picture of rising temperatures and declining rainfall in most areas, though the applicability of GCMs remains limited at local spatial scales. There will be an accelerated decrease in biodiversity (particularly in the originally less arid areas), increasing evaporation leading to water scarcity, low crop yields leading to food shortages and insecurity, declining marine productivity due to sea warming and predicted declining oxygen levels in the continental shelf, flooding and erosion of coastal areas and changes in the distribution of disease patterns and their vectors. As a signatory to the UNFCCC and other related international instruments, Namibia is taking concrete steps to minimise the impacts of climate change on the people and the economy by putting in place relevant policies, structures and institutions for dealing with climate change and enhancing adaptive and mitigation capacity. With assistance from national and international partners and stakeholders, Namibia has implemented a significant number of interventions in order to achieve the above. Namibia's greenhouse gas emissions are insignificant, and the country has remained a net sink for CO_2 as far as the latest (2018) analyses show. Hence, efforts should be less on cutting down current emissions but more on curbing any potential increases in GHG emissions, adaptation, coping strategies, and disaster preparedness and management.