

Co-producing climate information for Windhoek decision making

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FUTURE RESILIENCE FOR AFRICAN CITIES AND LANDS

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The Future Resilience for African Cities and Lands (FRACTAL) project aims to address the challenge of providing accessible, timely, applicable and defensible climate information that is needed by decision makers operating at the city-region scale in southern Africa. FRACTAL has been running since June 2015. It is part of the Future Climate for Africa (FCFA) multi-consortia programme. FCFA's major objective is to generate fundamentally new climate science focused on Africa, and to ensure that this science has an impact on human development across the continent. FCFA is funded by the Department for International Development (DFID) and the Natural Environment Research Council (NERC).

These knowledge products have been developed to share findings from the research in the hope of fostering dialogue and eliciting feedback to strengthen the research. The opinions expressed are therefore those of the author(s) and are not necessarily shared by DFID, NERC or other programme partners.

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1. Introduction

Windhoek is a fast growing city situated in an extremely dry region. There are many decisions, facing those tasked with managing Windhoek and the resources it relies on, that are climate sensitive. Two issues identified to be priority concerns (or burning issues) in light of climate variability and change, by those participating in the first FRACTAL¹ Learning Lab, are those of water insecurity and inadequate services in informal settlements (notably water, sanitation and energy services).

Learning Labs (LLs) are facilitated events bringing together a broad range of stakeholders to constructively engage with complex issues and collaboratively develop new understandings and innovative solutions (Arrighi et al. 2016). A key aspect of the work undertaken in the first phase of the FRACTAL project was collaboratively exploring patterns and trends in the climate, both historical and future, that impact on Windhoek's water security and informal settlements.

This document consolidates the work done on co-producing, communicating and sharing climate information of relevance to the burning issues and climate sensitive decisions being faced in Windhoek. It serves as a resource for those wanting to know what climate data and information relating to Windhoek was analysed, produced and made available through FRACTAL, what it has been used for, and what it has or could lead to.

The document ends by identifying some gaps and needs that have not yet been filled or met that we suggest might be priorities for future research and capacity strengthening activities.

2. What are climate risk narratives and why produce them?

The concept of a Climate Risk Narrative (CRN) was first developed in summarising climate projections within the South African 3rd National Communication, and further iterated in the first phase of FRACTAL as a way to describe plausible future climates and related risks which are meaningful to decision makers in a specific context and presented in non-technical language (Jack et al., 2020). The construction of the narratives is designed to qualitatively combine climate science evidence, which is often diverse and sometimes contradictory, with context-specific information and knowledge through a co-production process, involving a range of academic and societal stakeholders.

By developing multiple narrative descriptions or 'pathways' based on the range of plausible future climates, the narratives are able to capture and communicate uncertainty within the underlying scientific information. This uncertainty stems from the fact that (1) the climate is inherently unpredictable on daily through decadal time scales, and (2) models, no matter how complex, can never perfectly capture and reproduce all the processes and variability in the real climate, and different models encapsulate different representations of the climate system, and (3) the projections are driven by a few selected scenarios of future anthropogenic forcings on the climate. The third factor, future concentrations of greenhouse gases in the atmosphere, is driven by estimations of global energy usage, changes in land cover, transport patterns, etc.

We cannot yet know how realistic and accurate they might be because factors such as the global COVID-19 pandemic change the picture in unforeseen ways. So the CRNs include multiple plausible future narratives to

¹ The first phase of the Future Resilience for African Cities and Lands (FRACTAL) project (2016 to 2019) was coordinated by the Climate System Analysis Group (CSAG) at the University of Cape Town, and funded by the UK's Department for International Development (DFID) and Natural Environmental Research Council (NERC), through the Future Climate For Africa (FCFA) programme. In Windhoek the project was undertaken through a partnership between the University of Windhoek and the City of Windhoek, with support from the international partners involved in FRACTAL. See <http://www.fractal.org.za/> for further details, including on the Learning Labs methodology and outcomes.



capture and convey the range of future climate conditions that could realistically emerge in the central region of Namibia, impacting Windhoek. Typically three different futures are described as this allows enough alternatives to be presented without overwhelming the process with a large number of possibilities. The process of developing CRNs in each of the FRACTAL focus cities, including Windhoek, has been iterative and driven by contexts specific to these cities, meaning slightly different processes have been followed in each city. However, the FRACTAL CRNs have typically taken a text-based written format, while also being represented visually using infographics.

A key role of CRNs is to act as prompts or 'conversation starters' between scientists, decision makers, technical advisors and those impacted and affected by climate conditions, allowing the climate evidence and associated uncertainty to be communicated, questioned and explored in an accessible and relevant manner. The CRNs, while describing the future, were written in the present tense to encourage participants to relate to being in the situation.

Through the FRACTAL city engagements, such as Learning Labs, City Dialogues and training workshops, CRNs have emerged as "boundary objects", or collaborative learning tools that facilitate engagement across disciplinary and practice boundaries (Jack et al., 2020; Star 2010). They help to overcome the communication barriers in transdisciplinary engagement through the building of transparency and trust (Daniels et al., forthcoming) by enabling focused conversation and deliberation across the science-policy-practitioner spectrum on climate sensitivities and impacts facing the city. These conversations explore what climate conditions and patterns exist, how these might change into the future, and what needs to happen to try and reduce negative impacts.

3. What are the Windhoek climate risk narratives?

The Windhoek CRNs describe three plausible future climates for the 2040s, which were derived through analysing climate projection outcomes for Namibia using multiple sources to ensure a wide range of plausible future climates was captured (see Figure 1 infographic and Appendix 1 for the text version).

The three future climates were described using the following headline messages:

1. Much hotter with a drier rainy season
2. Hotter with rainfall later in the season
3. Warmer with a similar rainy season

In scenario 1, Namibia experiences a temperature change of more than 2°C, with twice as many very hot days (days which exceed 35°C) and one-third less total annual rainfall than is experienced in the present day. In scenario 2, temperature changes are slightly less than scenario 1, with only 50% more very hot days and more rain later in the rainy season. In scenario 3, temperature changes are lesser still at 1-1.5°C, with total annual rainfall remaining roughly the same, but with shorter, more intense rainfall events.

The CRNs then describe how these three future climate scenarios may impact the relevant sectors and livelihoods in Windhoek, such as water security, energy, health, biodiversity and ecosystem services. Potential impacts were constructed collaboratively between climate scientists and colleagues at the University of Namibia (UNAM), discussed in more detail in Section 4. The sector-specific sections provide an opportunity to outline possible adaptation options to consider.

- For water security, all three climate scenarios lead to increased evaporation due to higher temperatures, which impacts water availability in reservoirs and dams. This impact is compounded by population and economic growth in the Windhoek municipal area, both from internal growth



and migration into the city. Adaptation options could include improved and expanded water treatment facilities to increase water reuse and the use of desalination plants, although desalinated water comes at a very high cost.

- For energy efficiency and supply, scenarios 1 and 2 could lead to more sunshine hours due to less cloud cover, resulting in an increase in the production of solar power and thereby a quicker return on investments in solar energy infrastructure. All three scenarios could lead to an increased demand in air conditioning due to higher temperatures. Options for adaptation include promoting municipal and national programmes and policies for renewable energy, smart grids and promoting energy-efficient technologies and practices.
- For the health sector, all three scenarios could lead to increased occurrence of heat-related health issues such as heat stress/stroke. Access to clean sanitation, related to the risk of exposure to water-borne diseases, could be negatively affected in scenarios 2 and 3 due to the risk of flooding. Adaptation options include conducting public health campaigns in vulnerable communities, improving sanitation services and expanding clinic facilities.
- For biodiversity and ecosystem services, the rise in temperature and changes to rainfall in all three scenarios could lead to biodiversity loss, shifts in habitats, and the prevalence of invasive species. The degradation to landscape and wildlife could negatively impact the tourism industry. Sustainable land management and conservation measures will be required to reduce this impact.

Lastly, the CRNs look at the combined impact of the three future climates and risks to the sectors mentioned above on the built environment, namely critical infrastructure, waste minimisation and management, and

human settlements. The impacts of flooding are highlighted in relation to narratives 2 and 3, suggesting the need to reconsider buffer zones and setback lines to limit building near water courses, enhancing transport infrastructure to reduce flood disruptions and costly repairs, improving waste management to reduce drainage blockages, and improving sanitation services and industrial pollution controls to avoid the health impacts of contaminated flood waters.

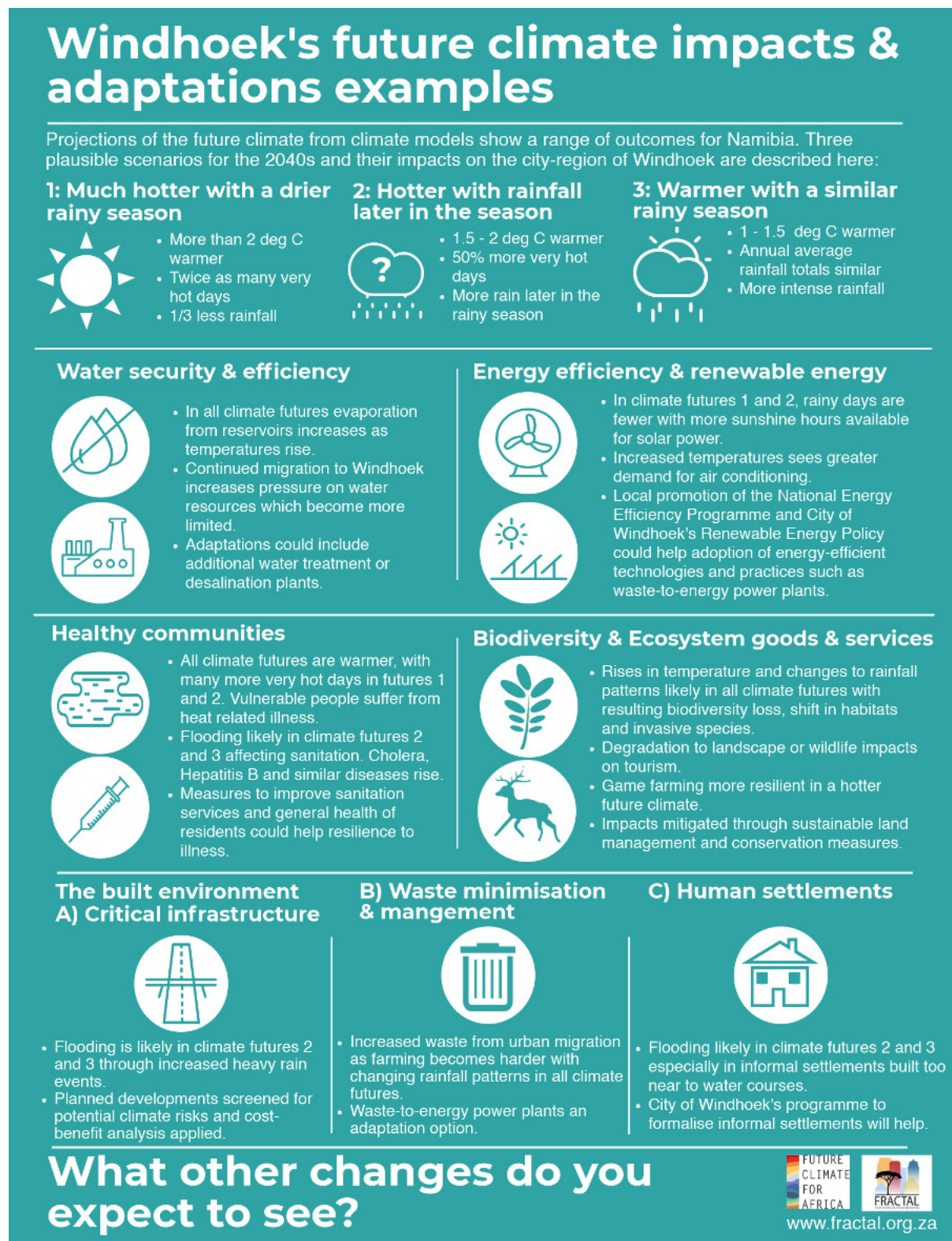


Figure 1 | Climate Risk Narratives infographic for Windhoek, with sector impacts aligned to the City of Windhoek's Climate Change Strategy and Action Plan (see Figure 4 for an earlier draft that was used to gather feedback from stakeholders and informed the development of this second version).



4. How were the Windhoek CRNs (co) produced?

Climate evidence from a range of existing climate information sources was collated and distilled into the key climate messages presented in the CRNs for Windhoek. This evidence included low-resolution CMIP5² projections from global climate models (GCMs), as well as dynamically downscaled high-resolution projections using regional climate models (RCMs) (Buontempo et al, 2014). The projections were then tailored specifically for Namibia using standard climate science analysis techniques (i.e. calculating future anomalies, assessing variability in time and the spread of results across models).

An example of this primary analysis is shown in Figures 2 and 3, with a more detailed description of the interpretation of this analysis given in Box 1. Temperature projections for Namibia were relatively consistent across the evidence base used here, with all models suggesting increased temperatures by the end of century (varying in magnitude depending on their climate sensitivity - see Figure 2). While many climate models pointed to high uncertainty in projected rainfall changes for Namibia, downscaled climate model data showed a stronger tendency towards drier conditions in the future, particularly later in the century (Figure 3), which informed the choice of rainfall scenarios to include in the CRNs for Windhoek.

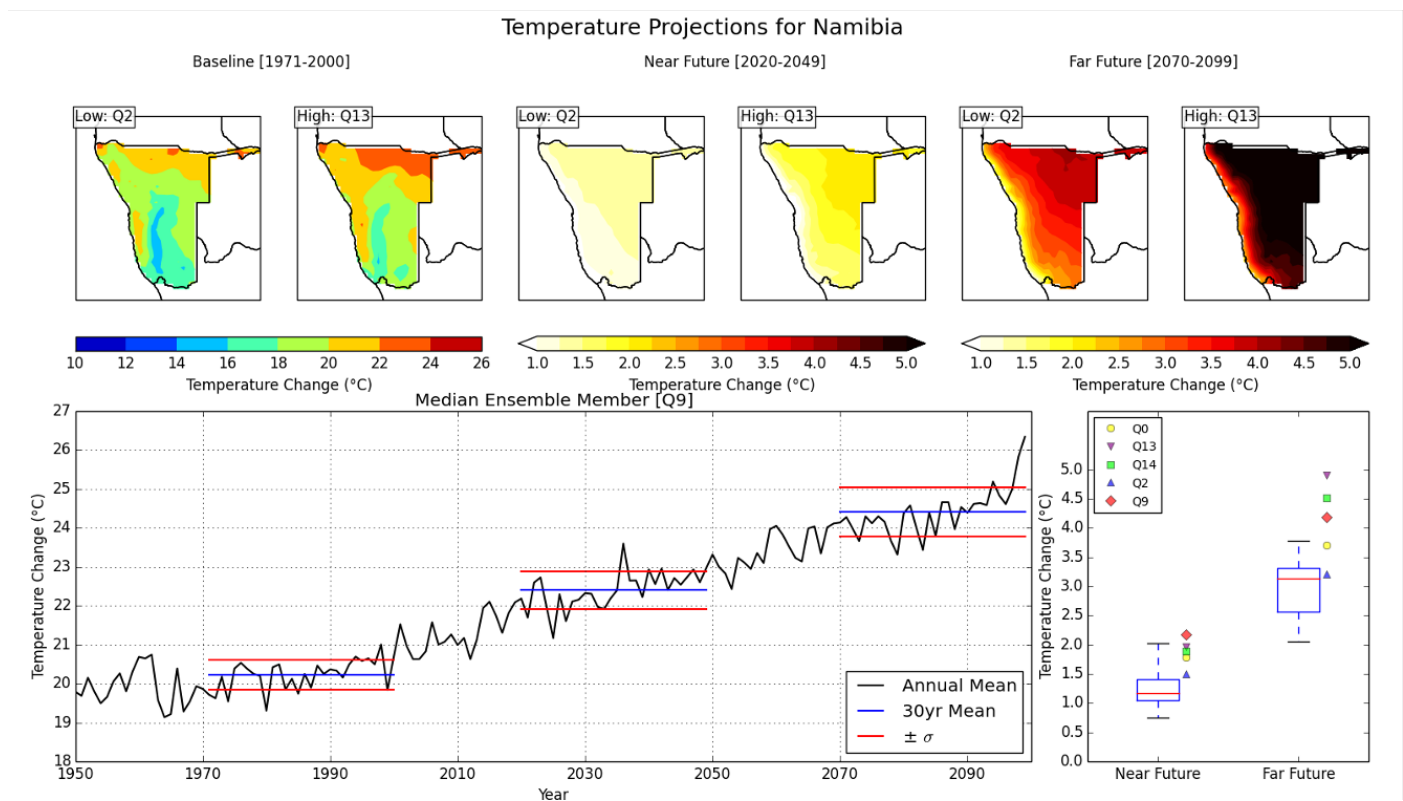


Figure 2 | Temperature projections for Namibia. Top row: Annually averaged surface temperature ($^{\circ}\text{C}$) for the baseline period (1971-2000), and projected changes for the near future (2020-2049) and far future (2070-2099), for the Regional Climate Models (RCMs) with the lowest and highest projected sensitivities in the far future time period. Bottom left: Evolution of annual mean surface temperature from 1950-2100 for the median ensemble member of five RCMs (denoted Q9), as well as the 30-year mean and associated standard deviation ranges for the baseline, near and far future periods. Bottom right: Annually averaged temperature changes for near and far future time periods, for the five RCM experiments as well as 18 CMIP5 GCM experiments using RCP6.0³.

2 The Climate Model Intercomparison Project Phase 5 (CMIP5) is a standard set of GCM simulations used to inform the IPCC's Fifth Assessment Report (AR5). More information can be found here: <https://pcmdi.llnl.gov/mips/cmip5/>.

3 RCP6.0 is one of four Relative Concentration Pathways (RCP) depicting future greenhouse gas concentration trajectories, adopted by the IPCC for use in the fifth Assessment Report on climate change (AR5) and within CMIP5. The regional climate models used in our analysis used older emission scenarios than the RCPs used in, and RCP6.0 was identified as the closest RCP to use when comparing our results to CMIP5.



Seasonal (DJF) Total Rainfall Projections for Namibia

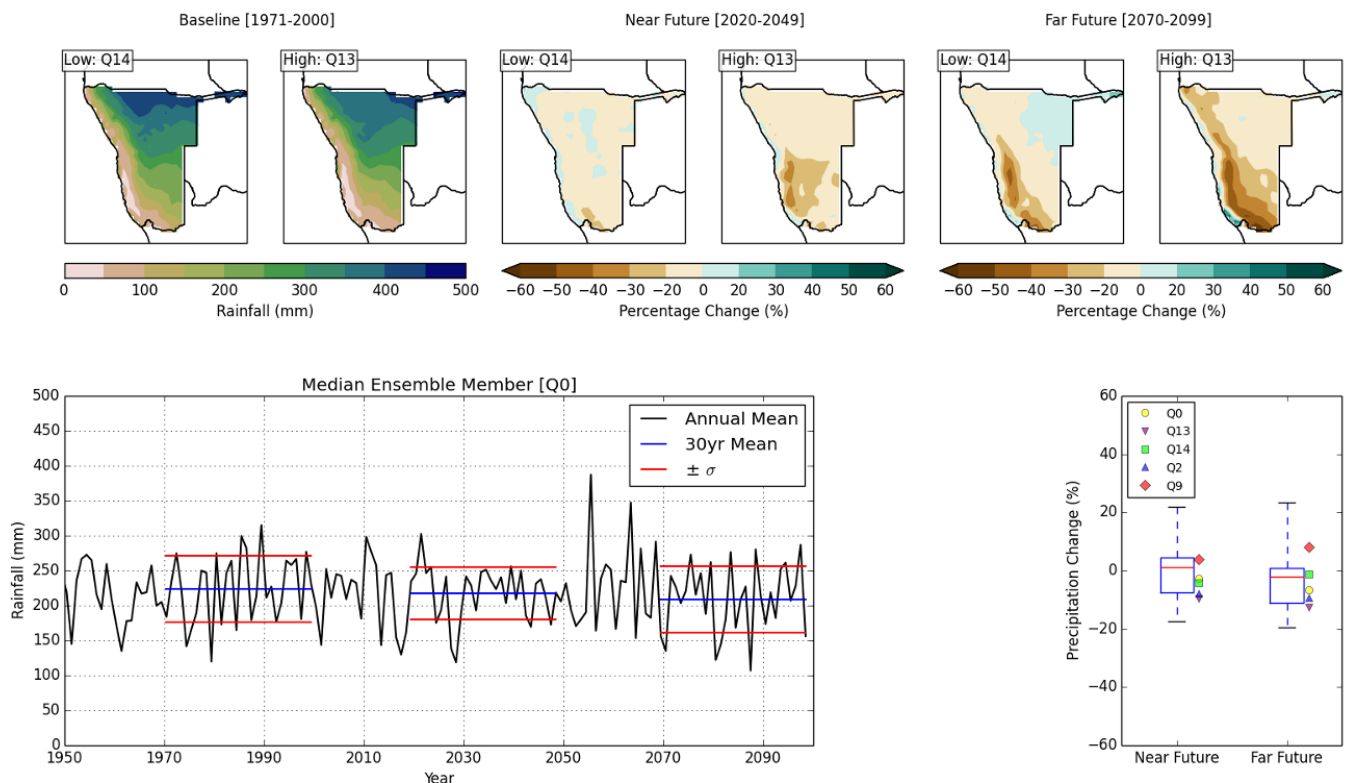


Figure 3 | Rainfall projections for Namibia during the December, January, February season. Top row: Seasonal total rainfall (mm) for the baseline period (1971-2000), and projected changes (in %) for the near future (2020-2049) and far future (2070-2099), for the RCM models with the lowest and highest projected sensitivities in the far future time period. Bottom left: Evolution of seasonal total rainfall from 1950-2100 for the median ensemble member of five RCMs (denoted Q9), as well as the 30-year mean and associated standard deviation ranges for the baseline, near and far future periods. Bottom right: Seasonal rainfall changes (in %) for the near and far future time periods, for the five RCM experiments as well as 18 CMIP5 GCM experiments using RCP6.0.

Box 1 | Interpretation of Figures 2 and 3

Figures 2 and 3 depict examples of primary analysis of climate information, which were used alongside additional climate evidence in the development of the Windhoek CRNs.

Figure 2 shows annual temperature projections for Namibia, from a collection of five RCM simulations ranging in sensitivity to future climate changes. The maps along the top row show results from the two RCMs with the highest and lowest sensitivity, for near-future (2020-2049) and far-future (2070-2099) time periods. These maps show that temperature is projected to increase across Namibia in both models, with larger temperature changes projected in the model with the highest sensitivity (nearly 5°C warmer by 2100). The line graph helps to visualise the year-to-year fluctuations or variability in country-averaged annual temperatures for the 'middle' of the five models. The horizontal lines show that the spread within the thirty-year near-future and far-future time periods widens over time, suggesting that there could be larger swings between relatively colder and warmer years. Finally, the box plot on the bottom right shows where the country-average projections of the five RCMs sit within the range of CMIP5 results - the five RCMs used here are project slightly warmer temperatures by the end of the century than some of the CMIP5 models, so should be considered as an 'upper end' for temperature changes in Namibia.

Figure 3 shows seasonal total rainfall projections during December, January and February for Namibia, from the same five RCMs. As above, the maps along the top row show results from the two RCMs with the highest and lowest sensitivity, for near-future (2020-2049) and far-future (2070-2099) time periods. These maps show how percentage change in rainfall is relatively small across Namibia in both of these models, with a tendency towards drier conditions in the model with the highest sensitivity. The line graph helps to visualise the year-to-year fluctuations or variability in country-averaged seasonal rainfall for the 'middle' of the five models, which is relatively consistent throughout the century for this model. Comparing these projections with those from CMIP5 in the bottom right box-plot, the five RCMs used here don't quite capture the full range of plausible outcomes in seasonal rainfall by 2100. CMIP5 projections indicate that both an increase and decrease in seasonal rainfall for Namibia are plausible when considering the evidence available within CMIP5. Care is therefore needed when interpreting results from our collection of five RCMs, highlighting the importance of incorporating multiple sources of climate evidence in the distillation process.



Ahead of the first Learning Lab (LL1) in Windhoek, an initial attempt to derive a number of climate futures based on the evidence described above was carried out by a climate scientist from the UK Met Office (UKMO). These plausible climate futures were then assessed and iterated in discussions with other climate scientists from UKMO and the University of Cape Town's Climate System Analysis Group (CSAG), resulting in three climate futures capturing a spread across the range of possibility within the climate information, all supported by the scientific evidence. Three was deemed as a suitable number to capture the range of plausible climate futures, i.e. combinations of variables with different trends, without becoming too repetitive or too much information for stakeholders to readily engage with (Jack et al., 2020).

High-level biophysical and socio-economic impacts of these three climate futures were initially drafted by climate scientists to help facilitate discussion and engagement with diverse participants during the co-production session in LL1 (held 14-15 March 2017). This was done based on broad system knowledge and a scan of readily available scientific and grey literature (that had been collated in a Windhoek city background report prepared at the start of the FRACTAL project), rather than any detailed impact analyses. A range of positive and negative impacts were included for each narrative where possible to generate discussion between various stakeholders and knowledge-holders.

A first draft of text-based CRNs was presented during LL1 by an experienced climate scientist, in a session which aimed to raise awareness of possible climate projections for Windhoek in the 2040s. Emphasis was placed on the need to further iterate this draft based on the knowledge and expertise held by the participants in the Learning Lab, which included representatives from various government departments (local and national)

and agencies, research organizations, NGOs and civic organizations. Following deliberations in small groups, feedback on both the content and format of the draft CRNs was provided to the FRACTAL project team. Key topics that arose throughout the discussions were the importance of language choice for better user understanding (especially for those without scientific training) and reflect local terminology (e.g. rainy season instead of wet season) and place names, as well as the importance of including opportunities for adaptation to counter the outlook of extensive negative climate impacts. Many participants commented that a visual format would enhance the CRNs and encourage users to engage with the details contained in the written format.

An infographic was subsequently co-designed between climate scientists and the University of Namibia (UNAM) colleagues involved in FRACTAL, using accessible and concise language to convey the key sector impacts of each of the three future climates (see Figure 4). The infographic was introduced at the second Learning Lab (LL2 held 30-31 October 2017) to gather further feedback.

CRN-specific sessions within subsequent Learning Labs⁴ were focused on further co-producing an infographic based on participant feedback from LL1 and LL2 (see Figure 1 for the updated infographic that integrated feedback and was reformatted to align with the sections of the City of Windhoek's Integrated Climate Change Strategy and Action Plan). Participants frequently referred to the CRNs and they became a shared reference point, reflecting the participants' concerns and ambitions for their city (Jack et al, 2020). As such the CRNs were used to spark multi-stakeholder discussions to draw together their knowledge on climate impacts and adaptation measures in light of the three scenarios, and feed into various decision-making processes, notably including the development of Windhoek's Integrated Climate Change Strategy and Action Plan.

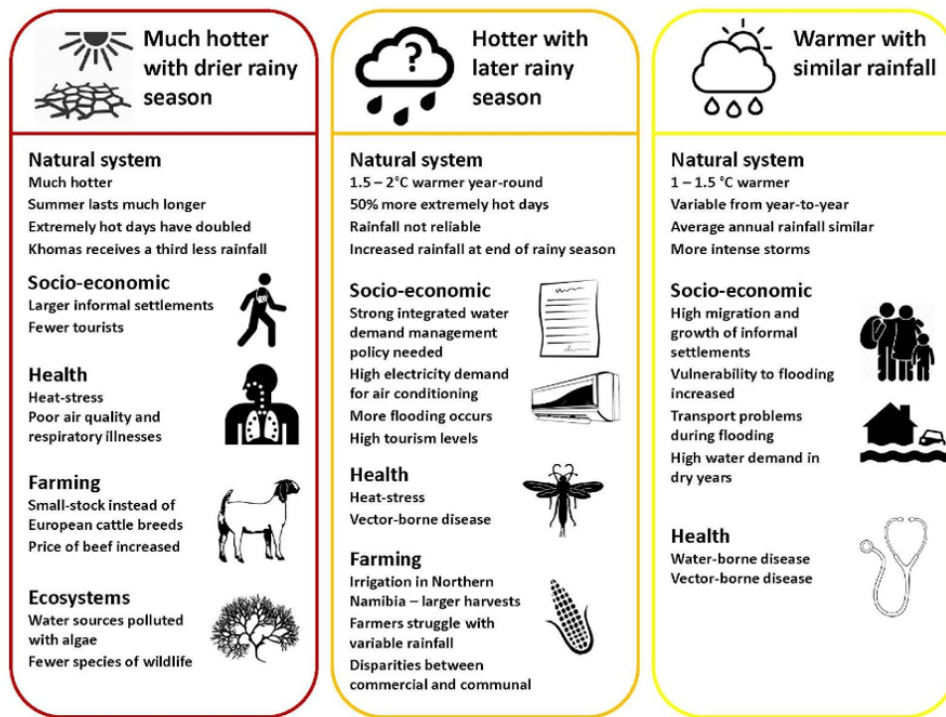


Figure 4 | The first draft of an infographic CRN, presented at LL2.

5. How have the Windhoek CRNs been used in FRACTAL phase 1?

The Windhoek CRNs were used in a range of different engagements and activities throughout phase 1 of FRACTAL (February 2017-September 2019), predominantly as a way of promoting discussion and understanding of the wealth of information and evidence available (including from across sectors and societal organisations) and how this might relate to policy, planning and operational decisions being made.

The City of Windhoek (CoW) has taken proactive steps to improve its climate resilience by addressing potential and actual climate change impacts faced by the city. The CoW has developed its Integrated Climate Change Strategy and Action Plan (ICCSAP) to act as a framework for the city's response to climate change and to ensure that national obligations are streamlined into the city's operations. Supported by FRACTAL, a stakeholder workshop for the ICCSAP took place on 13-14th March 2018 that brought together CoW's

Departments and other relevant stakeholders, including the Ministry of Environment and Tourism, and Namibia Energy Institute. During this workshop main sectors and areas in the city that are affected by climate issues were identified, and adaptation and mitigation measures were proposed. The Windhoek CRNs were used as a basis to explore what scientific knowledge lies behind them - one example of this is the historical global mean temperature record and its relationship with measured carbon dioxide concentrations in the atmosphere, see Figure 5 below, and how this compares with historical temperature trends in the central region of Namibia, see Figure 6. The session also delved into available rainfall records and historical rainfall trends in Namibia, before discussing how climate models work to generate simulations of possible future climates, and what climate projections for the Khomas Region suggest might be expected.

Through the process of developing and refining the ICCSAP, the FRACTAL team was able to engage more deeply with participants

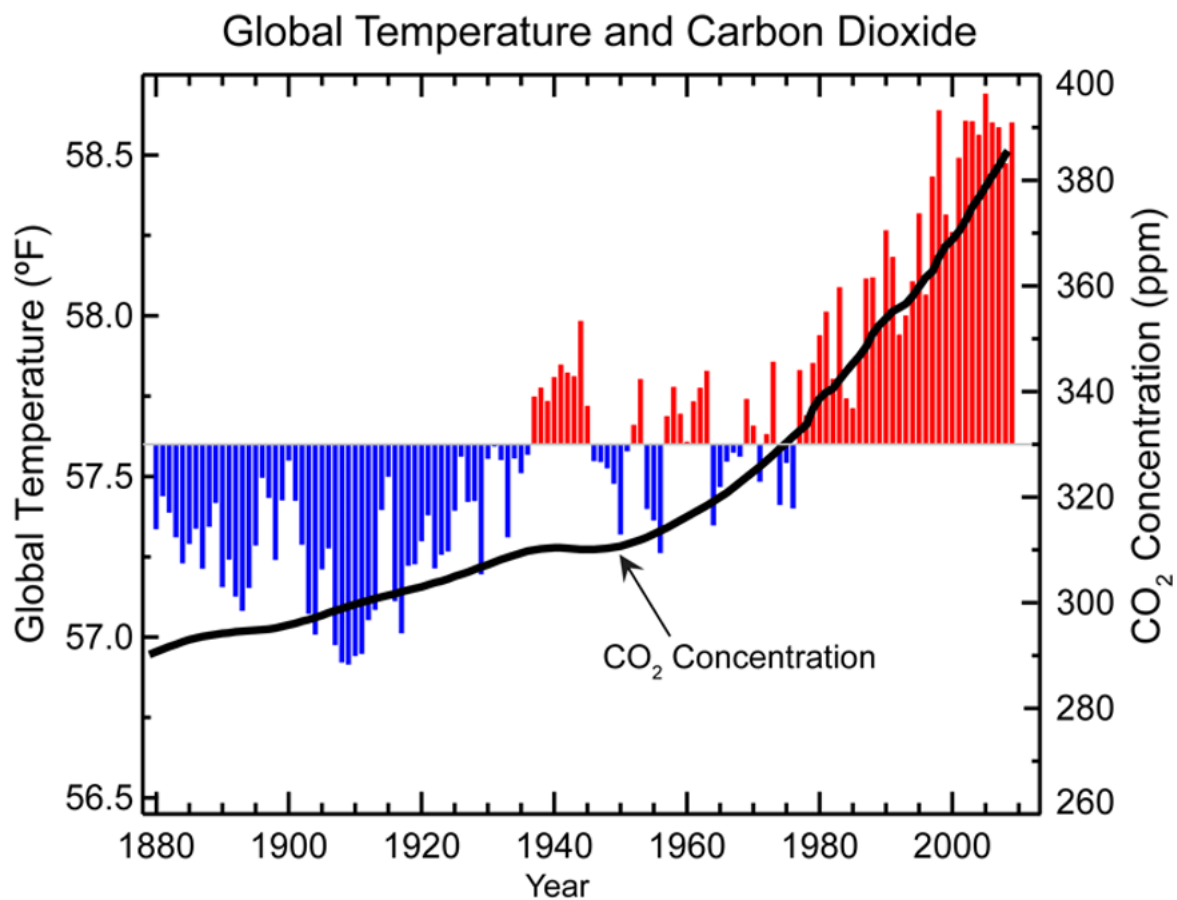


Figure 5 | Global annual average temperature (as measured over both land and oceans) has increased by more than 1.5°F (0.8°C) between 1880 and 2012. Red bars show temperatures above the long-term average, and blue bars indicate temperatures below the long-term average. The black line shows atmospheric carbon dioxide (CO₂) concentration in parts per million (ppm). Figure source: updated from Karl, T.R., Melillo, J.M. and Peterson, T.C. (2009) NOAA/NCDC Report on Global Climate Change Impacts in the United States.

and build on the common understanding developed through previous discussions on the CRNs. An updated, sector-specific CRN infographic (as shown in Figure 1) was requested and then co-developed with a City Council member after reflection on the CRN process and feedback from a previous Learning Lab. This showcases the highly iterative nature of CRNs, and the importance of tailoring CRNs to specific decision contexts in order to ensure their effectiveness.

In the Transformational Leadership on Climate Change (TLCC) workshop held with City of Windhoek Councillors, Windhoek Constituency Councillors, the City of Windhoek's Chief Executive Officer and Strategic Executives, representatives of the Association for Local Authorities in Namibia, the Okahandja Town Council, Rehoboth Town Council and Walvis

Bay Municipality, and the Governor of the Khomas Regional Council in April 2018, the CRNs infographic (Figure 1) was shared with participants. The infographic was used to raise awareness of climate change projections for Namibia and prompt discussions amongst participants about: how their area of work might be impacted by these scenarios; what other factors may be important which had not yet been considered in the scenarios; what adaptation options could be implemented in their constituency or area of work to reduce potential impacts; and what 'seeds' had already been planted to build Windhoek and Namibia's resilience to avoid or deal with the impacts raised in the CRNs.

In the third Learning Lab (LL3) held in August 2018, the CRNs were used again to set the scene for further discussions in small groups

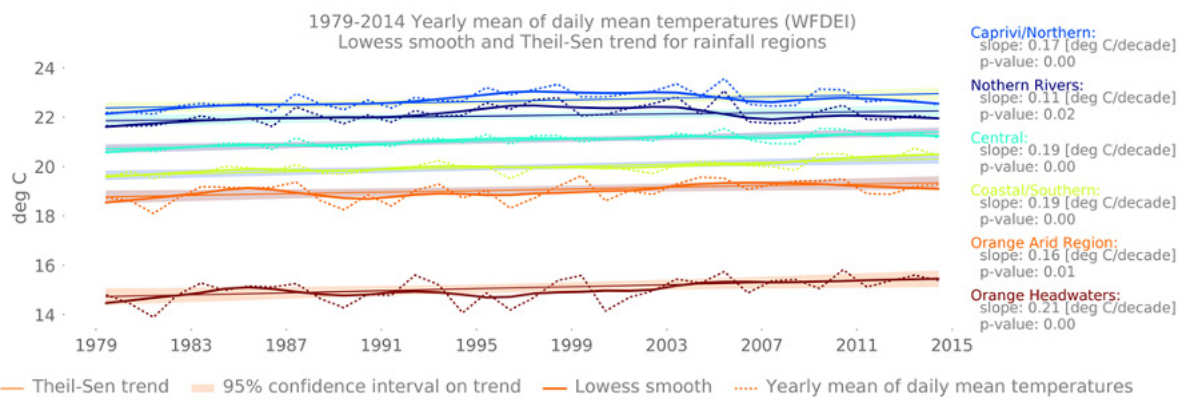


Figure 6 | Graph showing observed historical temperature trends and inter-annual variability for 6 biophysical regions across Namibia, indicating that the whole country has warmed significantly over the past 35 years with central Namibia warming at nearly the same rate as the globe, while northern Namibia is not warming as rapidly as southern Namibia (Source: Piotr Wolski and Christopher Jack, presentation given at Windhoek ICCSAP meeting, March 2018).

to consider the implications on their own decision-making practices.

"I think now, the city is waking up. In the latest city transformation strategy, climate issues are mentioned as issues that need to be addressed. Although for many years, the city has not really embraced these issues as an organisational problem, where it was noticed but left up to the environment to deal with. That mentality is slightly changing; it's everybody's business now. So, we cannot run away... from a finance person, HR person... it's your business. That consensus is there now... one of the major lessons is climate change mainstreaming...[...]. into city operations and also that bridge between academia and local authorities...I think it's the first of its kind. That cooperation between academia and the simplification of scientific information, information of narratives, infographics, that the layman in the city corridors can understand. Those two are very important.."

Olavi Makuti, CoW Environment Division.

as an example of this distillation in practice. Participants then had an opportunity to craft their own CRN (either textually or visually) based on the climate evidence they had been exposed to in the training event. To showcase the distillation process in an interactive way, the trainers introduced a 'Climate Evidence Box' where participants could contribute pieces of climate evidence relevant to Windhoek for consideration in a hypothetical distillation process.

The 'Climate Evidence Box' from the training above was then linked to the activities held in the fourth Learning Lab (LL4), held 17-18 June 2019. This lab contained a session focused on the distillation of climate information, which highlighted the assumptions that climate scientists often need to make when producing and analysing climate information, and the risks associated in these assumptions when it comes to understanding and interpreting the resulting evidence. Using the pieces of climate evidence provided in the Climate Change Training event, participants worked in small groups to identify the key messages contained in each piece of evidence, and discuss what assumptions were made by the scientists or providers of the information. Climate scientists were on hand for this session, and were able to engage in the group discussions when they were asked by participants, as a way of simulating the importance of this open dialogue and co-exploration process between

The CRNs were showcased more thoroughly at the Climate Change Training event held in June 2019. In this event, participants were provided with training on the basics of climate science, as well as some exposure to the interpretation of complex, often contradictory, pieces of climate evidence. Trainers introduced the concept of distilling multiple sources of climate information into relevant messages that are co-produced and accessible to decision-makers, using the Windhoek CRNs



users and providers of scientific information. These discussions proved useful in building a common understanding of the assumptions made by scientists, specifically whether these assumptions were appropriate for decision-makers in Windhoek. For example, one piece of scientific evidence presented in this session was the projected change in the number of days exceeding 30°C by the end of the century. A city engineer participating in the session noted that the temperature threshold of 30°C was not relevant for her decision-making activities - she was more concerned with temperatures nearing 40°C, at which point the structural integrity of manhole covers could be affected. This interaction revealed to the climate scientists a temperature threshold worth exploring in their analysis that would yield information more suited to a context-specific decision need. At the end of this session, the CRNs were showcased as an example of a possible output that could be produced through undertaking the distillation process when tailored to specific decision-making contexts.

6. Future directions

The work undertaken during the first phase of the FRACTAL project focused on opening up conversations with a variety of stakeholders about Windhoek's climate sensitivities and resilience, exploring relevant scientific climate data and information, including projections of possible future climates for Namibia's central region, and how this relates to the policy, planning and operational decisions being made. Because the CoW were at the time undertaking the development of the ICCSAP, the work fed most directly into setting the context for the plan and for exploring the priorities to be set out in the plan to reduce climate risks and impacts (see a reflection on the process and lessons learnt in the FRACTAL Impact Story 9: Moving Towards Integrated and Inclusive Climate Change Planning in

Windhoek⁵). Once the ICCSAP is approved, then the focus will be on implementation. One future direction for this work will be to address additional needs for climate data, information and knowledge that may emerge as the operational details of the plan are worked out to implement specific measures prioritized in the ICCSAP, with relevance for city development planning and technical decision making (i.e. at the Division and Strategic Executives levels) and for the policy making (i.e. Council level). Monitoring climate patterns and refining climate projections to identify if and when additional, more ambitious and costly measures might be justified, could be one aspect of this. Another possibility would be to produce a new version of the CRNs describing what the city could look like given full implementation of the ICCSAP, as well as a current day climate risk narrative, to compare plausible trajectories of climate risk in light of adaptation interventions. This could include finding ways to translate the CRNs into formats and language useful for working with local communities, especially those living in informal settlements.

In the fourth LL, FRACTAL partner Aurecon (now Zutari) hosted a session on the work they were just beginning with CoW to develop the Windhoek Integrated Water and Wastewater Master Plan (IWWWMP). This involves taking an Integrated Urban Water management (IUWM) approach, looking to optimise the linkages between wastewater, potable water and energy. The plan aims to improve the city's resilience to climate change - notably increasing temperatures and evaporation rates, as well as potential shifts in rainfall, runoff and recharge patterns - by expanding water recycling systems. Through engagements with stakeholders from the technical, institutional, financial and environmental spheres, a strategic and operational plan will be developed determining the required works, costs, impacts and sequencing of investments. A climate change

5 <http://www.fractal.org.za/wp-content/uploads/2020/03/IS9-Moving-towards-integrated-and-inclusive-climate-change-planning-in-Windhoek.pdf>



risk assessment will be undertaken as part of the process of developing the IWWWP, which will entail quantifying probable effects of climate change on water demand, water resources and water balance and assessing the vulnerability of existing facilities to extreme climatic events, mainly floods. Three scenarios of the next 20 years, including biophysical, socio-economic and demographic changes affecting Windhoek, will be used to help the CoW screen the possible options to include in the Master Plan. This is one area of work that holds considerable promise for building on and taking forward the CRNs developed in phase 1 of FRACTAL.

From a research perspective, the production of CRNs in other focal cities within FRACTAL (specifically Lusaka) uncovered a need to better understand the representation of extreme rainfall within climate models in order to tailor the CRNs towards the information needs of those dealing with flood risk management, water management and various infrastructure requirements. This has led to novel climate science research on the usability and limitations of a ground-breaking, convective-permitting climate model for Africa (CP4A), developed in the FCFA-IMPALA project. Knowledge developed here could be applied in the Windhoek context to better understand projected changes in extreme rainfall for the city, as part of further multi-stakeholder engagements, feeding into city planning processes through an updated set of CRNs. More research is also needed to better understand the complex ways in which scientific climate information interacts with various other factors to shape policy and planning outcomes, as a basis for enhancing climate service offerings and improving context-relevant approaches to support evidence-based decision-making at the urban scale. One aspect of such research is exploring how citizen science with urban residents, especially those living in informal settlements experiencing climate impacts, might contribute to shaping not only household decisions but also government policy and planning decisions.

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Appendix 1

Windhoek Climate Risk Narratives

The following set of three narratives were developed through the Windhoek Learning Lab process and contain inputs from a diverse group of participants.

Narrative #1: “Much hotter with a drier rainy season”

In the middle of the 21st century, Windhoek and the region of Khomas experience temperatures which are much hotter than they used to be. The hottest years which were experienced by the region at the start of the century are now normal. The number of extremely hot days (above 35°C) has doubled on average, although some years are cooler and some are even hotter. The summer time lasts much longer than it used to with many more extremely hot days being felt at the start and end of the rainy season. In central and northern Namibia, rainfall totals have also reduced since the start of the century. On average, Khomas Region receives about a third less rainfall than it did previously in the rainy season but this varies greatly year-to-year due to the influence of El Nino and its interactions with local scale processes such as the availability of soil moisture to drive convective rain systems.

The rise in temperatures and reduction in rainfall have hit agricultural areas badly. Ephemeral rivers contain water for less time due to evaporation and less inflow and water tables have fallen. Farmers can no longer raise European cattle breeds due to heat stress, so many farmers now only farm small stock such as goats and the price of beef has greatly increased. These pressures on rural populations have resulted in a large influx of migrants to Windhoek.

Due to the hot weather, dams such as Von Bach Dam, Swakoppoort Dam and Omatako Dam in Khomas and Otjozondjupa Regions experience large evaporative losses. Multi-year droughts are common and in these years Windhoek struggles to meet the water demands of its industrial, commercial and residential sectors. Further pressure on water resources is applied by the increase in the urban population and the extreme hot weather. Demand for air cooling systems is high and many parts of Windhoek’s society often require treatment for heat-stress related illnesses conditions.

The influx of rural-urban migrants has resulted in large informal settlements where electricity is limited and firewood is used as an alternate fuel source. The burning of coal and firewood has contributed to poor air quality in the city and many more residents seeking medical attention for respiratory problems.

Lower rainfall, lower runoff and higher evaporation rates have seen water sources become more polluted by blue-green algae and contain higher concentrations of salts. These have wide ranging impacts on the finely balanced ecosystem of Namibia. The Okavango Delta and Etosha pan see fewer species of wildlife. Coupled with the increasingly hot temperatures, tourist visits to Namibia are now fewer and the economy of Windhoek has suffered.

However some benefits from the hotter and drier climate have been felt by the city of Windhoek and region of Khomas. Flooding, and its associated damage, is less common and warmer temperatures in the dry season allow some crops to be grown by those who can afford irrigation.



Narrative #2: “Hotter with more rainfall later in the rainy season”

The climate of Windhoek in the middle of the 21st century is hotter than it was previously. Temperatures are about 1.5°C to 2°C warmer on average in all months than they were at the start of the century. Extremely hot days are more frequent, particularly in the rainfall season. Days where temperatures rise above 35°C have increased by about 50% compared to the start of the century. Intense convective downpours, triggered by the hot weather and the high moisture content of the atmosphere, occur frequently towards the end of the rainfall season. However the rains are not reliable and some years are still as dry as the dry years at the start of the century.

The increased rainfall late in the rainy season sees ephemeral rivers contain water for longer than they did in previous decades. Inflow into dams and aquifers is high at these times. However, due to the high temperatures, evaporation rates from uncovered water storage facilities are high and careful management of water is needed. The City of Windhoek continues to run a strong integrated water demand management policy with components of policy, legislation, public awareness and technology. Namibians continue to be experts in the development of sub-surface water storage such as at Omaruru Delta and reclamation technologies e.g. Goreangab Wastewater Treatment Plant. As a result, efficient use is made of the slight increase in rainfall in the rainfall season. Most households in Windhoek have adequate access to water.

Irrigation systems have also been invested in by farmers in Northern Namibia by those who can afford to do so. Combined with warmer temperatures in the dry season, particularly warmer minimum temperatures, larger harvests and a wider range of crops can be grown in the irrigated areas. This has led to an increase in the agricultural sector’s contribution to Gross Domestic Product (GDP). However, disparities between the commercial and communal sectors have grown since the start of the century, with poorer farmers seeing little difference to their earnings. Complacency can also set in during wet years and when rain totals are smaller than expected can farmers can be poorly prepared requiring Namibia to import large amounts of grain. At times when rainfall is high, pooling surface water allows insects to breed and vector-borne disease in humans and livestock occurs more frequently.

The demand for electricity is high in Windhoek, particularly for air cooling systems to cope with the high temperatures. This demand is mainly met with the use of renewable energy sources such as solar, resulting in low air pollution. Parks and recreational areas have been planted with native drought-resistant succulent plants. Windhoek remains an attractive, clean city with high numbers of tourists. However, poorer and vulnerable parts of society often require medical attention for heat stress related conditions during the commonly occurring periods of sustained high temperatures.

Windhoek suffers from more flooding than it did a few decades ago as a result of the commonly occurring convective storms during the rainfall season. Informal settlement areas of the city suffer disproportionately and costs for rebuilding damaged areas are expensive for the city council.

Narrative #3: “Warmer with similar rainfall”

In Windhoek and the surrounding region of Khomas, cycles of warmer and wetter conditions followed by drier and cooler conditions persist in the middle of the 21st century. Conditions continue to be quite variable from one year to another but on the whole temperatures are about 1-1.5°C warmer than they used to be. Average annual rainfall totals are much the same as they



were in previous decades. The influences of El Nino and La Nina continue to be experienced by the region resulting in some years undergoing a prolonged dry season and others being wetter than normal. When rain storms occur in the rainfall season they are typically more intense than they used to be as a result of the warmer atmosphere.

The increase in temperature has been gradual, and due to only a very small increase in the number of extremely hot days, the general public have not noticed a change in the climate in their day-to-day lives. Namibia's Climate Change Strategy and Action Plan was not fully implemented. As a result, minimal investment has been made in the city of Windhoek to make it robust to the impacts of the change in climate.

The low level of investment in adaptation for the city has left it vulnerable to high levels of flood damage. Large numbers of people continue to migrate from rural to urban areas in Namibia, and Windhoek's informal settlements continue to grow. Many of these settlements are built in or near river beds so the effects of flood damage are disproportionately felt by these communities. Drains are blocked as they are used as conduits for illegal electricity and this also contributes to more frequent flooding in the informal settlements. Water-borne diseases are more common at these times and the standing water allows more insects to breed causing enhanced levels of vector-borne disease in both humans and livestock. Transport around the city suffers at times of heavy rain showers, as adequate drainage to cope with high surface run-off has not been built. The flooding and transport disruption degrades the pleasant atmosphere and living standards for citizens and visitors to the city.

In the hotter years where the rainfall season is shorter, the city can struggle to meet water demands as a result of low runoff into the dams in the Upper Swakop catchment. The warmer weather also results in higher evaporative losses from dams and other uncovered water storage areas. The variable nature of rainfall totals in the rainfall season and low use of artificial recharge schemes makes it hard to plan and store water for dry years.