**INVESTIGATING IMPACTS OF CLIMATE CHANGE AND RESPONSES OF BOTANICAL GARDENS IN GAUTENG PROVINCE**

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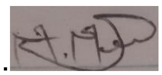
**Date: 02 August 2022**

**Declaration of independent work**

This thesis/dissertation is the result of my own independent work/investigation, except otherwise stated.

Other sources are acknowledged by giving explicit references. A reference list is appended.

Signed: ……….

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## Abstract

Worldwide, botanical gardens are used as critical recreational centres for urban tourism, where people can relax and learn about flora. Botanical gardens have a crucial role to play in conservation and tourism and have an essential role in conserving and maintaining plants and animal species. However, there is growing concern that botanical gardens and other protected areas could be at risk from climate variability and change. Regardless of this concern, very little on how climate variability and change will affect botanical gardens worldwide is known.

This study sought to respond to this knowledge gap identified and aimed to examine the evidence, impact, and response to climate variability and change by the Pretoria National botanical gardens and Walter Sisulu botanical gardens in Gauteng province.

The study adopted a pragmatism paradigm, with a case study that used a mixed-method approach. The study used multiple research techniques to collect data, such as; an online survey (324), key informants interviews (15), field observations and secondary data analysis. Data was analysed using a Mann-Kendall Trend Analysis, Microsoft excel sheet and Question-Pro analysis tools. Content and thematic analysis were used to analyse secondary and interview data.

The study found evidence of climate variability and change at the two botanical gardens, characterised by intense rainfall activity such as flooding, extreme droughts, generally decline in rainfall amounts, and increasing temperature, posing a threat to infrastructure, flora, and fauna of the garden. Recreation makers complained that climate change adversely affects botanical gardens' aesthetics and general experience.

In response to climate variability and change, botanical gardens in Gauteng are trying to adapt and mitigate the effects of climate change to foster climate resilience. As much as there are fears of climate variability and change impacts, botanical gardens are underprepared to deal with climate change, given the vast knowledge gaps that exist.

This study recommends that scientific studies be conducted to ascertain how climate variability affects flora and fauna in the botanical gardens as there are many grey areas.

Hopefully, this will prompt the gardens to adapt to climate variability and change effects appropriately.

Keywords: climate change impact, variability, botanical gardens, Gauteng province, tourists, South Africa

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**List of Acronyms**

| | |
|---|---|
| SANBI | South African National Biodiversity Institute |
| SAWS | South African Weather Service |
| SDGs | Sustainable Development Goals |
| GHG | Greenhouse Gas |
| NEMBA | National Environmental Management Biodiversity Act |
| DEA | Department of Environmental Affairs |
| NBGs | National Botanical Gardens |
| NDP | National Development Plan |
| IUCN | International Union for the Conservation of Nature |
| UN | United Nations |

# Chapter 1: Introduction and Background of the study

## 1.1 Introduction

The chapter focuses on the background of tourism and climate change, providing the significance of botanical gardens. The chapter also hihglights climate change effects on the natural environment and tourist destinations. The justification of the study is also covered to clearly understand climate change impacts and the botanical gardens response to climate change. The chapter discusses the gaps on the issues of climate change on nature-based tourism. It also covers the aims and the objectives the study aimed to achieve.

## 1.2 Background of the study

Tourism is recognized as one of the world's largest growing economic sectors in many countries. It contributes to sustainable development by creating jobs and providing access to a formal economy for previously disadvantaged communities (Dube, Mearns, Mini & Chapungu 2018:1). Tourism has many positive impacts, as it is a creator of foreign income in both developed and emerging nations (Amusan & Olutola 2017:2). According to Rogerson (2016:322), Dube and Nhamo (2020a:1) and Rasoolimanesh *et al.* (2020:1), tourism is a pillar for poverty reduction and contributes toward the achievement of Sustainable Development Goals (SDGs). Tourism is critical to raising living standards, increasing economic advantages, preserving cultural integrity, safeguarding natural areas, and addressing the requirements of people in developed countries (Zolfani, Sedaghat, Maknoon & Zavadskas 2015:2; Smith 2013:1).

According to Amusan and Olutola (2017:2), South Africa is one of Sub-Saharan Africa's most popular tourist destinations because of its diverse tourism products. Because of its exquisite beauty and rich cultural and national legacy, the country attracts numerous tourists from all over the world (Rasoolimanesh *et al*. 2020:1). South Africa is regarded as a key to the leisure and recreation segment (Friedrich, Stahl, Fitchett & Hoogendoorn 2020a:1). The top four leisure tourist destinations in South Africa include Kruger National park, iSimangaliso Wetland Park, the Garden Route, and Kirstenbosch Botanical gardens (McKelly, Rogerson, Huysteen, Maritz & Ngidi 2017:226).

South Africa accounts for a significant portion of the tourist business in Sub-Saharan Africa, with 10.5 million international arrivals in 2018 and 44.4 million domestic overnight excursions in 2017 (Friedrich, Stahl, Hoogendoorn & Jennifer 2020b:2; Amusan & Olutola 2017:2). The draft National Botanical Garden Expansion Strategy (2019-2030) indicated that botanical gardens alone receive nearly two million visitors annually. Visitors consider a few botanical gardens to be among the best places to visit for fun, research, and education (South African National Biodiversity Institute 2018).

Botanical gardens, therefore, play a critical role in tourism and recreation in South Africa and abroad. Botanical gardens play a pivotal role in offering venue options for recreation activities. While many people visit them as a relaxing picnic site, others choose to use them for special events such as weddings and music concerts, thus showing relevance to leisure tourism (Dodd & Jones 2010:4). In addition, botanical gardens have acquired appeal in the educational realm in recent years, serving as instructional centres where students can learn about flora (Moskwa & Crilley 2012:404). The draft National Botanical Garden Expansion Strategy (2019-2030) identifies botanical gardens as a key contributor to South Africa's climate change mitigation and adaptation efforts (SANBI 2017/18).

In other countries such as Australia, botanical gardens are essential for urban tourism and crucial for cultural preservation (Schweinsberg, Darcy & Cheng 2017:241). Botanical gardens have a long-standing history as anchors of colonial expansion (Brockway 1979:415). Some of the most famous botanical gardens with a colonial legacy are the Royal Botanical Gardens in Kew (United Kingdom), Royal Botanical Gardens in Sydney, and the Cairo-based Orman Gardens in Egypt (Schweinsberg *et al*. 2017:241). This marks botanical gardens as important cultural tourism sites. Whilst botanical gardens in South Africa also play an important role as cultural tourism sites, and they are also preserved as national heritage sites, which play a significant role in conserving the environment (Willis 2018:9).

According to Ginn (2009:36), botanical gardens have an essential horticultural and conservation significance apart from being an iconic colonial heritage. Despite its substantial community significance, evidence reveals that botanical gardens, like any other component of nature, are increasingly threatened by climate change, which affects their tourism socio-cultural, environmental, and economic worth (McClean, Lovett, Kiiper, Hannah, Sommer, Barthlott, Termansen, Smith, Tokumine & Taplin 2005:140). There is an increased awareness and concern among the global tourism and recreation industry and the populace about the dangers of climate change on human civilization (Dube & Nhamo 2020b:28). The relationship between tourism, recreation, and climate change has increased academic interest and exploration by range (Dube & Nhamo 2020b:28; Pandy 2017:1).

Climate variability and change have increased the frequency and intensity of extreme weather occurrences around the planet. Some of the most unfavourable weather conditions have plagued South Africa, including severe flooding, cyclones, fires, and extreme droughts (Madzwamuse 2010:1). Such extremes have disturbed the natural ecosystems, resulting in a devastating impact on the natural ecosystem that supports tourism products (Dube & Nhamo 2020c:2). Climate change, directly and indirectly, impact leisure and exploration by changing the facilities, activities, and environments in which tourism takes place (Dube & Nhamo 2018:113). However, on the positive side, tourism adds to the generation of Greenhouse Gases (GHGs), which contributes to climate change (Hambira, Saarinen & Moses 2020:1; Scott, Gossling & Hall 2012:213).

This is a concern as climate change threatens the natural environment on which tourism is dependent (Friedrich *et al.* 2020a:1). In South Africa, several studies identified nature tourism to be at risk due to the influence of climate change (Smith & Fitchett 2020:108; Linsheng, Hu & Yuxi 2019:2086). Climate, weather, and seasonality impact tourist satisfaction, behaviour, and travel motivations (Fitchett, Grant & Hoogendoorn 2016:1; Friedrich *et al*. 2020a:1).

A study by Dube and Nhamo (2020b:29) reported that tourists are increasingly sensitive and conscious of the ramifications of climate variability on iconic tourist resorts in Southern Africa, such as Victoria Falls, Okavango Delta, and Kruger National Park.

Friedrich *et al*. (2020a:2) indicate that tourist incentives are highly influenced by climate change travel. Climate change directly affects tourism seasonality (Linsheng *et al.*

2019:2086). Tourists are sensitive to changing weather conditions, depending on the attraction and activities they want to participate in, such as rainfall, storms, and wind speed, which influence the destination's recreation (Smith & Fitchett 2020:107). Botanical gardens are no different. Their appeal as a tourism and recreational facility option is also dependent on critical decision-making factors like climate and weather conditions.

Botanical gardens are acknowledged as important tourist destinations for conservation and preservation of indigenous plant and animal species to prevent biodiversity loss and extinction (Lee, Roehrdanz, Marquet, Enquist, Guy, Wendy, Jon, Richard, Derek, Butchart, Brad, Xiao, Brian, Javier, McGill & Cory 2020:2). Plant diversity is currently being lost at an unrivalled rate, resulting in an associated decrease in ecosystem services (Chen & Sun 2018:182). There is a change in many plant species and animals due to the ramifications of global climatic conditions (Primack & Miller-Rushing 2009:303). Climate change is revamping environmental ambience in all parts of the world, both on land and sea, where ocean species are dramatically shifting their distributions in reaction to the new environment (Lee *et al.* 2020:2; Paweł, Theo, Maceij, Katarzyna, Paul, Geoffrey, Joanna & Justyna 2019:6834). The earth's notable rich botanical diversity is living in the Anthropocene (Svenning 2018:963).

Plants, including those in botanic gardens, are already being affected by anthropogenic climate change, as global warming drives species towards the poles and upslope mean (Svenning 2018:964; Ming, Zhe, Wen, Cannon, Niels & Slik 2014:405). Climate change is causing significant shifts in species while also resulting in some of them to occupy new regions (Lee *et al.* 2020:2; Timothy, Chris & Symes 2017:340). Species advance individually in reaction to global climate change because species' climate niches are unique (Lee *et al.* 2020:2). Climate change affecting local species distribution patterns is central for developing dynamic strategies to reduce climate change in biodiversity (Ming *et al.* 2014:405). There are fears that such changes will affect the sustainability and attractiveness of botanical gardens as recreational and tourism facilities.

## 1.3 Rational and Motivation of the Study

Anthropocenic climate change impacts are causing the immense spread of global warming and facilitating the earth's ecosystem services, causing rapid vegetation changes and threatening biodiversity (Osborne, Charles-Dominique, Stevens, Bond, Midgley & Lehmann 2018:10). Regarding the impact of climate change on biodiversity, more than half of the earth's habitable surface has been reported to be significantly altered by humans. As a result, plant and animal species are now at the extinction limit (Akinyoyenu, Majid & Zen 2017:111). Amedie (2013:10) discloses that over 40% of the world's physical environment accountable for primary capacity has been contrarily modified through the environmental impact of agriculture, contamination, non-indigenous species, transformation, and disruption.

Several studies indicate that climate change is expected to bring significantly warmer atmospheric temperatures and increased aridity to the earth's ecosystems over the next century (Hultine, Majure, Nixon, Arias, Bu'rquez, Goettsch, Puente-Martinez & Zavala-Hurtado 2016:1059). While many studies have documented global warming, which is expected to continue in the foreseeable future, its impact on botanical gardens is challenging to comprehend and acknowledge (Panchen, Primack, Anisko & Lyons 2012:751).

Climate change constitutes the most significant environmental problem in tourism and many protected areas worldwide (Amusan & Olutola 2017:4). Dube and Nhamo (2020d:2) indicate that climate change poses significant threats to wildlife, the environment, and the national budget. Over the years, climate change has been identified to have adverse effects on flora and fauna, as evidenced by the decline in bird-life species and other animal populations (Dube *et al.* 2018:1). Increased evidence in extreme weather events, droughts, heatwaves, flooding, among others, have emerged as significant threats to wildlife tourism in protected areas across Southern Africa (Dube & Nhamo 2020d:2).

Climate change is a foreseeable and remediable forecast negative to the practicality of nature tourism recreation (Fitchett *et al.* 2016:1). Climate change threatens nature-based tourism's sustainability and aesthetic value (Friedrich *et al.* 2020a:2; Hambira *et al.*

2020:1). Pandy and Rogerson (2018a:104) highlight that climate change puts significant biodiversity at risk and various aspects of national life such as agriculture and forests, energy use, and transportation. Provided with the measure at which global environmental change occurs, policymakers need to be equipped with the requisite data and information that would lead to appropriate adaptation and mitigation approaches to climate change (Hambira *et al.* 2020:2).

The researcher was motivated to conduct this study to clearly indicate botanical gardens' impact and response to climate change. Their role in climate change mitigation enhanced this under the National Environmental Management Act, National Environment: Biodiversity Act 2004 (ACT NO. 10 OF 2004) read together with the Department of Environmental Affairs Notice 607 OF 2019.

## 1.4 Problem Statement

There are rampant fears and evidence of climate change affecting urban tourism in South Africa and numerous protected regions. Vast knowledge gaps still exist on how different tourism sectors and subsectors are affected by climate change (Hoogendoorn & Rogerson 2016:356). There has been numerous calls from National Development Plan (South African Government, 2012), Agenda 2030 on Sustainable Development Goals (SDGs) (United Nations- UN, 2015), the Paris Agreement (United Nations Climate Change, 2015), National Tourism Climate change action plan for South Africa and National Climate Change Adaptation Strategy (Department of Environmental Affairs, 2019), for the tourism sector to develop a climate change strategy for the industry. Despite these strong calls, there are significant knowledge gaps in that area in addressing climate change impacts, with little progress made to far. This study seeks to address this shortcoming.

## 1.5 Aims and Objectives

### 1.5.1 Primary research objective

The primary objective of this study was to investigate, impacts and response to climate and change by botanical gardens in Gauteng Province.

### 1.5.2 Secondary research objectives

The secondary objectives of this study were:

- To understand visitor perceptions of the impact of extreme weather events have on botanical gardens in Gauteng Province**.**
- To examine evidence and the impact of climate variability and change on botanical gardens in Gauteng Province**.**
- To explore climate mitigation and adaptation strategies that are being adopted by botanical gardens in Gauteng Province.

## 1.6 Research questions

- What are visitor perceptions on the impact of climate variability and change on botanical gardens?
- What is the evidence and impact of climate variability and change on botanical gardens in Gauteng?
- Which mitigation and adaptation strategies are being adopted by Gauteng botanical gardens to address climate change?

## 1.7 Contribution of the study

The study made an essential contribution to the threat of climate variability and change in botanical gardens in Gauteng and filled the knowledge gaps through information attained during the study. The study also made a significant contribution towards the level of understanding of climate change, and the effects thereof, within botanical gardens. The study covered the impacts of climate variability and change responsible for the threat to botanical gardens. The study also covered mitigation and adaptation approaches applied in botanical gardens in response to the impacts of climate change. The study advanced knowledge on the visitor perceptions of extreme weather events and contributed to reducing climate change.

## 1.8 Limitations of the study

There are limited investigations on the impact of climate change and low adaptive and mitigation capacity in the tourism industry regarding previous literature. However, this study made a significant contribution to the existing literature. It was not easy to collect data from the respondents during the survey as some were not eager to complete the survey. Even though the survey had a high response rate and data was significant enough to be analysed. It was also not easy to conduct the interviews as it was difficult to interact with people due to Covid 19.

## 1.9 Chapter Outline

### Chapter 1: Introduction and Background to the study

This section explores the problem and problem statement. It highlights the significance of the study and the research objectives the study aims to achieve.

### Chapter 2: Literature review

This chapter elaborated on recent developments in nature-based tourism, focusing on botanical gardens that conserve biodiversity in South Africa and the effects of climate variability within the context of South Africa. The chapter also discussed the role of botanical gardens in tourism and recreation and presented the potential impacts of climate change on biodiversity conserved in the botanical gardens.

### Chapter 3: Research Methodology

This chapter described the research methodology applied. It outlined the study's design, target population, sampling frame, sample size, and different approaches/instruments to collect data for the analysis.

### Chapter 4-5: Interpretation of results

This chapter presented the findings of the analysis. An interpretation was provided in the form of graphs and charts to present the study's main results and discuss them in light of previous publications in the field of tourism and climate change. The results of the findings are discussed and compared with the findings that were highlighted in the literature review.

## Chapter 6: Conclusions and recommendations

This chapter provided recommendations on how policies and practices can be adapted to ensure that steps are taken to mitigate the potential impacts of climate change on biodiversity conserved in the botanical gardens.

# Chapter 2 : Literature Review

## 2.1 Introduction

This chapter focuses on botanical gardens to better understand recent developments in nature-based tourism in the context of climate change. The effects of climate change on botanical gardens is investigated in this chapter. It examines how these critical biodiversity conservation areas answer to the impacts of climate change. The chapter comprises the following key sections; an overview of botanical gardens, botanical gardens in the South African context, the role of botanical gardens as tourism and recreation centres, climate change and the biodiversity debate, tourism and climate change in South Africa, mitigation and adaptation in the tourism sector, and the knowledge gaps with regards to botanic gardens and nature-based tourism and recreation.

## 2.2 Botanical Gardens

Botanical gardens are known as places open to the public and where people learn more about plants (Krishnan & Novy 2016:2). Botanical gardens educate visitors on programs such as plants' origins, uses, importance, and value, amongst other such crucial information (Błaszak, Rybska, Tsivitanidou & Constantinou 2019:1). There are different definitions of botanical gardens. Karaşah and Var (2013:803) defines botanical gardens as *"innovative institutions that can help local people in many ways through the introduction of new economically valuable plant species, a creation of a friendly and secure environment, an improvement of settlements, a city greening, a restoration and a repatriation of rare plants, the gardening therapy, and a continuous education for the public".* Botanical gardens are also defined as *"places of collections of living plants managed scientifically for academic interest, examination, protection, and exhibition"* (Sanders, Ryken & Stewart 2018:1078).

Botanical gardens offer programs such as maintaining biodiversity and serving as a comical reservoir of plant germplasm for the long-term preservation of species (Cudjoe & Gbedemah 2019:25). Deshpande and Yadav (2017:471) noted that botanical gardens play a critical role in the ex-situ conservation of endangered plants, maintaining seeds, and propagating seed banks. According to Deshpande and Yadav (2017:471) and

Arnautova and Yaroslavceva (2019:851), botanical gardens also act as redeem centres for revival and rehabilitation of rare, endangered, and eradication of vulnerable species of vascular plants.

Moreover, botanical gardens serve unique roles in conservation and are grouped according to the following characteristics. Among others, they must be relatively permanent (Krishnan & Novy 2016:2), scientifically-based (Cudjoe & Gbedemah 2019:24), monitor the plants in its collection (Borsch & Löhne 2014:121). In addition, they must be accessible to the general public and must be able to share their results with other gardens, institutions, and organizations, as well as the general public (Akinyoyenu *et al.* 2017:117).

According to Spencer and Cross (2017:43), botanical gardens are essential historical repositories of plants' evolution. Botanical gardens stretch back to the middle of the 16$^{th}$ century when European universities were popular in physic gardens for studying medicinal plants (Hengky & Kikvidze 2018:8; Krishnan & Novy 2016:1). The botanical gardens offer a safe area for plant species to thrive, where people can interact with them, and a place to evaluate and research (Wassenberg, Goldenberg, & Soule 2015:148). In the 1600s, the study of plants in botanic gardens originating from the European colonies was increasingly explored, exhibiting new, unknown, highly decorative, economically, and essential plants for the public (Borsch & Löhne 2014:115; Hengky & Kikvidze 2018:8; Krishnan & Novy 2016:1).

Botanical gardens offered new scientific research and education to the field in the 17$^{th}$ century (Hengky & Kikvidze 2018:8). Taxonomy and plant classification appeared to be a focus on botanical gardens in the 17$^{th}$ century (Hengky & Kikvidze 2018:8). However, in the 19$^{th}$ century, public interest in gardens grew as the urban middle class emulated upper-class recreation pursuits (Lipovská 2013:115; Wassenberg *et al.* 2015:148). Interest in visiting botanical gardens increased from a simple desire to see flowers right through to a compound blend of societal, theoretical and individual reasons. (Wassenberg *et al.* 2015:148). However, the newest trend in gardens is that they are progressively becoming essential components of urban green space in an increasingly urbanizing world (Hengky & Kikvidze 2018:8).

Today's botanical gardens are strictly preserved natural green places with a controlling organisation that launches landscaped gardens (Cudjoe & Gbedemah 2019:25). They also contain documented collections of flora and some animals for a variety of purposes, including scientific research, education, public demonstration, preservation, long-term use, exploration, and leisure activities (Cudjoe & Gbedemah 2019:25). Nowadays, botanical gardens exhibit and accumulate different collections of plant species for scientifically based investigations and environmental protection purposes. They also contribute unique opportunities to tourists and citizens, such as guided tours, temporary exhibitions, and educational activities (Carrus *et al*. 2017:1). These gardens allow individuals to acquire more information about plants and eventually study distant lands (Wassenberg *et al.* 2015:148).

Worldwide botanical gardens are known for their rich traditional leading plant research and conservation programs (Hultine *et al.* 2016:1057). They increased awareness of biodiversity loss and ecosystem function, leading to a greater focus on conservation and sustainable use of biodiversity (Krishnan & Novy 2016:2). Botanical gardens are also considered for their particular type in the stimulating environment and constitute vital areas to investigate environment etiquette interrelations (Carrus *et al.* 2017:2).

### 2.3 Botanic Gardens in South African Context

In South Africa, botanical gardens are urban green spaces serving leading community-based, intellectual, well-being, creative, and environmentally friendly roles within the urban environment (Ward *et al.* 2010:49). These urban green spaces have recently become more well-known in various disciplines of research and politics, particularly for the benefits they provide to people's well-being (Peschardt, Schipperijn & Stigsdotter 2012:235). In addition, urban green spaces contribute to a wide array of economic, social, physical, and theoretical resources to city dwellers by enhancing the quality of life and standard of cities and towns from stressful urban lifestyles and relief from the crowd (Chishaleshale, Shackleton, Gambizaa & Gumbo 2015:817; Peschardt *et al.* 2012:235; Ward *et al*. 2010:49).

According to Ward *et al*. (2010:49), botanical gardens as urban green spaces also offer tranquillity and peace to visitors, upgrading, and amusement. They can also be used as a stress-free area to enjoy peace, in addition to delivering unique experiences to visitors that may have a favourable impact on their health (Wassenberg *et al*. 2015:149). Research has shown that in South Africa, botanical garden visitors are often motivated by outdoor and leisure activities (Wassenberg *et al*. 2015:149). As indicated by the National Botanical Garden Expansion Strategy 2019-2030, there are more than two million visits to South Africa's National Botanical Gardens (NBG) annually. Figure 2.1 depicts the distribution of these visits throughout several botanical gardens around the country. These visits promote tourism and add to economic growth (SANBI 2019). The most popular botanical gardens which enjoy high visitor numbers are Kirstenbosch, Free State, Karoo Desert, Kwazulu-Natal, Lowveld, Walter Sisulu, and Pretoria NBGs (SANBI 2019).

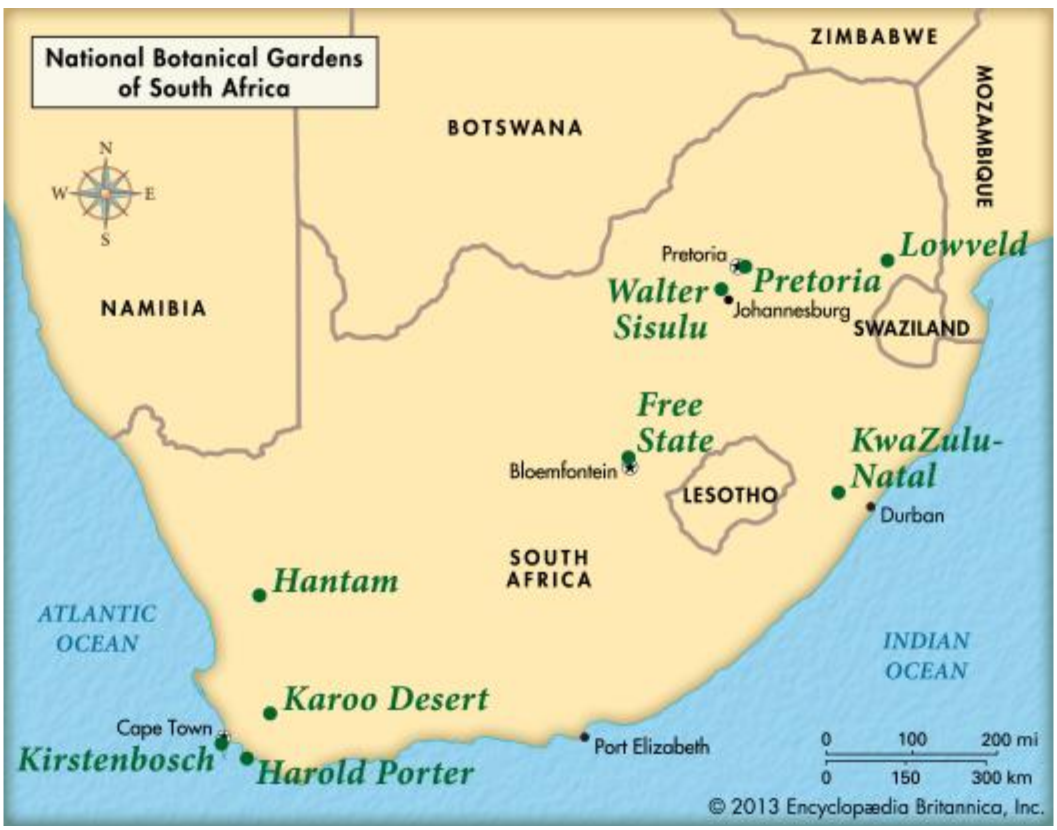



*Figure 2.1*: *Geographical location of South Africa's National Botanical Gardens across the country*

Source: (Kruger 2010:4)

Worldwide, there are 2500 registered botanical gardens. South Africa contributes to this total, with ten of them receiving national status and being administered successfully by the South African National Biodiversity Institute (SANBI) (Ward *et al.* 2010:50). The South African NBGs are “windows” of biodiversity for enjoyment and education (SANBI 2018). They increasingly serve essential roles in conservation, education, and recreation, while simultaneously providing a necessary medium of information about biodiversity through which people can acquire knowledge, develop ideas and construct new visions for themselves and society (Wassenberg *et al.* 2015:149).

### 2.4 Botanical gardens as an important tourist and recreational centers

Prior to the advent of COVID-19, tourism was considered one of the fastest and largest growing global industries (Nhamo, Dube & Chikodzi 2020:9). At that point, the industry played an essential role in promoting national and leisure economic development worldwide (Yu, Li & Guo 2020:1; Wikins, Urioste-Stone, Weiskittel & Gabe 2018:274). Tourism in Africa depends mainly on natural resources (Gössling & Hall 2017:1; Friedrich *et al.* 2020a:1). In Eastern and Southern Africa, tourism is the most prominent tourist magnet, favoured by a wide range of biodiversity; including birds, insects, fish species, and fascinating mammals such as deer, jackals, and the big five in national parks (Gössling & Hall 2017:1). In many national and local economies, recreation and tourism are the fundamental activities contributing immeasurable ways to the standard of life, sense of place, community relationship, physical well-being, learning, and other tangibles (Wood, Guerry, Silver & Lacayo 2013:1).

Worldwide, recreation and tourism significantly impact plant species, contributing to species decline and extinction (Wraith & Pickering 2017a:3). The influence of tourism and recreation on plants is linked to the construction of tourism facilities such as transport and accommodation, particularly those that include tourism activities (Gössling & Hall 2017:5; Wraith & Pickering 2017a:3). Tourism facilities and construction use can necessitate significant habitat modification, including the considerable impact on the environment, causing the complete removal of existing natural vegetation (Wraith & Pickering 2017b:308; Wraith & Pickering 2017a:4).

So far, botanical gardens are valuable resources for environmental education because of their complex representation of biodiversity, which has multifunctional roles in conservation, research, display, and education (Risna & Yuriawan 2019:94; Sanders, Ryken & Stewart 2018:1078). Botanical gardens attract a significant number of individuals seeking relaxation due to their central role. Botanical gardens are fundamental in their role in creating urban green spaces. They act as essential tourist attractions, where people relax, and for other functions such as venues for wedding photography, picnic sites, and generating revenue for conservation in the process (Faraji & Karimi 2020:1). Due to their location in urban areas, botanical gardens play an important role in bringing people and plants together and play an essential role in providing a green escape route to nature lovers (Demir 2014:161; Karaşah & Var 2013:803; Arnautova & Yaroslavceva 2019:851).

Botanic gardens have significant roles in environmental, research-based, societal, artistic, recreational activities and participate in education and conservation of plant and natural resources (Catahan & Woodruffe-Burton 2017:144; Karaşah & Var 2013:804). As such, they are often visited by education tourists and recreation seekers. In South Africa, many primary and secondary school students visit botanic gardens to learn about flora and fauna (Błaszak *et al*. 2019:1).

The NBG's in South Africa are a refuge of biodiversity that promotes the value of biodiversity and ecosystem services while also providing recreational and educational opportunities for the general public (Ward *et al.* 2010:49). The National Botanical Garden Expansion Strategy 2019-2030, indicated that these gardens play an important role in addressing climate change, conservation, tourism, recreation, and public environmental education programs.

The NBG’s provide unique experiences for visitors to explore and enjoy the rich biodiversity and nature in South Africa through an abundance of plant and animal species, birding spots, educational facilities, hiking trails, biking routes, wedding venues, and recreation facilities as bookshops (SANBI 2016). The number of visitors to South African national botanical gardens increased by 16% per cent to 14 million in 2018/19, compared to the previous financial year (12 million). Of these visitors, Kirstenbosch botanical garden was the one where most visitors went for the summer sunset concerts totalling 91 602, compared to 81 925 in 2017/18, representing a 12% annual increase (SANBI 2019). Consequently, the Kirstenbosch botanical garden is considered one of the most iconic tourism features in Cape Town (Dube, Nhamo & Chikodzi 2020:6).

## 2.5 Climate change and the biodiversity debate

There is compelling evidence that biodiversity is strictly under threat from a range of anthropogenic impacts, contributing to the sixth wave of mass extinction (Wraith & Pickering 2017b:1). The rate and scale of human activities have increased dramatically, leading to a significant impact on tourism. (Gössling & Hall 2017:2016:1). There are 11,500 threatened plant species with extinction on the International Union for the Conservation of Nature (IUCN) Red List (IUCN 2016). Of the endangered species, 94% are threatened flowering plant species (Wraith & Pickering 2017a:3). As a result, it is widely acknowledged that environmental change will profoundly impact ecosystems, social systems, and economic systems. On the other hand, land-use changes will have the greatest impact on biodiversity, followed by climate change (Gössling & Hall 2017:5).

According to Brooker, Young and Watt (2007:14), the earth's rich diversity of flora and fauna is reported to be negatively impacted by a variety of anthropogenic impacts, invasion by alien species, natural disasters, and climate variability. However, in South Africa, all these factors act individually, erode biodiversity and effect declines in ecosystem health, and cause a reduction in ecosystem services (Berjak, Bartels, Benson, Harding, Mycock, Pammenter & Wesley-Smith 2011:66). Reddy (2012:28) agreed that these factors increasingly affect South Africa's biodiversity. Ecosystem damage, species extinction due to human activities, and invading alien species are among the risks (Reddy 2012:28).

Thus far, climate change and biodiversity loss are presented frequently as two major environmental problems with implications for biodiversity (Skogena, Helland & Kaltenborn 2018:1; Dube & Nhamo (2020d). Skogena *et al.* (2018:1) stated that globally the impact on biodiversity is increasing and decreasing at a consistent rate. Turner (2018:3) agreed that climate change constitutes an additional influence on the environment, affecting biodiversity and goods and services.

Climate change has resulted in substantial environmental issues (Ferguson, Mueller, Graefe & Mowen 2018:53). These changes have had a noticeable effect on biodiversity at the species level regarding community composition, phenological patterns, ecosystem structure, and marine ecosystem (Li, Clinton, Si, Liao, Liang & Gong 2015). However, the impacts of climate change, including phenological changes and range shifts, have already been documented for many species (Aukema, Pricope, Husak & Lopez-Carr 2017:2). From a human perspective, anthropogenic climate change impacts are causing disadvantageous consequences on the world's natural resources and creating a swarm of vicinity issues (Zelenika, Moreau, Lane & Zhao 2018:581; Lenzen, Moran, Kanemoto, Foran, Lobefaro & Geschke 2012).

Several studies further accepted that biodiversity would decrease at an unprecedented rate due to human activities. It was evidenced that more than 80% of the world's crust has been changed by human actions, resulting in two-thirds of extensive marine fisheries decreasing. Furthermore, biodiversity is reduced in the face of changing climate conditions providing anticipated and unanticipated menaces to contemporary and upcoming inhabitants (Xu, Zhang, Xie, Xu, Zhao & Tian 2017:1; Zelenika *et al.* 2018:281). However, climate change is still widely acknowledged to have a considerable impact on many biological variety elements and pose a significant threat to plant distributions over the world (Rannow & Neubert 2014:45; Dyderski, Paz, Frelich & Jagodzinski 2017:1150). Brooker *et al*. (2007:14) indicated that climate change and land-use change might soon be assumed as a long-term threat to species survival.

Dyderski *et al*. (2017:1150) claimed that many species are expected to go extinct due to climate change on a regional and global scale. Species extinction is ascribed to climate change because of these interlinks with other anthropogenic threats like habitat loss (Aukema *et al*. 2017:2). Xu *et al.* (2017:1) agreed that the tremendous loss of biodiversity is caused widely by the natural environment and deterioration arising from a change in nature. Wang, Wan, Mu and Zhang (2015:2384) further added that climate change has the worse effect on biodiversity and the environment they reside in; species are on the edge of extinction or eliminated because of changes in the weather, making it harder to protect endangered species.

## 2.6 Tourism and Climate Change in South Africa

South Africa has always had a thriving tourism industry, contributing significantly to the national economy (Hoogendoorn, Grant & Fitchett 2016:60; Smith & Fitchett 2020:107). The country is considered widely to have a range of tourist destinations, of which many rely relatively on the region's welcoming climate, characterized by warm weather and clear skies (Hoogendoorn *et al*. 2016:60; Fitchett *et al.* 2016:1). Beach and nature-based tourism contribute to the most significant part of the country's tourist sites, which are firmly reliant on improved climatic conditions (Hoogendoorn *et al*. 2016:60; Fitchett *et al*. 2016:1; Giddy, Fitchett & Hoogendoorn 2017:58). In addition, South Africa has a large number of small towns that rely on exploration, and these contribute to a variety of tourist destinations; these are centered predominantly around outdoor activities, including game drives, hiking, water sports, and fishing (Hoogendoorn *et al.* 2016; Smith & Fitchett 2020:107; Fitchett *et al*. 2016:1).

The link between global warming and exploration has long been investigated (Mushawemhuka, Rogerson, & Saarinen 2018:116). Climate and tourism have a dual relationship, each impacting the other (Amusan & Olutola 2017:1; Dube & Nhamo 2019:2026). South Africa is caught between the coins as the country ranks as a high contributor to GHG and is one of the hardest-hit nations by climate change (Amusan & Olutola 2017:2). By any measure, South Africa has a relatively massive record of GHG emissions and ranks amongst the world's top 15 greenhouse gas emitters (Amusan & Olutola 2017:2). South Africa is at significant risk of climate fluctuation long-term effects (Pandy 2017:2).

South Africa is expected to see extreme temperature increases of up to 40-degree Celcius by 2100, as well as changes in the timing, quantity, and severity of rainfall, variations in wind speed and strength, and a rise in sea level (Fitchett *et al.* 2016:1). The country is estimated to be highly impacted by climate change impacts (Hoogendoorn & Fitchett 2018:3). These climate change factors are predicted to threaten tourism's local economic development future in South Africa (Pandy 2017:2).

In Southern Africa, the impact of climate change is predicted to be extreme and arises faster than in other parts of the world (Smith & Fitchett 2020:108). If proper adaptation measures are not created, climate change will have a negative impact on South African resources, tourist attractions, activities, and small tourist towns (Hoogendoorn *et al.* 2016:59). Therefore, there is no doubt that the botanical gardens will also be affected directly and indirectly, as evidenced from a study by Dube *et al*. (2020:5) on the impact of Day Zero on tourism in the Western Cape.

The Sub-region of Southern Africa is said to be at risk because of the changing climate conditions. Climate change impacts in South Africa are explored as "not a narrow environmental problem, but a fundamental development challenge" (Pandy & Rogerson 2019b:226; Pandy & Rogerson 2018a:105). According to Hambira *et al.* (2020:1), climate change is recognized as a more impactful challenge in the global South of Africa than the Global North. The continent of Africa is at risk because of its low capacity to adapt, and both human and natural systems are consequently affected (Hambira *et al.* 2020:1).

There is a broad consensus that climate change and the environment are the core of tourism worldwide (Friedrich & Stahl 2019c:26). Climate and weather are important factors that motivate inbound travel to South Africa (Giddy *et al*. 2017:59). Besides climate and weather, environmental settings also either favor or limit tourism. They "directly and indirectly influence global demand patterns" (Friedrich & Stahl 2019c:26; Friedrich *et al*. 2020b:1). Weather influences the behaviour and satisfaction among tourists and is said to be distinguished by its uncertainty (Fitchett *et al*. 2016:1; Friedrich *et al*. 2020a:1).

Climate is divided into three different facets: physical, aesthetic, and thermal facets of climate, which have differing significance and impacts on a tourists' stay (Friedrich & Stahl 2019c:26). Weather does not only influence the tourist's travel decision; it can also affect tourist safety or cause delays of transport, accidents, and travel cancellations (Clemente, Lopes & Ambrósio 2020:3; Smith & Fitchett 2020:107). In addition, tourism is closely affected by climate change (Hoogendoorn & Fitchett 2018:3).

Climate change contributes to five types of impacts on tourism: direct impacts of a changing climate; indirect impacts of environmental change; mitigation policy and tourist mobility; societal change related to reduced economic growth; consumer cultures and social-political stability (Reddy 2012:9). Direct consequences of climate change on tourism critically influence policy decision-making and even tourists (Odimegwu & Francis 2018:49). They disregard the pessimistic sequel of impacts of climate change on the tourism sector and tourist terminus; timing and effectual reconstruction and soothing are needed in discovering the degree of climate change impacts (Atzoria, Fyallb & Millerc 2018:13).

**2.7 Mitigation and Adaptation in the Tourism Sector**

Mitigation and adaptation are two critical methods used in the tourism industry to fight against climate change (Odimegwu & Francis 2018:54). To respond to the ever-increasing effect of climate change, the tourism sector must take part in adaptation plans, and at the same time, indulge in mitigation strategies to minimize the expansion of impacts of climate warming that are too big to be tackled through adaptation (Odimegwu & Francis 2018:54). Adaptation is defined simply as *"those actions or activities that people undertake, individually or collectively to accommodate, cope with, or benefit from, the effects of climate change including changes in climate variability and extremes"* (Atzoria *et al.* 2018:13).

On the other hand, adaptation is those strategies planned at revamping the current standard to meet and adapt to the impacts of climate change (Dogru, Marchio, Bulut & Suess 2019:294). Finally, mitigation is the process of taking steps to reduce the impact of tourism on climate change (Steyn 2012a:553).

Mitigation and adaptation responses are closely related and work cohesively (Clemente *et al.* 2020:2). The two can be modified to be a benefit on the spatial scale (Robinson 2016:29). According to Clemente *et al.* (2020:2), the effects of climate variability on the demand pattern of tourism can be produced by the acknowledgements of tourists to the implication of mitigation and adaptation procedures and their impacts on transport systems, as well as the wide range of effects of climate change on destinations, society, and economic development. The assistance of mitigation is felt worldwide. In contrast, the benefits of adaptation are felt only in communities that can adapt the measures (Robinson 2016:29).

Adaptation consists of two forms. Firstly, it comprises developing the adaptive capacity to improve human beings' ability to adjust to new environmental conditions; and secondly, it involves administering the familiarization verdicts (Robinson 2016:25). The two adaptation forms might be disseminated before climate change or as responses to climate change (Robinson 2016:26). It is important to note that administering adaptation strategies or adaptive measures approaches is crucial for the successful design; therefore, adaptation techniques can not be regulated at destinations unless those destinations can do so (Odimegwu & Francis 2018:55; Reddy 2012:32).

According to Dogru *et al.* (2019:294), climate change adjustment in the tourism sector is thoroughly reviewed. Robinson (2016:26) revealed that some tourism stakeholders have already begun implementing various adaptation strategies in response to the impacts of climate change that have been experienced, predicted, or are now occurring. Even though some stakeholders are more knowledgeable in managing the collision of climate change, accessory measures are still needed to decrease the revolting effects of the changing climate (Reddy 2012:32). Adaptation measures can be technical, managerial, policy-linked, educational, or behavioural (Hambira *et al.* 2020:2; Pandy & Rogerson 2018a:107; Robinson 2016:27; Reddy 2012:32). These measures are summarized in Table 2.1 below.

*Table 2.1: Climate change adaptation methods and strategies in the tourism industry*

| | ***Tourism stakeholders*** | |
|---|---|---|
| ***Type of adaptation*** | **Tourism businesses** | **Tourism industry association** |
| *Technical* | Recycling of water. Infrastructure improvement. | They should observe early warning systems. Enlighten tourism businesses of extreme events—issue up-to-date information on adaptation methods. |
| *Managerial* | Contribute to regions that haven't been adversely influenced by climate change | Provide conference training on climate change adaptation—sustainability planning. |
| *Research* | Discover specific tourism products. | Distinguish tourists and knowledge gaps. Evaluate businesses sensitivity to climate change adaptation options |

| | | |
|---|---|---|
| *Behavioral* | GHG emissions offset initiatives | GHG emissions offset initiatives Water conservation programs |
| *Education* | Staff or visitors should be educated on the importance of conservation. | Discussions about public education and awareness initiatives. |
| *Policy* | Compliance with environmental policy and regulations | Implement adaptation strategies. Cooperate to reduce GHG emissions through adaptation and mitigation. |

Source: Hambira *et al.* 2020; Pandy & Rogerson 2018:107; Robinson 2016:27; Reddy 2012:32.

From a research and policy perspective, adaptation measures present forbidding provocations (Hoogendoorn & Fitchett 2018:3). As the influences, acuteness, and increase of the changing climate are not geographically consistent, climate change's probable effects, and challenges facing local communities, tourism, and destinations worldwide, may not be the same (Pandy 2017:7; Pandy & Rogerson 2018:107). It is important to address different types of business and the relative size of the tourism business, which may have substantial kinds of actions and policies pursued and the general effectiveness of such adaptation attempts (Pandy & Rogerson 2019:226).

As a result of reduced GHG emissions, mitigation can be achieved through several changes such as technological, economic, and social changes (Steyn 2012a:553). Mitigation is said to decrease and limit the concentrated emissions of GHG and develops possible actions for those gases (Clemente *et al*. 2020:2). As GHG emissions from tourism increase considerably, mitigation constitutes consequence challenges for the overall tourism sector (Reddy 2012:33). Furthermore, while reducing GHG emissions and encouraging the tourism sector as a tool for societal and economic advancement, mitigation measures to find a balance within the tourism sector are vital (Reddy 2012:33).

Besides, there are several proportions that mitigation needs to appraise; the need to stabilize the global climate and the right of people to rest, recovery, and leisure (Steyn 2012a:554). Therefore, there are four different types of mitigation strategies for minimizing the greenhouse gas ooze:

- Decrease energy use, which can be stimulated by changing travel patterns.
- Increasing the use of renewable resources in tourism.

- Enhancing power capability; using new technology that allows reductions in energy emissions.
- Segregating carbon through sinks within the tourism industry (Steyn 2012a:555; Steyn & Spencer 2012b:14; Robinson 2016:28).

According to Dube and Nhamo (2020e:5), climate change mitigation and adaptation in Africa are central to nature-based tourism sustainability. The importance of understanding how botanical gardens adapt to and prevent climate change inside botanical gardens cannot be overstated.

**2.8 Knowledge Gaps in Tourism and Climate Change**

While there is a push to fully develop climate change and tourism impacts and raise awareness among academics and the tourism industry, there is a lack of knowledge and impediments, particularly in the global south (Scott & Becken 2010:286). The tourism business has been under the unfavourable impacts of climate change and has been less knowledgeable and skilful to tackle these impacts in the industry (Pandy & Rogerson 2018:108; Ma & Kirilenko 2019:2). Little research has been done concerning the effects of climate change and tourism in Africa; no precise information has been fully discovered on how the natural environment will affect tourism businesses, society residing in it, and local citizens (Hambira *et al*. 2020:2). As a result, new plans and techniques have not been fully explored in response to climate change with the benefit of developing the tourism industry (Hambira *et al*. 2020:2).

There is a massive gap in adaptation and mitigation capacity. This has astounded the tourism sector, making them doubt that they will ever overcome the effects of climate change (Ma & Kirilenko 2019:2). In economic sectors, climate change adaptation plans are far less developed (Scott & Becken 2010:286). In developing measures to mitigate future climate change impacts, there is a lack of strategic planning and limited evidence and awareness (Scott & Becken 2010:286). Most developing countries, including South Africa, have a limited adaptive capacity; the government cannot reduce and repair damage caused by catastrophic weather occurrences (Giddy *et al.* 2017:58). However, Hambira *et al.* (2020:2) agreed that South Africa's capacity to react to climate change is slow, and it lacks resources to deal with the tourism climate change link.

Limited investigations are conducted from a tourism stakeholder perspective regarding the impacts of climate change (Ma & Kirilenko 2019:2). Pandy and Rogerson (2018:108) revealed that the tourism industry is increasingly aware of the importance of climate change and its potential global impact, and it is no longer regarded as a pressing concern. Ma and Kirilenko (2019:2) stated that even though climate change is no longer seen as a global threat to many tourism businesses, adaptation and mitigation practices are still barely observed. However, Scott and Becken (2010:286) suggested relatively high adaptability in the tourism industry to cope with the impacts of the changing climate should be kept in mind. However, the tourism sector must combine its skills to manage upcoming climate impacts and the narrow ecological issues and social implications (Scott & Becken 2010:286). Future investigations must also continue to infuse new ideas and establish multi or interdisciplinary coalitions and research techniques (Scott & Becken 2010:287). In addition, they must also ensure that the adverse effects of climate change are effectively included into relevant strategic tourism techniques and policy frameworks (Scott & Becken 2010:287).

Some scholars have made a significant effort to research the impact of climate change on various tourist sites such as national parks (Dube & Nhamo 2020d; Kilungu, Leemans, Munishi, Nicholls & Amelung 2019), coastal areas (Fitchett *et al.* 2016; Hoogendoorn *et al.* 2016; Atzoria *et al.* 2018), water-based tourism activities (Ferguson *et al.* 2018; Dube & Nhamo 2019a; Dube & Nhamo 2018), beach tourism (Friedrich *et al.* 2020a; Friedrich *et al.* 2020b; Friedrich & Stahl 2019), aviation tourism (Dube & Nhamo 2019b), etc. However, no known studies have been conducted to document the impact and response of botanical gardens in South Africa in its entirety. This remains a significant knowledge gap that needs to be covered. This research, therefore, is feedback in response to that knowledge gap.

The study highlights the general overview of botanical gardens in South Africa. Botanical gardens are explained to offer unique experieces to visitors as they are motivated by outdoor and leisure activities. The study investigated the impacts of climate change on botanical gardens and their responses to climate change. The study explained that climate change has changed botanical gardens in affecting the general species they maintain. Significant knowledge gaps are covered in the study. From the existing literature, there are limited investigations in addressing climate change impacts. Mitigation and adaptation measures are developed but are hardly practised.

### 2.9 Summary

The general overview of botanical gardens in this study highlights botanical gardens as important places open to the public, where people learn and enjoy the nature of the gardens; they are also regarded as significant creative, societal, and scientific organizations that contribute to the advance of the society. Secondly, the section on the botanical gardens in South Africa highlighted botanical gardens as urban green spaces serving important societal, theoretical, well-being, inventive, and environmental purposes within urban environments. Thirdly, botanical gardens play essential roles as tourist attractions and recreational centres and conserve plants and natural resources. The climate change and biodiversity section highlights that biodiversity is affected by various factors such as anthropogenic drivers, including land-use change, non-native species, natural interferences, and climate change.

The section on climate change and tourism in South Africa highlights the importance of tourism, the link tourism and climate change have, and the fact that climate change and tourism can impact one another. The section on mitigation and adaptation highlights the two as paramount techniques to reduce the impacts of climate change in the tourism industry. It is essential to report that mitigation and adaptation strategies need to be adapted to minimize and strengthen the tourism sector and tourist destinations against climate change. Although it is said that tourism is both a contributor and a victim of climate change, there is a need for the tourism industry to devise measures for adapting and mitigating climate change. Lastly, there are critical knowledge gaps and limitations between tourism and climate change. It has been stated that there are few findings on the impact of climate change, even though every effort made was not successful enough to measure the effects of climate change on the tourism industry around the world.

# Chapter 3 : Methodology

## 3.1 Introduction

Research methodology is the systematically applied approaches and arranged analysis to the field of study. It consists of the logical considerations, techniques, and ideas coordinated with a branch of data (Kumar 2014:16). Given its flexibility and advantages in examining issues under investigation, a mixed-method approach utilizing a case study research design was adopted. This chapter also includes an outline and analysis of each research method. In response to the research question, the chapter examines the theoretical and practical benefits and challenges of employing this particular research approach. This chapter also covers aspects of how ethical issues were dealt with in this research study.

## 3.2 Study area

The study was conducted at two national botanical gardens in Gauteng Province, namely Walter Sisulu National Botanical Garden and Pretoria National Botanical Garden, as shown in figure 3.1. The Walter Sisulu botanical garden is located 30km west of the City of Johannesburg, South Africa. The garden was established in 1982 and was previously known as the Witwatersrand National Botanical Garden. Later the garden was renamed Walter Sisulu botanical garden in memory of the late Mr Walter Sisulu (former ANC leader). The garden has a long history of being an iconic attraction because of the Witpoortjie waterfall and pristine forests and picnic sites. The Witpoortjie waterfall's name is derived from the station where people got off the train from Johannesburg and walked down the waterfall (SANBI 2016). Walter Sisulu Botanical Garden covers 300 hectares of landscaped and natural veld. The garden contains a variety of over 600 flowering plant species and shrubs, a record of over 230 bird species, several reptiles and mammals and indigenous trees. It is also a popular spot for two famous black Verreaux eagles residing in the garden (South African History Online 2020). In the 2017/18 financial year, this garden received 301 965 visitors (DEAT 2018).

The Pretoria Botanical Garden is located east of the City of Pretoria's central business district. This garden was established in 1946 and was previously a research facility managed under the Botanical Research Institute (SANBI 2019). It serves as a recreational space and scientific research centre. The garden covers 76 hectares of the land, including South African plants, a record of about 200 bird species, reptiles, and small mammals (SAHO 2019). In 2019, the Pretoria Botanical Garden hosted several events, during which it was declared the world's largest Parkrun venue. The garden registered 52 000 participants participating in the Parkrun (SANBI 2019/2020).

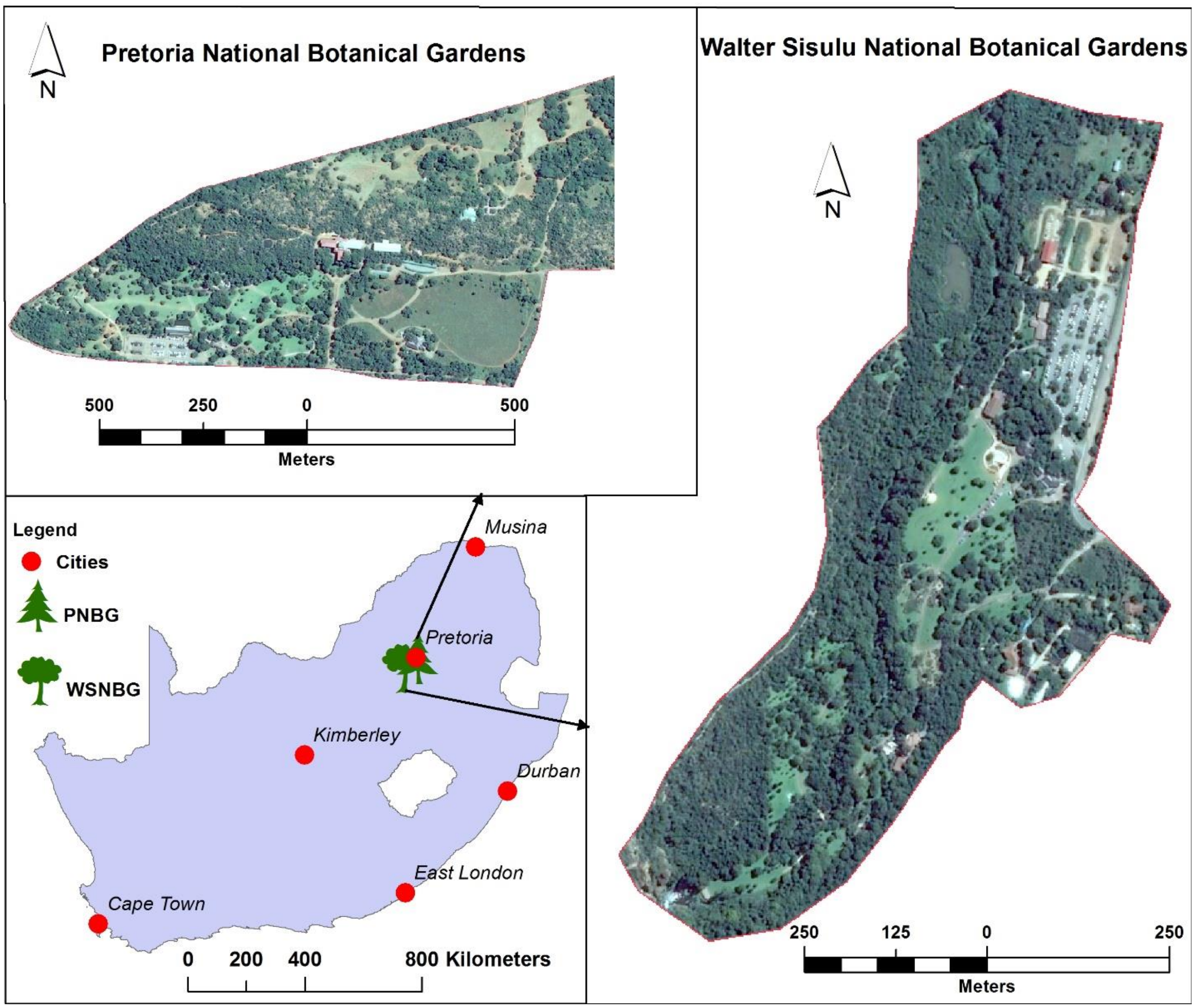



*Figure 3.1: Geographical location of Walter Sisulu botanical garden and Pretoria botanical garden across the Gauteng province*

Source: Authors

The botanical gardens are nature-based ordinarily, so they are potentially vulnerable to climate variability and change. Plants and flowers are susceptible to changes in wind, temperature and precipitation. Aspects such as droughts and temperature can affect plants, animals and other insects central to plants performance in these gardens and waterfalls.

## 3.3 Theoretical Framework

Positivist, interpretive, critical, and pragmatic are the four types of paradigms (Khaldi 2017:19). According to Kaushik and Walsh (2019:2), the term pragmatism is derived from the word pragmatic. Pragmatism is considered an advanced philosophy that provides the epistemology and the logic for combining the quantitative and qualitative approaches and methods (Maarouf 2019:5). Pragmatism is seen as an essential aspect of deliberation in the researcher's worldview and can also influence the way researchers conduct their projects (Kaushik & Walsh 2019:6). Pragmatism is the conviction that empowers the mixing of paradigms, assumptions, approaches, and methods of collecting data and analysis (Maarouf 2019:5). The core assumption of pragmatism is that it provides a complete understanding of the research problem as opposed to when only one research method is used. Therefore, pragmatism allows researchers to choose the best design and techniques suitable to address the research question (Kaushik & Walsh 2019:6). Hence, this study applied a pragmatic paradigm as it allowed the researcher an opportunity to address the questions under investigation without worrying about whether they are quantitative or qualitative (Kivunja & Kuyini 2017:36).

## 3.4 Research Design

To collect research data, there are three methods: qualitative, quantitative, and mixed-method. Quantitative research is defined as an approach that ascertains numerical data, while qualitative research is an approach that analyses non-numerical data (Marczyk *et al.* 2005:17). The mixed-method combines both qualitative and quantitative methods (Creswell & Creswell 2017:205; Marczyk *et al*. 2005:17). A mixed-method research design was used in this study. This allowed an in-depth and comprehensive response to all issues under investigation and their varying data needs. At this level of the study, it also provided the rigour needed (Almalki 2016:291). Various studies in tourism and climate change studies in the past have adopted a mixed-method research design (Smith & Fitchett 2020:109; Fitchett *et al.* 2016:2).

Mixed-method is differentiated into three research designs: explanatory sequential design, exploratory sequential design, and convergent parallel design (Creswell, Ebersohn, Eloff, Ferreira, Ivankova, Jansen, Nieuwenhuis, Pietersen & Clark 2016:319). In this study, a convergent parallel design was applied. Using this design, the researcher simultaneously collected qualitative and quantitative data, and the final results were collated for clarification as prescribed by Schoonenboom and Johnson (2017:117). The advantage of using this design is that the researcher acquired information from different sources, using both qualitative and quantitative methods (Almalki 2016:292).

### 3.5 Case Study Research

A case study is defined as a *"research method used to create a multi-faceted and thorough understanding of a compound subject to a matter in its real-life context"* (Hardwick 2016:1). Creswell and Creswell (2017:73) stated that case study research is not a procedure but an alternative to a study. Others present it as a master plan of an inquiry, a process, and a universal research technique (Hardwick 2016:1; Crowe, Cresswell, Robertson, Huby, Avery & Sheikh 2011:1). This method allowed the researcher to examine data both within reach and beyond conditions (Gustafsson 2017:2). Supported by Crowe *et al.* (2011:1), the case study research approach allowed the researcher to answer the 'how' and 'why' questions within the factors of life. In addition, the method allowed for a broader exploration into research problems and the evolution of theory (Gustafsson 2017:2).

Case studies can be advantageous and disadvantageous. The method can be obstructive, complex, and expensive for the researcher to use (Avella 2016:307). On the other hand, a case study can be used to display, communicate, and explore (Crowe *et al.* 2011:4). For example, these can help the researcher demand sufficient information and clarify the matter or situation (Marczyk *et al.* 2005:16). The case study method is applied in this study as it allowed several data-collection instruments. The case study approach offered numerous advantages to the researcher and the investigation.

### 3.6 Population

Population refers to the group of individuals from which a research sample is chosen for a study and against which the research findings captured from testing cases should be generalized (Marczyk *et al*. 2005:18). Alvi (2016:10) described the population as a *“complete set of elements that possess the same characteristics described from the sampling criteria established by the researcher with the research questions and the study's objectives in mind being used as a guideline”.*

The target population of this research comprised various key stakeholders such as; the SANBI Chief Director of Conservation Gardens and Tourism, Director of Marketing and Commercialization in SANBI, managers of the garden, and guides from both the Pretoria National Botanical Garden and Walter Sisulu Botanical Garden. Tourists who have used the facilities also formed part of the research population.

Table 3.1 represents the various key stakeholders who participated in the research. They were from both gardens.

*Table 3.1: Sample Group of Key Stakeholders formed from Pretoria botanical garden and Walter Sisulu botanical garden*

| Sample Group | Total |
|---|---|
| SANBI Chief Director of Conservation Gardens and Tourism | 1 |
| Director of Marketing and Commercialization in SANBI | 1 |
| Botanical Garden Managers | 7 |
| Botanical Garden Guides | 6 |
| Visitors | 324 |

Source: Authors

### 3.7 Sampling Techniques

Sampling is a process through which a small group of people, cases or elements are taken from a more significant population; thus, a sample is a “group of people in which the researcher’s interest lies” (Alvi 2016:11). There are two types of sampling methods, namely probability sampling and non-probability sampling. Probability sampling uses “random sampling techniques”. In probability sampling, every member of the population in the sample has a possibility of being included. Non-probability uses “non-random techniques like “researcher judgment or convenience sampling” (Taherdoost 2016:22). As it is impossible to study every member of the population, the best method was sampling participants. This research used a choice of three sampling techniques: snowballing, purposive (for interview participants) and convenience sampling technique (for botanical garden visitors).

### 3.7.1 Purposive Sampling

Given the significance of this study, a non-probability sampling technique was used to collect data. According to Etikan *et al*. (2016:2), purposive sampling is defined as *“a non-random method where the researcher thoroughly selects a sample by their judgment”.* In purposive sampling, participants are conveniently chosen and recommended due to their familiarity with the study (Tongco 2007:153). With this technique, each participant is individually selected based on the purpose of the survey to bear unique and rich information for the study’s value (Etikan *et al*. 2016:4). Purposive sampling allowed a small group of individuals who were knowledgeable about tourism and climate change to participate in the study. In addition, this technique allowed the researcher to distinguish interview respondents’ knowledge about the subject matter under investigation. Purposive sampling offers robust and valid data (Tongco 2007:154).

### 3.7.2 Snowball Sampling

On the other hand, snowball sampling is a non-probability sampling technique where the selected sample is not easily accessible (Saunders, Lewis & Thornhill 2009:240). Snowball sampling is the “chain sampling” method (Alvi 2016:33). This technique enabled the researcher to distinguish the remaining interview participants further. According to the National Botanical Garden Expansion Strategy 2019-2030, there are over 2 million visitors annually to the botanical gardens; and the sample size of 569 was measured as an adequate size to obtain sufficient information from the participating respondents. Therefore, a sample size of 569 was described in this study. 554 questionnaires were distributed to visitors/tourists who have visited the botanical gardens, with 324 questionnaire responses received. The remaining 15 questionnaires were completed by conducting interviews.

### 3.7.3 Convenience Sampling

According to Saunders, Lewis and Thornhill (2015:15), convenience sampling is a *"specific type of non-probability sampling method where data is collected from the conveniently available population members ready to participate in the study".* Convenience sampling allows the respondents willingness to take part in the study. This technique enabled the researcher to collect data from tourists at the botanical gardens. The sample is limited to a broader population (Valerio *et al*. 2016:3). The target population is congruent (Etikan *et al.* 2016:2). Convenience sampling is affordable, quick, and easily approach the sample (Alvi 2016:30).

## 3.8 Pre-Testing

Pre-testing refers to testing the questionnaire, on a small group of people, before collecting data to differentiate and eliminate potential problems (Hilton 2017:21). According to Ikart (2019:1), a questionnaire should not be used without a proper test in the research area against the respondents. To well prepare a questionnaire, the content of the question, language, sequence of the questionnaire questions, and requirements should all be tested. Testing a questionnaire is essential for researchers to guarantee questions are understood distinctly. The response options should be more suitable, extensive, and exclusive to be answered (Sheran & Sarbaum 2012:610).

To identify potential problems and errors, the questionnaires were piloted amongst local academics and friends who are researchers in the field of Tourism and Hospitality. Interviews were piloted with experienced researchers familiar with the study area and knowledgeable about tourism and climate change issues. To interpret each question, the researcher requested an interview with the respondents. The benefit of piloting is to ensure that questions are arranged in an intended way. The online questionnaire was then piloted with local residents with the background of tourism and climate change and familiar with the study area, following the initial pre-testing and consequential familiarization and improvements. Grimm (2010:2) stated that pre-testing a questionnaire helps to improve the credibility of data significantly.

The online questionnaire was also piloted with people who spent their free time visiting botanical gardens as visitors. The respondents aided in the identification of several technical issues with the online questionnaire. The feedback obtained was utilized to improve the questionnaire. After the piloting phase was concluded, the online questionnaire was distributed to tourists worldwide. The questionnaire was emailed with an introductory note and link for online completion.

### 3.9 Research Tools

This study used various gathering tools, namely key informant interviews, self-administered online questionnaires, direct field observation, secondary and archival data analysis. All the instruments were pretested before the fieldwork, which led to adjusting and refining the tools better suited to gather data.

#### 3.9.1 Key Informant Interviews

Interviews are one form of research instrument for collecting qualitative data. They can involve a one-on-one, face-to-face conversation between a researcher and participants, or the interviewees can respond to a written set of questions sent to them (Rubin & Rubin 2005:413). Interviews could either be structured or semi-structured, depending on the scope of the study. Structured interviews are based on a set of self-completed questions with limited responses that are established in advance (King, Horrocks & Brooks 2018:17). On the other hand, semi-structured interviews are managed through face-to-face communication with an interview guide assisting the interrogation of the topic under investigation (Brinkmann & Kvale 2015:425; Rubin & Rubin 2005:413). For this study, the researcher made use of semi-structured in-depth interviews through an online interview process.

Furthermore, key informant interviews are one method of interviews that "involve interviewing people who have particularly informed perspectives on an aspect of the subject of investigation" (OEPP 2012). Key informant interviews provide a deeper view and understanding of the questions being investigated. They foster clarity of ideas and information on an ongoing basis (Cossham & Johanson 2019:3). Key informant interviews allow a researcher to get ample comprehensive information on the field (Ali, David & Ching 2013:134).

The researcher conducted online semi-structured in-depth key informant interviews with SANBI officials (2) responsible for all national botanical gardens and experts knowledgeable about tourism and climate change. This was done using an interview guide which forms part of this report as Appendix 2.

Using this method, the researcher was able to ask questions exploring how climate change affected visitor numbers, tourist arrivals, garden conservation efforts, the budget and information sought on policy position, plans, activities, and perceptions. Further, the measures and approaches taken by the organization to investigate climate change and programs developed for visitors to raise awareness were discussed. Interviews were scheduled in advance of discussions taking place, through appointments and requests to better-prepared respondents. Appointments were made through emails and telephone calls, explaining the study's purpose and conducting interviews. The respondents' contact details were obtained through Botanical Garden Management, who had provided the necessary permission.

Most of the interviews were done online using Microsoft Teams, based on COVID-19 protocols to ensure physical distancing. Interviewers were recruited and accessed through the help of the curator and horticulturist of the gardens. The questionnaire guide was followed by probing questions to understand the issue under investigation during the interviews thoroughly. Participation was voluntary, and informed consent was attained. Permission to record interviews was sought initially, and interviews were recorded for transcription purposes only. Notes were also made. These interviews took between 45 minutes and 1 hour.

### 3.9.2 Online Questionnaire

A questionnaire is a written instrument involving a list of questions designed to collect data from the respondents during a research study. It requires target participants to provide their knowledge about a phenomenon of interest to a researcher (Krosnick & Presser 2018:265).

An online questionnaire survey was used to gather data from botanical garden visitors. The questionnaire tool comprised 16 questions that had both closed and open-ended questions in line with the mixed-method approach adopted. The survey was used to collect information about tourists' perceptions of the impact of climate-related weather events on garden operations, garden experience, aesthetics and how such events can affect future visits to the garden (See Appendix 3). QuestionPro hosted the survey tool. This tool offers the researcher an opportunity to reach a broader geographic audience.

The tool also offers many other advantages as it is cost-efficient, flexible, and saves respondents and researchers time because it allows the responses to be instantly captured and analysed. In addition, questionnaires were also distributed to visitors at the gardens for completion. For this research, the questionnaire was uploaded onto tablets that were later administered at the gardens between March and April 2021, attracting 324 completions from 554 extended invitations that were made. The average completion time was 10 minutes.

### 3.9.3 Direct Observations

Direct observation is widely used to collect qualitative and quantitative data (Marczyk *et al.* 2005:119). Direct observation enables the researcher to qualitatively collect data that is impossible to manage with other data collection techniques (Maxwell 2012:76). Direct observations were done to document climate change impacts at Gauteng Botanical Gardens (see appendix 4). The procedure involved photographing and walking across the garden to check climate adaptation and mitigation strategies adopted in the two botanical gardens that formed part of this study. The researcher collected information in a photo format, such as pictures of plants, trees, and infrastructure extracted by extreme weather events. Permission was obtained from the management of the gardens to manage such data in a picture format. The researcher also got help from the guides who knew the area's climate history indicators during this process.

### 3.9.4 Secondary and Archival Data

Secondary data is an analysis of data collected through primary sources involving archived survey data, tape-recorded interviews and recorded interviews (Johnston 2014:619; Dube 2018:60). Secondary data is inexpensive and advantageous to use while also saving researchers time and resources. Since data is readily available, researchers do not have to worry about financial resources to collect data (Johnston 2014:624; Hox & Boejie 2005:593).

Secondary and archival data were used to trace climate change documentation impact of past extreme weather events that affected the gardens. Various official data, such as reports from SANBI, were interrogated to gather information about the study. In addition, the South African Weather Service's monthly and annual climate data record was analysed better to understand climate trends in the two botanical gardens. Climate records gathered were for the period 1994-2020 and 1985-2020 for analysis.

### 3.10 Content Analysis

Content analysis is a qualitative technique used to analyse data (Vaismoradi, Turunen & Bondas 2013:400). Content analysis was administered for the final analysis of secondary data documents. The final analysis of open-ended questions from the tourist survey was used to obtain tourists' perspectives and speculations about climate change impacts and perceptions of future botanical gardens results. Problems related to the effects of extreme weather events in botanical gardens were raised from tourist's posts. Lessons tourists learned about climate change, how it affects their travel experience, and what they think should be done to address these impacts were identified.

### 3.11 Data Analysis

After completing the questionnaires, data was organised and saved in the Microsoft Excel spreadsheet, graphs, charts, and tables. This allowed further reading, rereading, and the identification of specific categories. The analysis of all data is described in the following sections.

#### 3.11.1 Climate Data Analyses

Climate data obtained from South African Weather Services was grouped into various categories, namely temperature and rainfall data in Microsoft Excel Sheet. XLTSTAT 2021 was used to run trend analysis for climate data and track the climatic trend. A Mann Kendall Trend Test was conducted on both rainfall and temperature data. Several studies in tourism and climate change were used to track evidence of climate trends in the use of Man-Kendall Trend Analysis (Dube & Nhamo 2020d:4; Dube & Nhamo 2020c:3). The

Mann Kendall Trend Analysis was used to analyse climate trends for 1994-2020 and 1985-2020. The Mann-Kendall Trend Analysis is an accepted tool used in climate and meteorological studies (Dube & Nhamo 2020c:3).

The Mann Kendall Trend Test analyses earlier and later data elements collected constantly to increase or decrease ‘Y trend’ values. The test is not parametric and does not ordinarily entail information delivery. Because of the inhomogeneous time series, the test has low sensitivity to abrupt breaks (Karmeshu 2012:4). This test assumes the “null hypothesis (H0) assumes there is no trend, and this is tested against the alternative hypothesis (H1), which assumes that there is a trend” (Roknian 2012:214). Mann Kendall trend test used a data set whose confidence level was set at 95%, and the Significance level was established at the default of 5%.

Other quantitative data collected from QuestionPro was processed using QuestionPro Analysis tools. QuestionPro has various analysis tools capable of running quantitative and qualitative data simultaneously. Amongst other things such as functionalities, QuestionPro is strong enough to conduct trend analysis, Correlation Analysis, Conjoint analysis, MaxDiff Analysis, Cross Tabulations, heatmap, and hotspot analysis. In addition, confidence levels, standard deviation, and standard errors were also calculated using QuestionPro.

Text Analysis functionality on QuestionPro was used to analyse qualitative data collected through the questionnaire.

### 3.11.2 Interviews Data Analysis

The researcher transcribed interview data collected on the field into written text. The researcher listened to voice recordings and converted them into text in preparation for data analysis. Thematic analysis was applied in the transcription of interviews. The researcher examined the data to identify themes, ideas and patterns from a set of qualitative data (Caulfield 2020). The thematic analysis allowed the researcher to interpret and approach large data sets by efficiently sorting them into broad themes. Theme development was primarily informed by the research questions that needed to be answered.

According to Hsieh and Shannon (2005:1278), content analysis is another method used in qualitative data to analyse text. Content analysis is a “systematic coding and categorizing approach used for exploring large amounts of textual information unobtrusively to determine trends and patterns of words used, their frequency, their relationships, and the structures and discourses of communication” (Vaismoradi *et al*. 2013:400). Content analysis and thematic analysis are homogenous (Braun & Clarke 2006:29). Both content and thematic analysis can examine data by separating the text into small data components and submitting it to descriptive treatment (Vaismoradi *et al*. 2013:400). Content and thematic analysis were conducted in this study. Content analysis can simultaneously analyse qualitative and quantitative data; thematic analysis can qualitatively offer accurate and refinement of data (Vaismoradi *et al.* 2013:400).

### 3.11.3 Descriptive Statistics

Descriptive statistics are used to represent, distinguish and summarize the numerical data variables. Descriptive statistics necessitate considerable measures that sum up unique attributes of the data set (Conner & Johnson 2017:52). Online data collected was analysed using the inbuilt analysis capability of the QuestionPro. An online survey hosted by QuestionPro can conduct simple statistics and provide a quick interface for inputted data. With QuestionPro, the researcher could generate the frequency of any response of interest.

## 3.12 Ethical Considerations

In line with international best standards, ethical considerations were of prime concern in the design and execution of this research study. To this end, permission to conduct research was obtained from SANBI authorities which paved the way for the investigation. Furthermore, the study ensured that participation was voluntary through tourists being informed or written consent. The study also provided anonymity and adhered to all data protection policies. The reporting of results is made in aggregate to ensure the information cannot be traced back to the research participants. In line with that, the research obtained an ethics approval Ref Number: FREC/HS/14/08/2020/6.1.7, and the ethics approval is attached as Appendix 1.

### 3.13 Reliability and Validity

According to Drost (2011:106), reliability is the repetition or replication of research findings. In other words, the results are said to be the same when the same instrument is utilized at different times or administered to different respondents from the same demographic (Creswell *et al*. 2016:238). On the other hand, validity refers to the extent to which a research instrument accurately measures what it is intended to measure (Yilmaz 2013:318). Therefore, reliability and validity are critical parts of research in determining the findings' trustworthiness, dependability, and worthiness (Heale & Twycross 2015:66). Moreover, the two are crucial measures in determining the appropriateness and accuracy of scientific research techniques (Mohamad, Sulaiman, Sern & Salleh 2015:165).

Several steps and procedures were followed throughout the research process to assure reliability and validity, including the design, data collection, analysis, and interpretation of results. The researcher carefully designed the methodological design to ensure reliability and validity by developing a logical relationship between the study's questions and objectives. To guarantee the morality of research findings, the primary research tools were checked with local academics, friends, and experts in the related field of research to ensure question reliability. All participating respondents were those that had visited the botanical gardens. Participation was voluntarily in this research. After all, permissions were done, the researcher investigated to guarantee that the findings were reliable. To confirm the findings, a report was sent back to the research area. The use of multiple research tools provided the triangulation of results, which ensured internal and external validity. Talking to various botanical gardens also confirmed that diverse views and observations were collected to ensure the findings were as valid as possible.

### 3.14 Summary

This chapter significantly presented the critical steps used to gather data from both sources and alternative sources. A case study mixed-method approach was used in this research with a pragmatism theoretical framework. The researcher used various techniques to collect data, such as online surveys, secondary data analysis, field observation, and online semi-structured interviews to generate data that answers the research question. Purposive, snowball and convenience sampling were used to identify ideal candidates for the research. The researcher conducted research ethically in line with universal ethical standards. Data was analysed using Microsoft Excel spreadsheets, Man Kendall Trend analysis, and thematic and content analysis. The various methods and techniques used assisted in responding to the study's research questions and objectives. The researcher addressed each research question to ensure the reliability and validity of the study. The following chapter presents the results of this study.

# Chapter 4 : Perceptions on the impact of extreme weather events

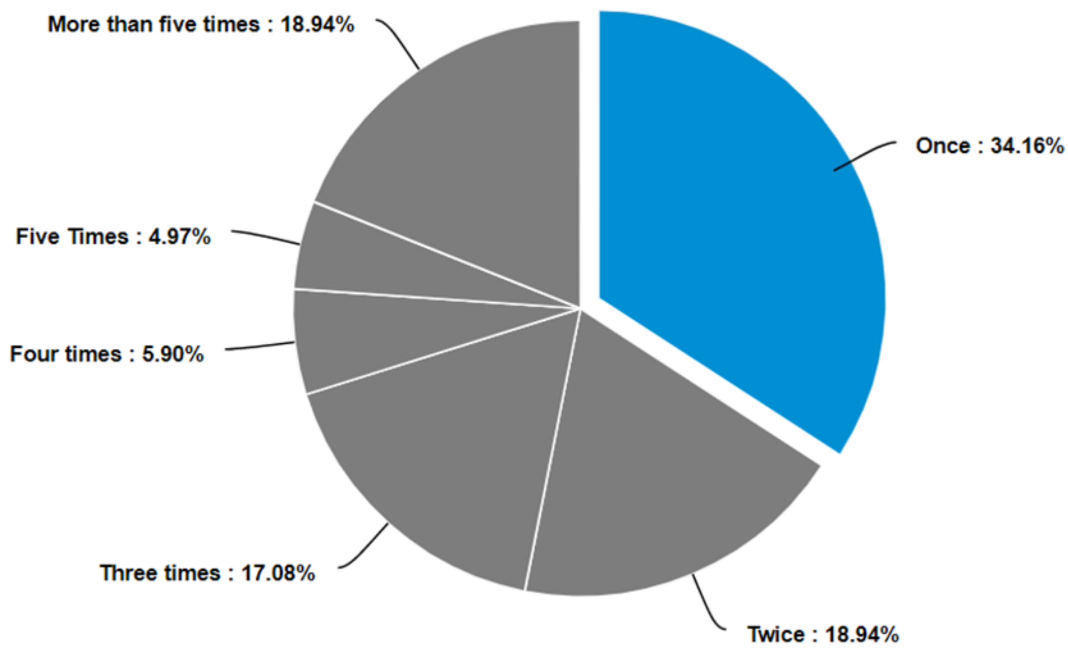
## 4.1 Introduction

This chapter highlights the results from a visitor survey aimed at investigating visitor perceptions of the impact of extreme weather events on botanical gardens in Gauteng. It addresses the first objective of this dissertation research. The chapter reports on the analysis of findings derived from 324 visitors who participated in the study. The survey was restricted to two botanical gardens in Gauteng province, namely Walter Sisulu Botanical Garden in Johannesburg and Pretoria Botanical Garden in Pretoria.

## 4.2 Profile of respondents

The study gathered views from 324 respondents comprising 66% females and 31% males, with the remaining 3% falling into the other category. Of these respondents, 59% had only visited the Pretoria Botanical Garden, and 41% had visited the Walter Sisulu Botanical Garden, while the remainder (14%) had visited both botanical gardens. It emerged from the study that most respondents are knowledgeable about the gardens, given the repeat visits they made to the botanical gardens over the last decade, as shown in Figure 4.1.

Approximately two-thirds of the respondents had visited the botanical gardens more than once, with only 34% having made single visits. This shows that a number of the research participants had observed the changes in the garden over time. Knowledge of the garden and adaptations is an essential parameter to this study. It highlights that the respondent is well placed to have made the relevant observations leading to an informed and considered perception.

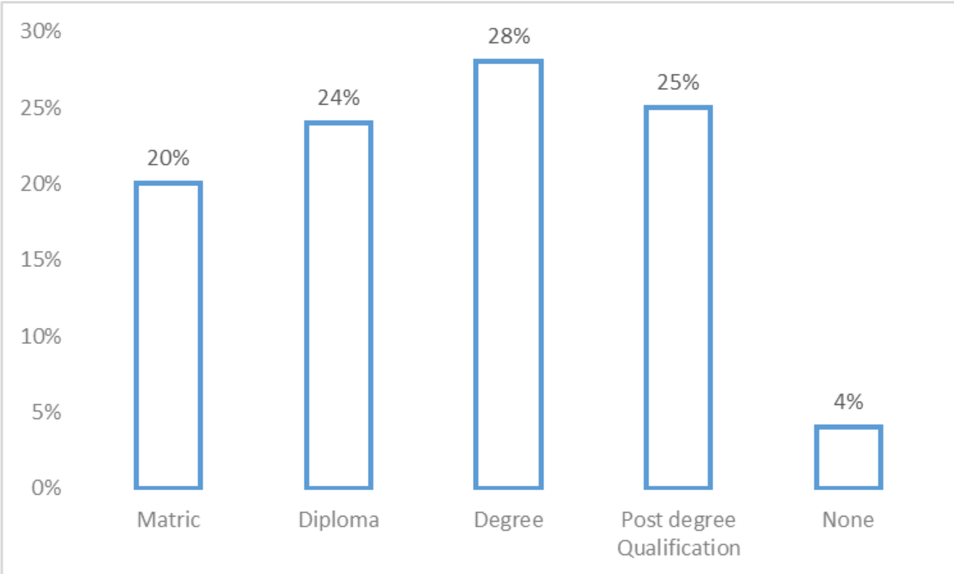



Mean: 2.854 | Confidence Interval @ 95% : [2.649 - 3.059] | Standard Deviation : 1.873 | Standard Error : 0.104

*Figure 4.1: Number of Visits to botanical gardens in the last 10 years (n=322)*

Source: Fieldwork 2021

Figure 4.2 shows that most respondents were at least educated with a higher degree. This indicates that a survey had high participation of educated respondents who completed a tertiary level qualification, ensuring they have adequate knowledge of climate change, the impacts, and response strategies. This showed that the respondents had qualifications related to this subject matter. Ordinarily, the profile of nature lovers such as ecotourists shows that these are highly educated individuals who are reasonably knowledgeable and, as such, are preferred in climate change studies (Ana 2017:8). Also, education plays a role in shaping informed perceptions and beliefs (He & Chen 2012:105). As such, the findings of this study can be assumed to be valid and arise from a credible source.



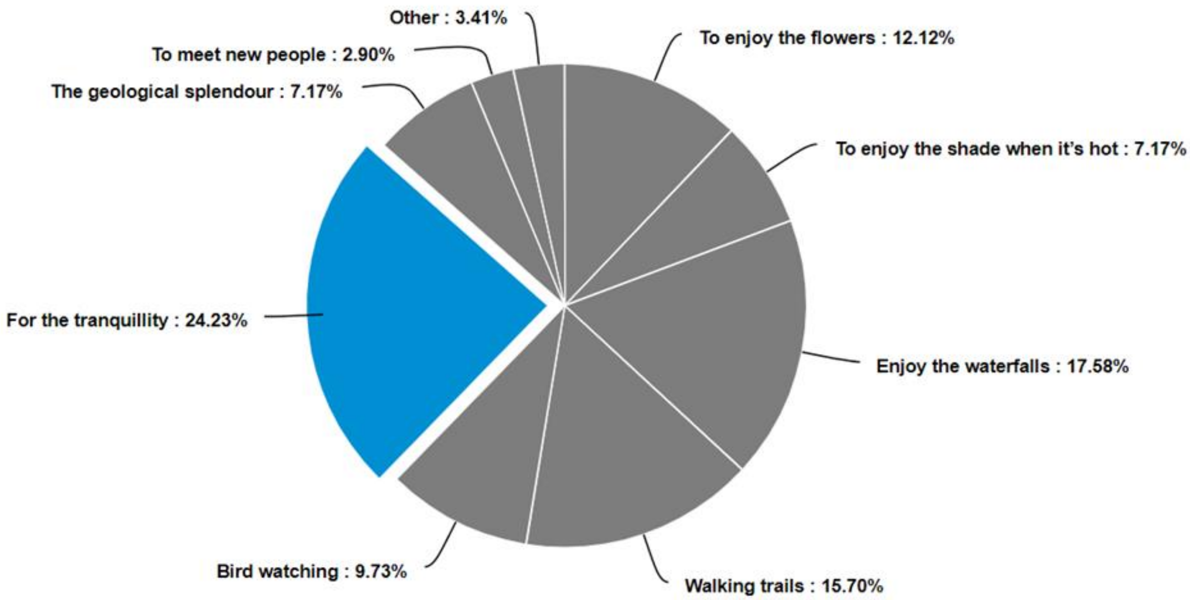

Mean: 2.703 | Confidence Interval @ 95% : [2.576 - 2.829] | Standard Deviation : 1.160 | Standard Error : 0.065

*Figure 4.2: Level of education of respondents*

Source: Fieldwork 2021

Respondents indicated that they often see the botanical gardens during different seasons to experience various seasonal activities. However, most of these visits seem to be have been concentrated around the summer months. 71% of respondents indicated that they frequented the gardens during summer, 16% during autumn, and 10% during spring. With a visitor rate of only 3%, it was clear that the winter months attracted a minimal number of visitors. This could be because summer provides ideal conditions for outdoor activities such as picnics and special events, often hosted by these botanical gardens.

Summer also coincides with the peak water flow at the Walter Sisulu Botanical Garden waterfalls, one of the garden's most popular tourist features (see figure 4.3). Besides, summer is associated with greenery and blooming vegetation in botanical gardens, providing much-needed shade during the peak of the summer heat. Furthermore, the flower seasons also attract many visitors to the botanical gardens. About 10% of visitors to the gardens indicated that they are attracted to birds, with a substantial percentage alluding to the geological splendour of the gardens. At the same time, some are attributed to the waterfalls. Also, hikers who frequent these two botanical gardens find their walking trails very pleasant. These activities and attractions are potentially susceptible to climate variability and change like any other tourism activities (Hambira, 2017:5; Santos-Lacueva *et al*. 2017:6; Scott *et al.* 2019:50).




Mean: 4.401 | Confidence Interval @ 95% : [4.231 - 4.571] | Standard Deviation : 2.104 | Standard Error : 0.087

*Figure 4.3: Reasons for visiting botanical gardens*

Source: Fieldwork 2021

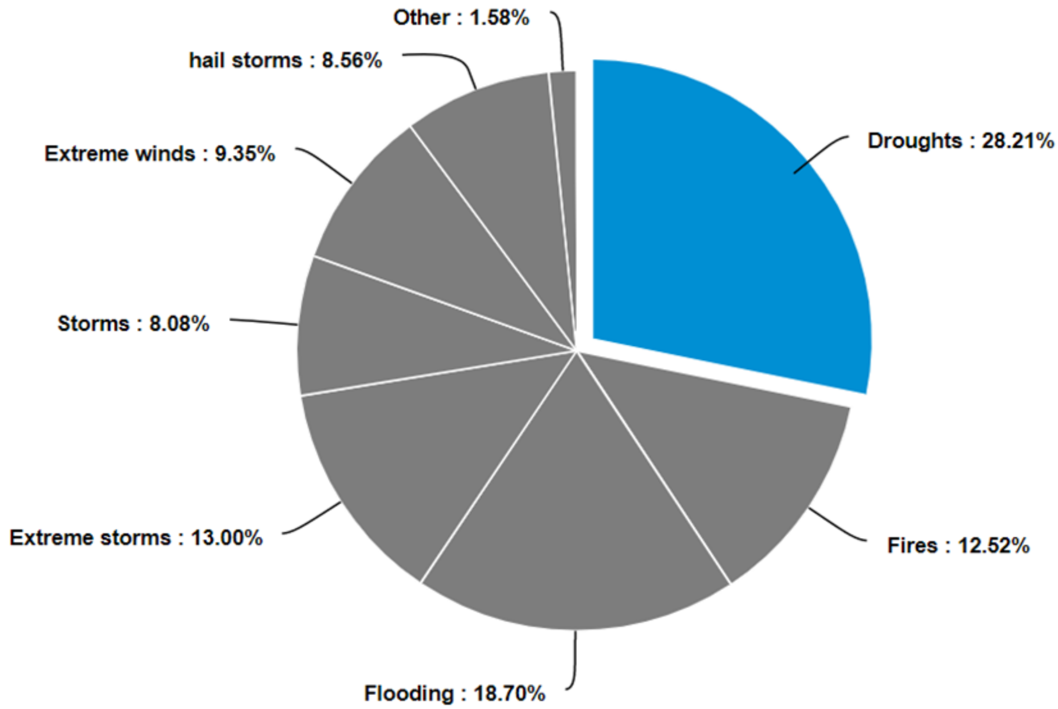
### 4.3 Potential impacts and response to climate variability and change

According to Alim *et al.* (2016:135), perception is how an individual gathers, processes and interprets information from the environment. Climate and weather have a relatively high impact on tourism, tourist destinations and tourist perceptions, affecting tourists' experiences at a destination (Zhang 2016:16). Climate and weather-related events are susceptible factors to the tourism industry, limiting tourists from travelling (Urioste-Stone *et al*. 2015:34).

Tourists were asked if they believe that extreme weather events attributed to climate change threaten botanical gardens, to which 75% agreed. Only a minority (13%) believed that climate change does not threaten botanical gardens, with the remaining (13%) unsure. The large number of respondents who said that climate change is a threat to botanical gardens is testimony to recognising climate change as a threat to the global economy, biodiversity and other activities as has been the norm across the world (Lovisolo 2021:261; Weiskopf *et al.* 2020:16).

A staggering 84% of the respondents reported that extreme weather events contributed to adverse experiences in the botanical gardens, with the remainder (16%) not having had an unpleasant experience in the botanical gardens that can be linked to climate change. An unpleasant experience in a tourism-related industry attributed to climate change impacts is not new, as Brownlee *et al.* (2013) observed and argued that climate change adversely affected visitor experience at botanical gardens.

The visitors highlighted what they think are the biggest climatic threats to botanical gardens, as shown in figure 4.4. More than a third of the respondents identified drought as a significant threat. This was unsurprising given the potential adverse impacts of droughts that adversely impacted nature-based tourism activities in South Africa and beyond. In respect of botanical gardens, the Kirstenbosch Botanical Gardens suffered a decline in visitor arrivals due to the drought (Dube *et al.* 2020:10). Given that the botanical gardens are predominantly nature centres, a drought can disrupt vegetation and flower growth with an adverse consequence on the aesthetics of the gardens. Droughts can also, directly and indirectly, result in the loss of species due to die-offs. Akinyoyenu *et al*. (2018:87) noted that botanical gardens lost vegetation species in Nigeria because of climate change. Similar trends were recorded in other botanical gardens globally, with Hultine *et al*. (2016:1059) citing the decline in some of the iconic succulent plants in botanical gardens and calling for increased conservation efforts.




Mean: 3.304 | Confidence Interval @ 95%: [3.144 - 3.465] | Standard Deviation : 2.056 | Standard Error : 0.082

*Figure 4.4: Major climatic threats to botanical gardens*

Source: Fieldwork 2021

It is also important to note that droughts have been noted to have adverse impacts on water-based tourism features elsewhere in the region. Droughts led to a considerable decline in water flow at the Victoria Falls waterfalls in Zimbabwe and Zambia at the height of the 2016 and 2019 droughts (Dube & Nhamo 2020a:5). Therefore, visitors to Walter Sisulu have a well-founded fear of the possible deterioration of the Witpoortje Falls, principally fed by about six springs located in Roodepoort. The upper basin of the Crocodile River that feeds into the Witpoortje Falls is particularly vulnerable to rainfall and temperature changes. According to Leketa and Abiye (2019:1), the impact of climate change on the Crocodile River is that if temperatures were increased by 1.5 °C and rainfall decreased by 20%, this would decrease by 39% in total streamflow and 28% in baseflow. This would undoubtedly have an adverse impact on the water flow at the waterfalls, much to the dismay of tourists. It would also adversely affect the aquatic life in that river.

Other weather events cited as particularly concerning are flooding, storms, and fire. Flooding is problematic for parts of the Walter Sisulu Botanical Garden located along the Crocodile River that feeds onto the Witpoortje Falls. Field investigations carried out at the Crocodile River revealed that flooding is closely associated with storms and cloud bursts, which was becoming more frequent in Johannesburg. In the past, such events had led to flooding, which resulted in damaged bridge infrastructure and walking trails cutting off certain parts of the garden.

Thunderstorms can be problematic, as Gauteng, where the gardens are located, often experiences violent storms that can curtail recreational activities and cause fires. Fires were also reported to be a menace, particularly to Walter Sisulu Botanical Garden. With large sections of the garden lying at the periphery of settlements, and some areas of the garden being on wetland, fires that break out are damaging to the environment. These fires also threaten infrastructure in the botanical garden and produce a lot of atmospheric, land and general aesthetic pollution. Such pollution makes the botanical garden unsuitable for any recreation activities or special events that are sometimes hosted in the gardens. Under climate change, fires are expected to be more frequent and intense (Restaino & Safford 2018:495), which could prove challenging and disruptive for recreational activities in Walter Sisulu Botanical Gardens.

Extreme weather events are problematic and disruptive to the aesthetics of botanical gardens. Visitors love the botanical gardens for the beautiful scenery and aesthetics. Often, botanical gardens are used for photography during special events such as weddings, graduation ceremonies and other special events. Therefore, the disruptive nature of extreme weather events undermines the aesthetic integrity of botanical gardens, which can cause the loss of their recreation value. It is expected that an increase in the number and occurrence of extreme weather events might increase the number of days that are unsuitable for visiting the botanical gardens, which might affect the annual number of visitors. The result will be a loss of revenue for conservation.

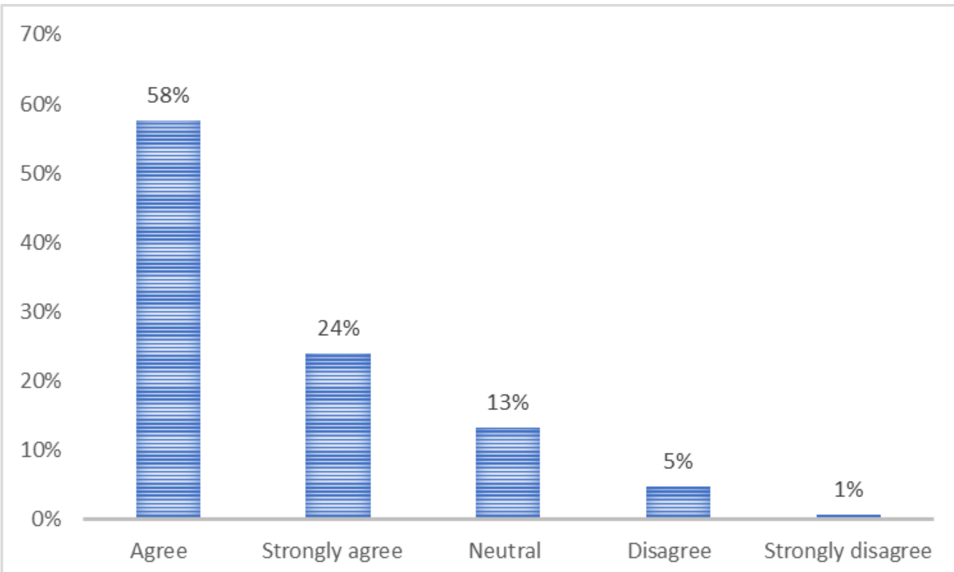
Besides the loss in the aesthetic value of botanical gardens, tourists complained that extreme weather events hurt bird species. Both botanical gardens have bird species that form part of the attraction. At least 311 respondents noted that they had witnessed a decline in bird species in the gardens. Such loss could be attributed to habitual loss and reduced habitat quality in and outside the botanical garden. This warrants attention by garden officials and society at large as this could potentially adversely affect bird watchers to the two botanical gardens.

The other concern was a general decline in biodiversity in the gardens. About 312 (80%) of the visitors felt that the botanical gardens were losing biodiversity because of climate change. A loss in biodiversity has far-reaching consequences beyond botanical gardens and impacts people's quality of life in urban environments in the vicinity of these gardens. Loss of biodiversity has been of significant concern globally in the recent past, as noted by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services-IPBES (2019).

Extreme weather events adversely affect several of visitors' activities in the gardens. Most respondents (41%) identified picnic activities as the most affected activity by severe weather events. About 22% complained about the impact of extreme weather events on walking trails, 13% on bird watching, 12% on waterfall viewing, 9% on guided tours and 3% on other activities. It would seem the extreme weather events would curtail several operations in the botanical gardens in Gauteng with possible negative implications for repeat visits from tourists.

As much as visitors believed that climate variability and change impacted botanical gardens, tourists were divided in their opinion on the effects of botanical garden operations on climate change. At least 41% of respondents noted that botanical garden operations contributed to climate change, with another 41% indicating that the garden operations, including visitors, did not contribute to climate change. 18% of respondents were unsure if the garden operations contributed to climate change. This is not unique, as other studies have previously demonstrated that several tourists and visitors still deny their contribution to climate change (Dube *et al*. 2018:10). This means there is a need to raise more education and awareness in botanical gardens and other protected areas to environmental impacts of human activities, which are often ignored or understated.

Visitors were asked to provide an account of whether the impacts of travel decisions can be potentially affected by climate change (figure 4.5). 75% believed that climate could play a central role in shaping travel decisions to botanical gardens. This is a critical finding as it means that any planning done by botanical gardens has to consider climate change as it potentially affects future visitor numbers, with consequences on revenue. Wilkins *et al*. (2018:275) had earlier noted that climate change could cause delays or trip cancellations and ultimately affect satisfaction and duration of stay at a destination.




Mean : 1.670 | Confidence Interval @ 95% : [1.569 - 1.771] | Standard Deviation : 0.920 | Standard Error : 0.052

*Figure 4.5: Climate change affects tourists travel decisions to botanical gardens*

Source: Fieldwork 2021

The survey revealed that most respondents (65%) were generally fearful that climate change would adversely affect the recreational function of botanical gardens. In response, visitors were asked to suggest solutions to climate change in botanical gardens. One of the proposed solutions was to ensure that botanical gardens reduce their energy and proxy carbon emissions to deal with the threats of climate change (Figure 4.6). Achieving carbon neutrality has been pushed as one solution to tackling the climate emergency that is facing the world. This suggestion finds resonance with both the Paris Agreement and the Sustainable Development Goals (Agenda 2030) as an antidote to the impending dangerous climate if emissions are not drastically cut. The world will need to cut at least 45% of carbon emissions by the year 2030 (Li & Qin 2019:862) to avoid climate backlash.


*Figure 4.6: Word Cloud on suggested solutions to climate change challenges in botanical gardens*

Source: Fieldwork 2021

One proposed solution is that botanical gardens should go green to conserve energy, reduce water use, transportation and recycle waste. This recommendation can be adopted by botanical gardens in Gauteng, the country at large, fostering a spirit of green and sustainable living amongst the visitors. With evidence from the field observation indicating that some of the buildings aren't designed to ensure resource efficiency, there might be a need to invest in green building design to reduce the carbon footprint at botanical gardens. According to Mozingo and Arens (2014:15), green buildings could reduce as much as 50% of greenhouse gas emissions and reduce water and waste produced by a building. Consequently, green buildings can limit the impacts of climate change (Knowles 2008:2).

Tourists also suggested that botanical gardens should plant more trees to absorb carbon dioxide and mitigate greenhouse gas emissions produced by human activity. Trees play an essential role in carbon sequestration, capturing and storing excess carbon dioxide

(Derouin 2019). The issue of trees is also critical as they can also assist in cooling the atmosphere in botanical gardens during the hot summer months and provide adequate shade for picnics.

There were also calls for botanical gardens to increase environmental awareness on climate change, recycling, responsible consumption and indigenous plants. There are crucial issues that fall directly within the mandate of botanical gardens, and the South African National Biodiversity Institute (SANBI), the custodian of the botanical gardens. It is of utmost importance for botanical gardens to improve their environmental sustainability, minimise environmental impacts and increase environmental awareness to visitors (Erdogan & Tosun 2009:411). The call resonates with Chen and Sun (2018:185) and Cavender and Donnelly (2019:315), who believed that botanical gardens could be the centres for sustainable, conservation, and environmental science education.

Raising environmental awareness is essential in examining the damage perception of critical environmental aspects for improving personal interactions with surrounding nature (Garcia *et al.* 2012:326). It is also crucial for botanical gardens to cooperate with other businesses to build strategic plans that could reduce climate change impacts. Scott *et al.* (2016:15) stated that adaptation strategies hamper resilient tourism operations and destinations due to a lack of knowledge and communication about climate change impacts and adaptation strategies.

## 4.4 Summary

The study was conducted to investigate visitors' perceptions of extreme weather events on botanical gardens in Gauteng province. Results revealed that the study had high participation of educated respondents, said to be knowledgeable about the botanical gardens they visited. The survey revealed that most respondents visited the gardens during summer, given that summer is the best season and provide ideal conditions to enjoy picnics and other recreational activities for tourists. It emerged from the study that tourists visited the botanical gardens for different reasons that include their tranquil environment.

Results show that most participants believed climate change is a threat to botanical gardens, with drought singled out as the most significant threat. Drought was observed to disrupt flowering and vegetation in the gardens. Similar threats were also observed in other gardens that experienced a decline in succulent plants. Results revealed flooding, storms, and fire as the most disturbing factors in both botanical gardens.

It was revealed that extreme weather events are problematic to the aesthetics of botanical gardens. It emerged that an increase and occurrence in extreme weather events could also affect visitor numbers to the botanical gardens, resulting in loss of revenue for them. The study also revealed that bird species were seen to be harmed by extreme weather events. Such effects were assumed to lead to a decline in bird species. Besides, biodiversity was also revealed as the other concern in both the gardens, with most visitors concerned that botanical gardens are losing biodiversity because of climate change. Due to global warming and rainfall patterns, loss in vegetation and biodiversity was also a significant concern.

Given the activities tourists undertake in the gardens, picnics were identified as the most affected activity by extreme weather events. The study revealed that climate change affects tourists' travel decisions to botanical gardens, thereby affecting their experience when visiting the gardens. In addition to these findings, respondents suggested that the botanical gardens need to shrink their carbon footprint to deal with the threats of climate change. The next chapter thoroughly explains the climate change factors affecting the botanical gardens and their adaptation to those factors.

# Chapter 5 : Impact of climate variability and change on botanical gardens in Gauteng

## 5.1 Introduction

This chapter examines the evidence and the impact of climate change on botanical gardens in Gauteng. The chapter addresses the 2nd and the 3rd objective of this research study. Consequently, the chapter is divided into two sections, the first focusing on the climatic aspects and observed impacts. The second section focuses on climate change mitigation and adaptation strategies adopted by SANBI in both Walter Sisulu and Pretoria Botanical Gardens.

## 5.2 Rainfall pattern at the Pretoria Botanical Gardens

Given that botanical gardens act as sanctuaries for plants and some animals, the study looked at climatic patterns at the UNISA weather station, one of the nearest weather stations to the National Botanical Gardens, to track changes that could impact plants in the botanical gardens. Plants and animals are dependent on water for food and metabolism processes. Other climatic parameters such as temperature are also critical for plants sustenance and development.

It emerged from the study that the area has an average annual rainfall of about 641mm per year, considering the study period. Between 1996 and 2020, the rainfall pattern in the area around the botanical garden was highly variable. Such high variability could adversely have an impact on flora and fauna. An analysis of climate data shows that there hasn't been a statistically significant change in rainfall trends, as shown in Figure 5.1. This could be a result of highs and lows cancelling off. Of note is that over the past 24 years, about 11 years witnessed rainfall below average, which could indicate increasing drought episodes between 2010 and 2020; approximately two years had significant rainfall above the annual average, with most years being below the average annual rainfall. Droughts generally negatively impact both flora and fauna, and on the contrary, rainy years favour plant growth.

During this episode, the area also witnessed one of the worst drought periods recorded, in 2015, where only 319mm of rainfall was received, which is less than half of the annual expected rain for the area. This drought episode coincides with the period that marked the start of one of the worst El Niño events that ever affected Southern Africa (Siderius *et al*. 2018:5; Kolusu *et al*. 2019:1753). There is a general consensus that climate change's impact worsened during the same drought.

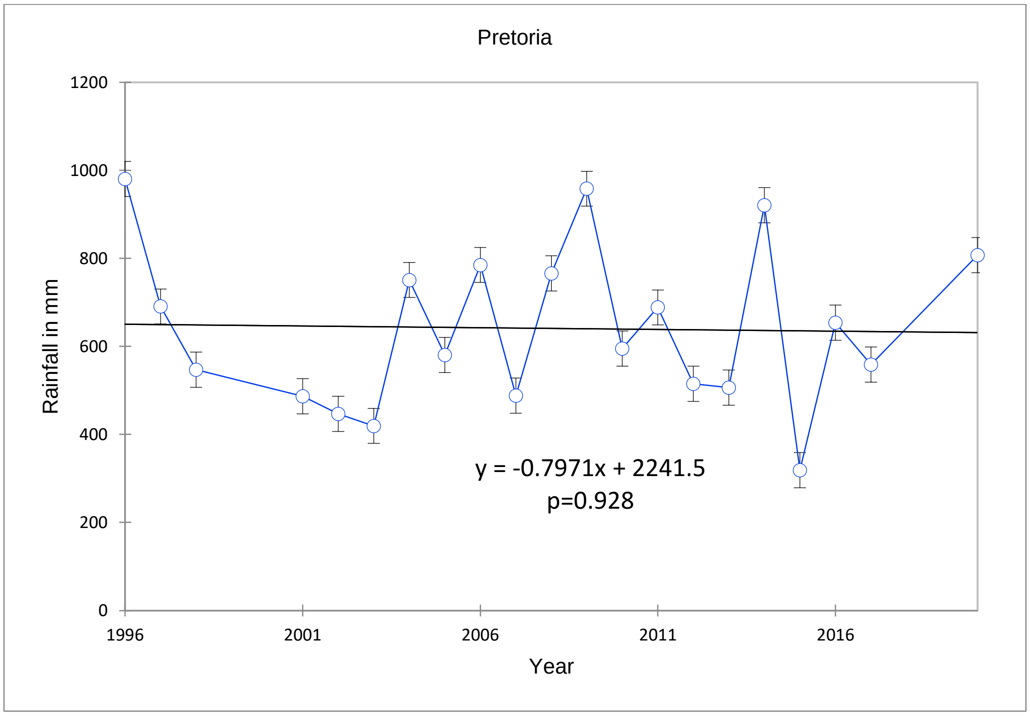



*Figure 5.1: Annual rainfall trend for Pretoriabetween1994 and 2020*

Source: Authors

The 2015 drought resulted in food challenges for animals residing in national parks in the region and caused the death of flora and fauna in national parks in South Africa (Dube & Nhamo, 2020d:3). Droughts cause environmental stress, resulting in plant reduction (Kaur & Asthir 2017:202). Evidence from interviews suggests that the droughts are becoming more frequent and affecting flora and fauna of the garden. Drought was highlighted to affect the garden's flowering and soil fertility, resulting in some seeds not germinating in time. Such a development can potentially affect bird species in the botanical garden if flowers cannot produce nectar or seeds as they depend on these for survival. It also emerged from the interviews that the nomadic birds, which are popular in the gardens, are sensitive to climate change, and such trends could affect their migration patterns as the habitat changes. Such changes could also adversely affect the park's aesthetics and diminish the visitor experience.

On a monthly basis, there is also evidence of monthly variability in rainfall patterns, which could also point to seasonal changes, particularly for the summer months, given the high values of Standard Deviation (Table 5.1). The months with the highest variability, such as December, January, February and March, point to the unpredictability of rainfall patterns in those months, which was also confirmed by interviewees who work in the garden, who indicated that rainfall patterns were highly variable and unpredictable. The winter months, by and large, have predictable rainfall patterns, which is generally low rainfall patterns.

*Table 5.1: Monthly average rainfall pattern in Pretoria*

| Variable | Observations | Obs. with missing data | Obs. without missing data | Minimum | Maximum | Mean | Std. deviation |
|---|---|---|---|---|---|---|---|
| JAN | 27 | 1 | 26 | 22,6 | 356 | 123,8 | 89 |
| FEB | 27 | 2 | 25 | 0,000 | 359,6 | 86,8 | 76 |
| MAR | 27 | 3 | 24 | 7,2 | 282,4 | 94,5 | 83 |
| APR | 27 | 4 | 23 | 0 | 145,2 | 39,3 | 39 |
| MAY | 27 | 3 | 24 | 0 | 109,8 | 12,6 | 24 |
| JUN | 27 | 4 | 23 | 0 | 31,2 | 5,8 | 9 |
| JUL | 27 | 1 | 26 | 0 | 13,2 | 2 | 3,4 |
| AUG | 27 | 0 | 27 | 0 | 33,6 | 4,4 | 8 |
| SEP | 27 | 0 | 27 | 0 | 61,6 | 14,1 | 19,6 |
| OCT | 27 | 2 | 25 | 0 | 148,4 | 50,4 | 35,4 |
| NOV | 27 | 1 | 26 | 22,6 | 296,4 | 94,7 | 62 |
| DEC | 27 | 2 | 25 | 9,8 | 326,8 | 121 | 71,1 |

Source: Authors

Although several months had witnessed a slight increase in rainfall activity, these were not statistically significant but could have an environmental effect on plant species. Generally, there are fewer months with an increase in average rainfall, with only March, June, September, October, and December having recorded a rise in average rainfall. The rest of the months reported a decrease in average rainfall patterns. When subjected to the Mann Kendal trend analysis, only February had a statistically significant reduction in the amount of rain received (Figure 5.2). Although there are slight changes in rainfall patterns, these can impact plant and animal life cycles in the garden. Therefore, the high variability of rainfall witnessed in some months is a cause for concern.

About five months had witnessed a decline in the average rainfall throughout the study period. Rainfall decline was recorded in January, with average rainfall declining from about 149mm to about 123mm. February is the only month that witnessed a statistically significant decline in rainfall, with average rainfall decreasing from about 150mm to 86mm (see figure 5.2). In April, the decline was from just above 40mm to slightly less than 39mm, in average rainfall. In May, the decline was from 20mm to about 5mm, whilst August reported a decrease from about 20mm to 4mm. November rainfall remained unchanged, with its rainfall averaging around 94mm.

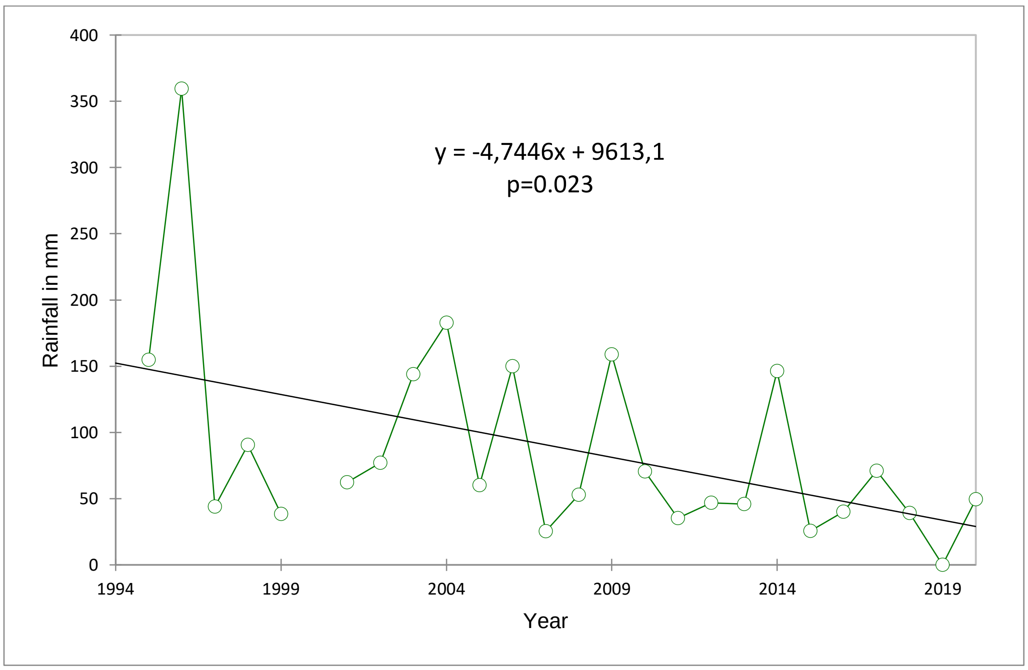



*Figure 5.2: Rainfall pattern for February in Pretoria*

Source: Author

The other months also recorded a slight increase in rainfall, although these are not statistically significant. In March, there was an increase from 75mm to about 95mm, while June increased from about 4mm to an average of about 6mm. July started at 0.5mm and witnessed an increase to about 4mm, while September had seen an average rise from about 10mm to 16mm of rainfall. October also noted an increase in rainfall from 41mm to about 50mm, while the increase in December was from about 99mm to 121mm of average rainfall. Such minor changes in rainfall could have far-reaching effects on plant life in botanical gardens. As reported earlier, changes in rainfall patterns could have a more significant impact on flower, grass and other plant life with consequences for fauna.

### 5.3 Temperature pattern in Pretoria (1994-2020)

The study found evidence of climate variability and change on monthly maximum temperatures for Pretoria. Statistically, significant temperature increases were observed in the summer months of September, October and November, as shown in figure 5.3. In September, the temperature increased from an average of 26°C to about 27.8°C marking an increase of 1.8°C. October temperature increased by 3°C, rising from 27°C to about 30°C, while November witnessed a temperature increase of 2.6°C with the temperature rising from 27°C to 29.6°C. These average temperature increases are way above the observed global average temperatures of about 1.3°C (Liu *et al.* 2018:448).

Significantly such an increase is concerning as the rate of increase is very high. An increased temperature in the summer months will likely draw more people to the botanical gardens for picnics, given the ambience and shade options that can help with the need for cooling. The Pretoria Botanical Garden has stunning gardens and an artificial waterfall that provides a refreshing experience to the botanical garden. However, an increase in temperature has potentially adverse impacts on the waterfalls. It increases evaporation rates, thereby increasing the water demand for watering purposes, hence the need for a better water management strategy. On the other hand, high temperatures during the drier months mean increased watering demands for the garden, which pushes up irrigation costs on water.

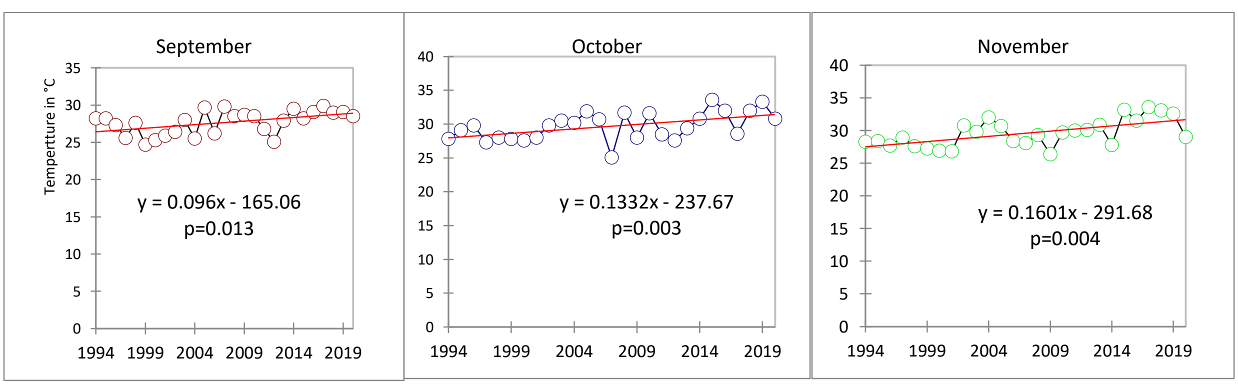


*Figure 5.3: Months with the statistically significant increase in temperature in Pretoria*

Source: Authors

Besides the above months, there were no observed temperature changes for January, whose temperature remained unchanged at an average temperature of 30°C, and April at 24°C, while December reported a constant of 29°C. In February, the temperature slightly increased from below 30°C, to about 30°C. May witnessed an increase of temperature from 21°C to 22.3°C. The June temperature rose from 19°C to about 20°C. July saw a rise of 1°C with a temperature rising from an average of 19°C to 20°C. In essence, all the months during this study period experienced some sort of temperature increase save for the two months. There is a global narrative that the global average temperature is increasing. Therefore temperature rise was expected.

Increasing temperatures generate environmental challenges, threatening biodiversity and the ecosystem's functionality, resulting in species loss in many countries, including South Africa (Garc´ıa *et al.* 2018:325). Warming temperatures shift species geographical ranges and may locally go extinct (Nunez *et al.* 2019:352). Temperature rise is, therefore, a severe concern regarding the loss of biodiversity worldwide, as many ecosystems lose suitable conditions for the survival of their species (Garc´ıa *et al.* 2018:326).

The minimum temperature was also observed to be on the increase in the main. However, the increase in most cases is not statistically significant, with only one month, December, having recorded a statistically significant temperature increase as shown in Figure 5.4. January's temperature seemed constant, at a minimum of 16.7°C, February remained steady at about 16.5°C, and March constant at about 15°C. The April temperature also seemed unchanged at 11.8°C. In May, the temperature increased from 7.9°C to 8.3°C, June 4.9°C to 5.1°C, and August 7.8°C to 8.1°C. September saw an increase of 0.5°C with temperature increasing from 11°C to 11.5°C. November also witnessed an increase of about 0.6°C, where temperatures increased from 14.2°C to 14.8°C. A more than 1°C temperature increase was reported in December, as reported in Figure 5.4. Generally, there seems to be an increase in monthly average minimum temperature, which could have environmental impacts.

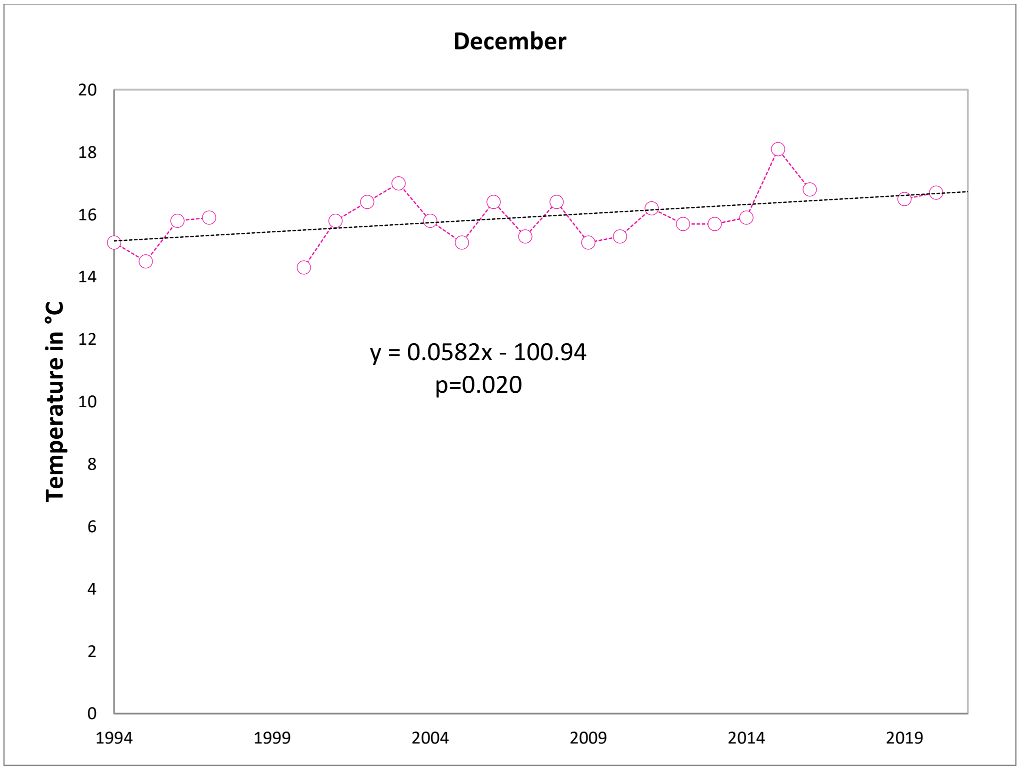



*Figure 5.4: A month with a statistically significant increase in temperature in Pretoria*

Source: Authors

### 5.4 Observed impact of climate variability and change on Pretoria Botanical Garden

Climate variability and change are severe issues in Pretoria botanical garden, affecting the recreational space of the garden and the natural environment. The gardens, plants, trees and bird species are vulnerable to climate variability and change impacts. Climate change factors such as extreme rainfall events, temperature and droughts affect the garden's natural environment, including flora and fauna and water supply. Emerging from the interviews, two respondents indicated that succulent plants are vulnerable to extreme rainfall events as they do not require a lot of water because they store water by themselves. To adapt to this effect, the botanical garden needs to locate the plants that need more attention in the same section. In Southern Africa, succulent plants are predicted to be more vulnerable to climate change impacts with ongoing significant declines (Burke 2013:326). Rainfall variability and increased temperatures cause a substantial reduction in species and tree density in South Africa (Lawal *et al*. 2019:2).

Heavy rains reduce the garden's aesthetic, causing soil erosion. Attention to this matter is a need for mulching and planting of trees.

Drought is another factor affecting the plants and animal species in the garden. From discussions, one of the respondents indicated that as it may take some time for the rain to fall, many plants in the garden don’t flower as expected due to lack of rain. Plants such as strelitzia and combretum species were observed to be heavily affected by droughts. Drought was indicated to affect the flowering pattern and season. Respondents also indicated that the garden's soil fertility is adversely affected by the impacts of climate change. In addition, seed germination rates are being observed to be adversely affected, which could affect the introduction of new trees and plant species.

Changes to plant and flowering challenges are also suspected to affect birds, butterflies, bees, and other insects, as there is suspicion that flowers might not produce as much nectar or seeds as these species are dependent on. It also emerged from interviews that climate change had upset the visiting patterns of nomadic birds, which are part of the attraction in the garden.

Higher than usual temperatures associated with drought were highlighted to increase demand and water usage in the garden. This subsequently affects the water footprint and water-related costs at the garden. Given that aridity caused by droughts affects the garden outlook, regular visitors reportedly complain if the vegetation looks whittled; as such, irrigation schedules are often increased to cope with the demands from both plants and visitors.

### 5.5. Rainfall pattern in Johannesburg (1985-2020)

The study found that the average rainfall at the Walter Sisulu Botanical gardens has been declining on an annual basis. However, this was not statistically significant using Mann Kendall Trend Test (Figure 5.5). Against the annual average rainfall of 631mm received in Johannesburg, evidence shows that between 1987 and 2020, the rainfall events had been quite variable, which could have had significant effects on plant and animal species in the garden. The highest amount of rainfall was received in 1987 when the area received 1093mm of rain. The second highest rainfall was received in 1989 when an annual rainfall amount of 959mm was received. On the other hand, many other years have witnessed a decline in average rainfall. Out of these 33 years, about 17 years witnessed below-average rainfall.

The years 1999 and 2002 recorded the lowest rainfall in Johannesburg. In 2002 the area received about 195mm of rainfall, close to about three times lower than the average rainfall. Other severe droughts were in 1999 (318mm), 2020 (368mm), and the years around 2000 witnessed several years of droughts in figure 5.5. The droughts seem to be on an increasing frequency generally if data from the station is anything to go by. Drought is an essential driver of vegetation change in South Africa (Lawal *et al*. 2019:2). The frequency and intensity of global warming lead to an enormous decline in vegetation (Ge *et al*. 2021:3). Increased activities in drought and heat are reported to lose vegetation capacity in Southern Africa likely (Kang *et al*. 2018:728; Lawal *et al*. 2019:2). Evidence from the interviews suggests that drought significantly impacts vegetation at Walter Sisulu garden and can affect plant productivity. It also emerged that high temperatures often associated with drought substantially impact the gardens' water resources, leading to the high demand for irrigation water.

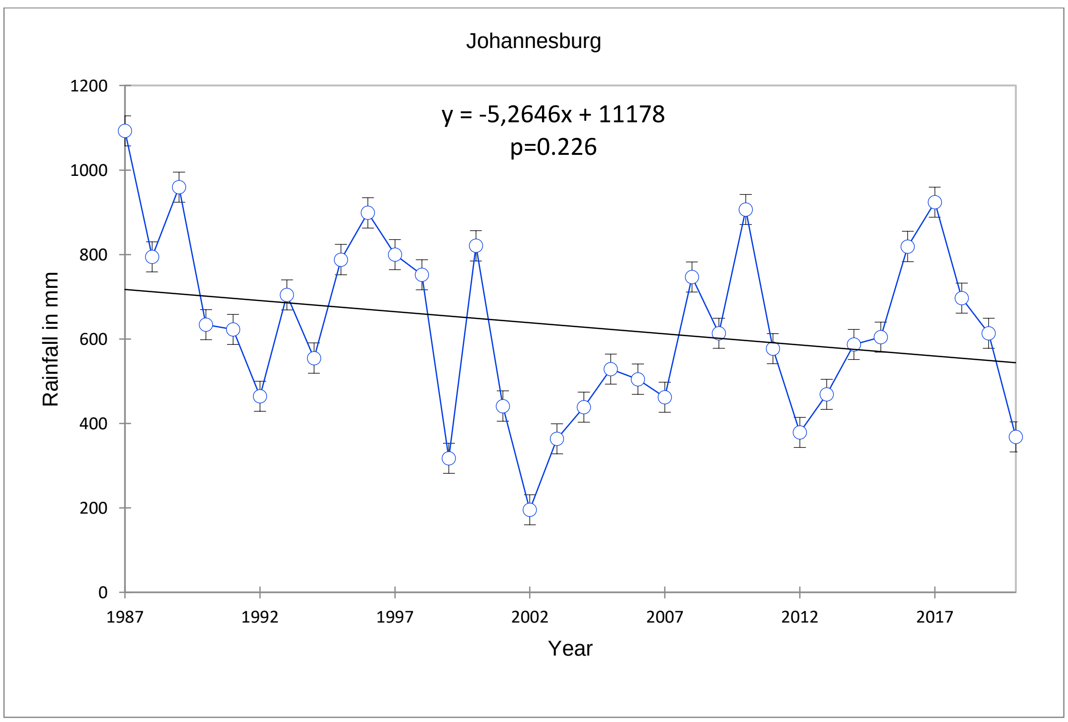



*Figure 5.5: Trend in average annual rainfall in Johannesburg between 1985 and 2020*

Source: Authors

On a month to month basis, the study found evidence of climate variability on a monthly rainfall pattern, pointing to seasonal changes. The average monthly rainfall for the Johannesburg area is shown in Table 5.2. The annual rainfall variability shown by standard deviations indicates high rain extremes in January, February and March. Some months witnessed a slight increase in rainfall activity, which were not statistically significant. The only months which have noticed an uptick in average rainfall amount includes April, May and July. The rest of the months have seen evidence of a decrease in rainfall amount received. October almost has a static average rainfall amount, although there is a slightly declining trend. As much as there is a decline from month to month, August is the only month with a statistically significant change in average rainfall amount (see figure 5.6). As a result, a slight change in rainfall can adversely affect vegetation structure and animal life cycle in the garden.

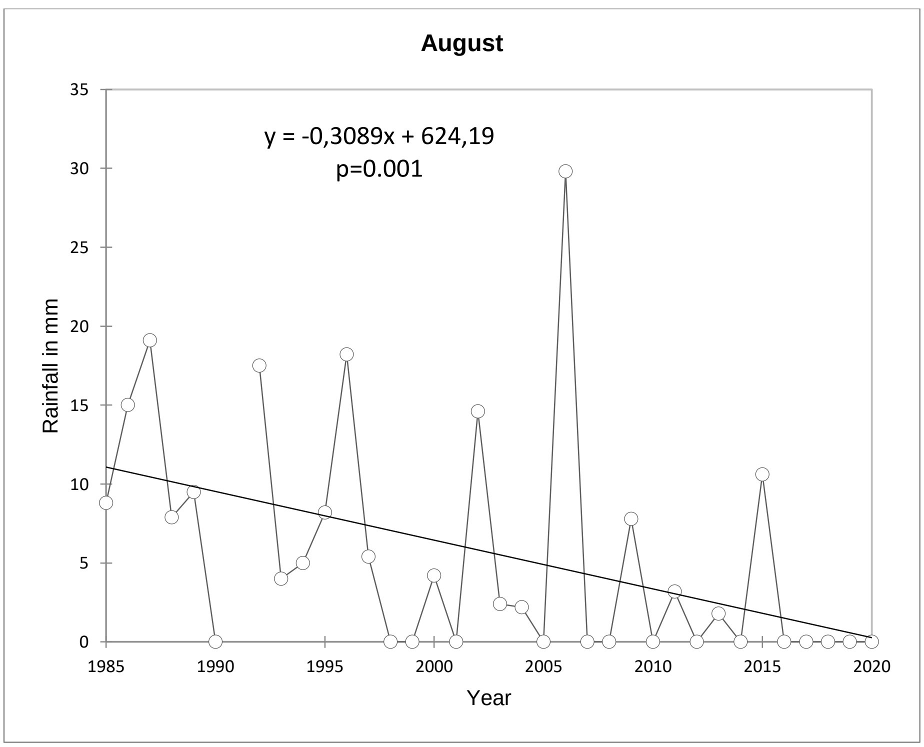



*Figure 5.6: Rainfall pattern for August in Johannesburg*

Source: Authors

*Table 5.2: Average Monthly Rainfall in Johannesburg*

| Variable | Observations | Obs. with missing data | Obs. without missing data | Minimum | Maximum | Mean | Std. deviation |
|---|---|---|---|---|---|---|---|
| JAN | 36 | 1 | 35 | 1 | 349 | 121.1 | 72.3 |
| FEB | 36 | 2 | 34 | 0.2 | 302.4 | 98.8 | 70 |
| MAR | 36 | 2 | 34 | 0.4 | 246.2 | 88.3 | 66.5 |
| APR | 36 | 0 | 36 | 0 | 130 | 32.4 | 33.7 |
| MAY | 36 | 1 | 35 | 0 | 104 | 13.8 | 21.9 |
| JUN | 36 | 0 | 36 | 0 | 46.4 | 6.6 | 11.5 |
| JUL | 36 | 0 | 36 | 0 | 21 | 2.4 | 5.2 |
| AUG | 36 | 1 | 35 | 0 | 29.8 | 5.6 | 7.3 |
| SEP | 36 | 0 | 36 | 0 | 162.3 | 17.9 | 29.7 |
| OCT | 36 | 0 | 36 | 1 | 201.7 | 64 | 47 |
| NOV | 36 | 0 | 36 | 0.2 | 206.1 | 80.3 | 53.6 |
| DEC | 36 | 1 | 35 | 7.6 | 192.7 | 114.9 | 50.6 |

Source: Authors

Only three months witnessed a slight increase in average rainfall throughout the study. In April, rainfall increased from 29mm to about 36mm. May recorded rainfall increase from 10mm to about 18mm, while July had 1mm and showed an increase to about 4mm. October showed a slight decline in rainfall from 69mm to about 58mm. The month of August recorded a statistically significant decrease in rainfall from 11mm to about 0mm. Other months showed evidence of rainfall. In February, there was a decrease in rainfall from 111mm to about 89mm. June noted a rainfall decrease from 9mm to about 5mm. September reported a reduction from 30mm to 3mm. In November, a decrease recorded was from 99mm to about 68mm. December recorded a decrease in rainfall from 127mm to about 107mm. Such changes could significantly impact vegetation in the garden, as stated earlier.

### 5.6 Trend in Maximum average monthly temperature in Johannesburg

The study found evidence of climate variability and change in the monthly maximum temperature in Johannesburg. Generally, there was an observed average maximum temperature increase in all the months. Statistically significant temperature increases were observed in May (p-value 0.03), July (p-value 0.01), September (p-value 0.013), October (p-value 0.03) and November (p-value 0.004). This means in both summer and winter; there was a significant temperature increase in the area (Figure 5.7). The monthly temperature increases were higher in summer than winter months, with 3 and 2 months respectively.

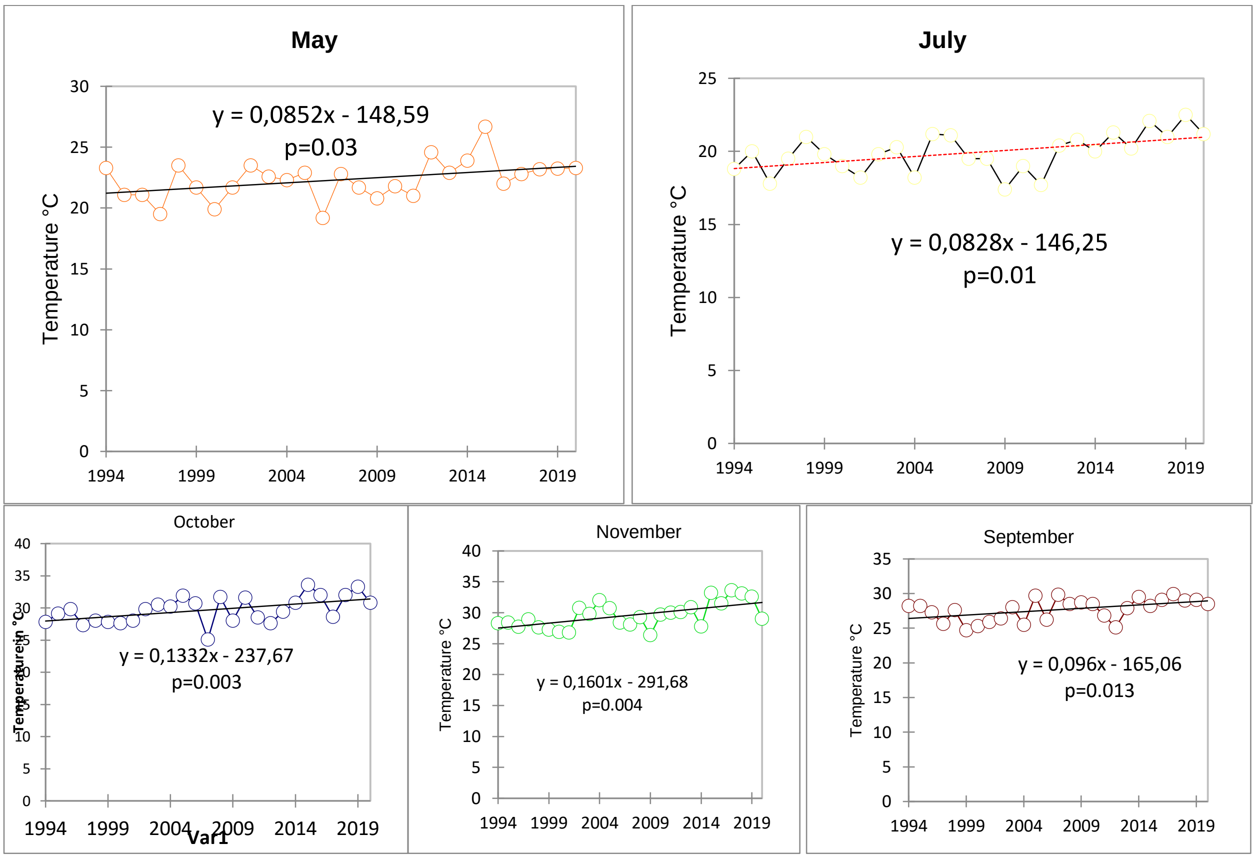



*Figure 5.7: Maximum temperature trends for Johannesburg*

Source: Authors

It would naturally follow that the months represented in Figure 5.7 had the most significant temperature increase. For example, the May temperature increased from 19°C to 22.5°C, July from about 19°C to slightly above 20°C, while temperatures in September rose from about 26°C to about 27°C. October and November's temperatures rose from 28°C to 30°C. Summer months have therefore seen the most significant temperature increase. This could have severe impacts on the Witpoortjie Falls. Another study had found the adverse effect of climate change on the Victoria Falls waterfalls located between Zambia and Zimbabwe (Dube and Nhamo 2018:115). Such a considerable increase in temperature can increase evaporation rates in the feeder river to the waterfalls, which is the main attraction at the botanical gardens, and reduce the aesthetics and ambience of the garden.

Table 5.3 shows the monthly minimum temperature for Johannesburg. All months of the year had witnessed some form of temperature increase, although these vary from month to month. The only month which recorded a statistically significant increase in temperature was December (Figure 5.8). The minimum temperature for December increased from about 15°C to about 16°C. When a Sens Lope Analysis was conducted, it emerged that May and June have the highest degree of temperature change. This raises issues of concern over warming winter and its potential impact on plant life, length of growing season and impacts on flowering plants.

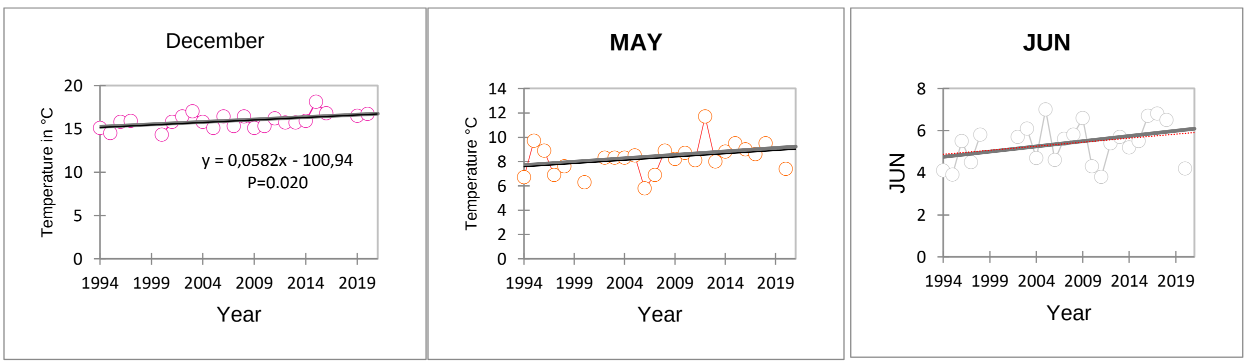



*Figure 5.8: Minimum temperature increases in Johannesburg*

Source: Authors

In January, the temperature increased from 14°C to about 15.3°C; there was an increase of 1.3°C. February recorded a temperature increase of 1.2°C with temperatures rising from 14°C to 15.2°C. June realised a temperature increase from 2.5°C to about 3.4°C and risen to 0.9°C. July recorded a temperature increase of 2.2°C to 2.9°C and risen to 0.7°C. In May, the temperature rose from 5.7°C to 6.5°C. In August average temperature rose from 4°C to 5.3°C, which is an increase of 1.3°C. In September, the temperature rose by 0.6°C, rising from 8.1°C to 8.7°C. October recorded a temperature increase from 10.7° to 11.5°C and risen to 0.8°C.  November showed an increase from 12°C to 12.9°C and March recorded a rise from 12.7°C to 13.6°C. An increase in minimum temperatures could also affect plant and animal species in the garden.

*Table 5.3: Monthly Minimum Temperature in Johannesburg*

| Variable | Observations | Obs. with missing data | Obs. without missing data | Minimum | Maximum | Mean | Std. deviation |
|---|---|---|---|---|---|---|---|
| JAN | 36 | 1 | 35 | 13.4 | 16.9 | 15.3 | 1.0 |
| FEB | 36 | 1 | 35 | 12.7 | 18 | 15.2 | 1.1 |
| MAR | 36 | 1 | 35 | 11.4 | 16.2 | 13.6 | 1.0 |
| APR | 36 | 0 | 36 | 7.5 | 12.4 | 10.2 | 1.3 |
| MAY | 36 | 1 | 35 | 3.9 | 8.8 | 6.5 | 1.2 |
| JUN | 36 | 0 | 36 | 1.4 | 5.4 | 3.4 | 1.0 |
| JUL | 36 | 0 | 36 | 0 | 5.3 | 2.9 | 1.1 |
| AUG | 36 | 0 | 36 | 3.4 | 9 | 5.3 | 1.3 |
| SEP | 36 | 0 | 36 | 6.3 | 11.2 | 8.7 | 1.2 |
| OCT | 36 | 0 | 36 | 8.6 | 14.1 | 11.5 | 1.1 |
| NOV | 36 | 0 | 36 | 11.5 | 15 | 12.9 | 0.9 |
| DEC | 36 | 2 | 34 | 12.4 | 17.1 | 14.6 | 1.1 |

Source: Authors

### 5.7 Observed impact of climate variability and change at Walter Sisulu National botanical garden

Climate variability and change are environmental issues in the Walter Sisulu botanical garden. Plants and animals are susceptible to climate change impacts, including the garden's waterfall. Factors such as droughts, temperature, frost, fires and floods affect the gardens' flora and fauna and cause damage to the gardens' infrastructure. It emerged from the interviews that high temperatures were observed to damage the growth and germination of plants in the garden, causing a reduction in plant productivity. One of the interviewees noted that plants are not flowering,  possibly due to hot cycles. Loss in succulent plants and orchids were reported to be most adversely affected by climate change. Frost was also highlighted to have a long-term effect on plants, thus changing the flowering pattern in the garden. The botanical garden needs to grow plants according to the weather conditions they adapt to.

Besides, drought was experienced as the biggest threat reducing the water flow at the waterfalls, which affects the garden's aesthetics. Field observations found that the alien species and gum trees around the waterfall might also be harmful as they may suck a lot of water. There is a need for a botanical garden in reducing or clearing the alien vegetation species. The interviews noted that drought reduces water quality in the botanical garden, which is needed for irrigation requirements. Therefore, it is an essential variable for the botanical garden to consider irrigation development.

Floods are frequently experienced in the Walter Sisulu Garden, damaging infrastructure and causing soil erosion. From interviews, it was deduced that floods washed away the garden's bridge across the river and rails by the waterfalls. The botanical garden upgraded roads to reduce erosion and bridges to decrease the danger of flushing away again. Fire was reported as another factor damaging the ambience and affecting the cycle and population of plants in the garden. One respondent noted during the interviews that the garden lost a collection of about 100 plants due to fire occurrence. Following this matter, there is a need to create fire breaks.

### 5.8 Climate change mitigation and adaptation in botanical gardens

This section investigates mitigation and adaptation strategies adopted by Walter Sisulu botanical garden and Pretoria botanical garden in Gauteng province. The section presents the study results obtained from field observations and interviews with SANBI officials, managers and guides. It also presents documentation obtained from secondary data analysis to address the impacts of climate change in botanical gardens. The section identifies the climate change factors responsible for the threat in botanical gardens and how the gardens addressed those climate change impacts.

#### 5.8.1 Climate change adaptation at botanical gardens

The tourism stakeholders were asked how extreme weather events have affected the gardens' activities, plants, and visitor numbers. As stated earlier, the stakeholders mentioned that plants in the botanical gardens are vulnerable to extreme weather events such as temperature and frost, which damages the growth of plants, affects the seedlings survival, and causes a decrease in plants. In addition, a reduction in succulent's plants, orchids, agapanthus and cycads due to temperatures was noted. One of the botanical gardens initiatives was planting different plant species to respond to the changes resulting from different seasons and their temperature shifts.

Drought was seen to play a significant role on plants in the gardens as plants could not flower properly due to dry seasons. Plants such as indigenous flora adapted to natural extremes. The botanical garden initiative was growing plants that could adapt to low water conditions. The impact of climate change on plants was also considered to affect visitor experience to the gardens. The botanical garden initiatives were to develop a climate change garden as part of awareness to raise climate change amongst visitors. From interviews, rainy days and cold weather negatively impacted outdoor activities such as picnics in the gardens. It was also noted that rainfall impacts visitor numbers and budget loss as visitors stay away. A recommendation was made to put warning signs around the garden informing visitors about extreme weather events and building an environment to climate change threats.

The stakeholders were asked how extreme weather events affected infrastructure in the gardens. It was discovered from the interviews that Walter Sisulu Garden has been affected by floods that happened between 2013 and 2015. Almost all Walter Sisulu garden interviewees knew and confirmed that the low-level bridge across the river and wooden rails by the waterfall were washed away by the floods. This report was also confirmed by a news report that advised the paving at the waterfalls, and the wooden post railways were washed away by the flooding waterfalls (Rood 2020).

Given the recurrence and impact of such floods, the botanical garden upgraded some of its infrastructures in an effort to reduce damage caused by such events in the future. There was also the upgrading of some low bridges in the garden to handle more water, among other things done. Concrete was applied to some sections of the river channel to reduce soil erosion amount occurring near the waterfalls and around the channel. In addition, on some portions of the stream (river) bank, gabions were added as a measure of erosion control.

The study also found that drought is a significant concern for botanical gardens. It was confirmed in the interviews that drought impacts most water consumption of the gardens and the general public. Interviewees mentioned that they struggle to irrigate plants in the gardens during droughts. Interviewees were asked how the gardens ensure water efficiency during droughts, to which respondents said they use borehole water for irrigation and river water to irrigate the plants.

Given the impacts of droughts, the gardens embarked on several initiatives to ensure they were water-smart. Part of the botanical gardens' strategy was to conduct environmental education on water-wise ways of gardening. This included a dedicated section of a water-wise model for replication by visitors. Such models also had water harvesting technology to promote water-saving and self-sustenance. From field observations, figure 5.9 shows the use of stormwater tanks for saving water to irrigate the plants in the garden.

*Figure 5.9: Water harvesting technology*

Source: Fieldwork 2021

The study also found that drought impacts plant species in the botanical gardens causing some trees to deteriorate. As per intellect attained during the interviews, the Walter Sisulu Garden was reported to experience loss in Celtis Africana trees due to a shortage of rainfall. Drought was also confirmed to affect soil fertility, causing some seeds not to germinate on time. The respondents were asked how drought affected the garden's waterfall. The Pretoria botanical garden waterfall was reported to have 0% ability to natural extremes since it is artificial. In contrast, the Walter Sisulu Garden waterfall was highly affected by climate change as it was mentioned that during droughts, the volume of water decreases.

The Pretoria botanical gardens conducted water-wise ponds and fountains to manage drought impacts in the gardens to conserve water and reduce water surface and high-pressure water movement from the waterfalls. The botanical gardens also conducted irrigation systems using sprinklers to water wisely and prevent heavy flow water droplets. The gardens adopted mulching to save water and reduce water run-off and soil erosion. Mulching is also said to minimise weed growth and store soil moisture.

The botanical gardens adopted some strategies, observed from field observations, to manage climate change impacts: the Working for Wetlands Programme, to restore and conserve their wetlands. SANBI partners with the Mondi Wetlands Project and Water Research Commission to improve wetland sustainability practices. As stated earlier, adopting water conservation programmes and investing in harvesting rainwater tanks to reduce water costs and store water for later use during drought times is highly advantageous. The gardens also developed Environmental Education Centres to raise awareness of biodiversity amongst their visitors and teach them about the effects of climate change on biodiversity in the garden and how they can deal with these impacts.

According to SANBI (2021), the national botanical gardens also developed biodiversity ecosystem-based agriculture projects focusing on restoring ecosystems by reducing the vulnerability of communities. The stewardship biodiversity approach focuses on managing resources and areas of biodiversity. Adaptation approaches in disaster risk management warn communities about extreme weather events (DEA 2019; SANBI 2021).

The information gained from the interviews showed that the botanical gardens also developed invasive species projects highlighting the sections mainly affected by invasive alien species and found methods to deal with this invasive species. It was also noted that SANBI was seen to be part of the farming climate change alliance to help farmers maintain food security and production against changes in temperature and rainfall.

The National botanical gardens are also part of the international climate change alliance strategy in response to botanical gardens to climate risks. According to the Royal Botanic Gardens Victoria (2016), the climate change alliance brings botanical gardens and organisations together to tackle the impacts of climate change and enable the adaptation of botanic landscapes. The landscape succession strategy extends to the working wet-lands adaptation projects, focusing on a shift in botanic gardens forecasted to climate and environmental conditions by 2090 while keeping the heritage character and quality of the garden and landscape as well as the diversity of species (Entwisle, Cole & Symes 2017:339).

### 5.8.2 Climate change mitigation at botanical gardens

One of the botanical garden initiatives to reduce GHG emissions was waste management and recycling. Botanical gardens initiated programmes to use less electricity to go green. As observed from field observations, the Pretoria botanical garden uses a generator to pump water from the waterfall, which recycles from the gardens reservoirs. Abdallah and El-Shennawy (2013:2) recommended that reducing energy use will reduce the amount of electricity needed to produce, reduce GHG emissions, and cut carbon footprint in the environment through energy efficiency measures. The botanical gardens also had initiatives in planting indigenous trees to cut carbon emissions. It is important to note that trees mitigate GHG emissions in the environment and assist in cooling to lower the temperatures in the summer and winter months (Derouin 2019).

Botanical gardens had initiatives to build greenhouses. It is important to note that building green can reduce the impact of climate change (Huynh 2021). There were initiatives introduced to make use of irrigation in order to save the leaks of water around the gardens, and reduce pollution and sewage. It is also important to note that saving water means conserving energy which inevitably reduces GHG pollution (Zhou *et al*. 2013:5). One of the interviewees pointed out that the botanical gardens try to stay as natural as possible to cut their carbon footprint. As confirmed in the interviews, SANBI is adapting to 70% of mitigation strategies but still needs more measures introduced to reduce their carbon footprint in the gardens. Even though botanical gardens have done more to mitigate the impacts of climate change, respondents mentioned that the gardens needed ongoing research to minimise climate change impacts.

### 5.8.3 Key challenges faced by botanical gardens in dealing with climate change

The study found that the botanical gardens still face ongoing challenges due to climate change. The interviews showed that irrigating plants in the botanical gardens is one of the key challenges during droughts. One of the interviewees stated, *“although there is an irrigation system, they don’t rely on it 100% because when there are rains, there is much difference in the garden, but if there are no rains, they see much change of the lawn”.* Temperature increase, impact on plants and mitigating of extreme weather events was also mentioned as a challenge for the gardens. Another respondent noted a challenge with unwanted plants that grow a lot during rainy seasons. One of the interviewees mentioned challenges in a reduction in water quality.

The study found that botanical gardens face challenges in financial resources to manage the impacts of climate change. As confirmed during the interview process, “Covid-19” was mentioned as playing a pivotal role in the botanical garden's budget. It was confirmed that botanical gardens struggle to cover costs such as equipment, infrastructure and facilities to manage climate change impacts, so they will never be self-sufficient.

During the interviews, it was mentioned that even though botanical gardens have some sponsors to manage climate change impacts, they still need more financial investment to maintain and cover the costs of damaged facilities and infrastructures in the garden and budget to upgrade the gardens.

Of note, one of the interviewees mentioned that if there was enough budget for the gardens, they would *“make a bigger concert stage for the events and make the structure that can cover the lawn”.* Another noted that they would wish to improve development on projects such as “managing programs of butterflies” that was currently not taking place due to lack of finance. It was also mentioned that they would install automatic irrigation systems if budget permitted. According to the National Botanical Garden Expansion Strategy 2019–2030, SANBI is a public entity under the Department of Environmental Affairs and Fisheries (DEA). It directly gets its financial resources from DEA to manage and maintain botanical gardens.

### 5.9 Summary

This chapter aimed to examine the evidence and impact of climate variability and change on botanical gardens and investigate mitigation and adaptation approaches employed by Gauteng botanical gardens. The study confirmed climate variability impacting on and causing changes in botanical gardens, with significant threats to the flora and fauna of the gardens. The study did not find any statistically significant differences in annual rainfall trends for both gardens. Over specific years, an increase in droughts was of concern, with substantial declines in average annual rainfall indicating frequent droughts. The increased frequency of droughts is a threat to flora and fauna in the gardens and threatens water usage and supply to the garden. The other concern noted was the occurrence of damaging floods, particularly in Walter Sisulu Botanical Gardens, which often caused infrastructure damage to the garden, erosion and bridge damages. Regarding temperature, the study found that there has been a substantial increase in average temperatures over some months, which could have phenological impacts on plants. There was also an increase in evapotranspiration and watering demands for the gardens. The gardens are responding to climate variability and change threats by putting in place various measures to mitigate and adapt to the impacts of climate change. However, some of these efforts are fraught with challenges.

# Chapter 6 : Conclusions and Recommendations

This study aimed at examining the evidence, impact, and response to climate variability and change by Walter Sisulu botanical garden and Pretoria botanical garden in Gauteng Province, South Africa. The study set out to respond to the following research questions: a) What are visitor perceptions on the impact of climate variability and change on botanical gardens? b) What is the evidence and impact of climate variability and change on botanical gardens in Gauteng? c) Which mitigation and adaptation strategies are being adopted by Gauteng botanical gardens to address climate change?

In order to respond to the research questions, the study adopted a pragmatism paradigm approach which utilized mixed methods and a case study research approach. Various research tools were used to collect data, such as online surveys, key informant interviews with SANBI officials, managers and guides, field observations, and secondary data analysis. Qualitative and quantitative data analysis techniques were utilized in the analysis of data using various tools, among other QuestionPro analytics, Mann Kendall Trend Analysis, content and thematic analysis to make meaning of the collected data.

## 6.1 Main findings of the study

Visitors to the botanical gardens believe that climate variability and change adversely affect botanical gardens. A significant number of visitors have had a bad experience in botanical gardens due to extreme weather events in the botanical gardens. The study found that visitors generally believed that climate change adversely affects visitor experience in the botanical gardens. As a consequence of extreme weather events, visitors have witnessed a decline in the aesthetics at the two botanical gardens, which formed part of this research. Visitors to botanical gardens believe that the biggest challenges to the gardens in Gauteng are droughts, fires, flooding, and intense rainfall activity.

Visitors believe that climate change adversely affects biodiversity in these two gardens. Regarding Walter Sisulu botanical gardens, there were heightened fears that drought episodes would adversely affect the water flow at the waterfall, which is one of the garden's main attractions. Climate change affects visitor behaviour and patterns to the botanical gardens significantly. The study found that visitors believe there is room for botanical gardens to adapt and mitigate climate change effectively. The findings of this study are consistent with results from other studies on tourism and climate change, which found that climate change has adverse effects on nature tourism enterprises.

Evidence from climatic data confirms observations from visitors who observed evidence of climate variability and change. There haven't been any statistically significant changes to rainfall patterns; nonetheless, climate records indicate high annual rainfall variability and a slight decline in average rainfall receipts for Pretoria and Walter Sisulu Botanical gardens. With regard to temperature, evidence points to a general increase in the temperature trend, with summer months witnessing the most significant temperatures increasing demand for ecosystem services from the botanical gardens.

Field observations and in-depth interviews with botanical gardens at Water Sisulu and Pretoria botanical showed that extreme weather events adversely impact visitor experience in botanical gardens, confirming the observations made by visitors and climatic data. Drought was identified as the biggest climatic threat from extreme weather events that disrupt botanical gardens. Drought was reported to disrupt vegetation and flower growth in botanical gardens, with significant consequences on the aesthetics of the gardens. Drought was also declared to have adverse impacts on water-based tourism features in the gardens.

Other extreme weather events such as floods, storms, and fires affected parts of Walter Sisulu botanical garden. These extreme weather events undermine the aesthetic integrity of botanical gardens, which can cause loss of recreational value. An increase and occurrence of extreme weather events affect visitor numbers to botanical gardens, resulting in a loss of revenue.

The study revealed evidence of climate variability and change in botanical gardens. The study recorded a non-statistically significant change in annual rainfall trends for both Pretoria botanical garden and Walter Sisulu botanical garden. In 2015, the Pretoria area recorded one of the worst drought periods, where only 319mm rainfall was received, which is less than half of the expected annual rainfall for the area. During the years 1999 and 2002, the lowest rainfall in Johannesburg was recorded. It emerged that droughts are becoming more frequent in both regions, affecting the gardens' flora and fauna and plant productivity. It was also observed that high temperatures associated with droughts significantly impact the gardens water resources, leading to increased demand for irrigation water.

Changes in monthly rainfall differ, as some months recorded a non-statistically significant change in rainfall, and others recorded a statistically significant change. Only August recorded a statistically significant change in average rainfall amount in the Johannesburg area. Pretoria recorded a statistically significant decrease in average rainfall from an average of about 150mm to 86mm.

The study found evidence of climate variability and change in monthly temperatures, with some months pointing to higher temperature increases. An increase in temperature was said to be a challenge in the gardens. It emerged that irrigation of plants in the gardens is a challenge, and mitigating extreme weather events was mentioned as a challenge for the gardens. It occurred that botanical gardens do not have adequate resources to manage climate change impacts.

The study revealed extreme weather could potentially threaten bird species in botanical gardens, with observed significant declines in them. A decline in biodiversity was reported as another concern in botanical gardens. Out of visitors activities in the botanical gardens, picnics were reported to be most affected by severe weather events. From the findings, some tourists denied that botanical gardens operations impact climate change, with others believing that botanical gardens, including visitors, had no impact on climate change. Climate change was also revealed to shape tourist travel decisions to botanical gardens.

Based on the findings, climate variability and change are evidenced to threaten the botanical gardens. It emerged that the frequency of extreme weather events such as droughts, floods, storms, fires and temperatures are observed to be problematic in the botanical gardens. These extreme weather events are observed to threaten the recreational value of botanical gardens, threatening flora and fauna and the gardens' most water resources. An increase in the frequency of extreme weather events affects visitor arrival to the botanical gardens. This reduces visitor numbers, resulting in the loss of income. Drought was observed to be the number one factor disrupting the gardens vegetation and the growth of plants, also increasing watering demands for the gardens. Based on the findings, tourists were in denial that botanical garden operations contribute to climate change, with others believing that botanical gardens and visitors don’t contribute to climate change. This is a concern for the botanical gardens as there is a need to raise more awareness amongst their visitors about climate change.

## 6.2 Recommendations and future research

It is recommended that botanical gardens management must improve research on tourism climate change to address and administer more adaptation strategies to reduce climate variability and change on tourism experiences in botanical gardens. Based on the findings, it is recommended that botanical gardens should contribute toward building a safer environment for visitors during times of rain to protect their wellbeing while in the gardens. It is also recommended that botanical garden management raise more education and awareness amongst visitors to understand the impacts climate change has on the gardens.

In addition, there is also a need for improved environmental sustainability to avoid a reduction in plant and animal species. The study recommends engagement and knowledge sharing between tourism businesses and climate scientists in the future management of extreme weather events. The study also suggests strengthening of building design in respect to mitigating the impact of floods. There is a need for long-term planning against climate change impacts in the gardens and further maintenance. There is also a need for water demand management and improved irrigation efficiency measures.

There is a need for drought monitoring and assessment, with improved communication involving other tourism businesses to reduce drought impacts. There is a need to develop further knowledge on water conservation efforts and implement long-term plans for the effects of future droughts. There is also a need for increased use of varying species of drought-resistant plants. Due to rising temperatures, there is a need for effective adaptation strategies to be developed to offset the impacts of temperature associated with a changing climate and implement climate change mitigation measures.

Regarding financial assistance to reduce climate change impacts, there is a need for climate change campaigns to support the botanical gardens and other tourism businesses and build mitigation and adaptation measures to address climate change. To assist the tourism sector in reducing climate change impacts, grants from local governments can be sourced. There is also a need to expand knowledge on mitigation and adaptation strategies to tackle climate change impacts within the context of the botanical garden.

With a change in rainfall variability and increased temperatures in the area affecting flora and fauna, considerable more research is needed to reduce and manage the impact of climate variability and change in protected areas. The study found that mitigating extreme weather events is a challenge in botanical gardens as well for the tourism sector; therefore, further research is needed to improve mitigation measures. If new mitigation and adaptation measures are not developed to overcome climate change impacts, the increased influence of climate variability and change is set to continue.

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## Appendices

### Appendix 1: Ethics approval letter

**Vaal University of Technology**

*Your world to a better future*

VUT

**Faculty of Human Sciences**
**Tel: +27(0)16 950 9000**
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Chairperson
Faculty Research Ethics Committee
Faculty of Human Sciences
Vaal University of Technology
13 October 2020

RESEARCHERS: **M Mosia**

PROJECT TITLE: An investigation into climate change impact and response of botanical gardens in Gauteng Province

QUALIFICATION: Masters of Management in Travel and Tourism Services Management

| Decision: Approval |
|---|

| Ethics Reference Number: FREC/HS/14/08/2020/6.1.7 |
|---|
| Student number: 219047898 |

Dear Ms Mosia:

Thank you for submitting the above-mentioned research proposal for research ethical consideration and approval. This application was considered through a full review process and subsequent expedited review of revisions. The committee accepts the responses to the reply letter of 28 August 2020 and full approval is therefore given.

*In all correspondence concerning this research project please use the Ethics Reference Number provided above.*

*Any revisions to the research documents, as shared in this letter, must reach the FREC by the 14 September 2020.*

*As the primary researcher you undertake:*

- *To follow only those procedures for which the approval has been given;*
- *To inform the committee should there be significant deviations from that which has been approved;*
- *To report any Adverse Events that might occur, within 14 days of the event (following the Guidelines procedure);*
- *To submit to the committee annual progress reports, where your reporting date is 1 June 2020; and*
- *To inform the committee on the completion of the project, when the findings have entered the public domain.*

Lastly, we would like to take this opportunity to you well with your research endeavours.

Sincerely,

Dr A de Klerk
(016 9506851)
Chairperson: Faculty Research Ethics Committee
Faculty of Human Sciences
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## Appendix 2: Interview guide

Title of the Study: An investigation into climate change impact and response of botanical gardens in Gauteng Province

Tourism stakeholders (SANBI chief director in the conservation department, SANBI director of marketing and commercialization, managers, guides or staff).

1. Please provide an overview of the climate in botanic gardens in Gauteng.
2. There have been talks of extreme weather events in the province. How have these affected your operations, activities and visitor numbers if it has?
3. Which extreme weather events would you say have a significant impact on botanical gardens in the province?
4. What are the specific challenges faced by each of the botanic gardens in the province?
5. How well prepared are you to deal with the threat of climate change in botanic gardens as an organization or as a botanic garden?
6. How does climate change affect the recreational function of the botanical gardens?
7. Would you say extreme weather events have an impact on tourist arrivals to botanical gardens?
8. How does climate change affect conservation efforts?
9. How has SANBI responded to the threat of climate change?
10. What is SANBI/ Botanic garden doing to raise climate change awareness amongst its visitors?
11. How has climate change affected the botanic garden infrastructure, plants and other important aspects of the botanic garden?
12. What has been the cost of extreme weather events on infrastructure?
13. Have there been damages attributed to extreme weather events?
14. How has the organization planned to deal with climate change impacts concerning climate change mitigation and adaptation?
15. How do you perceive the impacts of extreme weather events to be on visitor satisfaction?
16. What would you say are the key challenges of dealing with climate change in botanic gardens if any?
17. What opportunities are there in dealing with climate change within your organization?

18. How has extreme weather events shaped the life of botanic gardens?
19. What measures have you put in place to deal with water and energy in light of climate change impacts?
20. Is there any approach taken by the organisation about climate change in any form of response strategy? Mitigation and adaptation approach?
21. Are there any plans for the future about climate change?
22. Do you have strategy documents for the management of impacts of climate change?
23. Are there any positive returns from the implementation of the above strategies?
24. What are the further improvements required?
25. Do you have enough resources for managing the impacts of climate change? Human resources and financial resources?
26. How has recent droughts affected water supply and usage in the botanic gardens?
27. How has droughts affected the aesthetics of the park and the waterfalls?
28. How is the botanic garden ensuring water efficiency in the garden?

Thank you for your participation…

## Appendix 3: Online questionnaire survey

**<u>Link to the online survey</u>:**

**https://botanicgardernsclimatechangesurvey.questionpro.com**

| |
|---|
| Hello, you are invited to participate in our survey which seeks to examine the impact of climate change extreme weather events on botanical gardens in Gauteng Province. In this survey approximately 500 people will be asked to complete a survey that asks questions about National Botanical Gardens and Walter Sisulu Botanical Gardens it will take approximately less than 10 minutes to complete the questionnaire. Your participation in this study is completely voluntary. There are no foreseeable risks associated with this project. However, if you feel uncomfortable answering any questions, you can withdraw from the survey at any point. It is very important to learn your opinions. Your survey responses will be strictly confidential, and data from this research will be reported only in the aggregate. Your information will be coded and will remain confidential. If you have questions at any time about the survey or the procedures, you may contact Malehloa Mosia a Masters Tourism Management student at 078 012 6286 or by email at the email address malehloamosia55@gmail.com or the project supervisor Dr Kaitano Dube at kaitanod@vut.ac.za<br><br>Thank you in very much for your time and support. Please start with the survey now by clicking on the continue button below. |

I AGREE [ ]

Gender

Male [ ]

Female [ ]

Other [ ]

Prefer not to say [ ]

Level of education

| Matric | Diploma | Degree | Post degree | None |
|---|---|---|---|---|

Which of the two national Botanic gardens in Gauteng have you visited in the recent past?

Pretoria National Botanical Garden [ ]

Walter Sisulu National Botanical Garden [ ]

Both [ ]

How many times have you visited these parks in the past five to ten years?

Once [ ]

Twice [ ]

Three times [ ]

Four times [ ]

Five Times [ ]

More than five times [ ]

Which botanical garden did you visit frequently?

Walter Sisulu Botanical Gardens [ ]

Pretoria National Botanical Gardens [ ]

Which seasons would you say you often visit the botanical gardens?

Summer [ ]

Autumn [ ]

Winter [ ]

Spring [ ]

What are the top reasons for visiting a botanic garden?

To enjoy the flowers [ ]

To enjoy the shade when it's hot [ ]

Enjoy the waterfalls [ ]

Walking trails [ ]

Bird watching [ ]

For the tranquility [ ]

The geological splendor [ ]

To meet new people [ ]

Other please mention ______________________________

---

**SECTION A**

1. One of these activities you would want to undertake which ones has been undermined by extreme weather events?

Guided tours [ ]

Picnics [ ]

Bird watching [ ]

Walking trails [ ]

Waterfall viewing [ ]

Other [ ]

2. In your opinion would you say extreme weather events are a threat to botanical gardens?

| | | |
|---|---|---|
| Yes | No | Not sure |

3. Would you say activities in the botanical gardens contribute to global warming?

| | | |
|---|---|---|
| Yes | No | I am not sure |

4. Do you think extreme weather events have affected experiences in botanical gardens?

| | |
|---|---|
| Yes | No |

5. Which of the following has a significant impact on botanic gardens?

Droughts [ ]

Fires [ ]

Flooding [ ]

Extreme storms [ ]

Other [ ]

6. Which of these factors do you think are most disturbing to the aesthetics of botanic gardens in Gauteng province?

Droughts [ ]

Fires [ ]

Flooding [ ]

Extreme storms [ ]

Storms [ ]

Extreme winds [ ]

Hail storms [ ]

Other [ ]

Choose the most appropriate for the following statements

7. Climate change does not affect tourism activities and facilities

| Agree | Strongly agree | Neutral | Disagree | Strongly disagree |
|---|---|---|---|---|
| | | | | |

8. Climate change affects tourist's travel decisions to botanical gardens

| Agree | Strongly agree | Neutral | Disagree | Strongly disagree |
|---|---|---|---|---|
| | | | | |

9. Climate change affects the recreational function of botanical gardens

| Agree | Strongly agree | Neutral | Disagree | Strongly disagree |
|---|---|---|---|---|
| | | | | |

10. Climate change is responsible for the loss of biodiversity in the gardens

| Agree | Strongly agree | Neutral | Disagree | Strongly disagree |
|---|---|---|---|---|
| | | | | |

11. There is a decrease of plant and bird species in the gardens

| Agree | Strongly agree | Neutral | Disagree | Strongly disagree |
|---|---|---|---|---|
| | | | | |

12. Extreme weather events such as floods, droughts cause major threats to wildlife in the gardens

| Agree | Strongly agree | Neutral | Disagree | Strongly disagree |
|---|---|---|---|---|
| | | | | |

13. Climate change has an enormous impact on plant diversity in the gardens

| Agree | Strongly agree | Neutral | Disagree | Strongly disagree |
|---|---|---|---|---|
| | | | | |

14. Climate change impact tourist arrivals at the gardens

| Agree | Strongly agree | Neutral | Disagree | Strongly disagree |
|---|---|---|---|---|
| | | | | |

15. Climate and weather are important factors influencing destination image, tourism resources, travel season, and tourist's experience to botanical gardens

| Agree | Strongly agree | Neutral | Disagree | Strongly disagree |
|---|---|---|---|---|
| | | | | |

16. Increase in extremely high temperatures and intense precipitation impact on plant and bird species in the gardens

| Agree | Strongly agree | Neutral | Disagree | Strongly disagree |
|---|---|---|---|---|
| | | | | |

17. What do you think botanical gardens need to do to reduce the impact of climate change in the gardens?

______________________________________________________________________

______________________________________________________________________

Thank you for your participation.

## Appendix 4: Field observations guide

Title of the study: An investigation into climate change impact and response of botanical gardens in Gauteng Province

Direct observations were conducted to extract evidence of the impacts of climate change in Gauteng botanical gardens. The process involved taking pictures and walking across the garden. Also, doing follow up on the recording.

Impacts were observed at the gardens as a result of climate change on the following:

1. Damage of environment e.g. trees, due to extreme weather events
2. Destroyed nesting places of birds due to extreme weather events
3. Plants species affected by climate change and never grow again
4. Eroded areas as a result of extreme weather events or because of people walking every day
5. Broken bridges as a result of extreme weather events
6. Picnic sites destroyed due to extreme weather events such as floods
7. Destroyed hiking trails as a result of extreme weather events
8. Vegetation types destroyed by climate change

All these observations were observed and got how the gardens responded to this impacts.

**Appendix 5: ICE Certificate**

The 5th International Conference on Events

Making New Waves in Africa:
Exploring New Frontiers in Festivals and Events

Cape Town, South Africa
16-18 November 2021

## CERTIFICATE OF PARTICIPATION

Climate change and conservation challenges at botanical gardens in Gauteng

*Malehloa Mosia, Kaitano Dube and Veronica Labuschagne*

On behalf of the organising committee,

Professor Brendon Knott
*ICE2021 Conference Chair*

ICE2021