University of the Witwatersrand

Faculty of Science

School of Geography, Archaeology and Environmental Studies

Exploring Climate Change Vulnerability of the South African Tourism Sector – a high resolution application of the Climate Change Vulnerability Index for Tourism (CVIT)

A dissertation submitted to the Faculty of Science in fulfilment of the requirements for the degree Master of Science

Tamzyn Smith

Student Number 1349312

Johannesburg, December 2022

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

DECLARATION

I, Tamzyn Smith (Student Number 1349312), declare that this dissertation is entirely my own, unaided work - except where otherwise acknowledged. It is being submitted to the University of the Witwatersrand, Johannesburg, for the degree Master of Science by research and has not been previously submitted for any degree or examination at this or any other university.

Tamzyn Smith

06 December 2022

ABSTRACT

The impacts of climate change are already being experienced and are posited to intensify globally over the coming decades. Different sectors are likely to be impacted to varying degrees by the effects of climate change, with the tourism sector having been flagged as a particularly vulnerable sector. The Climate Change Vulnerability Index for Tourism (CVIT) is a composite index that uses 27 multidisciplinary indicators to quantify how sensitive a country's tourism sector is to the impacts of climate change. The CVIT is composed of six weighted components which quantify Tourism Assets, Tourism Operating Costs, Tourism Demand, Host Country Deterrents, Tourism Sector Adaptive Capacity and Host Country Adaptive Capacity. To date, the CVIT has only been applied at a global scale, compromising on spatial resolution, and blurring heterogeneity in vulnerability at a subnational scale. The global CVIT assessment found the South African tourism sector to be moderately vulnerable to climate change, scoring between 77-88 on a scale of 27 to 135. South Africa represents a promising first known local scale application of the CVIT due to the marked heterogeneity of its tourism sector, climatic conditions, socioeconomic context and biogeographical landscape. To account for these local scale differences, this project downscales the CVIT to quantify differential climate change vulnerability for 18 locations distributed across South Africa. Indicator data source options for local application of the CVIT were scoped and refined based on data availability, quality, and relevance to local contexts. Standard, equal indicator weighting (W1) yielded CVIT scores ranging between 92.37 and 67.31, confirming the presence of local scale heterogeneity in vulnerability. Two alternative weighting approaches were assessed: adaptive capacity focused weighting (W2) which yielded scores not significantly different to W1, and a novel tourism asset focused weighting (W3) which yielded scores significantly different to W1. The final CVIT scores allowed for identification of locations most vulnerable to climate change, with Gqeberha and Cape Town found to be the locations with tourism sectors most vulnerable to climate change using all three weighting sets. Different drivers were found to be contributing most to vulnerability at different locations. Although data challenges were encountered, the applicability and suitability of the CVIT for local scale application is confirmed. The findings of this research are of importance because they can feed directly into the climate change mitigation and adaptation strategies of the South African tourism sector.

Key Words

Climate Change, CVIT, Tourism, South Africa, Vulnerability

FOREWORD & ACKNOWLEDGEMENTS

"Unless someone like you cares a whole awful lot, nothing is going to get better. It's not."

– Dr Seuss, The Lorax

This dissertation represents the intersection of two of my greatest passions: tourism and climate change. Studying applied climate change and biometeorology can at times be a disheartening pursuit, with doom and gloom encompassing much of what you learn. There is, however, so much hope to be had because we are no longer at the point where information is the biggest obstacle to change, the hurdle now is what we do with the information we have. There are viable adaptation and mitigation paths available and there is a growing consensus that what we currently have is worth protecting and preserving for future generations.

Another major reason for optimism is the great minds who have dedicated their lives to understanding climate and climate change issues, and I have had the privilege of being supervised by one of the best of them: Professor Jennifer Fitchett. Jen, I cannot thank you enough for the invaluable contributions you have made to this work, guiding me academically, while supporting and encouraging me along the way. Your efforts to grow your students as both scholars and people is commendable and I feel incredibly lucky to have had you as a supervisor for both my honours and master's research.

Thank you to my family, friends and partner, Tristan, who bore the brunt of my stress and were so understanding when I needed to miss events or work long nights. Thank you for motivating me, feeding me and being such wonderful soundboards for my thoughts.

Finally, The University of the Witwatersrand Postgraduate Merit Award (PMA) is acknowledged for funding this research.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

AR5 – 5th IPCC Assessment Report

AR6 – 6th IPCC Assessment Report

BBBEE – Broad-Based Black Economic Empowerment

CCI – Camping Climate Index

CH_4 – Methane

CID – Climate Impact Driver

CIT – Climate Index for Tourism

CO_2 – Carbon dioxide

CORDEX–Africa – Coordinated Regional Climate Downscaling for Africa

COVID–19 – Coronavirus Disease 2019

CRED – Climate and Regional Economics of Development

CTCI – Coastal Tourism Climate Index

CVIT – Climate Change Vulnerability Index for Tourism

DOT – Department of Tourism

DWS – Department of Water and Sanitation

ENSO – El Niño Southern Oscillation

EPI – Environmental Performance Indicator

ESAF – East Southern Africa

FAR – 1st IPCC Assessment Report

GDP – Gross Domestic Product

HGH – Green House Gas

HCAC – Host Country Adaptive Capacity

HCD – Host Country Deterrents

HCI – Holiday Climate Index

HCI:Beach – Holiday Climate Index for beach contexts

HCI:Urban – Holiday Climate Index for urban contexts

HDI – Human Development Index

IDC – Industrial Development Corporation

IDW – Inverse Distance Weighted

IPCC – Intergovernmental Panel on Climate Change

ISB – International Society of Biometeorology

MEC – Member of the Executive Committee

N_2O – Nitrous oxide

NDC – Nationally Determined Contribution

PET – Physiological Equivalent Temperature

POPIA – Protection of Personal Information Act

RCI – Relative Climate Index

SADC – Southern African Development Community

SANBI – South African National Biodiversity Institute

SAWS – South African Weather Service

SDGs – Sustainable Development Goals

SIDS – Small Island Developing States

SPM – Summary for Policymakers

SREX – Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation

TA – Tourism Assets

TCI – Tourism Climate Index

TD – Tourism Demand

TEIP – Tourism Environmental Implementation Plan

TIP – Tourism Incentive Programme

TOC – Tourism Operating Costs

TSAC – Tourism Sector Adaptive Capacity

UNEP – United Nations Environment Programme

UNESCO – United Nations Educational, Scientific and Cultural Organization

UNFCCC – United Nations Framework Convention on Climate Change

UNTWO – United Nations World Tourism Organisation

UTCI – Universal Thermal Climate Index

W1 – Standard, Equal Indicator Weighting

W2 – Adaptive Capacity Focused Weighting

W3 – Tourism Asset Focused Weighting

WEF – World Economic Forum

WG1 – Working Group 1 of the 6th IPCC Assessment Report

WMO – World Meteorological Organisation

WSAF – West Southern Africa

CHAPTER 1 – INTRODUCTION

1.1. Background

Tourism is an important sector for combatting poverty, unemployment and inequality through the enabling of development and economic growth (Hambira & Saarinen, 2015; Dube & Nhamo, 2019). In South Africa, tourism was an economically important and rapidly growing sector (Hoogendoorn & Fitchett, 2018a) – however, in 2020, regulations that were put in place to curb the spread of the Coronavirus disease 2019 (COVID-19), including limitations on the gathering and movement of people, interrupted normal tourism operations and resulted in detrimental impacts for the entire sector (Rogerson & Rogerson, 2020). The COVID-19 pandemic triggered a national state of disaster to be declared in South Africa which limited domestic tourism (Rogerson & Rogerson, 2020) and resulted in a 71% decrease in international tourist arrivals in 2020 (StatsSA, 2020). The United Nations World Tourism Organisation (UNWTO) described 2020 as the worst year on record for global tourism to date, with current projections indicating between two and a half to four years for the sector to recover to pre-pandemic levels (CCSA, 2021). Despite positive outlooks that the sector is beginning to recover (StatsSA, 2022), the impact of the COVID-19 pandemic has highlighted the sensitivity of the tourism sector to disturbances from external factors (Rogerson & Baum, 2020; Duro et al., 2021).

There is scientific consensus that anthropogenically driven climate change is occurring, and that even if we were to stop the emission of all greenhouse gases immediately, the impacts of climate change have already begun to manifest and will likely intensify, continuing to be felt for many years to come (IPCC, 2021; World Bank Group, 2021). Recurring themes identified by Hoogendoorn and Fitchett (2018a) highlight projected impacts for Africa to include temperature increases, precipitation pattern changes, an increase in frequency and severity of extreme weather events and sea-level rise. There is academic consensus that climate change will impact the global tourism sector (Odimegwu & Francis, 2018; Scott et al., 2019) – with attempts to dispute or downplay the severity thereof being strongly disputed (Hall et al., 2014). These impacts will be driven in part by the influence that weather and climate variables have on the spatiotemporal patterns of tourist demand including destination choice, spending behaviour, and trip satisfaction (Gössling et al., 2009; Dubois et al., 2016). Furthermore, natural capital elements such as biodiversity, hydrological features and snow cover which underpin the attractiveness of many tourism locations, and the activities that tourists can partake in when at the destination, may be detrimentally altered by climate change (Gössling et al., 2009; Cevik & Ghazanchyan, 2021).

Within the climate change-tourism nexus there will be winners and losers – those who benefit from and those who suffer from the impacts of climatic change – with poorer, developing countries where tourism is a large contributor to Gross Domestic Product (GDP) generally posited to suffer most notably (Ehmer & Heymann, 2008; Scott et al., 2019). The Tourism Climate Index (TCI) developed by Mieczkowski (1985) considers climatic variables such as thermal comfort, wind, rainfall, and sunshine hours to determine climatic suitability of a location for tourism. This methodology has been used beyond its initial purpose to demonstrate that the climatic suitability and attractiveness of tourist locations is projected to change both spatially and temporally in the face of climate change (Amelung & Viner, 2007). Examples of these expected changes include a poleward geographical shift in ideal destination locations and seasonal changes in tourist flows (Amelung et al., 2007). Examining the TCI for South Africa, Fitchett et al. (2017) found South Africa's climate suitability for tourism at a city scale to be between "excellent" and "ideal" but cautioned that uncertainties regarding precipitation and temperature increases under future climate change scenarios may have complex and substantial impacts.

The Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report defines vulnerability as the degree to which a system is susceptible to and unable to cope with the adverse impacts of climate change (IPCC, 2001). Although multiple definitions for vulnerability exist, the IPCC definition will be used to align with the definition used by Scott et al. (2019) and the frequent use of this definition by policymakers globally and nationally (Republic of South Africa, 2021b). Tourism has been classified as more vulnerable to the impacts of climate change than the broader economy (Dorgu et al., 2019) and Africa is ranked as the continent most vulnerable to climate change impacts (Stanton et al., 2012). Vulnerability is a complex and dynamic property dependent on multiple variables (Scott et al., 2019) and thus the TCI which only considers climatic variables is not a sufficient tool to model multi-faceted climate change vulnerability. The newly developed Climate Change Vulnerability Index for Tourism (CVIT), however, is an approach that uses a broad range of indicators which quantify climate impacts, environmental change, socioeconomic impacts together with mitigation and adaptation variables in a climate change context to determine the vulnerability of tourism sectors at country scale globally (Scott et al., 2019).

1.2. Rationale

The CVIT has been applied at a low spatial resolution to produce differential climate change vulnerability scores for the tourism sectors of 181 countries and found South Africa to be moderately vulnerable to climate change with a score of 77–88 on a scale ranging from a minimum of 27 to a maximum of 135 (Scott et al., 2019). South Africa, however, is a highly heterogenous country in multiple dimensions including climatologically, socially, biologically, and geographically. This can, for example, be demonstrated by distinct summer, winter, and year-round rainfall zones (Roffe et al, 2019), one of the highest measures of inequality, the Gini coefficient, globally (Mtapuri & Tinarwo, 2021) and by the large variety of biomes and landscape features distributed across the country (Finch & Meadow, 2018). Whilst understanding the CVIT results presented by Scott et al. (2019) on a national scale is beneficial for quantifying relative climate change vulnerability in comparison to other countries, climate change impacts will likely be experienced differently at sub-regional or local scales (Mather et al., 2005; IPCC, 2021), a phenomenon acknowledged by Scott et al. (2019) when introducing the CVIT. The use of coarse grain, country scale data when quantifying climate change vulnerability for tourism therefore does not allow for a nuanced understanding of vulnerability at a scale appropriate for implementing effective and appropriate climate change responses including adaptation and mitigation plans.

The South African tourism sector is highly dependent on outdoor and nature-based tourism (du Plessis et al., 2015; Fitchett et al., 2017), therefore understanding the different ways in which different locations within the country will be impacted by and are vulnerable to climate change is essential. Examples of these notable differences include coastal cities potentially being more vulnerable to climate change due to the impacts of sea-level rise (Hoogendoorn et al., 2016), whilst destinations in savanna regions where nature-based tourism is prevalent may be more vulnerable due to climate change driven biodiversity shifts (Smith & Fitchett, 2020). Ultimately, understanding the key drivers of vulnerability along with identifying tourism locations most vulnerable to climate change allows for an opportunity for governance institutions to allocate limited financial resources effectively and for tourism sector stakeholders to reduce vulnerability and increase resilience to climate change impacts (Scott et al., 2019). This study serves as the first known high-resolution application of the CVIT, addressing the urgent need to understand climate change vulnerability of the tourism sector at a scale appropriate to mitigate harms and risks in South Africa (Fussel & Klein, 2006; Hoogendoorn & Fitchett, 2018a; Pandy & Rogerson, 2018).

Previous studies focused on South Africa using climate tourism indices have shown the value of applying global scale climate tourism indices at higher spatial resolutions to better understand local-scale drivers of findings, to allow for comparison of results between different locations within a heterogenous country and to identify spatial patterns within findings (Fitchett et al., 2017; Mushawemhuka et al., 2020; Noome & Fitchett, 2021). The need to explore the CVIT at a high resolution is further motivated by observations of climate change impact heterogeneity in an African context (Serdeczny et al., 2017; IPCC, 2021), where vulnerability levels are potentially higher than other regions in the world due to low community resilience, poor governance capabilities and high exposure to impact (Busby et al., 2014). This need is compounded by a general lack of information and uncertainty around impacts of climate change on tourism hindering progress towards suitable climate change adaptation in Southern Africa (Hambira & Saarinen, 2015). Finally, the COVID-19 pandemic has damaged and disrupted the tourism sector; and despite mechanisms being put in place to try help the sector recover (Rogerson & Rogerson, 2020), the financial burdens of the pandemic may limit the adaptive capacity of the tourism sector for climate change impacts as the financial means to implement infrastructural and other responses may be limited. This study addresses the concerns of Rogerson and Baum (2020) who highlight the need for the African research agenda following the COVID-19 pandemic to focus on climate change and contributes to a notable knowledge gap in tourism-climate research in the global South (Fang et al., 2018; Fitchett et al., 2017).

1.3. Study Aims

The aim of this study is to downscale and calculate the CVIT at a high spatial resolution for South Africa. This will be achieved through accomplishing the following objectives:

i. To scope, gather and standardise appropriate local scale data sources for each of the 27 indicators used in calculating the CVIT for 18 tourism locations distributed across the nine provinces of South Africa;
ii. To calculate CVIT scores for each of the 18 South African study locations distributed across the nine provinces of South Africa using:
    a. the standard (equal) weighting approach and;
    b. the adaptive capacity weighted approach
iii. To identify tourism climate change vulnerability hotspots and examine spatial variations in CVIT scores and vulnerability drivers across South Africa.

1.4. Structure

This dissertation is presented across eight chapters. **Chapter 1: Introduction** provides background and context to the study, along with presenting the motivating rationale and study objectives. **Chapter 2: Literature Review** begins by providing an overview of climate change drivers, projections and impacts from global to local scales. Thereafter, extant literature relating to the relationship between climate, climate change and tourism is synthesised and examined from the perspective of both tourists and destinations. Finally, this chapter explores the concept of sustainable tourism and reviews global and local scale policies addressing climate change and tourism. **Chapter 3: Study Region** introduces the study country, South Africa, by exploring the climate, geography, ecology and socioeconomic demographics of the nation. Thereafter, the South African tourism sector is discussed, including the history of tourism in the country and key tourism categories prevalent in the sector. Finally, this chapter identifies and justifies final selection of the 18 study locations examined in this study. **Chapter 4: Methodology** presents the development and composition of the CVIT, including a detailed exploration into data normalisation and index calculation techniques. **Chapter 5: Data Selection and Normalisation** begins by outlining the process used to refine and select data sources, including data checks and gateways passed to ensure validity of calculations. A detailed description of indicator data source options and final selection for each of the 27 indicators is then presented including normalisation techniques applied to datasets. **Chapter 6: Results** presents the findings of this study, beginning with a detailed review of indicator scores and trends per indicator by CVIT component. Thereafter, final CVIT scores calculated using three different weighting sets is presented. **Chapter 7: Discussion** reflects upon the process used to downscale the CVIT including limitations, concerns and successes then explores the implication of CVIT results. The final section, **Chapter 8: Conclusion** provides a synthesis and overview of key findings from this study, including a reflection on the achievement of study aims and recommendations for future research. The **Appendix** contains raw and normalised data including ancillary metrics used to calculate final scores for each indicator and is structured by the six CVIT components.

CHAPTER 2 – LITERATURE REVIEW

2.1. Introduction

Key themes and concepts within existing literature are explored in this chapter to contextualise and situate this study. This chapter begins with an overview of climate change including anthropogenic climate change drivers, projections and impacts, and examines the concept of vulnerability – the measure quantified using the CVIT. Once this foundation has been established, the tourism research field is then considered with an emphasis on the relationship between tourism with climate and climate change through the lens of the tourist and the destination. This includes development of the climate-tourism discipline, emerging themes and trends, along with common methodologies employed with a focus on index-based approaches. Thereafter, the intersection of tourism and climate change in policy is examined from global to local scales with consideration of policy development and implications. Finally, this chapter concludes by clarifying the knowledge gap to which the study contributes.

2.2. Climate Change

2.2.1. Overview

Earths climatic patterns are dynamic and vary greatly from place to place and across timescales from within a day, to between seasons and even across longer timescales of centuries and millennia (Perkins et al., 2018). The earth has been through multiple heating and cooling cycles across different spatiotemporal scales, including ice ages and even centuries of rain. Given that changes to weather and climate are not unexpected (Preston-

Whyte & Watson; Weir, 2017), the recent focus on climate change requires interrogation, with two distinguishing features making contemporary climate change interesting and different to typical climatic patterns. Firstly, the rate of modern climatic change is unprecedented as never before have changes been so rapid, extreme and unpredictable (Archer et al., 2010; IPCC, 2021). Secondly, whilst historical climate change has been driven by natural causes, there is strong evidence that indicates human behaviour is “unequivocally” the main driver of currently observed climatic change (IPCC, 2021). This has resulted in the phrase “anthropogenic climatic change” being coined in both academic and public spheres to describe the phenomenon (IPCC, 2021).

The most notable driver of anthropogenic climate change is the emission of greenhouse gases (GHGs; SAWS, 2017) which are biproducts from the burning of fossil fuels and other industrial processes (Abrams et al., 2018). The three GHGs which contribute most to climate change through amplification of the greenhouse effect, which in turn drives the global warming phenomenon, are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) and the concentration of these gases in the atmosphere has been steadily rising since 1750 (IPCC, 2021). South Africa is one of the largest contributors to Africa’s cumulative greenhouse gas emissions, accounting for nearly four times as much carbon emissions as any other African country which can be attributed to high coal dependence and outputs of activities associated with mining and manufacturing industries (Amusan & Olutola, 2017; Abrahams et al., 2018). In comparison to global carbon emissions South Africa, however, is not a major carbon emitter, with greater emission levels typically originating from developed countries in the northern Hemisphere (Lenzen et al., 2018; Moran et al., 2018). The concept of climate justice and a just transition has emerged as a result of the vast differences between emission patterns – both current and historical – by different nations (Shackleton et al., 2015).

One of the most prominent changes being observed as a result of climate change is in the increase in mean temperature, with global surface temperatures having risen by between 0.8^{o}C and 1.3^{o}C in comparison to pre-industrial levels (Weber et al., 2018). This increase in temperature is important to note as the magnitude of other future climate change impacts will be dependent on future warming levels, with higher warming scenarios suggested to have more detrimental impacts (IPCC, 2021; The World Bank Group, 2021). Early studies flagged +2^{o}C as the threshold beyond which impacts to human lives and economies would be substantial (Weber et al., 2018), however more recent findings suggest +1.5^{o}C to be the warming limit to prevent severe climate change consequences (Warren et al., 2018). These recent conclusions are important as the necessity for use of up-to-date climate change information and models when assessing the impacts of climate change has previously been highlighted (Hewer & Gough, 2018).

Climate changes beyond temperature increases have already begun to be experienced and observed globally including changes to precipitations patterns, frequency and volume (Konapala et al., 2020). There has been a poleward shift in mid-latitude cyclone storm tracks since the 1980s (Harvey et al., 2012). Changes to ocean variables that have been strongly attributed to human influence include CO_2 emission linked surface open ocean acidification, and near-surface ocean salinity pattern changes (Zika et al., 2018). Cumulative sea-level rise of 0.2m was observed between 1901 and 2018, with the rate of rise increasing, very likely as a result of human influence, from 1.3 mm yr^{-1} prior to 1971, to 1.9 mm yr^{-1} between 1971 and 2006, and further increasing to 3.7 mm yr^{-1} between 2006 and 2018 (IPCC, 2021; Allison et al., 2022).

GHGs are not the only variable driving and determining observed climatic changes. The warming effects of GHGs may, for example, be somewhat concealed by the cooling effects of other anthropogenic activities such as aerosol emissions which reduce the net human-induced temperature increase observed (IPCC, 2021). Furthermore, climate change impacts exist within the context of internal climate variability – natural fluctuations in earths climatic processes which usually contribute proportionally less than anthropogenic factors (Gu et al., 2019), however may nonetheless amplify or attenuate observed climatic changes (IPCC, 2021). For example, internal climate variability likely contributed to mean global surface temperatures by between -0.2°C and +0.2°C in 2019 (IPCC, 2021). The El Niño Southern Oscillation (ENSO) phenomenon is an example of internal climate variability that may compound climate change impacts for Southern Africa due to its strong influence on precipitation patterns (Davis-Reddy & Vincent, 2017; IPCC, 2021).

2.2.2. Climate Change Projections

Having understood changes that have already begun to be observed to Earth's climate systems and which have been largely in line with early projections (IPCC, 2021), projected changes under future warming scenarios can now be explored. Generally, projections include continued overall increases in atmosphere, ocean, and land surface temperatures and shifts in precipitation volumes, seasonality, and spatial patterns (Midgley et al., 2011). Climatic Impact Drivers (CIDs) refer to physical climate system conditions that affect an element of society or ecosystem and are also expected to change globally, following widely observed changes to the Earth's climate system components including the atmosphere, hydrosphere, cryosphere, and biosphere (IPCC, 2021). This includes extreme weather events such as tropical cyclones, heatwaves, heavy precipitation and droughts which are projected to increase in severity, frequency, and spatial extent over coming years (SAWS, 2017; Weber et al., 2018). A decrease in permafrost, glaciers, snow, ice sheets, sea ice and lake ice are also expected across the globe (Archer et al., 2018; IPCC, 2021). The influence of human activity is additionally increasing the probability of compound extreme events occurring – circumstances in which more than one extreme weather event such as a heatwave and drought may occur concurrently (Zscheishler et al., 2018). The possibility of further outcomes of climate change which are deemed "low likelihood", such as abrupt ocean circulation changes or warming substantially larger than the assessed "very likely" range, could not be ruled out by IPCC Working Group 1 (WG1; IPCC, 2021).

Climate change impacts will not manifest homogenously across the world and will instead impact different places in different manners (Archer et al., 2010), and differ across time scales with interannual and intra-annual variation expected (Davis-Reddy & Vincent, 2017). For Africa, notable temperature increases are almost certain and confidence in projections for this trend increases for more arid regions (Gemeda & Sima, 2015; Davis-Reddy & Vincent, 2017). Precipitation changes are also very likely but early projections associated less certainty with this variable than temperature changes which tend to be more easily detected and projected (Agnew & Viner, 2001; Deser et al., 2012). Uncertainty in climate change projections and modelling has been previously noted with systems being influenced by other variables – for example middle and high latitude conditions influenced by internal atmospheric variability and circulation and the tropics being impacted by ocean-atmosphere interactions (Deser et al., 2012), however the certainty has improved over time (IPCC, 2021), and these projections serve as a stark warning to humanity (IPCC, 2022).

Given the regional difference in impacts that are likely to be experienced under different potential warming scenarios, the IPCC has published an Interactive Atlas which allows users to manipulate variables and timeframes to dynamically explore the impact of climate change on specific regions (Gutiérrez et al., 2021). When examining regional scale climate change impacts, the IPCC 6th Assessment Report (AR6) WGI utilises reference regions (IPCC, 2021). South Africa is split across two of these: WSAF (West Southern Africa) and ESAF (East Southern Africa)(IPCC, 2021). An increase in hot extremes such as heatwaves has been observed in both regions with high confidence of human contribution to the changes (Weber et al., 2018; van der Walt & Fitchett, 2020). WSAF and ESAF both have observed and projected decreases in mean precipitation and increases in aridity, agricultural and ecological droughts (Archer et al., 2010; IPCC, 2021) which is of major concern given that Southern Africa has long since been flagged as sensitive to climate change impacts based on existing water scarcity concerns (Magadza, 1994; Kusangaya et al., 2014). Projected increases for ESAF include increases in tropical cyclone severity (Knutson et al., 2010), whilst notable projected increased for WSAF include increases in dryness from +1.5^{o}C warming and beyond (IPCC, 2021). These findings are in line with early climate change projections for South Africa which noted impacts including sea-level rise and increases in average and extreme temperatures (Steyn & Spencer, 2012). The regional segments employed by AR6 are useful scales for the purposes of global climate change analysis and do account somewhat for summer and winter season rainfall pattern heterogeneity observed in South Africa (IPCC, 2021). Given the marked internal heterogeneity of South Africa, however, the need for downscaling of climate change findings to more local scales, ideally the level at which environmental management occurs, has been noted (Kusangaya et al., 2014; Davis-Reddy & Vincent, 2017). Coordinated Regional Climate Downscaling for Africa (CORDEX-Africa) has been proposed and often utilised as a framework to achieve localisation of projections (Weber et al., 2018).

Unless major action to reduce CO_2 and other GHG emissions occurs in coming decades, global surface temperatures will exceed safe warming levels in the 21st century, and should insufficient evasive action be taken the current worst-case scenario of more than 4^{o}C increase in temperatures will occur and bring with it major detrimental consequences (IPCC, 2022). These includes extreme heatwaves (1 in 50-year events) occurring 39.2 times more frequently and being 5.3^{o}C hotter, whilst heavy precipitation events (1 in 10-year events) will occur 2.7 times more often and be 30.2% wetter (IPCC, 2021). Even if all emissions were to stop immediately, some climate change impacts are unfortunately irreversible – specifically those relating to ocean condition changes such as stratification, acidification, deoxygenation, ice sheet loss and global sea level rise (Zika et al., 2018; IPCC, 2021; Allison et al., 2022).

2.2.3. Climate Change Impacts

The need to understand potential impacts under multiple climate scenarios from possible to likely has been highlighted (Davis-Reddy & Vincent, 2017; Debortoli et al. 2019) because the effects of climate change extend beyond climatic system components, impacting the structure and functioning of ecosystems and society directly and indirectly at different spatiotemporal scales (Davis-Reddy & Vincent, 2017; IPCC, 2022). In southern Africa the most frequent climate-related events impacting society are floods, whilst droughts tend to impact the most amount of people and are responsible for the largest financial implications and result in the greatest number of deaths (Davis-Reddy & Vincent, 2017). Tropical cyclones in Southern Africa are responsible for injuring and displacing the most people (Archer et al., 2018). Whilst these and other climate-change related projected physical changes such as sea level rise and increased fire risk pose obvious threats to human life and infrastructure, other notable physical impacts of climate change which impact society indirectly are linked to ecology (Proenca et al., 2017). This includes a posited reduction in biodiversity because the adaptive capacity of ecosystems is often slower than the current rate of climate change (Pecl et al., 2017), thus physical heat tolerances and habitat suitability changes are driving changes in organism assemblages (Magadza, 1994; Trisos et al., 2020). This is important in a South African context as some South African ecosystems and biomes such as fynbos have been observed to be particularly sensitive to climate changes and thus are very vulnerable (Dzikiti et al., 2014). Other physical systems may be impacted by climatic changes including water cycle dependent components and systems such as river and waterfall flow regimes (Schlosser et al., 2014; Dube & Nhamo, 2019).

Despite early studies being potentially optimistic about the outcomes of climate change based on our ability to accurately model the rates of change and impacts (Preston-Whyte & Watson, 2005), climate change impacts on society are projected to be vast and negative (Serdeczny et al., 2017; IPCC, 2022). Weather related natural disasters had already resulted in cumulative impacts of US $10 billion for Southern African Development Community (SADC) at the time of publishing the climate risk and vulnerability handbook for Southern Africa, and South Africa had the most recorded climate events and largest relative cost in southern Africa since 1980

(Davis-Reddy & Vincent, 2017). Climate change is projected to affect human health (IPCC, 2022). Examples of health impacts can include detrimental changes to water and air quality, and changes in distribution of vectors of disease, such as flies or mosquitoes, with the normal distribution range of these organisms expanding both seasonally and spatially under climate change (Tonnang et al., 2010; Kim et al., 2019). Changes to precipitation patterns such as drought or floods have links to the Sustainable Development Goals (SDGs) including health and sanitation (Magadza, 1994; Dube et al., 2020). Droughts, other precipitation pattern changes and temperature shifts may furthermore impact society by affecting agriculture, and in turn food security, by changing growing seasons (Connolly-Boutin & Smith, 2015; Abrahams et al., 2018), as well as crop yield quality and quantity as was already observed by Masipa (2017) following the 2016 drought experienced in South Africa. This threat is concerning as Sub-Saharan countries are deemed high-risk relating to food security based on availability and affordability of food (Masipa, 2017). Secondary impacts of agricultural changes include loss of livelihoods (Magadza, 1994; Davis-Reddy & Vincent, 2017). Some sectors have received notable academic and scientific focus for climate change impacts; however, a low proportion of climate change research outputs consider tourism directly (Dorgu et al., 2019). In 2013, for example, only 0.5% of outputs made direct consideration of tourism (Pang et al. 2013). Weber et al. (2018) examined the potential impacts of climate change on health, agricultural and infrastructural sectors and flagged the need to extend the exploration of climate change impacts to other sectors.

Whilst there is general scientific consensus that anthropogenic climate change is occurring (IPCC, 2021), the debate on the veracity of climate change and its potential drivers still exists in the public domain (Perkins et al., 2018). Some of the doubts may come from the way media portrays climate change, with some outlets framing the issue as a problem external to the reader and beyond the control of any identifiable actor (Wozniak et al., 2015). The narration of climate change stories may also play a role in the acceptance of climate science as narration styles range from comical to apocalyptical (Wozniak et al., 2015). The rise of "fake news", the spreading of incorrect information disguised as credible reporting is, too, amplifying climate change denial (Drummond et al., 2020). Education levels and political stances may also play a role in the perceptions of different communities to climate change (Czarnek et al., 2021). These debates are, however, likely to reduce over coming years as the evidence for climate change gets harder to ignore (IPCC, 2022).

2.2.4. Vulnerability

Having understood climate change and some of its likely impacts, exploring variables which affect how those impacts are experienced and managed is necessary as regions with unique contexts often experience the same climate change hazards differently and thus have different risk levels over time. According to the IPCC 5th Assessment Report (AR5) and Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX) vulnerability assessment framework (figure 1; Davis-Reddy & Vincent, 2017), risk is a function of vulnerability, hazards and exposure, and thus requires the consideration of geophysical and socio-economic variables concurrently (Zanetti et al., 2016).

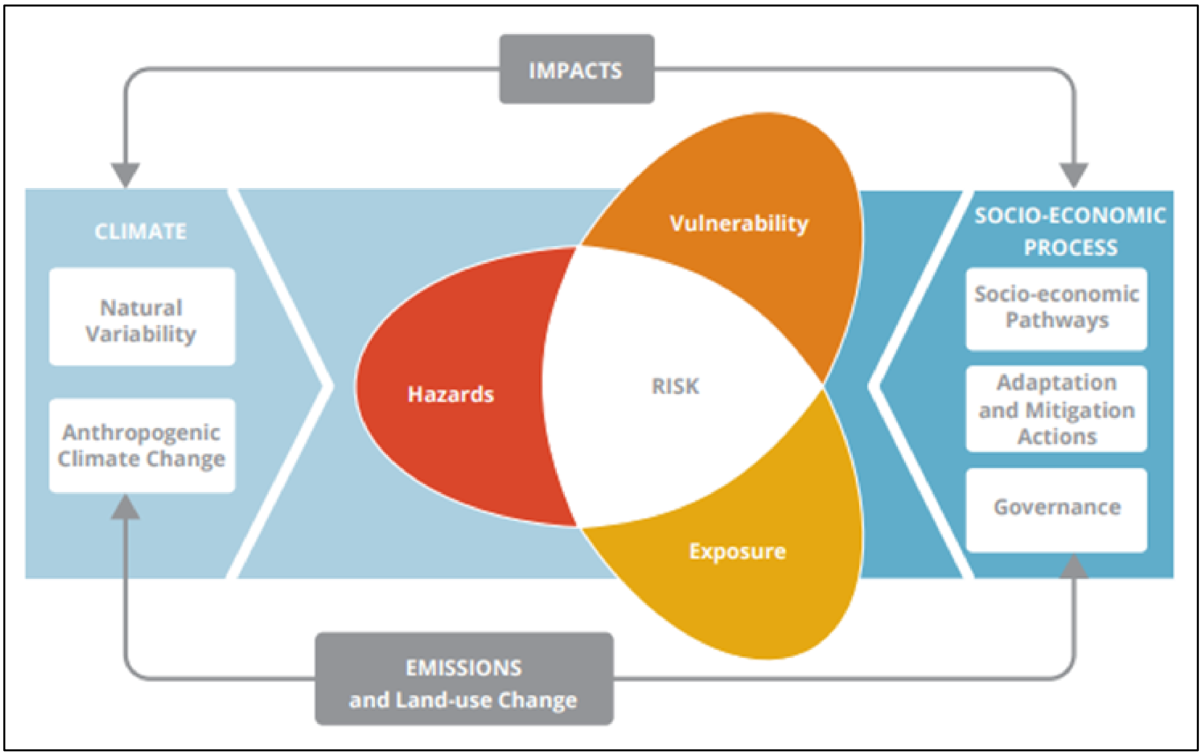


Figure 1. SREX and AR5 vulnerability assessment framework (Davis-Reddy & Vincent, 2017)

Climate change vulnerability, the variable quantified by the CVIT, is defined as the tendency or propensity of a subject to be detrimentally impacted by the effect of climate change and accounts for multiple considerations including sensitivity, susceptibility and ability to cope with the adverse impacts of climate change (IPCC, 2001; IPCC, 2022). Risk can be defined as the potential for negative impacts or consequences, hazard is defined as a physical event or trend which will cause harm to a system and exposure is defined as the presence of stakeholders, systems or assets in locations or settings which may be adversely impacted by climate change (IPCC, 2022).

Vulnerability is determined by more than just climate phenomena (Davis-Reddy & Vincent, 2017; Masipa, 2017). For example, impacts of extreme events such as drought are compounded by context specificities such as high levels of unemployment and poverty

(Masipa, 2017). Gradually there has been the inclusion in vulnerability studies of non-climate related variables such as adaptive capacity (Fussel & Klein, 2006). Integration between biophysical risk and socio-contextual frameworks has historically been limited in climate change vulnerability research (Debortoli et al., 2019), however systematic vulnerability assessment includes many variables including climatic, social, political and economic factors (Dorgu et al., 2019). Climate change vulnerability can be assessed at multiple scales depending on the purpose of assessment and changes over time (Masipa, 2017). Climate change vulnerability indices have been used for specific sectors and activities – including the aviation and marine transportation sectors in the Arctic region (Debortoli et al., 2019) and water, agriculture, ecosystems, coastal zones and settlements in southern Africa (Davis-Reddy & Vincent, 2017). The vulnerability of beach tourism to climate change has been explored by Perch-Nielsen (2010) at a country scale through the calculation of vulnerability, exposure, sensitivity and adaptive capacity measures. The tourism sector more broadly has, however, been largely neglected as a subject of interest until the work of Scott et al. (2019) who quantified vulnerability of tourism sectors at country scale globally. Tourism has been noted as particularly vulnerable as a sector due to the magnitude of impacts it will experience in the face of climate change, the importance of tourism to economies and livelihoods and adaptive capacity limitations of tourism stakeholders and components (Agnew & Viner, 2001; Scott et al., 2019). This paucity, particularly in a Southern African context, is of concern as vulnerability assessments are important for enabling identification of risks, strengths or weaknesses of the subject in question (Davis-Reddy & Vincent, 2017) and for guiding action and allocating funds (Scott et al., 2019). Climate change vulnerability assessments have been used to increase the scientific based understanding of climate change impacts, to inform mitigation targets and to develop policies for managing and reducing climate change impacts

(Fussel & Klein, 2006; Kajan & Saarinen, 2013), and it is thus important that these are considered at an appropriate scale.

With a score of 0.43 on the Climate and Regional Economics of Development (CRED) model where tourism GDP share is considered, Africa is ranked as the most vulnerable to the impacts of climate change (Stanton et al., 2012). The discourse is however mixed as some argue that Africa may as a whole be less vulnerable to climate change, particularly in rural areas, given the close relationship many African communities have with the environment and a long history of needing to adapt to the impacts of floods and droughts (Abrahams et al., 2018). If a community has never experienced a hazard before they are likely more vulnerable to changes in exposure levels (Debortoli et al., 2019). Sub-Saharan Africa specifically is often posited to be more vulnerable than the rest of the world to climate change (de Sherbinin, 2014) as the physical impacts of climate change are projected to be large (Rogerson, 2016). This high vulnerability can further be explained by compounding factors which increase susceptibility and decrease ability to adapt and respond to climate change impacts (Connolly-Boutin & Smith, 2015; Pandy, 2017).

An emerging concern with vulnerability assessments is the lack of a structured and consistent approach to assessing vulnerability (Moreno & Becken, 2009). This manifests in not being able to compare the vulnerability of different locations, sectors or communities as different approaches were employed or scales that were not useful were utilised (Fussel & Klein, 2006). The need to compare vulnerability to other industries and sectors within the economy has been highlighted (Dorgu et al., 2019), finding that although tourism may be more vulnerable than the other sectors, it too may be more resilient depending on the income status of the country in question. Furthermore, some subsectors of tourism may be more vulnerable than others with coastal tourism for example being potentially more vulnerable due to near-unavoidable hazards such as sea-level rise, exposure to extreme events and being highly populated (Moreno & Becken, 2009; Zanetti et al, 2016). Mitigation and adaptation measures need to be implemented in conjunction with one another to reduce vulnerability (Davis-Reddy & Vincent, 2017). The importance of resilience in cities has been noted (Musavengane et al., 2020), regions which comprise a large proportion of the South African tourism market. It is concluded that the need for assessing climate change vulnerability of tourism in South Africa at a high-resolution spatial scale is necessary and urgent, requiring a multidisciplinary and comprehensive approach.

2.3. Tourism, Climate and Climate Change

2.3.1. Overview

2.3.1.1. Tourism Research

Early tourism research often focused on either the business value of tourism or the consequential social and environmental impacts arising from tourism in destination countries (Leiper, 1979). When the field began to mature, the focus shifted to defining tourism, its segments, and different approaches to studying the field (Leiper, 1979). Many of the key findings from this era are still applicable today including that, when viewed with a systems approach, tourism is found to be a multidisciplinary, human-environment coupled system and comprised of many components (Moreno & Becken, 2009; Fang et al., 2018), including tourists, the originating region, the travel route, final destination and industries which support tourism either directly or incidentally (Leiper, 1979). Each component can be studied independently but are inherently connected spatially and functionally (Leiper, 1979). Across the entire tourism value chain, impacts, interconnection and dependency on other sectors is noted (Ehmer & Heymann, 2008; Burns & Bibbings, 2009). The international tourism research narrative has subsequently matured, engaging in cross-disciplinary studies such as the relationship between tourism with colonialism, feminism, and the political economy (Hoogendoorn & Rogerson, 2015).

The southern and South African tourism geography discipline has grown and developed over the last two decades but still typically focuses on applied studies and policy concerns rather than theoretical studies (Saarinen et al., 2022). Topics with high historical research output include the contribution of tourism towards economic development and studies centring on pro-poor tourism (Hoogendoorn & Rogerson, 2015; Musavengane et al., 2020). A thematic focus on leisure tourism and nature-based tourism can be observed along with instances of niche tourism studies, including adventure or sport tourism (Hoogendoorn & Rogerson, 2015). An example of this is as a deep dive into scuba adventure tourism dynamics by Giddy and Rogerson (2018), who noted the major contribution the sport offers to the South African tourism economy, the rising diversification of adventure tourism participants in relation to race and international status, and the relationship between scuba diving and small-town development. Urban or city tourism has emerged as a sub-focus both within the global north (Jiricka-Purrer et al., 2020) and in Southern Africa (Hoogendoorn & Rogerson, 2015; Musavengane et al., 2020). This focus has highlighted concerns around the gentrification of urban areas for the purposes of tourism and has raised questions around whether or not locals and the urban poor are included in development plans or, instead as Musavengane et al. (2020) suggest, potentially displaced and marginalised with neoliberal approaches underpinning development strategies. Other urban concerns include so-called “over-tourism” in metropolitan areas placing pressure on existing infrastructural resources (Jiricka-Purrer et al., 2020), a concern reiterated by the COVID-19 pandemic.

Climate tourism research falls broadly into the biometeorology discipline which describes the interdisciplinary study of interactions between atmospheric processes and living organisms with the International Society of Biometeorology (ISB) being founded over 50 years ago as a scientific collaboration organisation to develop the field (ISB, 2021). The links between climate and tourism were first established in the 1970s (Rutty et al., 2020b), with Lieper (1979) including it as one of the critical natural resources upon which tourism depends. The Commission on Climate, Tourism and Recreation was founded 23 years ago and focuses on the intersection of climatology and tourism (Rutty et al., 2020b). A focus on the relationship between climate and tourism has continued to grow, with climate noted as a key driving factor motivating tourist decisions – including when to travel, where to go, what to do once at the chosen destination, and how much a trip is enjoyed (Hoogendoorn & Fitchett, 2018a). With the rise of interest in climate change within academia and the public consciousness, it is unsurprising that research focusing on tourism and climate change intersection has grown notably over recent years and is argued to have evolved into a distinct and recognised knowledge domain or sub-discipline within tourism studies (Becken, 2013; Fang et al., 2018). The impact of climate change on tourism has even gathered notable attention beyond the scope of academic communities including stakeholders such as governments and financial institutions taking interest (Loehr, 2021). The Deutsche Bank, for example, conducted global scale research exploring potential impacts of climate change on tourism and found that there are mixed impacts, with risks significantly outweighing potential opportunities (Ehmer &

Heymann, 2008). Reducing vulnerability and carbon, water and energy footprints of tourism dominates aims across all media types including articles, reports and policy documents (Loehr, 2021). Early studies exploring the impact of climate change on tourism for South Africa delivered mixed outlooks (Preston-Whyte & Watson, 2005), however as certainty of the anthropogenic causes of climate change increased, likely detrimental and sometimes devasting impacts on tourism in different contexts began to be acknowledged (Steyn & Spencer, 2012) and are now certain globally (Gössling & Scott, 2018) and domestically (Hoogendoorn & Fitchett, 2020).

The focus on the intersection of climate variables, including climate change, with tourism will be the focus of this sub-section. The interconnectedness, feedback loops, fragmentation and complexity which characterise tourism (Burns & Bibbings, 2009; Moreno & Becken, 2009) appear to drive the modern study of tourism climatology through a geographical lens, and accounts for the large diversity of disciplines including environmental science, ecology, management and hospitality which contribute to the field (Pandy, 2017; Fang et al., 2018; Rutty et al., 2020b). Critical analysis and review of the field has been conducted by many at global scales including Becken (2013), Fang et al. (2018) and Rutty et al. (2020b) who found common recurring themes of climate change impacts, adaptation, mitigation and policy; along with vulnerability, emissions and tourist behaviour emerging as focus areas. Fang et al., (2018) employed scientometric analysis of literature outputs between 1990 to 2015 using CiteSpace to measure and describe the academic field including key features, nature and trends. This approach allows, amongst other powerful insights, for the visualising of emerging collaboration networks and dominant authors. Core knowledge groups identified include winter tourism, consumer behaviour and sustainable tourism (Fang et al., 2018).

2.3.1.2. Concerns and Representation

Before exploring the field, it is important to note that Africa and the rest of the Global South are not strongly represented in existing literature (Fitchett et al., 2017; Fang et al., 2018; Hoogendoorn & Fitchett, 2018b). This is concerning as climate change has been identified as an issue of priority in tourism studies for South Africa (Hoogendoorn & Rogerson, 2015) and other regions within the Global South which are often economically reliant on tourism (Hambira & Saarinen, 2015), particularly following the COVID-19 pandemic (Rogerson & Baum, 2020). This under-representation manifests in many ways with more obvious ways including the volume of research outputs across media types which are dominated by a focus on tourism within the Global North (Fitchett et al., 2016c; Loehr, 2021). This is of concern as these studies often cannot be extrapolated to other regions. Another measure of lacking Global South contribution to the climate-tourism field includes the arising networks of collaboration, with research outputs denominated by main networks and collaboration partners originating most commonly from Europe, North America and Oceania (Becken, 2013; Fang et al., 2018). Key authors found within the dominant core and often appearing in journals of high impact factor include Scott, Gössling, Becken, Hall and Amelung, with other emerging authors located in periphery groups (Becken, 2013; Fang et al., 2018). Co-authorship was seldom observed between the core and periphery which may be limiting development of the field and results in what has been described as clique-like research patterns (Becken, 2013).

The under representation of the Global South extends beyond academia, with the global North focused paradigm appearing in reports produced by international bodies such as financial centred work by Ehmer and Heymann (2008) who focus on Africa proportionately less in their examination of climate change interactions with tourism. Underrepresented regions occur within countries, too, with popular destinations and attractions typically receiving the most attention (Hewer & Gough, 2018). This can be argued to be justified in contexts where these are the most financially important tourism destinations for the country. Other subtle ways Global South under representation appears includes the naming conventions of papers, whereby the Global South is often observed to be adding location names to article titles, unlike papers focusing on the Global north. Craig and Feng (2018), for example, explore only the United States yet do not specify the regional focus in the title of the paper – unlike scholars from the Global South who often do so. Moreover, Africa is often viewed as a homogenous region, examined with much less detail than other regions with unspecified geographic features dominating Africa focused outputs (Loehr, 2021), despite the marked geographic heterogeneity of the continent. The focus on specific sub-sectors of tourism such as snow and coastal tourism has too been noted (Becken, 2013), with other potential research gaps in the field including the ethical dimensions of tourism and climate change (Becken, 2013) which will be actively considered when conducting this research.

2.3.1.3. Approach

Tourism, climate and climate change are complex topics with many interconnections and variables. A structured approach is therefore being employed to examine the relationships and themes manifesting at different timeframes of influence across the tourism journey. This will be done through the lens of tourists and destinations respectively (figure 2). These stakeholders are connected as the interplay of experiences, places, cultures, and people produce the overall commercial tourism product (Burns & Bibbings, 2009). Examining the two key segments separately allows for a more nuanced understanding, in line with the suggestion of Loehr (2021) to employ systems thinking to analyse components of the tourism and climate change knowledge domain. Recurring themes of perceptions, decisions, activities and satisfaction of tourists will be considered through the themes of: Flows and Seasonality; Information, Preferences and Sensitivity; and Activities and Satisfaction. Direct and indirect impacts of climate variables on destinations will subsequently be examined by exploring the themes of: Tourism Suitability, Climate-Tourism Indices, Climate-Linked Resources, Financial Implications, Extreme Weather Events, and Last Chance Tourism. Once these links have been established, sustainable tourism will be explored including the contribution of tourism to climate change, tourism resilience and climate change adaptation by the sector.

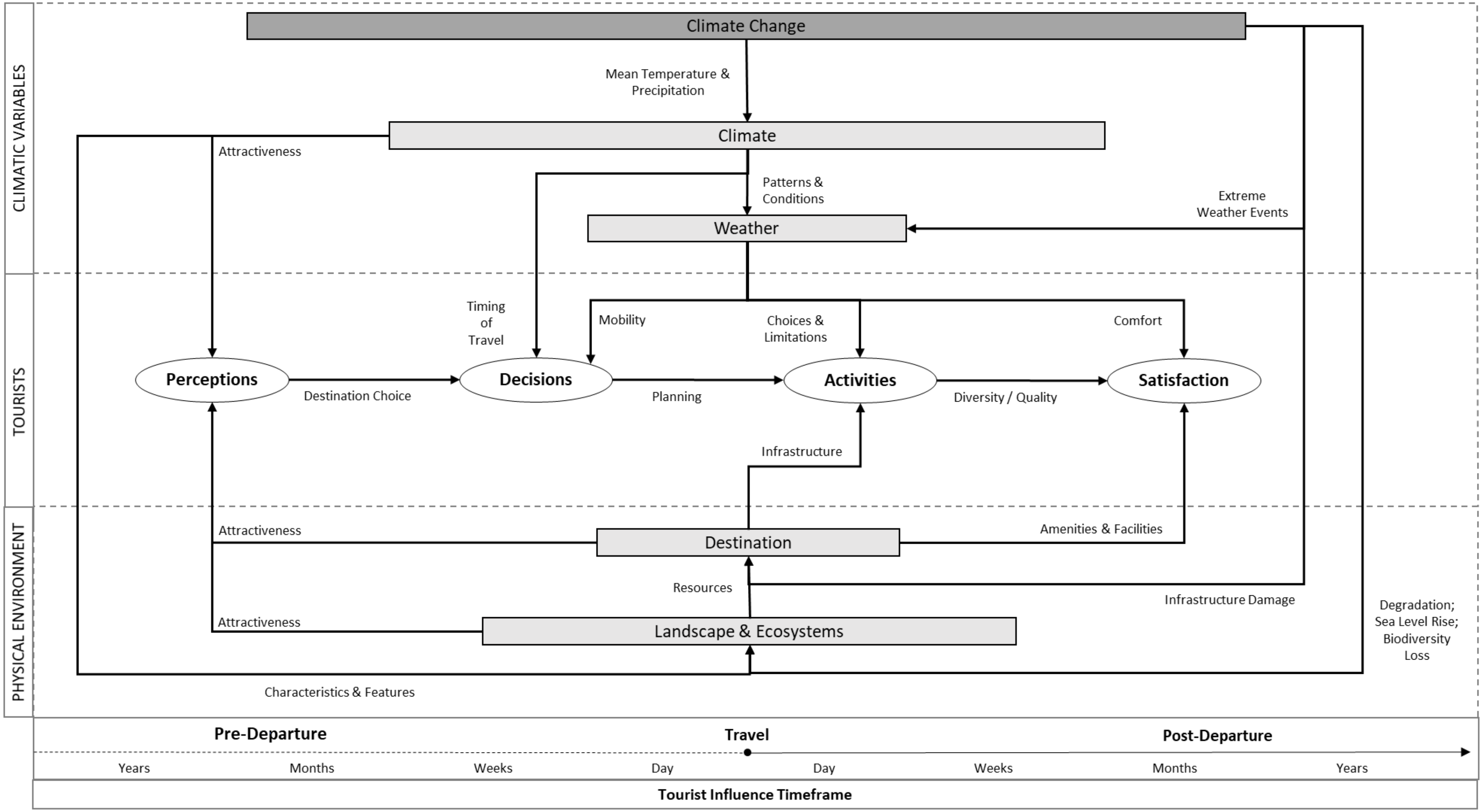


Figure 2. High level summary of interactions between climate, climate change and tourism through the lens of tourists and destination locations

2.3.2. Tourists

2.3.2.1. Flows and Seasonality

For tourists, the impact of climate and weather manifest differently across phases in a trip: pre-departure, travel and post-departure in line with the expectation, experience re-evaluation pattern identified by Gössling et al. (2012). Understanding tourist behaviour across different time scales is not merely an academic challenge but also has utility and tangible benefits for tourism sector stakeholders and governments for the purposes of tourism planning (Ehmer & Heymann, 2008; Gössling et al., 2012). On a global scale, Europe accounts for more than half of market share in international tourism based on arrivals (Ehmer & Heymann, 2008), with the Mediterranean emerging as a popular destination motivated largely by its favourable climate (Amelung & Viner, 2006). South African tourism grew rapidly post-apartheid (Agnew & Viner, 2001) and now represents one of the most desired destinations in Africa (Ehmer & Heymann, 2008) and potentially the world (Amusan & Olutola, 2017). South Africa's popularity as a tourist destination is attributed largely to its pleasant climate, scenery and game reserves (Agnew & Viner, 2001; du Plessis et al., 2015).

There are many attractor and deterrent variables which determine the generalised spatial flow volumes and temporal seasonality of tourist movements (Gössling et al., 2012; Dubois et al., 2016; Noome & Fitchett, 2019). Detractor variables can include governance, crime, safety and political instability concerns (Ehmer & Heymann, 2008; Musavengane et al., 2020) as well as vector borne and infectious disease prevalence (Gössling et al., 2009; Steyn & Spencer, 2012). With leisure being a dominant motivator for travel (Ehmer & Heymann, 2008) it is unsurprising that the timing of school and public holidays influences peak season lengths and tourist timing over long-time scales (Aylen et al., 2014; Noome & Fitchett, 2019, 2021). Price has been flagged as an additional factor of consideration for destination choice (Buckley, 2017), but general climate remains one of the most prevalent driving factors (De Klerk & Haarhoff, 2019) and thus understanding temporal and geographic trends of tourist's behaviour in response to climatic factors now and in the face of climate change is critical (Dubois et al., 2016).

There are many ways to measure tourist flows including modelling demand in different contexts (Rossello et al., 2020) or employing demand correlation using time series models (Aylen et al., 2014). Long term climate variables such as average and maximum air temperature have often been found to be correlated with timing and magnitude of general tourist demand as tourists want to travel in the most climatically favourable periods (Caldeira & Kastenholz, 2018; Coldrey & Turpie, 2020; Mushawemhuka et al., 2020). This significant relationship has also been found between occupancy and temperature in a South African context, explaining up to 50% of historical occupancy variance for national parks (Coldrey & Turpie, 2020). Craig and Feng (2018) identified construal level theory as a factor driving the scale of decision making in tourists. This phenomenon describes the propensity of people to be less concerned with details of an object (i.e. weather) the further away the object (i.e. trip) is. The closer the time comes to travel the more concerned they will grow at the day-to-day conditions; thus, weather can impact tourist movement decisions, however this impact occurs at a short-term scale especially for spontaneous or domestic travel (Aylen et al., 2014). The range of influence of weather for bookings has been suggested to be approximately two weeks (Craig & Feng, 2018). Movement of tourists across even smaller time scales is also linked to weather conditions as concluded by Caldeira and Kastenholz (2018) in a time-motion study in Lisbon enabled by GPS tracking, which found that movement dispersal was linked to solar radiation, air temperature and cloudiness and could limit how far a tourist can travel and explore from their accommodation. This range change consequently alters the financial sphere of influence of a tourist as multi-attraction intensity, the tendency to do more in a day or trip, decreases (Caldeira & Kastenholz, 2018). A heatwave, for example, may result in no change to intended plans or itinerary, however, if it is cold and rainy, tourists will almost certainly alter planned activities or movement (Dubois et al., 2016).

Given that climate is closely linked to tourist movement, it is unsurprising that previously observed trends in tourist behaviour are expected to change notably as a result of climate change (Amelung et al., 2007; Ehmer & Heymann, 2008; Rossello-Nadal, 2014; Buckley, 2017). This is because tourists are arguably the tourism stakeholder with the most adaptive capacity in the face of climate change as they can alter where they go and when they travel (Gössling et al., 2012) as alternatives will always exist in the competitive tourism sector (Pandy, 2017). This comparison can happen at site level or country scales (Buckley, 2017). One of the first climate change-tourism scenario simulation studies suggested that tourism demand as a result of climate change is understudied (Hamilton et al., 2003), however this gap is closing, and several studies have since modelled these potential changes (see Amelung et al., 2007; Rogerson & Visser; 2007; Gössling et al., 2012). Most approaches suggest warm destinations to be impacted most severely by climate change due to the high weighting of thermal comfort by tourists resulting in likely observed pattern shifts of tourist flows towards higher latitudes (Rossello-Nadal, 2014), possibly benefiting northern European countries such as Denmark or Germany (Amelung & Viner, 2006; Ehmer & Heymann, 2008). South African tourism was flagged as a potential “star of tomorrow”, being mapped as unaffected and possibly benefiting from climate changes (Ehmer & Heymann, 2008). This corresponds to more recent findings such as a study of tourist flows under climate change scenarios using temperature and rainfall occupancy correlation for South African National Parks, where net annual results were not ubiquitously detrimental across the country (Coldrey & Turpie, 2020). Some regions such as the Richtersveld National Park saw a projected increase in visitation, whilst other regions like Mokala National Park were unimpacted and others projected visitation numbers would decrease such as Marakele National Park (Coldrey & Turpie, 2020). At risk seasons have been observed and thus vulnerability of the tourism sector may change within a year and not only over longer time periods (Craig & Feng, 2018; Coldrey & Turpie, 2020).

Even in contexts such as urban tourism where booking behaviour has historically not always been correlated with climatic variables, the importance of general climate and day-to-day weather conditions could change as tourist heat tolerance (Caldeira & Kastenholz, 2018) and climate change mitigation measures play a role (Jiricka-Purrer et al., 2020). In modelled climate change scenarios, it is possible that globally most tourism sector growth will be in regions where economic growth is largest because closer destinations may be preferred over intercontinental travel due to potential climate change driven financial limitations or policy implications (Hamilton et al., 2003, Rossello-Nadal, 2014). Understanding what factors would serve as future travel detractors in the face of climate change is important with Giddy et al. (2017) citing constant rain, flooding and tropical cyclones as variables which may hold strong influence. The importance of having accurate climate change projections is thus noted, with, for example, uncertainty around changes to wind patterns being an issue of concern as tourists have been shown to be very sensitive to this factor (Buckley, 2017).

2.3.2.2. *Information, Preferences and Sensitivity*

Given that climate acts as an attractor or detractor variable motivating spatiotemporal trends in destination choice and travel timing, exploring how tourist perceptions are formed and where climate and weather information is acquired is necessary. Information sources about general climatic conditions ultimately act as input drivers affecting tourist behaviour (Scott & Lemieux, 2010; Rutty et al., 2020b). These can come either from research and marketing or may instead be informed by common conceptions perpetuated by media narratives and word of mouth (Ehmer & Heymann, 2008). The information is important as weather variability and general conditions in relation to expectations and anticipated climatic conditions can inform overall enjoyment and subsequently the return rate of tourists to a destination (Fitchett & Hoogendoorn, 2018; Stockigt et al., 2018). The focus on international tourist perceptions of climate variables – thus neglecting the perceptions of the domestic tourist – has been noted as an issue of concern when studying tourist climate perceptions (Dubois et al., 2016).

Long term climate patterns and smaller scale weather forecasts are often utilised by tourists – specifically where activities they wish to participate in can be notably impacted by weather such as camping or sunbathing (Dubois et al., 2016). Modern tourists have very easy access to information in the digital age – though how the information is perceived and the influence it may have on better decision making has not been properly understood (Scott & Lemieux, 2010; Gössling et al., 2012). Within South Africa, official climate information is disseminated by the South African Weather Service (SAWS), but it is possible that tourists additionally or alternately use privately managed sources, such as those which appear first when googling "South African climate" or "South African weather", and apps including AccuWeather or AfricanWeather. Surf-Forecast.com is another example of a private source used for many destinations swell and surf condition reports (Scott & Lemieux, 2010). Tourists may also be obtaining information about general climatic conditions and weather forecasts from tourism operators or destinations (Scott & Lemieux, 2010). The importance of effective science communication strategies by media, marketing of climatic variables by destinations and generally better climate services across the tourism sector is thus noted (Fitchett & Hoogendoorn, 2018; Dube & Nhamo, 2020; Rutty et al., 2020b).

Climate information and media coverage relating to climate change driven natural disasters and extreme weather events will also play an important role in driving tourist perceptions, as instances of exaggerations, sensationalisms and misrepresentations by the media have already been observed, with negative connotations of even single climate events being noted which do not necessarily correspond to on-the-ground experiences and therefore harm destination attractiveness (Gössling et al., 2012; Dube & Nhamo, 2020). This is particularly important as following natural disasters the recovery time for tourism to return to pre-disaster levels may be relatively fast and speaks to the potential resilience of the sector (Rossello et al., 2020), however negative media portrayals may impact public consciousness for longer than necessary. Furthermore, with climate variability increasing and patterns changing, tourists can potentially no longer rely on previous experience to inform likely climate conditions on return to a destination, but rather need to get more up to date information to inform decision making processes (Scott & Lemieux, 2010). Where tourists are getting climate change information from and their general stance on climate change (denialist or strong advocate for climate change action) will furthermore impact behaviour in relation to the arising cognitive biases of tourists (Gössling et al., 2012).

Having understood general tourism flow dynamics and potential sources of climate information, the subtlety and complexity of the individual tourist can now be considered. Understanding climatic preferences can be challenging as they can differ from individual to individual and tend to be context specific (Gössling et al., 2012). Country of origin has been suggested to impact weather preferences and sensitivity as tourists may use their differing home climates as a reference point (Fitchett & Hoogendoorn, 2018; Dubois et al., 2020). French tourists, for example, have been found to have a high tolerance to heat but are heavily detracted by rain (Dubois et al., 2016), whilst America tourist climate dissatisfaction has often been correlated with poor thermal comfort experienced during high temperatures and excessive wind conditions (Giddy et al., 2017). Thermal perceptions of experience can sometimes be quantified, for example using the Physiological Equivalent Temperature (PET) index, the Universal Thermal Climate Index (UTCI) or over 100 human thermal bioclimatic indices of varying complexity and composition (de Freitas & Grigorieva, 2015). The use of different indices to quantify human thermal climatic experiences would yield different results depending on the approach employed (de Freitas & Grigorieva, 2015) and does not always account for the individual preferences of tourists (Dubois et al., 2016). Other variables that have been suggested to impact sensitivity to climatic factors include age, income, type of tourism stay and whether there are children travelling in the group or not (Dubois et al., 2020). Personal factors such as expertise, interests, experiences, and risk tolerance may also be of influence (Gössling et al., 2012; Buckley, 2017). To understand these differences many methodologies have been employed, including TripAdvisor reviews which look for repeated mention of climatic factors by different audiences thus revealing the significance or importance of the variables for reporting parties (Stockigt et a., 2018; Fitchett & Hoogendoorn, 2019). The findings of such studies reveal that temperature fluctuations are important factors for tourism in South Africa – with cold being mentioned most frequently, although different destinations may have climate weigh differently in importance (Fitchett & Hoogendoorn, 2019). It must be noted that despite individual tourist differences, general tourist behaviour can still be modelled and is nonetheless important to understand in many contexts despite data limitations or lack of nuance, for example to test sensitivity to a variable – rather than serve as an accurate prediction of tourist flows (Hamilton et al., 2003).

2.3.2.3. Activities and Satisfaction

Other variables responsible for travel timing include activity offerings at the destination (Caldeira & Kastenholz, 2018). For example, snow conditions may not coincide with most suitable conditions theoretically for tourism – but are indeed necessary for winter tourism activities such as skiing (Noome & Fitchett, 2019). The importance of thermal comfort may therefore be negated by the offerings available and the capacity of tourism infrastructure to manage climatic experiences (Fitchett & Hoogendoorn, 2018). Optimal conditions in the specific context will nonetheless continue to exist, but the ranges, limits and levels thereof will vary for different types of tourism (Rossello-Nadal, 2014) as the timing, location and nature of activities is determined by climatic variables (Steyn & Spencer, 2012; Buckley, 2017; Caldeira & Kastenholz, 2018). In a southern African context where nature-based and adventure tourism is prevalent, weather conditions may for example hinder when one can conduct bush walks or go on open-vehicle game drives (Mushawemhuka et al., 2020), or the possibility of and safety associated with white river rafting and kite surfing (Steyn & Spencer, 2012; Buckley, 2017). Climate change may thus impact activities on offer and using a general equilibrium framework it can be concluded that holiday habits will undoubtably change as a result of climate change (Berritella et al., 2006).

Climate change impacts are however not always detrimental. In winter tourism studies it was concluded that whilst climate change posed a risk for cold weather activities, opportunities arose for more warm weather activities such as golf (Hewer & Gough, 2018). Expansion of tourism into winter months previously unsuitable for tourism may also occur, reinforcing the temporal variation in climate change impacts on tourism and the need to understand the relationship across multiple time scales (Rossello-Nadal, 2014). In a South African context, Friedrich et al. (2020) found that beach related activities, for example, may be positively impacted by higher temperatures and reduction in precipitation which are considered favourable conditions in the beach tourism context. The work of Friedrich et al. (2020) serves as a good example of the benefits to understanding climate change projections at a useful spatial scale whereby six key coastal destinations on the South African shoreline were considered using the hazard-activity pair methodology. This methodology developed by Moreno and Becken (2009) is a qualitative and descriptive approach that is used to assess climate change vulnerability for beach tourism. Kilungu et al. (2019) also engaged the hazard-activity pairs methodology and found that rainfall and temperature would positively benefit trekking and have mixed impacts on sightseeing in Kilimanjaro based in aesthetic appeal changes caused by land cover changes. Effects of secondary climate change impacts beyond day-to-day weather condition changes, such as drought occurrence, were acknowledged to be excluded from the study conducted by Friedrich et al. (2020). This is of concern as drought has been linked to tourism arrivals, spending and occupancy declines in Cape Town (Pandy, 2017; Dube et al., 2020) – one of the study sites considered by Friedrich et al. (2020).

2.3.3. Destinations

2.3.3.1. Tourism Suitability

Having explored the relationship between tourists and climate variables, destinations will now be the component of focus for examining the connections of climate and climate change with tourism. Destinations are important segments within tourism to consider as enterprises generally are a modern research imperative and can have notable influence on surrounding communities and livelihoods (Pandy, 2017). The observed spatial distribution of tourism destinations globally and within a country is not random – but rather is informed by the suitability of the location for tourism which differs for the diverse range of tourism types (Mieczkowski, 1985; Amelung et al., 2007).

Changes in tourism suitability climatologically and physically as a result of climate change and the significance of individual climate variables will vary depending on the context (Fitchett et al., 2017; Mushawemhuka et al., 2020). Temperature for example may be a bigger issue in larger cities where the impacts of heatwaves and mean temperature increases may compound the urban heat island effect (Jiricka-Purrer et al., 2020). A distinction between summer and winter tourism characteristics and climate change impacts has long-since been flagged (Wall & Badke, 1994). Summer and beach tourism, specifically in small island developing states and low-lying coastal towns, may have physical suitability for tourism impacted by sea-level rise and storm surge occurrence (Agnew & Viner, 2001; Fitchett et al., 2016c). Snow tourism is threatened by climate change globally (Hewer & Gough, 2018) and within Africa (Kilungu et al., 2019; Hoogendoorn et al., 2021) with general snow reductions and shifts in the timing of snowfall projected (IPCC, 2021). Not only could this alter the volume of tourist arrivals, but the coincident timing of snowfall with key events such as Christmas in the northern hemisphere could be impacted and thus reduce satisfaction of tourists in relation to expectations (Wall & Badke, 1994). The effects of climate change on destination suitability for cultural and heritage tourism is underexplored, despite impacts upon key sites and assets such as archaeological features, parks and gardens already being observed (Hall et al., 2016; Pandy & Rogerson, 2018; Fitchett & Roshan, 2020).

Some changes in suitability as a result of climate change will be positive for destinations, with rising temperatures, golf and zoo tourism, for example, may be benefited in Canada which previously had conditions too cold to cater to the needs of outdoor activities associated with these types of tourism (Hewer & Gough, 2018). Mount Kilimanjaro may benefit from changing temperatures as reaching the summit is made potentially easier due to changes in air pressure, breathing capacity, and a reduction in occurrence of altitude disease (Kilungu et al., 2019). Short term benefits of climate change however may not always outweigh long term detriments. The melting of the snow cap of Mount Kilimanjaro due to global warming was an early projected impact of climate change (Preston-Whyte & Watson, 2005), and has begun to be observed, resulting in a reduction of attractiveness and ultimately visitation rates which may outweigh aforementioned benefits for tourism at the destination (Kilungu et al., 2019). Another example of mixed outcomes is drought which may make day-to-day weather more favourable, however long-term impacts on agriculture would impact tourism harmfully (Wall & Badke, 1994). This is important as droughts akin to the Western Cape “day zero” drought have been projected to reoccur as a result of climate change in a South Africa context (Dube et al., 2020).

2.3.3.2. Climate Tourism Indices

There are many approaches to quantifying theoretical tourism suitability and attractiveness for a destination, with different approaches yielding different results based on the scale of study and considerations used (Rossello-Nadal, 2014), with the use of indices emerging as a popular methodology (Fang et al., 2018; Scott et al., 2019). Climate suitability at a destination can be attributed to the impact that temperature and other climatic variables have on the tourist user experience (Caldeira & Kastenholz, 2018). The TCI was developed by Mieczkowski (1985) to quantify destination suitability for tourism for the purposes of comparison between locations based on climatic variables including thermal comfort, precipitation, sunshine hours and wind. The scores range between -20 and 100, with higher scores reflecting better suitability (Perch-Nielsen et al., 2010). The weighting of TCI variables has been of academic debate with some arguing that different weighting should be applied in different contexts (Fitchett et al., 2016; Scott et al., 2016). Thermal comfort, for example, is suggested to be an important variable and thus potentially should be more strongly weighted (Dubois et al., 2016), whilst others argue that rainfall is an overriding factor that should be most important (Rutty et al., 2020a) thus resulting in adaptations of the initial TCI formula. Other instances which necessitate different weighting of variables or the use of proxies when calculating the TCI include instances of data limitations as suggested by Perch-Nielsen et al. (2010) and employed in a South African context by Fitchett et al. (2017) where sunshine hours and cloud cover data is often missing or limited.

The TCI has been broadly applied to the Global North but its use in the Global South has been less frequent (Fitchett et al., 2017). TCI usage in southern Africa has, however, increased notably over recent years including application in Zimbabwe (Mushawemhuka et al., 2020), Namibia (Noome & Fitchett, 2021), Lesotho (Noome & Fitchett, 2019) and South Africa (Fitchett et al., 2017). Using the TCI, South Africa is found to be generally more suitable for tourism than many other regions in Europe and North America, with scores ranging from 76.5 to 93 corresponding to ‘very good’, ‘excellent’ and ‘ideal’ classifications (Fitchett et al., 2017). There is intra-annual seasonality in when destinations will be more suitable for tourism (Amelung & Viner, 2006). In South Africa for example TCI scores may be lower for most destinations in winter months however the different regional weather patterns experienced in eastern and western parts of the country ensure climate suitability for South Africa throughout the year (Fitchett et al., 2017). Lesotho has a bimodal shoulder distribution in TCI scores, meaning two peak seasons for climate suitability are observed (Noome & Fitchett, 2019). Differences between different locations within a country or region may also arise thus examining results at finer spatial scales has been flagged as important (Mushawemhuka et al., 2020). This spatial variation can also be observed at higher resolutions for example the lowveld of Zimbabwe has winter peak suitability (Mushawemhuka et al., 2020). It is important to note that the TCI only quantifies theoretical suitability and results thereof do not always align with tourist flows, although the TCI can often be a good predictor of tourist arrivals (Rossello-Nadal, 2014; Noome & Fitchett, 2019). The TCI is nonetheless a useful measure as it allows for the comparison of relative attractiveness and suitability of different locations at different scales (Mieczkowski, 1985; Noome & Fitchett, 2021).

There are many qualitative and quantitative approaches, strategies and methods which can be employed to assess the relationship between variables such as tourism and climate change (Becken, 2013; Dubois et al., 2016). These can include time-series analysis, statistical data modelling and correlation, surveys and interviews, assessments, observations and workshops (Becken, 2013; Rossello-Nadal, 2014; Dubois et al., 2016). Climate tourism indices are one such common methodology employed in assessing the impact of climate change on tourism (Fang et al., 2018; Scott et al., 2019). The TCI, for example, has been used beyond its original purpose to examine the impact of climate change on tourism (Rossello-Nadal, 2014). This was first done on a large scale by Amelung et al. (2007) who compared global climate suitability in the 1970s with suitability under climate change projections for 2050 and concluded that a reduction in the number of months with 'good' TCI scores would be observed internationally including for southern Africa. For South Africa, winter months (June, July, August) were projected to become more favourable (Amelung et al., 2007) which aligns to the findings of Coldrey and Turpie (2020).

Although very commonly utilised, the TCI is not the only climate-tourism index employed in tourism studies and has been subject to much scrutiny, including but not limited to the northern paradigm through which it was developed, the subjectivity of rating and weighting of climatic variables and the lack of inclusion of tourist stated preferences (Scott et al., 2016; Demiroglu et al., 2020). Other indices have been developed to account for deficiencies identified in the TCI or to cater to different purposes as not all indices can be applied in all contexts (Debortoli et al., 2019). Several of these indexes include the Holiday Climate Index for beach contexts (HCI:Beach; Rutty et al., 2020a), the Holiday Climate Index for urban contexts (HCI:Urban; Scott et al., 2016), the Climate Index for Tourism (CIT; de Freitas et al., 2008), the Camping Climate Index (CCI; Ma et al., 2020), the Relative Climate Index (RCI; Li et al., 2017) and most recently the Coastal Tourism Climate Index (CTCI; Gao et al., 2022). Many studies have compared the results of two or more of these indices including Scott et al. (2016), Rutty et al. (2020b) and Yu et al. (2020). From these studies it can be surmised that all indices have strengths and weaknesses and application thereof is context specific. The need for more indices beyond those that have been developed has been noted. When using the TCI, for example, Noome and Fitchett (2021) suggest that a desert index may be more suitable for examining Namibian tourism than the TCI. How an index is developed often links to its success (Debortolli et al. 2019). Some considerations recommended to be included during development include review of existing academic literature, interviews with relevant stakeholders and comprehensive policy review (Debortoli et al. 2019). Other considerations suggested by de Freitas et al. (2008) include that the index be simple to calculate, easy to use and understand, be empirically tested, be theoretically sound and integrate multiple climate effect facets. Scott et al. (2019) considered many of these factors when developing the CVIT and the reliability thereof is thus strengthened.

2.3.3.3. Climate-Linked Resources

Examining only climate variables when examining the impact of climate change on tourism can be misleading and lead to a gross underestimation of impacts (Berritella et al., 2006). This was displayed by Friedrich et al. (2020) who concluded climate change would have a positive impact on South African beach tourism – without accounting for sea level rise which could destroy the resources upon which beach tourism dependents thus making the weather conditions redundant. Major alarm bells were sounded for tourism based on changes to environmental conditions when global warming levels were only at 0.5^{o}C (Agnew & Viner, 2001), but now tourism assets relating to environmental features are a key focus of climate change and tourism studies (Scott et al., 2019). Different biomes and ecosystems will be impacted in different manners and to different degrees Bellard et al., 2012; Pecl et al., 2017). Although climate and weather at a destination cannot be guaranteed to tourists (Steyn & Spencer, 2012), other variables such as environmental conditions which have long since been noted as destination attractiveness drivers (Leiper, 1979) are often climate dependent (Kilungu et al., 2019; Mushawemhuka et al., 2020). Beyond environmental conditions, key attractions may also be linked to climate patterns (Amusan & Olutola, 2017). Rivers and waterfalls, for example, are linked to precipitation, and observations of changes to aggregate flow volumes and peak flow timing have already been observed at the Victoria Falls, Zimbabwe (Dube & Nhamo, 2019). A major attractor for South African tourism is high biodiversity levels including viewing of the “Big-5” (Dube & Nhamo, 2020), thus making wildlife or nature-based tourism at high risk to the impacts of climate change due to projected changes to fauna and flora (Chung et al., 2018), including ecosystems beyond the terrestrial sphere such as coral bleaching in marine contexts (van Woesik et al., 2022).

Changes to underlying attractor variables driven by climate change are important, but how these changes are perceived will ultimately drive tourist behaviour (Gössling et al., 2012; Buckley, 2017). In the alpine ski industry, tourists may change where and when they ski in response to perceived changes (Hewer & Gough, 2018). Perceived resource quality is a framework which can be used to assess impacts of climate change on tourism and requires consideration of underlying resources, weather dependency of activities, access to resources, choice influencers and most sensitive indicators of changes (Buckley, 2017). Resource quality is particularly important to adventure tourism like snow, surf, wind and river activities which rely heavily on climate features to determine characteristics of resources and the ability to access them (Buckley, 2017; Dube et al., 2019). Communication with tourists may serve as a mitigating factor to manage expectations and avoid disappointment, for example by communicating updated hydrological calendars for waterfall flow rates which are linked to rainfall volume and timing changes (Dube & Nhamo, 2019), or by communicating drought conditions to tourists inbound to nature-based tourism destinations (Smith & Fitchett, 2020). The predictability of future conditions has however been noted as a concern in implementing this risk management strategy (Dube & Nhamo, 2019). Ultimately, changes to climatic variables could lead to changes in distribution patterns of tourism resources including attractions, facilities and destinations and thus through altering the comparative attractiveness of destinations result in geographic and seasonal shifts in tourism locations and tourist movements (Agnew & Viner, 2001; Amelung et al., 2007; Steyn & Spencer, 2012) which ultimately results in financial implications for the tourism industry.

2.3.3.4. Extreme Weather Events

Globally, natural disasters and extreme weather events have been observed to impact tourism in predominantly negative ways, with different types of disasters impacting in different manners and magnitudes both financially and operationally (Fitchett et al., 2016a; Rossello et al., 2020). Examples of extreme weather events and natural disasters include tropical cyclones, floods, droughts and wildfires (Gössling et al., 2009; IPCC, 2021), with implications thereof occurring both directly and indirectly (Southon & van der Merwe, 2017; IPCC, 2022). Damage to property and infrastructure incurs costs for destinations to repair following an event (Ehmer & Heymann, 2008; Fitchett et al., 2016a), to ensure they can still cater to the needs of tourists (Rossello et al., 2020). Where insurance is in place to mitigate repair cost harms, premiums may increase with increased risk of an event or following claiming for damages caused by an event (Fitchett et al., 2016a). Extreme events can hinder accessibility to destinations, which thus results in immediate loss of business (Agnew & Viner, 2001; Fitchett et al., 2016a; Southon & van der Merwe, 2017). Impacts beyond the control of a destination can include road damage and power supply interruptions which are typically considered the responsibility of governments to address (Fitchett et al., 2016a). Limitations in previous studies of natural disasters and tourism on an international scale include data granularity concerns as events may be short-lived and localised impacts may be missed (Rossello et al., 2020). Impacts of extreme weather events on tourism have been under-studied and present an avenue to better understand aspects of tourist behaviour under climate change futures (Rutty et al., 2020b).

2.3.3.5. Financial Implications

Tourism is critical to the economies of many developing nations including South Africa (Amusan & Olutola, 2017; Sifilo & Henema, 2017; Pandy & Rogerson, 2018), and growth thereof has been associated with wellbeing and positive financial outcomes for societies (Becken, 2019). Climate change impacts on tourism will have ripple effects on economic development and stability of nations (Burns & Bibbings, 2009; Hambira & Saarinen, 2015), and the small towns and peripheral areas which often surround tourism attractions (Rogerson, 2016). Examples of industries closely tied to tourism include agriculture and construction which build hotels and supply goods and services to the tourism sector (Sifilo & Henema, 2017).

Temperature and precipitation linked extreme events as a result of climate change may be linked to sales reductions for a destination (Craig & Feng, 2018). Financial implications of climate and weather events for South Africa have already been noted such as the 2015-2018 drought which affected the Western Cape, resulting in a reduction in tourist arrivals, spending, hotel occupancy and consequently revenue and job losses for the tourism sector (Dube et al., 2020). Some destinations are key to the attractiveness of a country, for example Cape Town is central to tourist arrivals to South Africa, and thus attractiveness changes in those destinations may have ripple effects on other destinations within the country (Dube et al., 2020). With climate change manifesting in social ramifications, global economic growth limits may reduce the cumulative amount of funds available for tourism, resulting in financial harms for tourism and the entire economy (Berittella et al., 2006; Gössling et al., 2012). This is important as climate variables are potentially less influential to tourism flows under climate change scenarios than population and income changes (Hamilton et al., 2003).

For destinations, changing weather and climates can financially present either an opportunity to be exploited or a risk to be managed (Craig & Feng, 2018). Business growth desires are, however, often contrasted with a lack of knowledge on how to adapt, modify to low carbon operations or to diversify offerings to ensure resilience, with measures to do so – such as ecotourism – potentially being more expensive than current operating models (Burns & Bibbings, 2009). Positive feedback loops linked to financial implications of climate change on tourism have been noted whereby operational cost changes are diminishing the profitability of the tourism sector (Dube & Nhamo, 2020). Protected areas for example are inherently tied to tourism as they often depend on visitation as a source of funding and extended justification for their existence (Coldrey & Turpie, 2020, Smith & Fitchett, 2020), thus with tourist volume changes, protected areas may lack financial resources to maintain themselves which in turn results in less tourism due to attractiveness reductions, thus compounding detrimental climate change impacts. Another example of the complex financial weigh up is the case of artificial snow making in ski locations, as not only has season length shortening reduced the net revenue of ski destinations, but moreover technological advancements to mitigate impacts are often expensive and come with cost implications which may threaten the financial viability and attractiveness of snow tourism in a given location such as Canada or Afriski, Lesotho (Hewer & Gough, 2018; Stockigt et al., 2018; Hoogendoorn et al., 2021). The timeframe of climate change action in comparison to benefits thereof differs and is of concern (Burns & Bibbings, 2009).

2.3.3.6. Last Chance Tourism

The impacts of climate change have resulted in a phenomenon known as "Last Chance Tourism" emerging whereby travellers choose their destination based on the likelihood that that destination may be impacted so notably by climate change that they would not be able to experience it in the same manner – if at all – in the future (Kilungu et al., 2019). This includes the visiting of destinations where biodiversity is threatened and endangered species are nearing extinction or low lying island nations or coastal towns which are threatened by rising sea-levels (Hoogendoorn, 2021). There has been anecdotal evidence of tourism destinations leveraging this perceived vulnerability as a marketing strategy to attract tourists, even if the features will not actually disappear in the near future (Gössling et al., 2012). Last chance tourism extends to cultural tourism which beyond locations can include loses in other irreplaceable features such as rituals, practices and ways of living as climatic and environmental conditions are altered due to climate change (Hall, 2016). Ultimately last chance tourism is a double-edged sword that may benefit tourism in the short term, but simultaneously harm the environments and infrastructure the tourists are trying to see (Hoogendoorn, 2021).

2.3.4. Sustainable Tourism

2.3.4.1. Contribution of Tourism to Climate Change

This literature review so far has had a thematic focus on the impacts of climate change on tourism, however, it must be noted that tourism itself if a major contributor to global carbon emissions and thus to climate change (Amusan & Olutola, 2017; Sifilo & Henema, 2017; Gössling & Scott, 2018). Awareness of and studies into this contribution are becoming more prevalent (Fang et al., 2018, Gössling & Scott, 2018), including within a southern African context (Hoogendoorn & Rogerson, 2015). The contribution of tourism to climate change has been included here to address the concerns of Pandy (2017) who cautions against the perpetuation of the "vector or victim" narrative which implies that a party either suffers from or contributes to climate change, when in reality the two can occur concurrently. An example of this is Rossello et al. (2020) who describe natural disasters – which may be driven by climate change – as exogenous to tourism. Impacts and contributions to carbon emissions of the tourism sector are unequally distributed globally, linking to concerns around climate justice as the footprint is driven predominantly by high income countries (Lenzen et al., 2018;

Becken, 2019). As a sector, tourism contributes more to climate change emissions than many countries do (Pang et al., 2013), accounting for up to 8% of all GHG emissions when considering transport, shopping and food production and consumption (Lenzen et al., 2018). Transport is the segment of tourism responsible for the largest contribution to carbon emissions, accounting for more than 50% of cumulative tourism outputs (Dickinson et al., 2011; Pang et al., 2013). Air travel is one of the largest contributors thereof, with rail and sea travel carrying arguably less carbon and environmental impacts (Ehmer & Heymann, 2008). The large role of aviation was reinforced during the COVID-19 pandemic where reductions in air transport saw global decreases of 6% in CO_2 emissions in 2020 (CCSA, 2021).

Given the bi-directional impact observed between tourism and climate change, it is thus in the best interest of tourism to reduce its contribution to climate change to limit potential impacts of climate change on the sector (Scott et al., 2015). Most authors do not suggest that tourism should be stopped all together to achieve this – but rather that the sector needs to acknowledge its contributions and adapt its carbon footprint and business models accordingly (Burns & Bibbings, 2009; Pang et al., 2013). One proposed path to reduce contribution to climate change is to reduce the GHG emissions of the end-to-end tourism chain (Gössling & Scott, 2018), a goal necessitated in context of the Paris Agreement (Becken, 2019) and acknowledged by tourism leaders (Gössling & Scott, 2018). Whether or not decarbonisation and decoupling goals are achievable or can align with tourism sector growth, however, remains unclear (Gössling & Scott, 2018; Becken, 2019). Obstacles preventing decarbonisation can include political and power dynamics that arise through institutionalisation of climate change concerns (Becken, 2019). Investing in carbon emission reduction approaches has proved to be more cost effective than carbon offsetting which bodes well for future liability concerns (Scott et al., 2015). Mitigation measures can include energy use reduction, efficiency increase, the use of renewable energy sources and the increasing of carbon sequestration (Steyn & Spencer, 2012). A narrowing window of opportunity to act on anthropogenic climate change driving behaviours has however recently been noted by the IPCC (2022) making the need to act more urgent than ever before. Mitigation of climate change contributions and adaptation to potential impacts thereof are not mutually exclusive, and concurrent implementation of both approaches has been encouraged in the face of inevitable impacts (Baker, 2011; Dube & Nhamo, 2020).

2.3.4.2. Tourism Resilience and Adaptation

A review of literature focused on tourism adaptation by Njoroge (2015) showed an increase in outputs focusing on adaptation, with themes including business, consumer, policy and destination adaptation emerging. Generally, the need for social and environmental sustainability in tourism to ensure longevity of destinations but also to drive sustainable development and green growth has been noted (Moreno & Becken, 2009; Amusan & Olutola, 2017). This is important as many scholars including Pang et al. (2013) and Lenzen et al. (2018) projected growth for the tourism sector prior to the COVID-19 pandemic, which may continue once influences of the pandemic subside. The growth of tourism, however, comes with emission increase consequences (Lenzen et al., 2018). Technology has been suggested as a solution thereto, however, is being implemented and developed incrementally at a rate potentially inadequate to mitigate harms fully (Gössling et al., 2018; Lenzen et al., 2018; Becken, 2019). Greenwashing has been observed where technology is presented as the solution in contrast to conservation measures, whereby the benefits and results of a solution are overstated and overreported (Becken, 2019). Risk management concerns thus perpetuate in the face of climate change, with many questioning the preparedness of destinations for the likely impacts of climate change and extreme weather events (Fitchett et al., 2016a). Infrastructure retrofitting or redesign, review of insurance policies and the changing of land use planning with the inclusion of new risks such as fire management are suggested as potential climate change adaptation approaches for tourism (Dube & Nhamo, 2020). These are important as poor recovery mechanisms and strategies to manage the impacts of extreme events such as floods has been observed (Southon & van der Merwe, 2017). Research on adaptation of the tourism sector is, however, potentially behind where it should be (Pandy, 2017), despite many papers being underpinned by the assumption that tourism will undeniably need to adapt in some manner to account for the impacts of climate change (Burns & Bibbings, 2009). This poor understanding of adaptation measures at an appropriate, context specific scale is worsened by concerns of maladaptation – the implementation of adaptation measures which may increase risk of or exposure to climate change impacts (Magnan et al., 2016; IPCC, 2022). Moreover, adaptive capacity may be low for tourism – especially within developing countries of the Global South – as attractions are often situated in high exposure locations and financial and physical means to adapt are limited, thus leaving South African tourism destinations in potentially highly vulnerable locations and circumstances (Moreno & Becken, 2009; Stockigt et al., 2018; Mushawemhuka et al., 2020). The need for sustainable adaptation has been noted (Njoroge, 2015).

Changing the business model of tourism has been suggested as a measure to encourage sustainable tourism through, for example, the use of tools, infrastructure and behavioural changes (Dube et al., 2020). An example is the 'slow travel' approach which encompasses a broad spectrum of tourists who opt for holiday types and travel mechanisms which are typically lower in carbon emissions and harmful social impacts (Dickinson et al., 2011). The time-use decisions and movement patterns associated with this travel type are typically motivated by a 'quality over quantity' attitude, for example by choosing a road-trip instead of a flight or choosing to visit one destination for a longer time period instead of moving rapidly between multiple destinations (Dickinson et al., 2011). This approach contrasts typical movement patterns of tourists which are often motivated by visiting as many places as possible during a trip (Burns & Bibbings, 2009), with short stays typically having more detrimental impacts socially and environmentally (Jiricka-Purrer et al., 2020). Learning from previous interactions of tourism with climate can be useful (Weir, 2017), for example lessons learnt from the day-zero campaign during the Cape Town drought which helped to reduce water consumption through water wise strategies can be used to prepare for future similar events (Dube et al., 2020). Tourism destinations have been encouraged to diversify their offerings to increase adaptability in response to climate change forcing pressures (Dorgu et al., 2019) as evidence has emerged of tourists enjoying diverse activities, especially when they extend beyond anticipated offerings (Stockigt et al., 2018). The diversified tourist economy of Italy, for example, may make it more resilient to climate change impacts than destinations with only a few offerings (Ehmer & Heymann, 2008). Within an African context, South Africa has been flagged as more heterogenous and offering multiple non-climatic dependent tourism products, thus potentially faring better under climate change scenarios than other African countries such as Kenya or Tanzania (Ehmer & Heymann, 2008).

A mechanism suggested to fund adaptation – particularly for developing countries which may lack the resources to fund adaptation – is to implement regulatory measures such as a fee, tax or levy for tourists (Baker, 2011; Dube & Nhamo, 2020). Suggestions are that a scaled US$11 amount per tourist per trip both domestically and internationally would be sufficient to meet costs of target emission reductions (Scott et al., 2015). Fees at destinations have however been suggested as a deterrent factor for travel and thus may have unintended implications on tourist flows (Scott et al., 2015). Implementing regulatory measures onto flight costs, such as the proposed International Air Passenger Adaptation Levy, may however be more viable due to the notoriously low-price elasticity of airline tickets whereby price fluctuations have not been observed to notably impact demand for flights (Baker, 2011). An alternative adaptation financing model is utilising the green climate fund (Davis-Reddy & Vincent, 2017).

The use of mixed-method approaches – although potentially more time and cost intensive – may add value to the findings of sustainable tourism research and assist in understanding the complexities of the dynamic system (Molina & Font, 2016). Tourists, the consumers of tourism, have demonstrated demand and willingness to pay for ethical tourism which moves beyond merely avoiding damage created as a result of tourism towards creating net positive benefit from tourism on environments and communities (Burns & Bibbings, 2009). Some scholars have argued that "sustainable" tourism is an insufficient approach and description as it implies theoretical, conceptual and values-based thinking instead of applied and actionable behaviour as described by "responsible" tourism (Mihalic, 2016). To counter this, Mihalic (2016) proposes the use of the "responsustable" tourism model which comprises expansion beyond current awareness only phase to the development of agendas and plans to drive the final phase of action.

2.3.5. Climate-Tourism Policy

2.3.5.1. Overview

The question of how to manage global tourism in the face of climate change is a long-standing concern (Burns & Bibbings, 2009; Rutty et al., 2020b), emerging as a regional concern for SADC (Davis-Reddy & Vincent, 2017) and a national priority for South Africa (Department of Tourism, 2012; Republic of South Africa 2021b). The complex problems that are brought about because of climate change often require integration with policy which considers both the impacts likely to be experienced by the sector whilst also acknowledging the contribution that tourism makes to global carbon emissions (Hambira & Saarinen, 2015; Becken et al., 2020). Having examined climate change and the complex, bi-directional relationship it has with tourism, the intersection of tourism and climate change in policy will now be explored. This is important as public policy can be both a driver of and mitigator of vulnerability to climate change (Santos-Lacueva et al., 2017).

2.3.5.2. Climate Change Policy

The latest IPCC reports (AR6) represent not only remarkable academic collaboration comprising of 234 scientists from 66 countries who together considered over 14 000 peer-reviewed papers to produce the robust and reliable Physical Science Basis report, but moreover, serves as a monumental political achievement with the collaboration of 195 different countries including South Africa agreeing line-by-line to the Summary for Policymakers (SPM; IPCC, 2021). The strong language used by the IPCC in these latest reports reinforces the definitive nature of findings and shows how certainty has increased since the first assessment report (FAR) where more ambiguous language was used in comparison to vocabulary such as “unequivocal” used in the AR6 (IPCC, 2021). On an international scale the need to limit carbon emissions to fight climate change has been reiterated many times (IPCC, 2021) as is documented in the Paris Climate Agreement, a legally binding treaty which South Africa adopted in 2015 and ratified in 2016 (Republic of South Africa, 2021b). This global commitment is notable as the importance of government buy-in to emissions reduction has been previously noted (Lenzen et al., 2018). International climate change responses may have unintended negative consequences for South African tourism with mitigation centred policies for example potentially impacting tourism demand (Gössling et al., 2012), particularly for long haul destinations such as South Africa (Ehmer & Heymann, 2008). South Africa has highlighted the need for multilateral frameworks to prevent potentially discriminatory taxes disincentivising travel (Department of Tourism, 2011).

South Africa commits to other international agreements such as the United National Sustainable Development Goals and the Sendai Framework for Disaster Risk Reduction (Davis-Reddy & Vincent, 2017). South Africa also aligns to regional climate change agreements such as the SADC Climate Change Strategy and Action Plan (2015) and the SADC Regional Green Economy Strategy (2015) in recognition of the transboundary nature of climate change impacts (Davis-Reddy & Vincent, 2017).

The first communication of Nationally Determined Contributions (NDC) for South Africa in response to the Paris Climate Agreement, last updated in September 2021 as per the 5-year communication requirement, details the latest climate change adaptation and mitigation strategies that the nation commits to and briefly mentions tourism as a sector of focus (Republic of South Africa, 2021b). The second NDC communication is scheduled to be released in 2025 (Republic of South Africa, 2021b). The NDC was not the first climate change policy for South Africa. In 2004 a National Climate Change Response Strategy was produced by the Department of Environmental Affairs and Tourism (2004). As with many other climate change centred works, the document begins by outlining the scientific basis of climate change, international context and key issues of concern, then notes strategies, actions and interventions to be followed for climate change adaptation and mitigation (Department of Environmental Affairs and Tourism, 2004). Despite mentioning the cross-cutting nature of climate change issues and the importance of biodiversity for tourism, the sector is not specifically noted in the listed interventions. The lack of focus on tourism in South Africa’s climate change policies is of concern as the international tourism sector has aimed for a reduction of 70% in emissions by 2050, however, is not on track to meet targets and is projected to surpass global levels threefold (Gössling & Scott, 2018).

2.3.5.3. Tourism and Climate Change Policy

Following 2011, the Department of Tourism became an independent department no longer grouped with environmental affairs. In 2011, the new department released the National Tourism Strategy in an effort to develop the sector (Department of Tourism, 2011). The strategy document noted natural disasters and climate change as a risk factor for sector growth, although the language used can potentially be interpreted as nonchalant, describing natural disasters as a mere “stumbling block for meeting the [growth] targets” (Department of Tourism, 2011: 48) and poor environmental performance framed only as a reputational risk that could deter travellers. In 2011 though, following the establishment of the Tourism and Climate Change Task Team by the Department of Tourism, a draft South African National

Tourism and Climate Change Response Programme and Action Plan was published for public comment and a final version was subsequently released in 2012 (Department of Tourism, 2012). This relatively short, 14-page document focuses on climate change mitigation and adaptation measures centred on resource efficiency including water and energy. This document refers to findings of the first International Conference on Climate Change and Tourism organised by The World Tourism Organisation (UNWTO) held in Tunisia in 2003 which resulted in the Djerba Declaration on Climate Change and Tourism. This declaration highlighted the obligation of the tourism industry to reduce their greenhouse gas emissions and recognised the two-way relationship between tourism and climate change (Department of Tourism, 2012). Another international declaration from which the South African National Tourism and Climate Change Response Programme and Action Plan document stems is the Davos Declaration of 2007 which highlighted the need for action to respond to climate change, provided sustainable tourism policy recommendations and launched a Climate and Tourism Information Exchange Service to enable tourism stakeholder access to research and data (Department of Tourism, 2012). This service has subsequently grown and disseminated technical publications addressing climate change impacts and adaptation responses – the most important of which are "Climate Change and Tourism Responding to Global Challenges" and "Climate Change Adaptation and Mitigation in the Tourism Sector: Frameworks, Tools and Practices" in coordination with the University of Oxford, the World Meteorological Organisation (WMO), and United Nations Environment Programme (UNEP), released in 2008.

The South African National Tourism and Climate Change Response Programme and Action Plan identified the need to improve the understanding of vulnerability to climate change to ensure resilience and adaptive capacity (Department of Tourism, 2012). This approach can be commended as the need to focus on resilience for sustainable tourism to be effective in Africa has been flagged by scholars such as Musavengane et al. (2020). In response to this need to understand vulnerabilities, the Department of Tourism engaged an external group to conduct research on climate change vulnerability for the South African tourism sector. This group went on to produce the "Baseline Assessment: Vulnerability and Impact of Climate Change on Major Tourism Attractions and Activities for South Africa" report (Golder Associates, 2012) and the "Basic Guideline for Vulnerability Assessment for Climate Change and Tourism in South Africa" (Schulze et al., 2012). The baseline assessment identified key attractions and elements thereof which are vulnerable to climate change. Focus attractions included the Cape Winelands and Garden Route, the KwaZulu-Natal Coast, The Maloti-Drakensburg Transfrontier Park, Gauteng, and Wildlife Ecozone game reserves including KNP, Madikwe and Pilanesberg. Research and education are the first steps towards responding to climate change threats to tourism assets and locations and thus the need to better understand these threats is important (Hall et al., 2016), however whether or not the studied assets represent a sufficient proportion of the national tourism sector can be questioned. Abrahams et al. (2018) emphasize the importance of adaptation considering local concerns and priorities rather than a blanket approach and thus one cannot have standardised responses and instead should be assessing vulnerability at appropriate scale and considering context specificities (Kajan & Saarinen, 2013). Workshops focusing on vulnerabilities were conducted with key stakeholders and considered temperature, rainfall changes, sea level rise and carbon emission related pressures to be projected changes of concern (Golder Associates, 2012). These workshops had multiple purposes including creating awareness, understanding stakeholder perspectives, identifying ongoing and upcoming initiatives, and created a platform for discussion (Golder Associates, 2012). To assess risks and guide stakeholder discussions the

Golder Climate Risk Mapping Tool was employed which considers variables such as governance, market factors, economic considerations, health, safety and environment concerns, stakeholders involved, infrastructure and processes in place (Golder Associates, 2012).

The climate change assessment document noted that several cities and municipalities have already conducted climate change vulnerability assessments of their own which do not always explicitly mention tourism but do consider factors upon which tourism is dependant such as infrastructure and biodiversity. The need to allow for and enable local players such as tourism operators to easily assess their vulnerability to climate change resulted in the basic assessment guideline release. The guideline focuses on services and energy, human health, food security, water resources and agriculture, business continuity, biodiversity and culture and is structured as a simple question response tally approach which highlights areas of concern contributing most to vulnerability of the subject (Schulze et al., 2012). The guideline encourages those who have conducted the basic initial assessment to develop a simple action plan to reduce vulnerabilities based on assessment results (Schulze et al., 2012). Whether or not users have the skills to be able to do this is unclear and no metrics are available to assess the quality of output plans. These assessments are 10 years old and thus also may be outdated, necessitating a reconsideration of climate change vulnerability for tourism.

2.3.5.4. Tourism Policy and Management

The Department of Tourism has released a new sector strategy document replacing the 2011 version (Department of Tourism, 2017). This document, although noting the increasing interest in green, sustainable, responsible, and ethical tourism, does not make direct mention of climate change – focusing instead on GDP, jobs, investments, tourist arrivals and trips. The five pillars of action include Marketing, Ease of Access, Visitor Experience, Destination Management and Broad-Based Benefits. Interestingly, the document does mention some of the key climate change vulnerability indicators as suggested by the CVIT, such as crime as a deterrent for visitors and the importance of diversification of offerings (Scott et al., 2019), however these are not discussed with reference to climate change. The need for a scaled approach to tourism management is once again noted, focusing on national, provincial, regional, and local concerns (Department of Tourism, 2017). Effective tourism planning is required to ensure that funds from tourism flow into local economies and broader society (Sifilo & Henema, 2017). A recurrent trend found within tourism policy, which aligns to the stakeholder perceptions discussed earlier, is that climate change is often viewed as a long-term concern and thus deemed less important than more current issues. Examples of this include recovery from the economic crisis of 2008 (Department of Tourism, 2011), Broad-Based Black Economic Empowerment (BBBEE) concerns (Department of Tourism, 2021b) or COVID-19 pandemic implication recovery (Department of Tourism, 2020b). The UNWTO encourages using crises as an opportunity to grow back better by developing green jobs and responding effectively to climate change (Department of Tourism, 2011).

There are several key current policies which underpin the South African tourism sector environmental management approach. The Tourism Environmental Implementation Plan (TEIP, Department of Tourism, 2021a) brings together the policy and legislation documents to date, beginning with the role of the White Paper on Tourism Development and Promotion in South Africa released in 1996 which was the first South African policy focused on responsible tourism. Responsible tourism encompasses a tourism management strategy centred on environmental protection and conservation, an appreciation and respect for local cultural practices and a focus on economic growth and quality of life for surrounding communities (Department of Tourism, 2021a). There has been a recurring focus on responsible tourism since the 1996 White Paper, including the release of the National Responsible Tourism Guidelines in 2002 and the introduction of a sustainability certification scheme in 2011 called the South African National Minimum Standard for Responsible Tourism (SANS 1162:2011; Department of Tourism, 2021a). There is acknowledgement in the TEIP of the contribution of the tourism sector to general environmental challenges and climate change with specific emphasis on persistent and degradable waste, greenhouse gases, pollution and reversible and irreversible environmental degradation (Department of Tourism, 2021a). Incentives exist in South Africa to encourage sustainable practices within the tourism sector – such as the Tourism Incentive Programme (TIP) which includes a Green Tourism Incentive Plan focused on waste, energy efficiency and pollution (Department of Tourism, 2021a).

There are mechanisms that have been put in place to plan, measure and monitor performance of the tourism sector nationally on a regular basis including annual performance plans and reports. Progress of the TIP for example was reported in the 2018-2019 Annual Report and showed that energy and water retrofitting projects were underway whilst also quantifying the funding acquired through the Industrial Development Corporation (IDC) to fund the initiative (Department of Tourism, 2019). The 2020/21 – 2024/25 strategic plan outlined the tactical plan for the sector including the vision for inclusive and sustainable tourism growth which focuses on governance, collaboration, communication and knowledge management, whilst recognising climate change and natural disasters as key risks to be mitigated (Department of Tourism 2020a). The 2020/21 – 2022/23 Annual Performance Plan focuses on four programmes: Corporate Management; Tourism, Research, Policy and International Relations; Destination Development; and Tourism Sector Support Services (Department of Tourism, 2020b). The subsequent Annual Performance Plan (2021/22 – 2023/24) noted that the TEIP would be reviewed and that a climate change adaptation report would be finalised soon (Department of Tourism, 2021b). More casual communications are also frequently released to the sector, including a newsletter-style communique named the Bojanala which in 2021 focused on COVID-19, international, cultural, youth and women concerns (Department of Tourism, 2021c). Climate change is only briefly mentioned in a quote from the North West Member of the Executive Committee (MEC) Kenetswe Mosenogi who flagged waste management and air quality as current issues of concern. Sustainable operations and management were briefly mentioned when highlighting Blue Flag beaches.

Two current legislative frameworks underly South African tourism practices, including the Tourism Act (Act No. 3 of 2014) and the National Environmental Management Act (Act No. 107 of 1998) (Department of Tourism, 2021a), although other sector legislations relating to energy, industry, waste and transport would also impact tourism operations with city planning for example potentially having overlapping goals and priorities (Jiricka-Purrer et al., 2020). There is currently the Climate Change Bill (Bill 9 of 2022) being tabled in parliament with the aim “to enable the development of an effective climate change response and a long-term, just transition to a low-carbon and climate-resilient economy and society for South Africa in the context of sustainable development” (Republic of South Africa, 2021: 2). Globally, sector and destination level management strategies are often determined by national policies

(Hall et al., 2016). This is true in a South African context whereby all departments listed in Schedule 2 under the proposed act would be required to develop sector level adaptation strategies – however tourism is not noted in this schedule despite tourism stakeholders having been consulted during the drafting of the legislation. This is not necessarily of concern as the decision to either integrate tourism with existing policies or develop entirely new mitigation and adaptation policies for the sector is a choice that countries need to make (Hambira & Saarinen, 2015), and South Africa has clearly already begun to establish sector specific policies for tourism and climate change (Department of Tourism, 2012). These policy developments are promising as a global policy review conducted by Becken et al. (2020) showed that South Africa is one of only a handful of countries to have policy documents directly addressing the intersection of climate change and tourism.

2.3.5.5. Policy Concerns

There is no clear best-practise strategy which should be employed to combat climate change for tourism through policy (Scott et al., 2015). The unclear timelines along with uncertainties about the role of governance structures compounds the observed ambiguity (Gössling & Scott, 2018). There are however a few considerations that can ensure better policy is developed. Globally, for example, there is an academic, practical and political knowledge mismatch observed across media types (Loehr, 2021). The need to collaborate with members of industry, academia and local communities in the development of policy has thus been flagged to ensure successful and comprehensive policy is produced (Burns & Bibbings, 2009; Musavengane et al., 2020; Rutty et al., 2020b). The need for communication with and upskilling of various tourism and external stakeholders has also been noted, along with the need to clarify roles and responsibilities (Rogerson, 2016; Gössling & Scott, 2018). South African policy does occasionally do this, for example in the TEIP a responsibility assignment matric is presented which at a high level demonstrates the responsibilities of departments and other role players, and notes the need to consult and inform local communities and tourism stakeholders, however the detail provided and communication of responsibilities to relevant parties may be insufficient.

Having relevant and comprehensive policies and legislation is important to manage sustainable tourism – but the implementation and enforcement thereof is even more critical as policies are only as effective as associated governance (Pandy & Rogerson, 2018; Musavengane et al., 2020). Concerns surrounding potentially poor implementation of policies resulting in a policy-practise mismatch in a South African context have been noted (Pandy & Rogerson, 2018; Musavengane et al., 2020). An example of this was considered by Masipa (2017) in exploring food security threats due to climate change who flagged the concern of weak governance institutions and limited technology access in South Africa in contrast to international counterparts. These implementation concerns are worrying as physical measures are required to adapt to changing weather and climatic conditions (Aylen et al., 2014), and thus having unactioned policies is useless. The implementation of policies can be limited by not only willingness to act but also financial and capacity constraints of stakeholders and thus the need for proper tourism planning strategies has been noted (Rogerson, 2016; Musavengane et al., 2020). The cost of adaptation in contrast to financial and education support offered by governments thus needs to be analysed (Masipa et al., 2017), especially because municipalities are often disproportionately funded and thus some are poorly resourced, limiting their adaptive capacity (Rogerson, 2016). Access to relevant policies and academic resources is also of concern as many global respondents historically have not been aware of research being undertaken to connect climate change and tourism (Wall & Badke, 1994), and despite being available on the Department of Tourism of South Africa website, whether or not stakeholders know to look for this research n the first place is unclear.

2.4. Conclusion

This chapter began by providing an overview of general climate change projections and impacts. In doing so, the importance of measuring and assessing vulnerability to inform mitigation and adaptation measures was reinforced along with the heterogenous nature of climate change impacts requiring investigation and understanding at local scale. Southern Africa and the tourism sector were both identified as being understudied, despite being particularly vulnerable to the impacts of climate change. The literature review then went on to establish the strong linkages between tourism and climate through the lens of tourists and destinations. In doing so, the importance of understanding currently observed and future projected impacts of climate change on tourism at a scale appropriate for action was reinforced. The manifestation of tourism and climate change, together and independently, in policy was then outlined. The need to quantify the CVIT for South African locations is thus great as identifying risks and vulnerabilities allows stakeholders to strategically plan and make decisions on viable options and thus potentially adapt to and better manage climate change impacts (Craig & Feng, 2018; Kilungu et al., 2019). Vulnerability studies have been shown to have far reaching implications for businesses, consumers, destinations, policies and management frameworks (Kajan & Saarinen, 2013), ultimately improving sustainable tourism

(Moreno & Becken, 2009). This project is in line with the need for regional and sector specific vulnerability studies (Weber et al., 2018).

CHAPTER 3 - STUDY REGION

3.1. Introduction

This study explores local scale climate change vulnerability for the South African tourism sector by calculating the CVIT for 18 locations. This chapter will begin by providing an overview of the demographic, geographical, climatic and ecological context of South Africa. Thereafter, the South African tourism sector is explored including the history of tourism and main tourism categories on offer in the country. Finally, this chapter will introduce and examine the study sites of focus, including justification for final study site selection.

3.2. Overview

The Republic of South Africa is situated, as its name suggests, at the southern tip of the African continent, lying between 22-35^{o}S and 17-33^{o}E (figure 3) and has an area of 1,220,813 km^2 (GCIS, 2020). The country is comprised of nine provinces and the Tropic of Capricorn intersects the north-eastern part of the country through the Limpopo province (figure 3). South Africa has three capital cities, Cape Town (legislative), Bloemfontein (judicial) and Pretoria (administrative), with the Constitutional Court located in Johannesburg (GCIS, 2020). Forming part of the Southern African Development Community (SADC) region, South Africa's neighbouring countries include Namibia, Botswana, Zimbabwe, Mozambique, Eswatini (formerly Swaziland) and landlocked Lesotho (figure 3). Key sectors and industries contributing to the developing nation's economy include mining, transport, energy, manufacturing, tourism and agriculture (GCIS, 2020). The economic hub of the country is Gauteng, with more than 25% of the country's population residing in the province (GCIS, 2020).

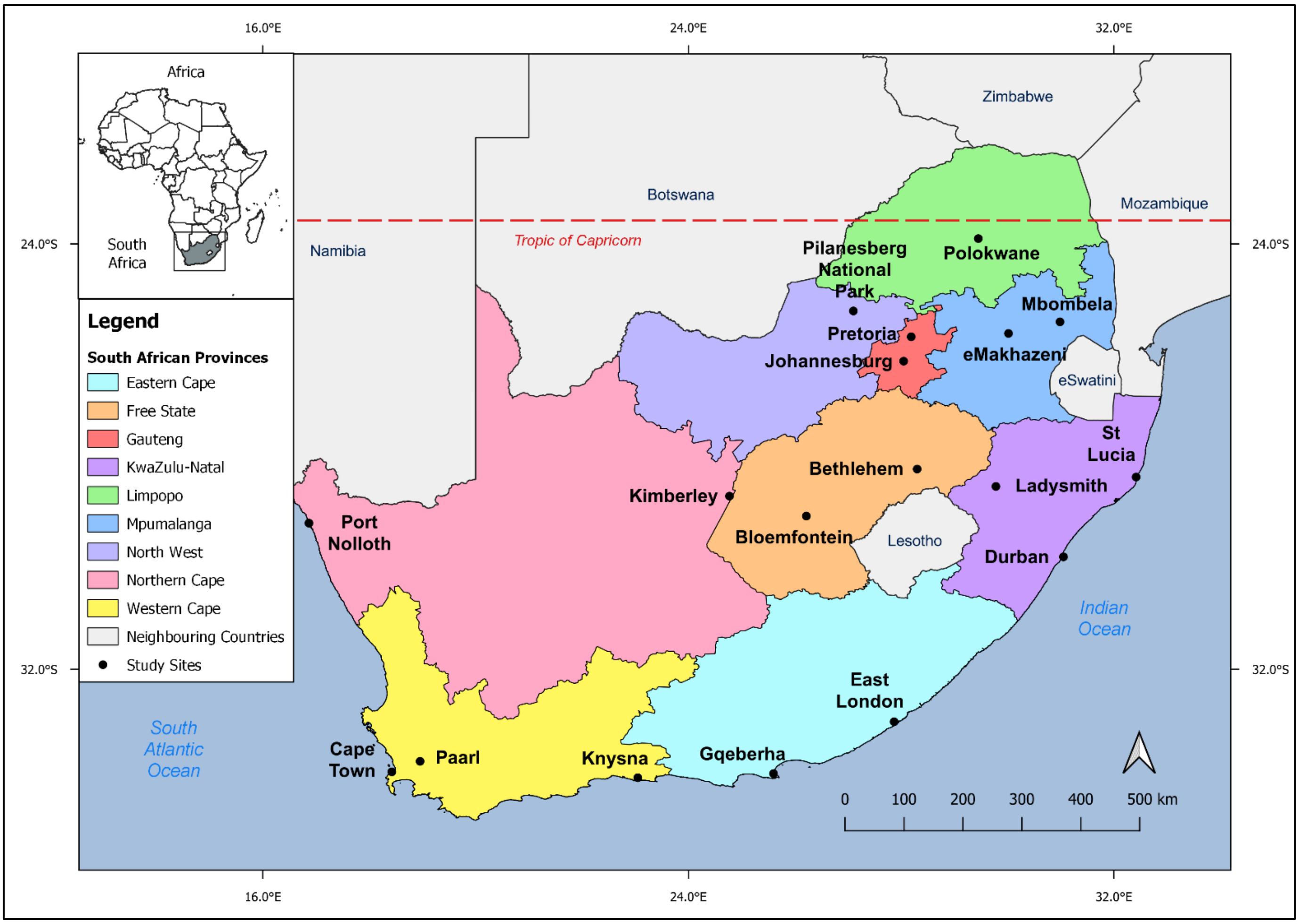


Figure 3. Map of South Africa, including selected study sites and neighbouring countries.

3.2.1. Population and Demographics

South Africa has a population of 59.62 million people and is often described as the "rainbow nation" owing to its diverse cultural, racial and religious composition. The country has 11 official languages and most South Africans are multilingual and able to speak at least two or more languages (GCIS, 2020). Extreme poverty and unemployment are rampant throughout the country, with latest statistics estimating a 34.5% national unemployment rate and a shocking 63.9% unemployment rate for those aged between 15 and 24 (StatsSA, 2022). The country is often recognised as one of the most economically unequal nations in the world.

Many attribute South Africa's modern socioeconomic context to the legacies of the apartheid regime, which despite having been replaced by democracy with the election of Nelson Mandela in 1994, continues to bear its mark on the structure of society (Mtapuri & Tinarwo, 2021). South Africa is often recognised for having one of the best constitutions globally, but simultaneously struggles with issues of poor governance, prevalent corruption and high violent crime rates (Linda & Nzama, 2020).

3.2.2. Geography

South Africa has a unique and diverse geographic landscape. A prominent, continuous relief feature defining the country is the great escarpment which surrounds the central plateau and separates the central interior from coastal regions (Knight & Rogerson, 2019). Elevation within the country ranges from sea-level to 3,482m.asl in the KwaZulu-Natal Drakensberg Mountain range (figure 4). South Africa has a long coastline, spanning more than 3, 000km (GCIS, 2020). The South Atlantic Ocean with the cold, north flowing Benguela Current borders the western coastline from Cape Agulhas to the Namibian border, whilst the Indian Ocean and warm, south flowing Agulhas Current border the southern and eastern coastline of the country to the Mozambiquan border (Allison et al., 2022). South Africa is generally classified as a water scarce country (Dennis & Dennis, 2012) but has several large rivers traversing the country including the Zambezi, Orange, Limpopo and Vaal River systems (figure 4).

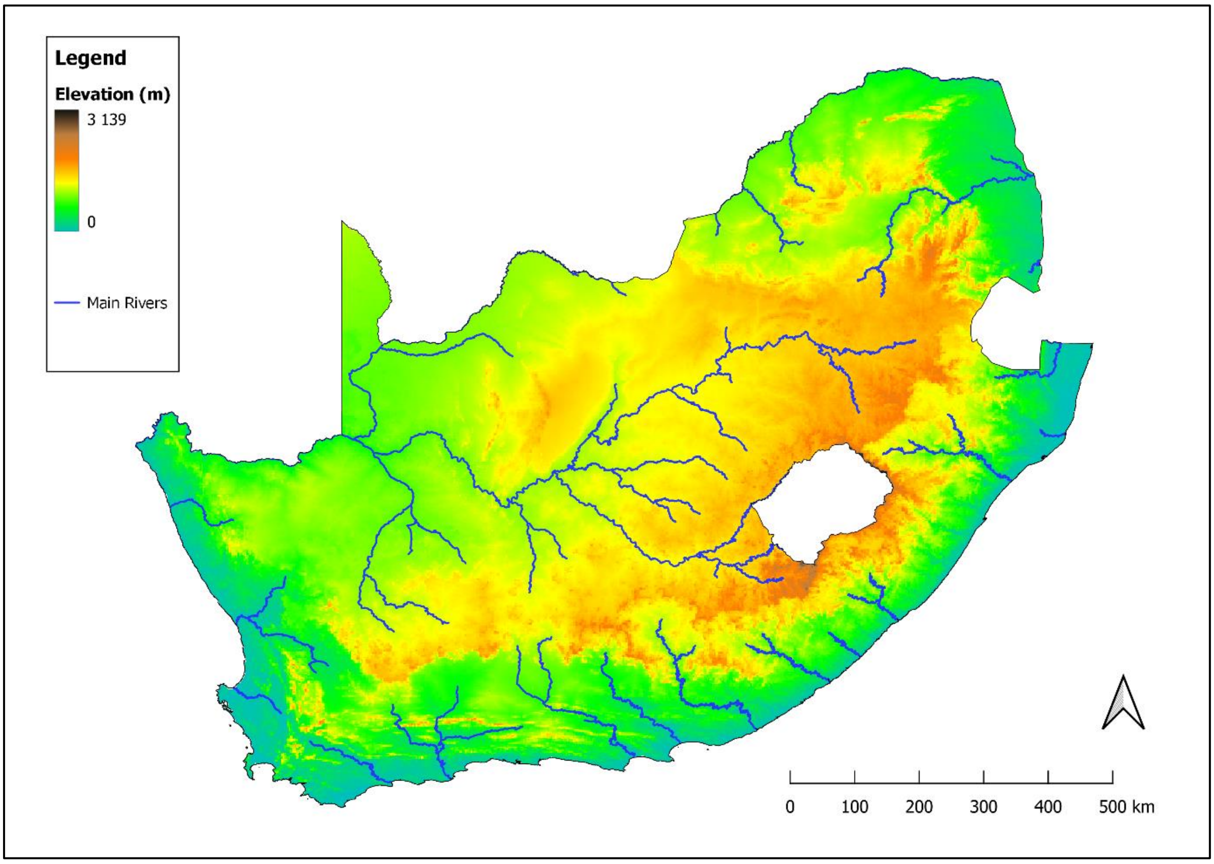


Figure 4. Elevation Map of South Africa including Major Rivers

3.2.3. Climate

South Africa can broadly be described as having a sub-tropical and temperate climate (SAWS, 2017). The geographic landscape of South Africa and proximity to ocean bodies are both major drivers of the observed long-term climate and short-term weather patterns (Dennis & Dennis, 2012). The country is recognised as having an ideal climate suitable for tourism year-round (Fitchett et al., 2017). South Africa does experience extreme weather events including flooding, storm surges and cyclones (Davis-Reddy & Hilgart, 2021).

Average annual daytime temperatures for South Africa range between 9.57^{o}C and 24.55^{o}C, with higher temperatures found towards the northern and eastern parts of the country.

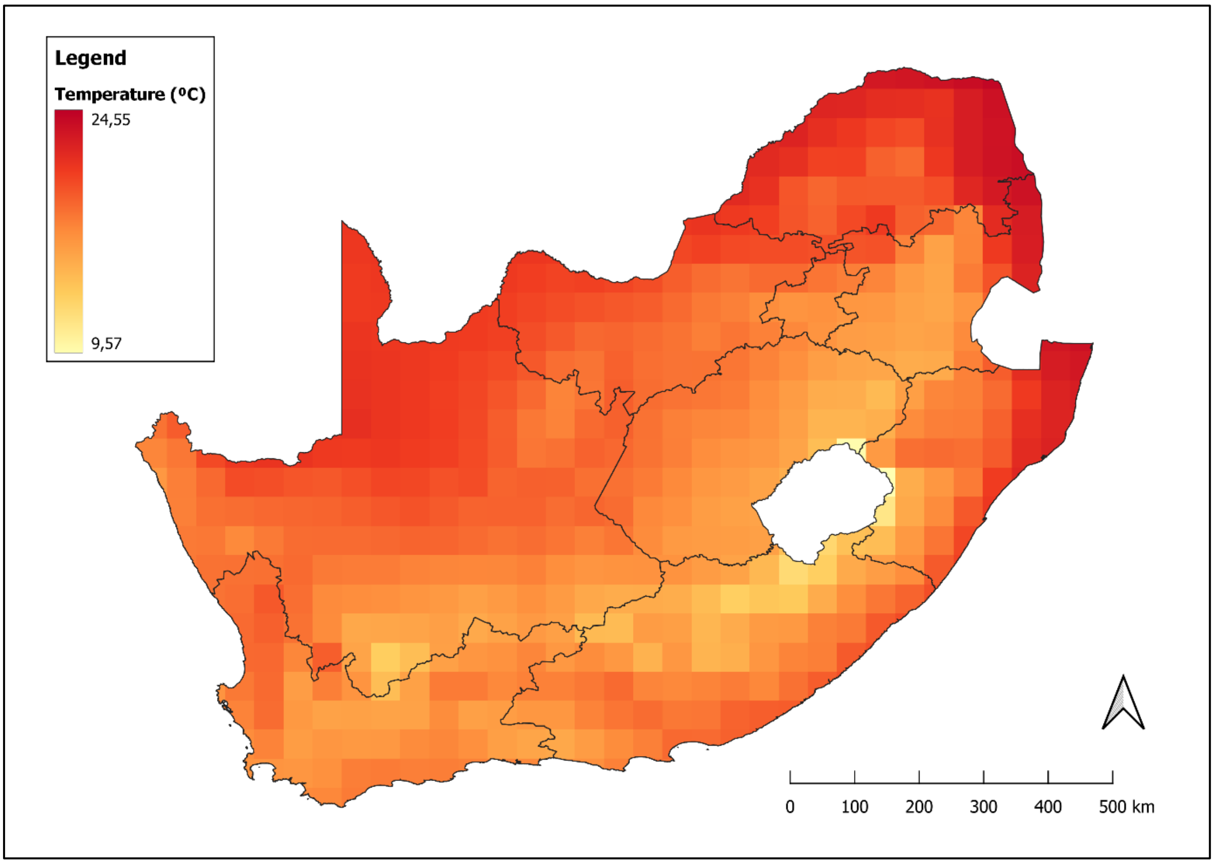


Figure 5. Mean Annual Temperature for South Africa (1901 – 2022) (using data from World Bank Group, 2022)

Average annual precipitation volumes are also heterogenous across the country and range between 35-1128 mm (figure 6). Greater rainfall volumes are typically found along coastlines and the eastern parts of the country. Approximately half of the country is classified as arid or semi-arid, with aridity increasing towards central and western parts of South Africa (figure 6). The generally low rainfall volumes are often attractive to tourists seeking outdoor recreation and has resulted in South Africa being marketed as "sunny South Africa" (SA Tourism, 2022).

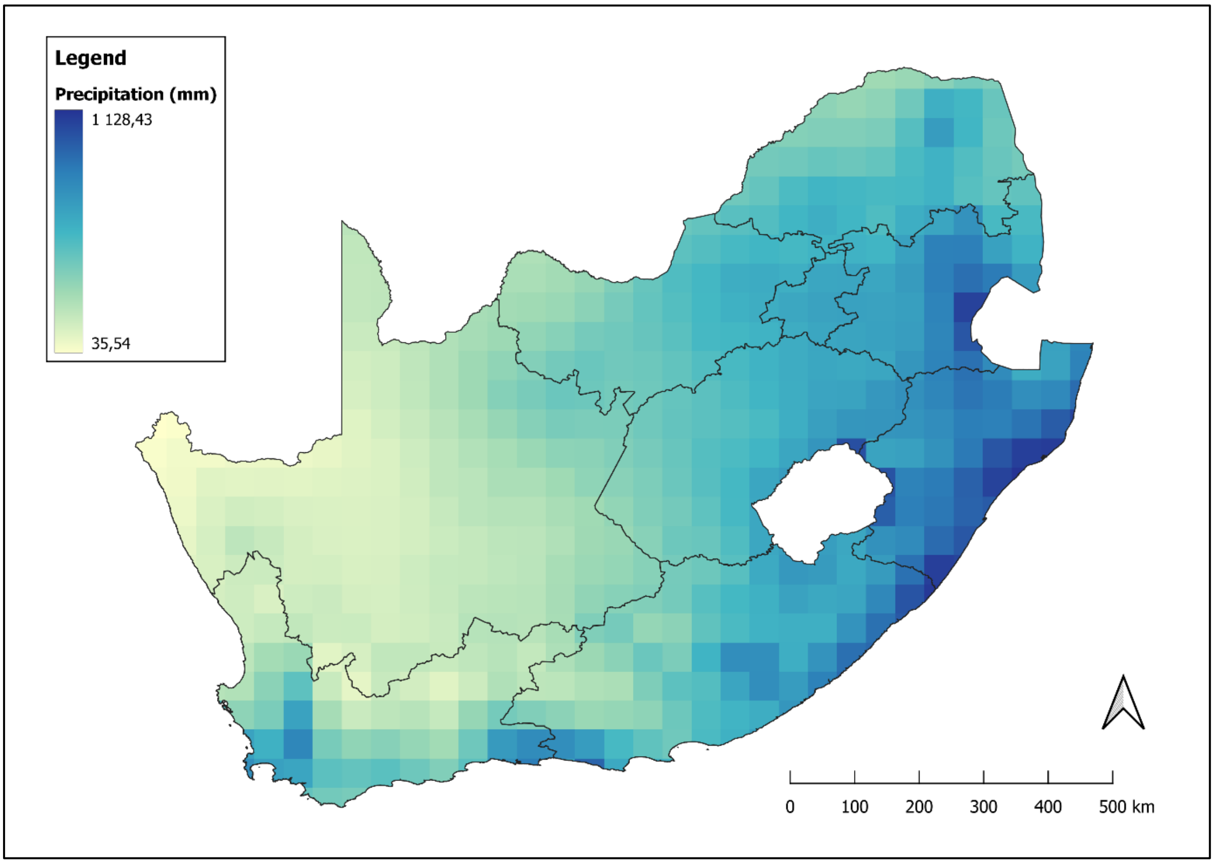


Figure 6. Mean Annual Precipitation (mm) for South Africa (1901 – 2021) (using data from World Bank Group, 2022)

Beyond spatial heterogeneity, the climatology of South Africa is too subject to significant interannual and intra annual variation. The cumulative annual rainfall for the country has historically ranged between a low of 318.82mm in 1992 and a high of 686.36mm in 1976 (figure 7), with long term trends showing cycles of wetter and drier years. Marked seasonality in precipitation patterns too exists in a South African context, with southwestern regions of the country typically experiencing winter rainfall, and central, northern and eastern regions more often being classified as summer rainfall zones (MacKellar et al., 2014). The delineation between these rainfall zones is a topic of academic contention, with the classification approach and datasets chosen yielding different results (Roffe et al., 2019).

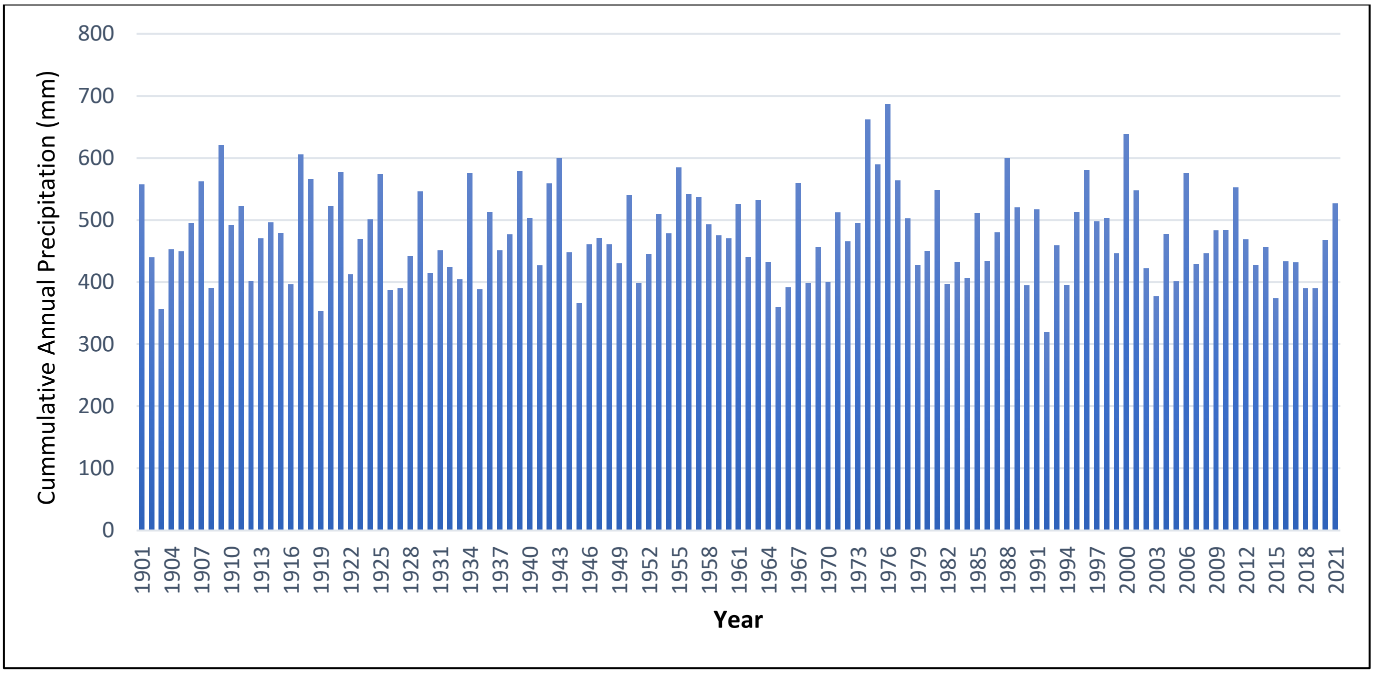


Figure 7. Cumulative Annual Rainfall (mm) for South Africa (1901 – 2021) (using data from World Bank Group, 2022)

Intra annual variation in average temperature and precipitations patterns for the country can too be observed, with June, July and August typically being the coldest winter months, and December, January and February accounting for the warmest summer months (figure 8). The large diurnal temperature range between the average minimum and average maximum temperatures in each month of the year reinforces the temporal heterogeneity of South Africa's climatic patterns.

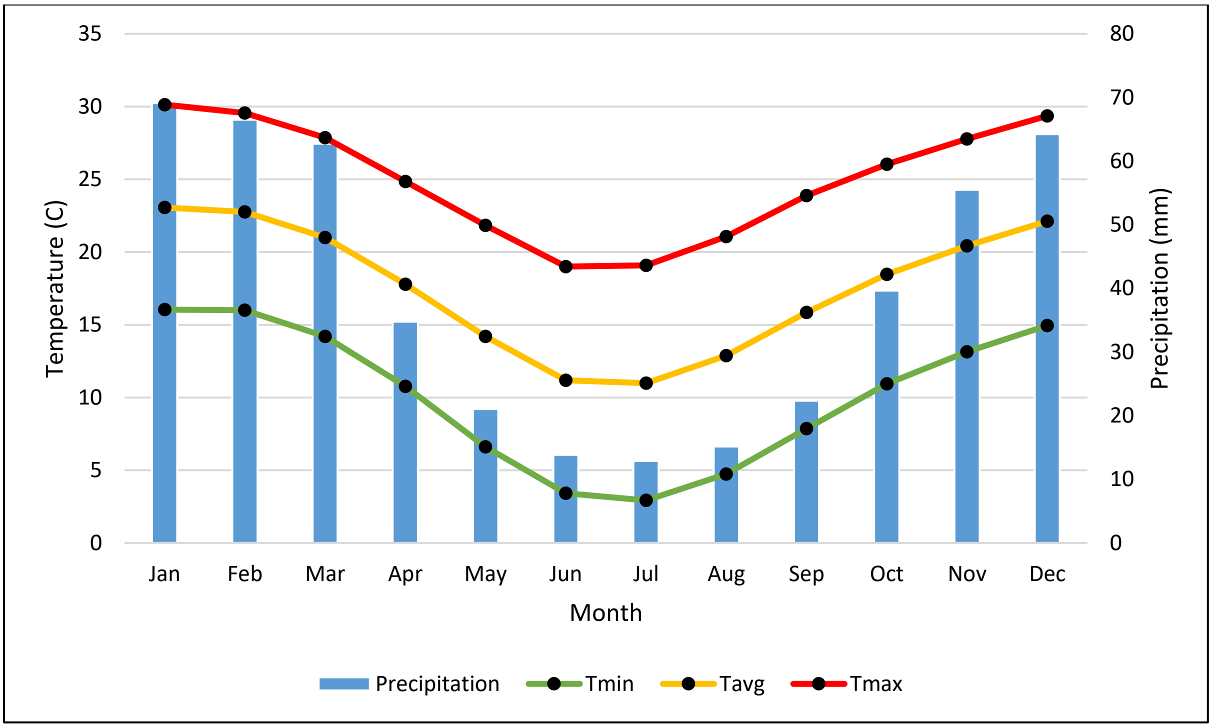


Figure 8. Monthly Average Climate Measurements for South Africa including precipitation, average temperature, minimum temperature and maximum temperature. (1901 – 2021) (using data from World Bank Group, 2022)

3.2.4. Flora and Fauna

Given the notable geographical and climatological heterogeneity observed within South Africa, it is unsurprising to discover that the country is characterised by high floral and faunal diversity (Abrahams et al., 2018). Ten key vegetation classifications are distributed across the country (SANBI-GIS, 2018). The savanna biome appears across the northern and eastern parts of the country, whilst grassland ecosystems dominate the eastern interior (figure 9). The Succulent Karoo and Nama-Karoo biomes coincide with regions of lower average annual precipitation in the western parts of the country (figure 9). The Cape region is home to a unique and endemic Floral Kingdom known as Fynbos (figure 9), which has been flagged as particularly sensitive to the impacts of climate change (Dzikiti et al., 2014).

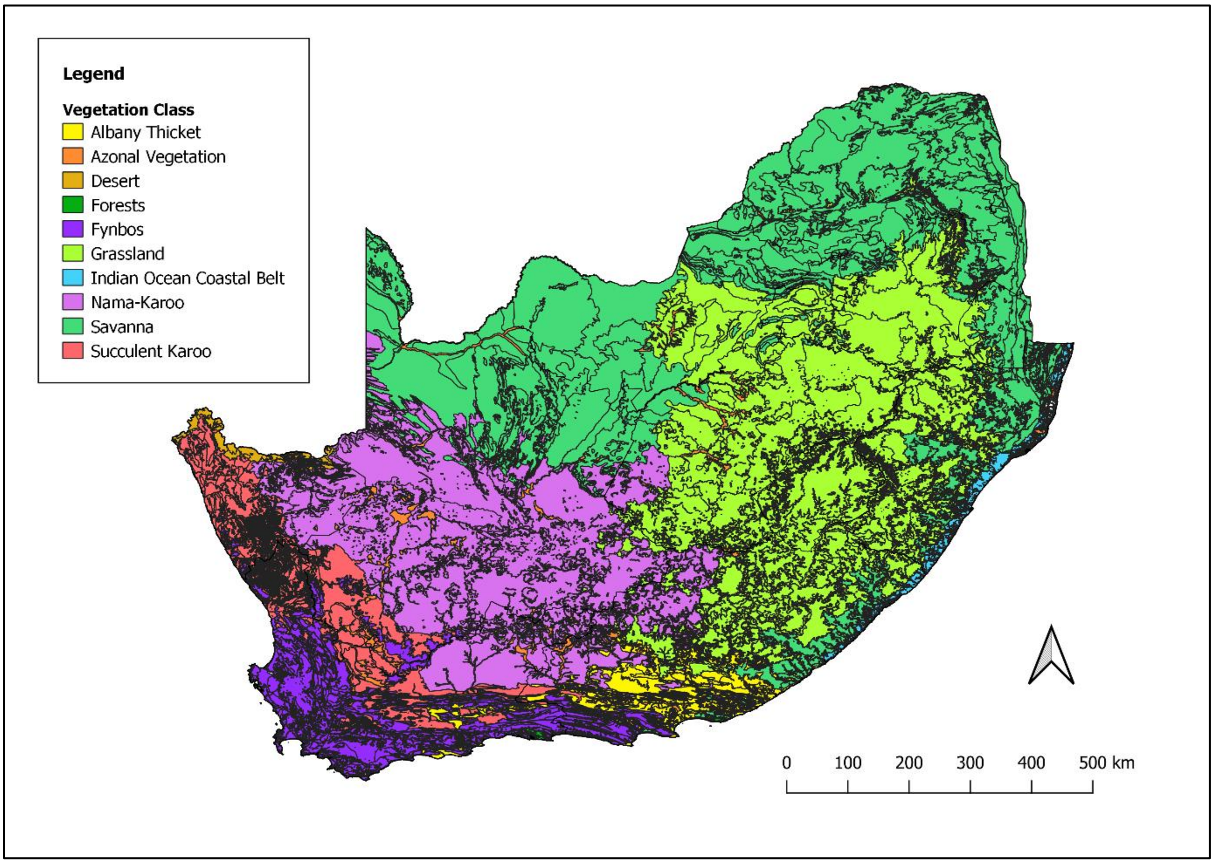


Figure 9. Biomes of South Africa (using data from SANBI-GIS, 2018)

3.3. South African Tourism

3.3.1. Overview

The South African tourism sector is an important contributor to the country's economy, accounting for R120 billion in inbound tourism expenditure in 2018, 2.7% of overall GDP and directly employing over 600,000 people (StatsSA, 2021). The tourism sector of South Africa can be divided into different categories including nature-based tourism, cultural and heritage tourism, golf tourism, business tourism, cruise tourism, and beach tourism (Pandy & Rogerson, 2018), of which each study location has a unique mix. The sector is appealing to both domestic and international tourists based on key attributes including a wide variety of activities to partake in and unique geographic features (Du Plessis et al., 2015; Grünewald et al. 2016), including Table Mountain, one of the New seven Wonders of Nature and the Kruger National Park, home to the "Big 5". South Africa is home to eight United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Sites (figure 10; DEA, 2022) and many National Parks designated for the protection and conservation of unique ecosystems (Smith & Fitchett, 2020).

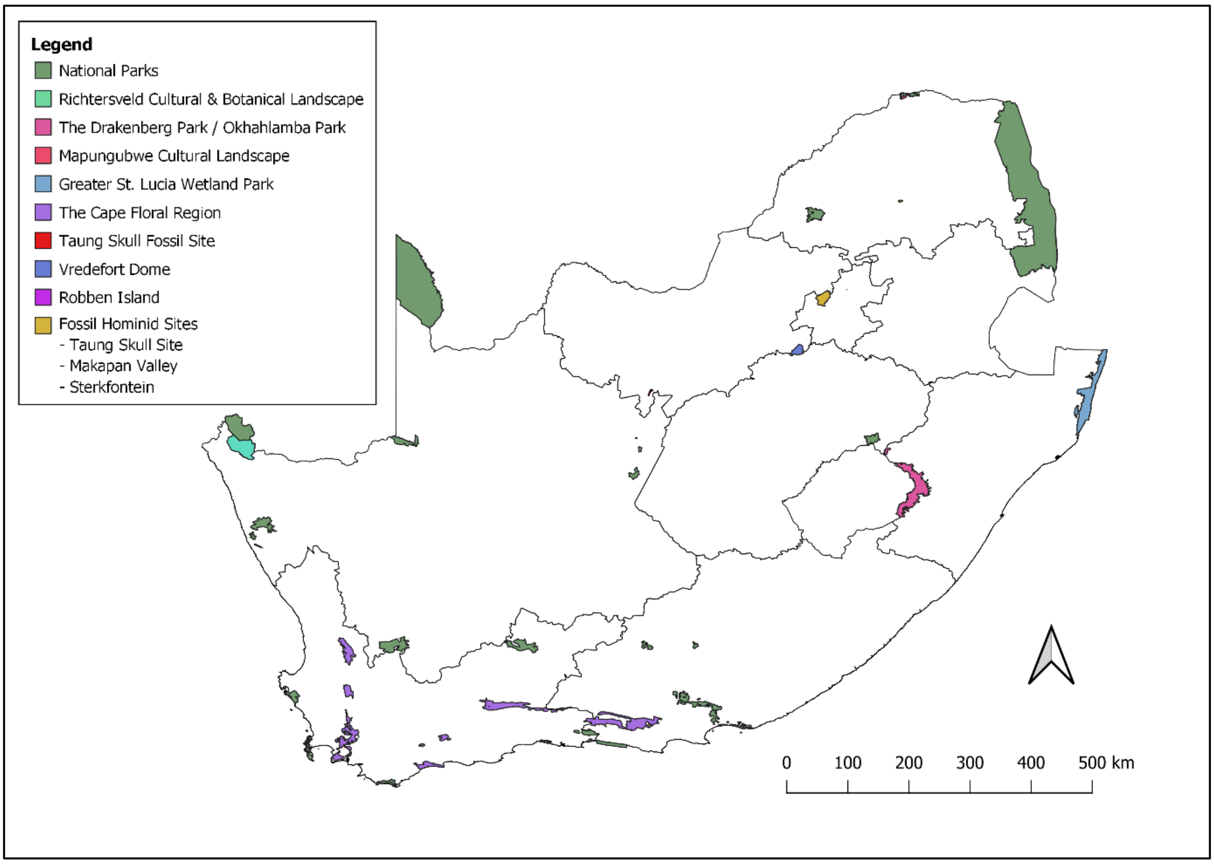


Figure 10. UNESCO World Heritage Sites and National Parks of South Africa (using data from DEA, 2022)

3.3.2. History

It has been 27 years since the end of Apartheid, but current day realities for the tourism sector are still inherently political and tied to history such as colonisation (Scheyvens & Hughes, 2019; Rogerson & Baum, 2020). Following the end of Apartheid, South Africa saw a massive rush in tourism and the sector has continued to thrive since. In 2010 South Africa had the privilege of hosting the FIFA World Cup, which saw an increase in tourism (George & Swart, 2012; Giampiccoli et al., 2015). More recently, there have been negative portrayals of South Africa by international media outlets including issues of political instability and looting and riot events which harm the international perceptions of South Africa (Harding, 2021).

3.3.3. Tourism Categories

South Africa has an incredibly diverse tourism offering and is made up of a diverse mix of tourism categories. These include nature-based tourism, beach tourism, heritage tourism, adventure tourism and business tourism to name a few. Figures 11 demonstrate a few of the wide variety of offerings available, including game drives (A), yachting (B), shopping (C), hot air ballooning (D), water sports (E) and cultural experiences (F). Other smaller segments of the tourism sector include niche tourism such as trail running (McKay et al., 2019) or beer tourism (Rogerson & Collins, 2015).

Figure 11. Examples of the diverse tourism offerings of South Africa including A) Tourists on a game drive in the Kruger National Park with the endangered White Rhinoceros (SA Tourism, 2018); B) Tourists on a yacht in Cape Town with Table Mountain in the background (SA Tourism, 2018); C) Timelapse of Sandton City at Night (Sandton Tourism Association, 2022); D) Hot air ballooning in Bethlehem (South Africa Info, 2022); E) Aerial view of the Knysna lagoon with Thesen Island in the foreground (Estate Living, 2017) and F) Ndebele cultural village in Groblersdal, Mpumalanga (SA Tourism, 2018)

3.4. Study Site Selection and Justification

Deciding on study sites for this project which downscaled the CVIT required careful consideration of the South African tourism landscape as picking too few study sites or study sites which were not adequately representative of the tourism sector would have led to inconclusive and incomprehensive results (Scott et al., 2019). The vast variety of destinations within South Africa includes some very popular sites which are important for the arrival of tourists to the country generally (Dube et al., 2020), whilst other destinations are less popular and less frequently visited (Rogerson 2017). To guide selection, previous country level studies of multiple study sites in South Africa were explored. The final selected study locations (table 1) were used as primary study sites when quantifying climate suitability for tourism in South Africa using the TCI (Fitchett et al., 2017). They were selected by Fitchett et al. (2017) to ensure that the sample was representative of most key tourism categories and destinations within South Africa and that the sample accounted for a balance between inland and coastal sites. Because the TCI is one of the key indicators used in the CVIT, the study sites used by Fitchett et al. (2017) were therefore suitable for application in this study. Additional checks were undertaken to ensure that the study sites were relatively evenly distributed between South Africa's provinces and that following data scoping, data availability was comprehensive for the selected sites for most of the 27 indicators in the CVIT. These study sites represent a diverse mix of climatic conditions determined by local geographic and meteorological drivers (table 1). Cities within neighbouring countries, including landlocked Lesotho and neighbouring Zimbabwe, represent promising locations for similar studies in the future but are not considered in this study as the tourism sectors of these sovereign nations had different CVIT scores in the country level CVIT assessment undertaken by Scott et al. (2019).

Table 1. Locations selected as study sites for this study including key local tourism drivers/attractions

Location	Latitude	Longitude	Annual Mean Temperature (°C)	Annual Mean Rainfall (mm)	Key Tourist Drivers/Attractions
Bethlehem	28.2333° S	28.3000° E	14.4	693	Hot Air Ballooning, National Heritage Sites
Bloemfontein	29.1167° S	26.2167° E	16.1	407	Game Viewing, Historical
Cape Town	33.9253° S	18.4239° E	16.9	853	Beach, Table Mountain, Wine Farms
Durban	29.8833° S	31.0500° E	20.9	975	Beaches, uShaka Marine World
East London	32.9833° S	27.8667° E	18.2	593	Beaches, Game Viewing
eMakhazeni *(Belfast)*	25.6833° S	30.0167° E	13.2	835	Fishing; Game Viewing, Historical
Gqeberha *(Port Elizabeth)*	33.9581° S	25.6000° E	17.4	453	Beaches, Historical
Johannesburg	26.2044° S	28.0456° E	16	543	Cradle of Humankind, Historical, Shopping
Kimberley	28.7419° S	24.7719° E	18	283	The Big Hole, Historical
Knysna	34.0356° S	23.0489° E	17	779	Estuary, Garden Route
Ladysmith	29.5597° S	29.7806° E	18.3	740	Historical, Drakensberg Mountains
Mbombela *(Nelspruit)*	25.4658° S	30.9853° E	19.8	796	Game Viewing, Kruger National Park
Paarl	33.7274° S	18.9558° E	17.6	770	Cultural, Historical, Wine Farms
Pilanesberg National Park	25.2611° S	27.1008° E	19.5	500	Game Viewing, Bird Watching
Polokwane	23.9000° S	29.4500° E	17.3	598	Culture, Game Viewing
Port Nolloth	29.2500° S	16.8667° E	14.7	72	Beach, Culture, Namaqualand Daisies
Pretoria	25.7461° S	28.1881° E	17.3	517	Cultural, Historical, Union Buildings
St Lucia	28.3833° S	32.4167° E	21.6	1129	Game Viewing, iSimangaliso Wetland Park

3.5. Conclusion

South Africa is characterised by considerable heterogeneity in climatological, demographic, geographic and ecological variables which in turn results in a diversified tourism economy with a large mix of offerings. South Africa therefore represents an ideal destination for local scale application of the CVIT as variation in multidisciplinary variables across the country could be hypothesised to result in differing vulnerability levels and drivers at different locations. The selected study sites represent a diverse range of tourism destinations that are representative of the majority of available South African tourism categories and are distributed across the country.

CHAPTER 4 – METHODOLOGY

4.1. Overview

This study undertakes a quantitative analysis to examine local scale differential climate change vulnerability of the South African tourism sector by downscaling the CVIT for 18 locations. This chapter will begin by describing the development of the CVIT then explains the composition of the index and criteria for indicators to be included. Thereafter, a detailed explanation of the various approaches to how the CVIT can be calculated is provided, along with methodology used to investigate and interpret output scores.

4.2. CVIT Development

This section begins with an overview of the processes followed by Scott et al. (2019) to develop the CVIT and contextualise the need for the compositive index. Tourism is one of only a few sectors that will be affected by all ten types of climate change impacts (Mora at al., 2018) and therefore understanding vulnerability in this context is of utmost importance, particularly for Africa where climate change impacts are poorly understood (Scott et al., 2016). Vulnerability, however, cannot be directly observed or measured and therefore needs to be constructed using indices (Hinkel, 2011). Most existing vulnerability indices do not explicitly consider tourism or have other notable limitations, thus motivating Scott et al. (2019) to develop a transparent and systematic differential vulnerability assessment methodology using a sectoral framework to address this knowledge gap. The goal of Scott et al. (2019) in developing the CVIT was to be able to identify vulnerability hotspots where further research should be prioritised, as recommended by de Sherbinin et al. (2014), and to identify where resources should be allocated when compared to GDP (Scott et al., 2019). This is necessary as there are often major differences between the projected costs of climate change adaptation and the actual financial resources available (UNEP, 2017), in which case resources should be allocated to regions found to be most vulnerable (Wheeler, 2011, de Sherbinin et al., 2019). The global scale CVIT assessment undertaken by Scott et al. (2019), which included 181 countries, found countries with the highest vulnerability to be in Africa, the Middle East, South Asia and Small Island Developing States (SIDS) whilst countries with the lowest vulnerability were found to be in Western and Northern Europe, Central Asia, Canada and New Zealand (figure 12).

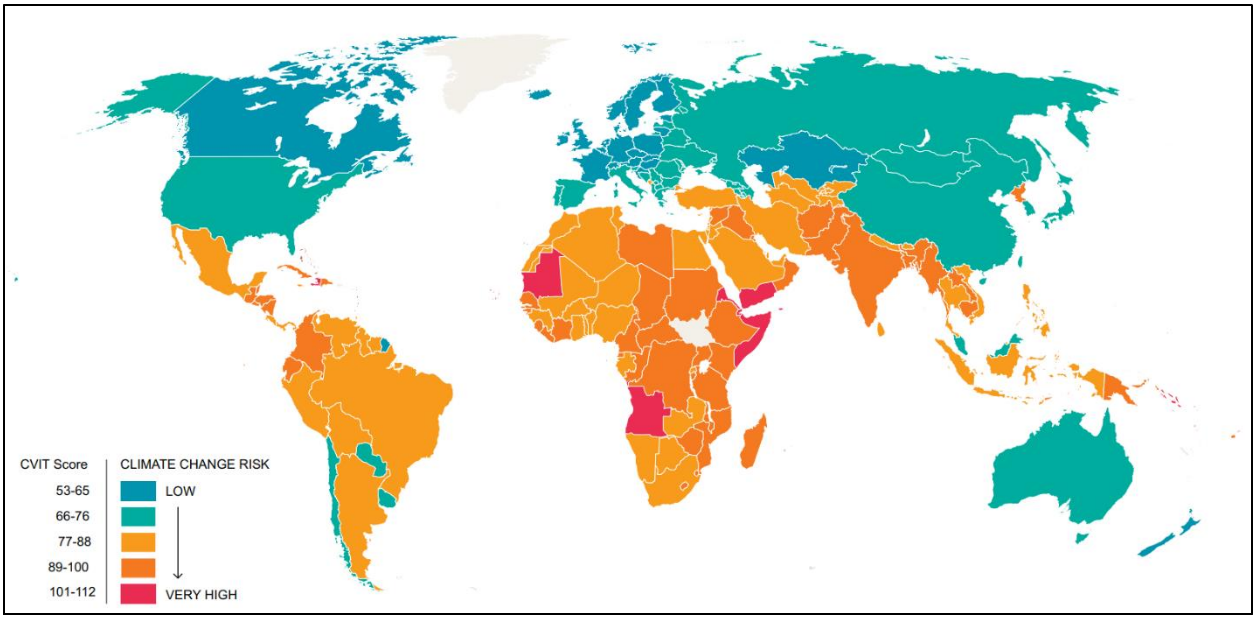


Figure 12. Global distribution of CVIT scores (Scott et al., 2019)

When Scott et al. (2019) were constructing and developing the CVIT, it was important to consider multiple variables to prevent potentially misleading or incomplete conclusions (Mora et al., 2018). In order to prevent oversimplistic conclusions the importance of well-constructed and correctly interpreted indicators is also of importance (Scott et al., 2019).

Indicator selection when developing the CVIT was therefore guided by a comprehensive review of existing literature and by a framework presented by Scott et al. (2012). This framework suggests that climate change vulnerability quantification for the tourism sector ought to include measures of direct climate impacts, indirect climate induced environmental and socioeconomic change as well as mitigation and adaptation responses outside of the tourism sector (Scott et al., 2012). This is necessary as tourism is interconnected with other sectors and often faces transboundary impacts (Hedlund et al., 2018). Selected indicators were compared by Scott et al. (2019) to existing vulnerability and climate-tourism indices to ensure no key measures or variables had been excluded from consideration.

Once desired indicators to be included in the CVIT had been identified, obtaining appropriate data sources for each indicator was the next priority for Scott et al. (2019). In this data source scoping phase, Scott et al. (2019) used guidance outlined by the OECD and Hinkel (2011). These guidelines suggest that data sources utilised should be of high quality and meet certain eligibility criteria including being consistent with current knowledge, being relevant to the sector domain, having broad spatial relevance and being open access. There were some indicators that Scott et al. (2019) had hoped to include in the CVIT, but for which appropriate data sources could not be found, including measures of insurance, degradation of natural and cultural heritage sites, decline of tourist attracting species and variables linked to wine tourism. Should these data sources become available in the future, Scott et al. (2019) recommends that they be included to enhance the robustness of global CVIT calculations. Some indicators included in the CVIT by Scott et al. (2019) used data sources which were composite indicators, such as the TCI which was used to measure climate suitability for tourism of the study sites. Where composite indicators were used, Scott et al. (2019)

compared data sources for overlapping variables to prevent duplication and consequent overweighting of individual variables. Once data sources had been refined, Scott et al. (2019) consulted with scholars and experts to validate data source comprehensiveness and relevance.

The final 27, multidisciplinary indicators included by Scott et al. (2019) in the CVIT to operationalise tourism sector vulnerability are grouped into six sub-index components (table 2). The Tourism Assets (TA) category includes indicators that represent impacts to tourist attracting natural resources and infrastructure including climate, and terrestrial and marine ecosystems, such as marine, coastal and terrestrial assets. Indicators within the Tourism Operating Costs (TOC) component include measures of climate sensitive, variable costs which impact tourism competitiveness such as water and food costs. Tourism Demand (TD) indicators include climate change impacts on domestic and international tourism patterns. Host Country Deterrents (HCD) includes detractor variables that influence the perception of a destination by tourists and discourage international tourist arrivals such as crime and disease prevalence. Tourism Sector Adaptive Capacity (TSAC) indicators consider variables that impact the resilience of the entire tourism sector to climate change impacts such as tourism infrastructure and destination competitiveness. The Host Country Adaptive Capacity (HCAC) component includes broader variables which would enable or hinder the capacity of the entire country to adapt to climate change and account for the sensitivity of the location to disturbances, such as governance and sustainability performance.

4.3. Data Normalisation

The data sources for each indicator used in calculating the CVIT all have different scales and units, and thus require normalisation before the CVIT can be calculated. Data normalisation was used by Scott et al. (2019) to yield an integer score of one to five for each indicator, with lower scores corresponding to lower vulnerability and higher scores indicating higher vulnerability. Although many techniques were available for normalisation, Scott et al. (2019) used common ranked quintiles to normalise linear datasets, whilst datasets subject to skewness such as sea level rise were normalised using Jenks Natural Breaks Optimisation. Similar methodology was employed in this study to conduct normalisation. Several alternatives to this approach were employed where data sources utilised were already provided in a one to five scale, or where quintile-based classification was not appropriate to represent local scale dynamics in relation to internationally comparable measures, such as HCAD1 which used the HDI or TSAC4 which measured Gini Coefficient.

Table 2. Indicators used in calculating the CVIT including shorthand nomenclature used for the remainder of this study (adapted from Scott et al., 2019)

Component	**Nomenclature**	**Indicator**
Tourism Assets (TA)	TA1	Climate suitability for tourism
	TA2	Ecotourism Impact (Terrestrial)
	TA3	Ecotourism Impact (Marine)
	TA4	Coastal / Beach Tourism Impact
	TA5	Ski Tourism Impact
Tourism Operating Costs (TOC)	TOC1	Water Competition & Costs
	TOC2	
	TOC3	Energy Costs
	TOC4	
	TOC5	Food Costs
Tourism Demand (TD)	TD1	Climate change influence on international arrivals
	TD2	Economic growth in county's top 5 international markets
	TD3	Distance to country's top 5 international markets
	TD4	% International leisure arrivals
	TD5	Climate change influence on domestic departures
	TD6	Economic growth in country (domestic GDP)
Host Country Deterrents (HCD)	HCD1	Weather disasters
	HCD2	Security impacts
	HCD3	Health impacts
Tourism Sector Adaptive Capacity (TSAC)	TSAC1	Tourism Competitiveness
	TSAC2	Country image and brand attractiveness
	TSAC3	Outbound market size
	TSAC4	Wealth distribution
	TSAC5	Quality of transport infrastructure
Host Country Adaptive Capacity (HCAC)	HCAC1	Socio-economic conditions that support adaptation
	HCAC2	Governance quality
	HCAC3	Sustainability governance and performance

4.4. CVIT Calculation

Once raw data have been collected and normalisation has been undertaken, the CVIT is a relatively simple arithmetic calculation (equation 1). Results of the standard CVIT calculation thus range between 27 (minimum; least vulnerable) and 135 (maximum; most vulnerable).

$$\boldsymbol{CVIT} = \boldsymbol{TA} + \boldsymbol{TOC} + \boldsymbol{TD} + \boldsymbol{HCD} + \boldsymbol{TSAC} + \boldsymbol{HCAC}$$

$$\begin{aligned}
&\boldsymbol{Where}:\\
&\boldsymbol{TA} = TA1 + TA2 + TA3 + TA4 + TA5\\
&\boldsymbol{TOC} = TOC1 + TOC2 + TOC3 + TOC4 + TOC5\\
&\boldsymbol{TD} = TD1 + TD2 + TD3 + TD4 + TD5 + TD6\\
&\boldsymbol{HCD} = HCD1 + HCD2 + HCD3\\
&\boldsymbol{TSAC} = TSAC1 + TSCA2 + TSAC3 + TSAC4 + TSAC5\\
&\boldsymbol{HCAC} = HCAC1 + HCAC2 + HCAC3
\end{aligned}$$

Equation 1. Standard CVIT Calculation, Weighting Set 1 (Scott et al., 2019)

After thoroughly exploring relevant literature, Scott et al. (2019) found little justification for the increased weighting of specific indicators in the calculation of the CVIT. They resolved to employ and compare only two different weighting approaches. First, an equal indicator weighting (weighting set 1) was used which gives no indicator more weighting over another. Weighting set 1 consequently results in higher weighting of those components which contain more indicators. Second, a weighting which favours adaptive capacity was employed (weighting set 2) due to the high adaptive capacity of the tourism sector observed within literature (Scott et al., 2019). When comparing the two weighting approaches Scott et al. (2019) found a 0.97 correlation between results and thus only presented the results of weighting set 1. The weighting of indicators was argued by Scott et al. (2019) to be of more relevance at country scale. Scott et al. (2019) describe, for example, that detrimental climate change impacts upon snow resources in a winter, ski tourism dependent country could likely not be compensated for by any climate change induced benefits to cultural tourism and should therefore be more strongly weighted on a case-by-case basis. Based on this observation, in addition to weighting set 1 and 2, a third weighting approach (weighting set 3) will be tested in this study which weighs Tourism Assets (TA) more than other variables due to the high dependence of the South African tourism sector on outdoor, nature-based and beach tourism as identified by Grunewald et al. (2016), Giddy (2018) and Tourism South Africa (2019). The proportional weighting of each component in the various weighting sets are outlined in table 3.

Table 3. The Sub Index Components used in calculating the CVIT, demonstrating the number of indicators per component and relative weighting of each component.

Sub Index Component	**Description**	**Number of Indicators**	**Weighting Set (relative %)**		
			1	2	3
			Equal Indicator Weighting	Adaptive Capacity Weighted	Tourism Asset Weighted
TA	Tourism Assets	Five	18.5	12.5	50
TOC	Tourism Operating Costs	Five	18.5	12.5	10
TD	Tourism Demand	Six	22.3	12.5	10
HCD	Host Country Deterrents	Three	11.1	12.5	10
TSAC	Tourism Sector Adaptive Capacity	Five	18.5	25	10
HCAC	Host Country Adaptive Capacity	Three	11.1	25	10
Total		27	100	100	100

To calculate CVIT scores for weighting sets 2 and 3, the scores of all sub-component indicators were summed to derive a cumulative component score for TA, TOC, TD, HCD, TSAC and HCAC respectively. Thereafter, each sub-component was weighted using the respective contributing percentages (table 3). Results of the CVIT calculation for weighting set 2 and 3 thus also range between 27 (minimum; least vulnerable) and 135 (maximum; most vulnerable).

4.5. CVIT Result Analysis

Several approaches were employed to investigate the outputs of the local scale CVIT calculation. First, the results of each component using weighting set 1 were explored independently to identify trends and outliers within the indicator scores making up each of the components. Thereafter, the results of the three different weightings sets calculated (weighting set 1, 2 and 3) were compared using a paired (dependant) t.test to identify statistical differences between the approaches. Spatial analysis of CVIT results was achieved through interpolation-based geostatistical mapping using the Inverse Distance Weighting (IDW) technique using QGIS, a technique employed by other researchers when assessing the spatial distribution of tourism climate index outputs (Noome & Fitchett, 2021). This method was chosen over Kriging due to limited data and the scale of application. A study site level exploration of indicators contributing most to the vulnerability scores of each of the 18 study sites was conducted. Finally, a vulnerability quadrant placement map is produced to compare the scale of potential impacts with the potential adaptive capacity of each study site. This was done by summing TA, TOC, TD and HCD and plotting these cumulative scores against the sum of TSAC and HCAC as detailed in table 4.

Table 4. Vulnerability Quadrant Placement Methodology

Vulnerability Measure	Components	Axis
Potential Climate and Carbon Mitigation Score	TA + TOC + TD + HCD	X
Adaptive Capacity	TSAC + HCAC	Y

4.6. Ethical Considerations

This study did not require the involvement of participants or stakeholders as the indicators used cover a broad range of variables representing multidisciplinary factors including social, environmental, economic and political factors and thus can be considered sufficiently comprehensive to achieve the aims of the study. The ethical considerations of this study were founded on responsible data acquisition, usage, management, storage, and dissemination in line with South African Protection of Personal Information Act (POPIA) regulations and the specific data limitations and agreements of each acquired dataset. This includes but is not limited to keeping information and data gathered on a password and bit-locker secured device, ensuring guidelines and procedures for non-public access data are followed strictly, and the responsible disposing of data once it has been used for its intended purpose.

CHAPTER 5 – DATA SELECTION AND NORMALISATION

5.1. Introduction

Having explored the development of the CVIT and methodology used to calculate the CVIT, this chapter will now explore the process followed in this study to downscale the CVIT for South Africa. This includes a process flow of data selection, indicator selection refinement and normalisation, and a summary of final data sources and normalisation techniques used for each of the 27 indicators.

5.2. Data Source Selection Process

Ideally, when downscaling an index, one would use the same indicators and data sources as the original study, but at a finer spatial and temporal resolution. Unfortunately, as experienced by other researchers using climate-tourism indices in a Southern African context (e.g. Fitchett et al., 2017 and Noome & Fitchett, 2019), data gaps and quality were a major hinderance in acquiring suitable data sources for this study. A decision tree (figure 13) provides an overview of the criteria used to decide on a final data source for each indicator. First, potential data source options were scoped using desktop-based research and a review of existing academic literature relating to the variable of interest. Where the same data source used by Scott et al. (2019) was available at city scale and representative of local scale dynamics, this data source was selected. If not, an alternative data source with the highest spatial resolution relevant to the local context was applied. Where datasets are not available in climate change vulnerability assessments, authors have been known to develop alternative constructs known as proxies to represent variables (Dorgu et al., 2019). This approach was used where the data source as used by Scott et al. (2019) was not available for an indicator, to substitute an appropriate and representative dataset such as in the case of TA2 and TA3. The lack of local scale data for some or all study locations could sometimes be explained and justified. Examples of this include inland sites having no data for sea level rise and no study sites having data available for ski tourism, where the lowest vulnerability score of 1 was applied to represent the lowest vulnerability score for this variable.

The temporal characteristics of datasets were the next consideration. Some data sources were too old to be representative of current dynamics in which case an alternative source was sought, where possible. Where data was available for a period which may have skewed normal trends (e.g. tourism during the 2010 FIFA World Cup held in South Africa or during the COVID-19 pandemic), these would not be representative of typical tourism trends for South Africa and an alternative time period was chosen. This applied particularly to travel patterns of 2010 and 2019-2020 for tourism demand variables. Other common issues encountered included appropriate data sources being restricted by paywalls and thus not publicly accessible as required by the selection criteria of Scott et al. (2019). The reliability of some data sources was also of concern, with obvious errors resulting in that dataset being excluded as a dependable source. An example of this is the SA Tourism dashboard in which cumulative percentages of tourist arrivals for all provinces totalled more than 100% and thus indicated potential errors in the data source or presentation methodology of results. Practicality and pragmatism were the final considerations, as datasets were often disjointed or compiled by different parties, thus potentially incomparable between study sites or impractical to collect. An example of this is the case of TSAC4 (Gini Coefficient) which is reported in the annual performance reports of each municipality but is calculated independently using different data sources over different time scales, thus requiring a centralised, more comparable data source to be found and utilised for this study where comparability between sites is paramount.

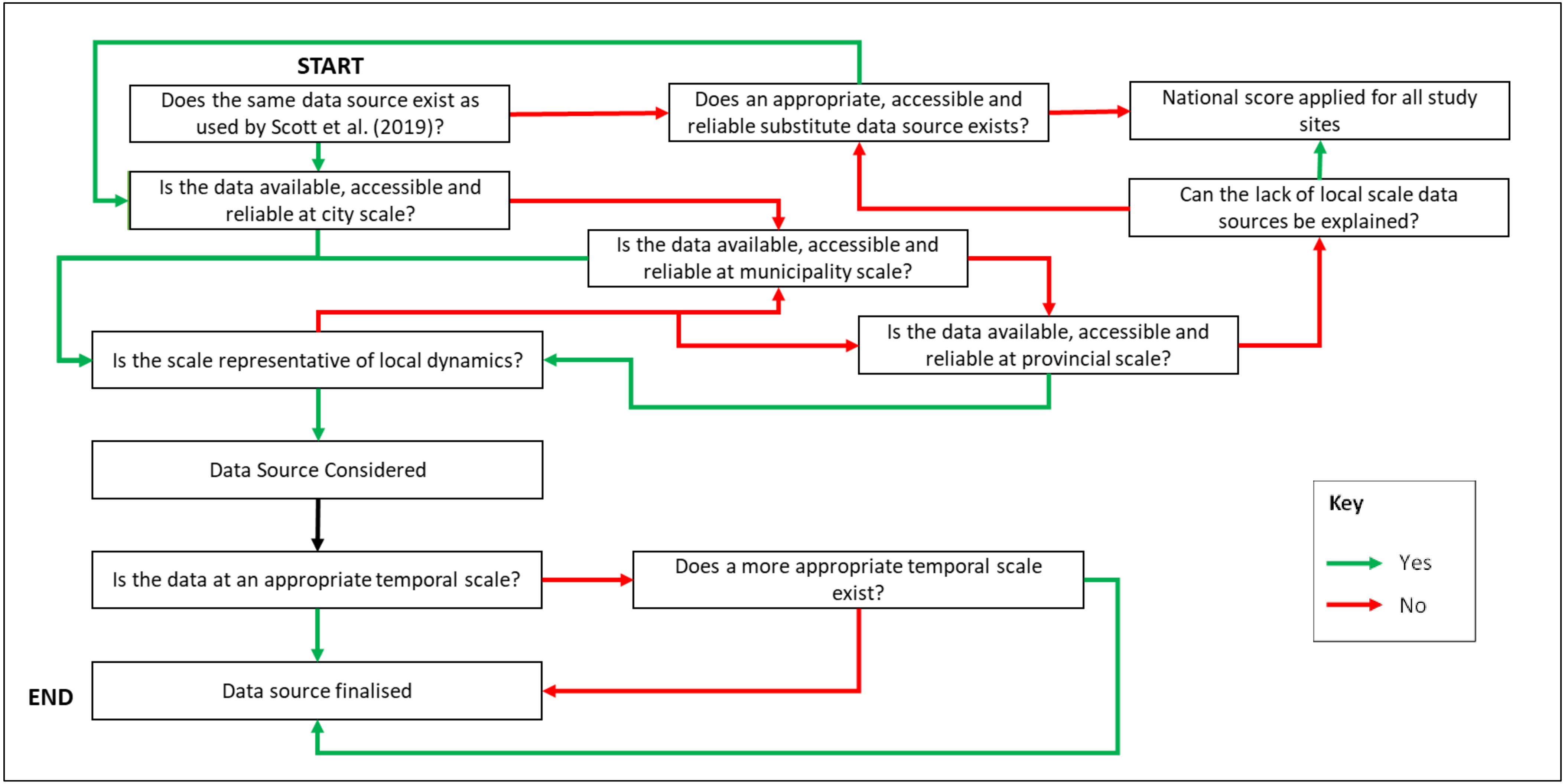


Figure 13. Decision tree used to guide data source selection for the 27 CVIT indicators at a local scale

5.3. Data Collection and Checks

Several data checks were completed on finalised data sources to ensure alignment with the criteria established by Scott et al. (2019). This included a check for commonality of indicator variables across compound indices in which no notable overlap was found. In an effort to include as many study sites as possible, Scott et al. (2019) made several accommodations in the CVIT calculation to account for missing data. Where a single indicator was missing in a component for a location for any reason, a pro-rated dimension score is to be applied for that sub-index component, weighing each of the other indicators in that category proportionally more to account for the missing indicator(s). In order for the CVIT to be statistically sound, Scott et al. (2019) recommend that at least 70% of all indictors are required to be present and that none of the six components may have more than half of their respective category indicators missing. Because only one indicator was excluded from this local scale application of the CVIT, namely TD1, the minimum threshold was attained and the CVIT could be reliably calculated for all study sites.

Raw datasets were collected and stored in Microsoft Excel. Data cleaning was required in many instances, including where sites have undergone a name change during the timescale of data recording and data collection. This included eMakhazeni (previously Belfast), Gqeberha (previously Port Elizabeth), Mbombela (previously Nelspruit) and Polokwane (previously Pietersburg). Several municipal boundaries changed during the data period – however, these changes did not notably affect the data sources used for the indicators in this study. The final data check was to ensure that all normalised datasets had been transformed such that high values corresponded to high vulnerability (table 5). Examples of datasets that required transformation include TA1 and TD2. Following data cleaning, region-based primary keys were used to index normalised indicator sources and allow for the reliable use of VLOOKUP formulas in Microsoft Excel to consolidate data per component and to subsequently calculate the CVIT for each of the 18 study sites using the three different weighting sets tested.

Table 5. Transformation approach employed in cases where normalised data scores had high values corresponding to low vulnerability.

Vulnerability	Original Score	Transformed Score
Very Low	5	1
Low	4	2
Moderate	3	3
High	2	4
Extreme	1	5

5.4. Data Source and Indicator Detail

The use of different data sources may produce different results when calculating the CVIT at a local scale, and therefore selecting the most suitable data source for each indicator is critical for the success of this study. This section will detail the purpose of each indicator used by Scott et al. (2019) and the original data source employed, (table 6). Potential options to be used for each indicator are explored including substantiation and justification for the final data source selected (table 12). Finally, the normalisation approach employed for each variable (table 13), is explained. Raw datasets and normalisation keys and scores can be found in the Appendix of this study.

Table 6. Summary of indicators and sources used by Scott et al. (2019) to calculate CVIT.

Indicator	Indicator Units	Data Source
TA1	TCI Score for 2050	(Amelung et al., 2007)
TA2	Biome distribution score (% land area projected to change biome type by 2070–2100)	(ND-GAIN, 2016)
TA3	Change in marine biodiversity score (species turnover by 2050)	(ND-GAIN, 2016)
TA4	% land area below 4 m above sea level exposed to storm surge with 1 m SLR	(ND-GAIN, 2016)
TA5	Change in ski season and snowmaking costs	Scores averaged from survey of experts
TOC1	Current water stress (all sectors)	(World Resource Institute, 2016)
TOC2	Change in water stress (2050)	(Schlosser et al., 2014)
TOC3	% electricity from fossil fuels	(World Bank, 2016a)
TOC4	National emission reduction ambitions	(UNFCCC, 2019)
TOC5	Food import dependency	(ND-GAIN, 2016)
TD1	% change in international arrivals	(Hamilton et al., 2005)
TD2	Change in GDP from climate change (2050)	(Burke et al., 2015)
TD3	Average distance (km) from geocentroid of destination country to top 5 markets – calculated based on arrival data	(UNWTO, 2012)
TD4	% of international arrivals for leisure tourism	(UNWTO, 2012)
TD5	% change in domestic departures	(Hamilton et al., 2005)
TD6	Change in GDP from climate change (2050)	(Burke et al., 2015)
HCD1	Climate risk index score	(GermanWatch, 2018)
HCD2	Fragile state index score	(Fund for Peace, 2018)
HCD3	Change in vector born disease (malaria by 2050)	(ND-GAIN, 2016)
TSAC1	Travel and tourism competitiveness index score	(World Economic Forum (WEF), 2015)
TSAC2	Country brand ranking (tourism edition)	(Bloom Consulting, 2018)
TSAC3	Number of international departures	(UNWTO, 2016)
TSAC4	Gini index (most recent year available)	(World Bank, 2018)
TSAC5	Trade and transport infrastructure score	(NDGAIN, 2016)
HCAC1	Human development index score	(UNDP, 2016)
HCAC2	Combined rank score of six World Governance Indicators	(World Bank, 2016c)
HCAC3	Environmental Performance Indicator score	(Yale University, 2016)

5.4.1. Tourism Assets

5.4.1.1. TA1 – Climate Suitability for Tourism

The first indicator used by Scott et al. (2019) is intended to represent the extent to which positive or negative changes in climatic suitability for tourism are projected to occur for different locations under climate change scenarios. Climatic suitability for tourism is a measure of meteorological variables such as thermal comfort, wind, rainfall and sunshine hours that determine tourist experiences and thus are important to consider under climate change contexts (Mieczkowski, 1985; Amelung et al., 2007). A global scale assessment was conducted by Amelung et al. (2007) to assess the projected TCI scores for countries in different periods under B1A and A1F IPCC Special Report on Emissions climate change scenarios – the most current knowledge at the time of the study. This data source was not available with greater spatial granularity for South Africa and thus this data source was not used and an alternative data source was sought to ensure the climatic heterogeneity of South Africa was accounted for. There have been limited applications of TCI in the Global South (Fitchett et al., 2017) – including a notable lack of TCI assessments under climate change scenarios. The only useful data source which could be applied for this indicator is the work of Fitchett et al. (2017) who assessed the rate of TCI change over time using both the traditional and a data limitation-adapted TCI for the longest continuous time period available for all study locations, 2005 to 2015. Results were notably different for each study site with marked seasonality in TCI scores being observed. To obtain future TCI scores, an attempt was made to extrapolate the rate of change to 2050 – the future year used by Amelung et al. (2007) – however this approach yielded results which fell out of traditional TCI score ranges. Normalised scores for this indicator were therefore calculated based on the rate of TCI change per year as calculated by Fitchett et al. (2017). A limitation with this data source is that significant results were only found for six of the 18 locations. The results were linearly distributed and quintile-based classification was therefore applied. Scores were transformed to ensure low scores (increasing TCI trend) corresponded to low vulnerability, whilst high scores (decreasing TCI trend) corresponded to high vulnerability.

5.4.1.2. *TA2 – Ecotourism Impact (Terrestrial)*

This indicator is intended to represent the effect that climate change will have on terrestrial ecotourism attractions through greater ecosystem change driven by changes to underlying and dependent variables such as rainfall and temperature. Thiswas measured using the projected biome distribution change score for 2070 to 2100 acquired from ND-Gain (Scott et al., 2019). This data source was only available at country scale and therefore an alternative indicator was sought to account for the marked ecological heterogeneity of South Africa (Finch & Meadows, 2019). The South African National Biodiversity Institute (SANBI) conducted a National Biodiversity Assessment which quantifies threat status and protection level for terrestrial ecosystems which could be used as a proxy for the likely potential impact of climate change on terrestrial assets and has the added benefit of accounting for the pressures associated with land degradation and urban encroachment. The raw, raster spatial dataset was obtained from SANBI B-GIS and clipped to municipality scale using QGIS. To normalise the data, integer scores were applied to each of the threat status categories (table 7). Each municipality had varying proportions of each threat level within the vector polygon. Net scores for each municipality were calculated by aggregating the proportional area each category accounted for.

Table 7. Normalisation key used for TA2 and TA3

Threat Status	Score
Critically Endangered	5
Endangered	4
Vulnerable	3
Near Threatened	2
Least Concern	1

5.4.1.3. *TA3 – Ecotourism Impact (Marine)*

This indicator is intended to represent the effect that climate change will have on marine ecotourism attractions through greater biodiversity change and was acquired from ND-Gain through a marine biodiversity assessment of species turnover by 2050 (Scott et al., 2019). This data source was only available at country scale and therefore an alternative indicator was sought to account for the high marine biodiversity of South Africa (Allison et al., 2022). The SANBI conducted a National Biodiversity Assessment which quantifies threat status and protection level for marine ecosystems which could be used as a proxy for the likely potential impact of climate change on marine assets. The raw, raster spatial dataset was obtained from SANBI B-GIS and clipped to a polygon which matched the municipality demarcations and approximate size using QGIS. To normalise the data, integer scores were applied to each of the threat status categories as per table 7. Each municipality had varying proportions of each threat level within the vector polygon. Net scores for each municipality were calculated by aggregating the proportional area each category accounted for.

5.4.1.4. *TA4 – Coastal / Beach Tourism Impact*

This indicator is intended to represent the damage which would likely be caused to coastal tourism infrastructure – both natural and manmade – as a result of climate change induced sea level rise and storm surges (Scott et al., 2019). The data source used by Scott et al. (2019) is the percentage land area below 4m.asl and thus exposed to storm surges under 1m sea-level rise projections (ND-Gain, 2016). These data sets were produced at country scale and an alternative data source was therefore sought to account for the notable variations in the coastline and coastal city contexts of each of the study sites in South Africa. Initially, raw data sets were sought to model exposure in a similar manner to the ND-Gain (2016) approach. Technical obstacles were, however, encountered whereby the National Oceans and Coastal Information Management Systems (OCIMS) data download function had a bad gateway and therefore shapefiles could not be extracted. Another alternative, the Green Book Coastal Flooding Assessment did not have information available for more than half of the coastal study sites used in this study. A suitable alternative was found in a recent, city-scale assessment of projected sea-level rise in South Africa conducted by Allison et al. (2022). This in-depth study explored projected sea level rise for six of the seven coastal sites of interest, with only St Lucia being excluded. The most extreme climate change scenario at the time of the study, RCP8.5, was chosen in line with least conservative climate change scenarios being applied across indicators by Scott et al. (2019). St Lucia, the only study site missing in the work of Alisson et al. (2022) was given the same score as Knysna due to their similar estuarine context. The lowest vulnerability score (1) was applied to non-coastal study sites. The global mean SLR under RCP8.5 was suggested by Allison et al. (2022) to be 0.78m. The range for South African coastal cities assessed was between 0.84m and 0.89m –higher than global averages and previous SLR projections made for the country. A high vulnerability score of either 4 or 5 was therefore allocated to coastal cities using the 50th percentile (0.85m) as the quantile division separator.

5.4.1.5. TA5 – Ski Tourism Impact

This indicator represents the impact that climate change would have on winter sports (ski) tourism through temperature associated changes to season length, increased operating costs due to the necessity for artificial snow production and increased travel distances for tourists to suitable snow tourism destinations (Scott et al., 2019). Although small instances of ski tourism can be found in South Africa and these are indeed vulnerable to climate change impacts, for example at Afriski (Hoogendoorn et al., 2021) in adjacent Lesotho, none of the locations of interest in this study were dependent on ski tourism and therefore all sites were assigned the lowest vulnerability score of 1.

5.4.2. Tourism Operating Costs

5.4.2.1. TOC1 – Water Competition and Costs

This indicator is intended to measure the existing water costs and restrictions that arise due to increased competition for available water resources and was quantified by Scott et al. (2019) through current water stress across sectors acquired from the World Resource Institute (WRI, 2016). This data source was available at a suitable spatial scale (municipality) to represent local dynamics as water management in South Africa occurs at the municipality scale (Dennis & Dennis, 2012). Other alternative measures were considered including proportional access to safe drinking water (StatsSA), water quality metrics (Blue Drop Reports) and water supply reliability data (Department of Water and Sanitation) – however none of these alternatives had substantial benefits to warrant being used over the same data source used by Scott et al. (2019). The WRI provided data in a one to five scale (table 8) and normalisation was therefore not necessary. Port Nolloth, however, did not fall on this scale and was classified as “Arid and Low Water Use”. Because tourism has previously been found to be a high-water use industry (Smith & Fitchett, 2020), the highest vulnerability score of 5 was applied to this study site.

Table 8. Water Stress Classification for TOC1 and TOC2 (adapted WRI, 2022).

Water Stress Classification	Score
Low (<10%)	1
Low – Medium (10 – 20%)	2
Medium – High (20 – 40%)	3
High (40 – 80%)	4
Extremely High (>80%)	5
Arid and Low Water Use	5

5.4.2.2. TOC2 – Water Competition and Costs

This indicator is intended to measure the future water costs and restrictions that arise due to climate change induced precipitation change associated adverse impacts on water resources and was quantified by Scott et al. (2019) through future water stress across sectors (2050) acquired from Schlosser et al. (2014). This data source was only available at country scale and therefore not representative of local dynamics in South Africa which has prominent spatial heterogeneity in water resource distribution (Dennis & Dennis, 2012). Other alternative measures were therefore considered including water depletion risk and aquifer stability. The most suitable data source located was from the WRI Water Risk Atlas which provides future water stress risk (2050) scores and was available at municipal scale. Data provided was in a one to five scale (table 8) and normalisation was therefore not necessary. Port Nolloth, however, did not fall on this scale and was classified as 'Arid and Low Water Use'. Because tourism has previously been found to be a high-water use industry (Smith & Fitchett, 2020), the highest vulnerability score of 5 was applied to this study site. East London and St Lucia did not have a score provided in the extracted data file, and manual interpretation of the interactive water atlas map was therefore conducted to assign the score of closest proximity to these sites.

5.4.2.3. TOC3 – Energy Costs

This indicator provides a measure of the likely decarbonisation costs that will be associated with transition to clean energy sources and is measured by proxy using fossil fuel dependency metrics (Scott et al., 2019). This variable is important to consider as fossil fuels are a finite resource and transitioning to alternative energy sources is a necessity to achieve climate change mitigation targets (Scott et al., 2016). At country scale, Scott et al. (2019) acquired this data from the World Bank (2016) through percentage of national electricity acquired from fossil fuels. The World Bank does not provide this data at finer spatial resolutions than national scale, however The South African Department of Mineral Resources and Energy has a Renewable Energy Data and Information Service (REDIS) platform which details the precise location and contracted capacities of all renewable energy sites in South Africa (DMRE, 2022). Renewable energy categories included onshore wind power, photovoltaic power, concentrated solar power, small hydro power, biomass power and landfill gas power. Due to the complex structure of the national electricity grid and the impracticality of assigning the 131 renewable energy sites to each of the 18 study sites of focus for this research, the data was aggregated to provincial scale and compared to national electricity generation statistics (StatsSA, 2016). Renewable energy generation in each province was found to be very different and showed a skewed data trend thus requiring Jenks Natural Breaks Optimisation to be used for normalisation. Renewable energy was found to account for less than 2% of national electricity generation for South Africa, in line with StatsSA (2016) findings (figure 14), and thus a score of between 4 and 5 was applied to each province using Jenks Natural Breaks Optimisation to break the data into two classes, with 1570,23MWp used as the class separator.

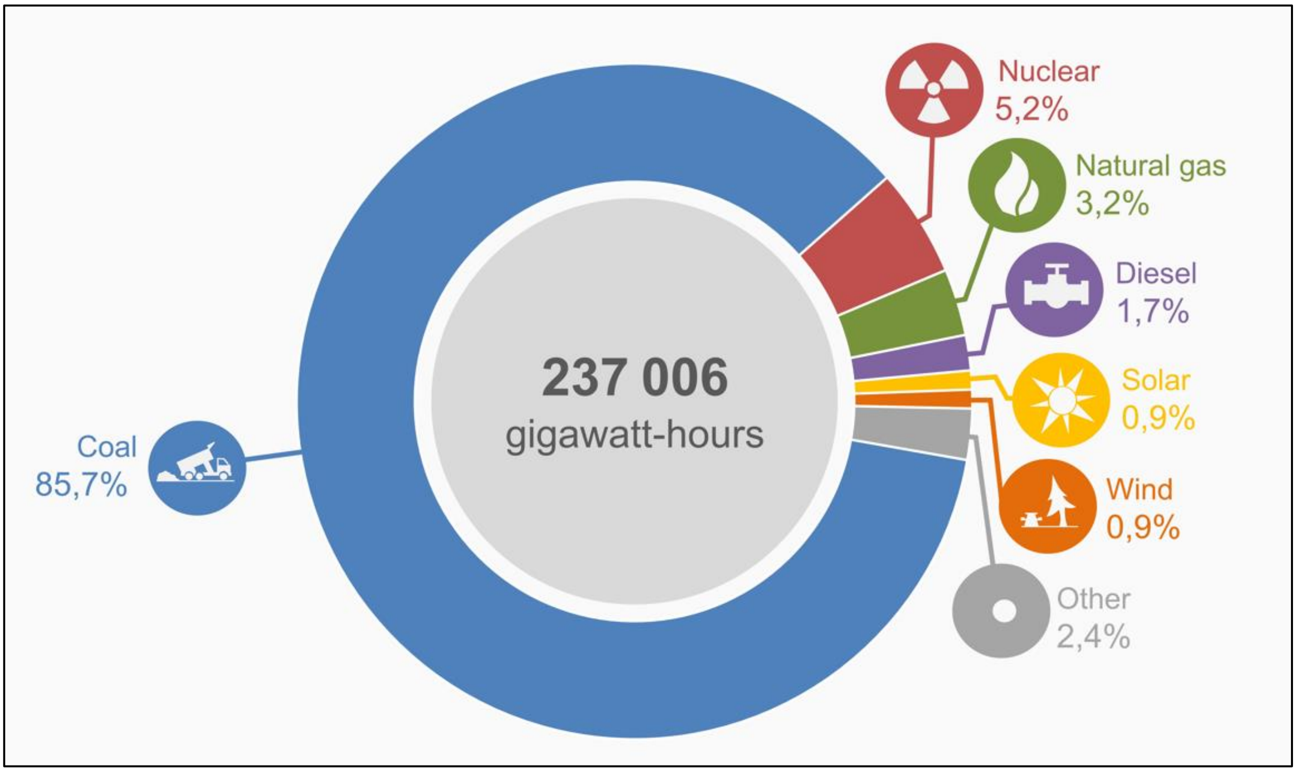


Figure 14. Total electricity generated by source (StatsSA, 2016).

5.4.2.4. TOC4 – Energy Costs

This indicator is intended to represent the marginal cost increases that are incurred proportionally in line with greater greenhouse gas emission reduction ambitions (Scott et al., 2019). These costs often arise from measures such as carbon taxes or other disincentive mechanisms (Republic of South Africa, 2021). The United Nations Framework Convention on Climate Change (UNFCCC, 2019) consolidated national emission reduction ambition targets were used as the data source for this indicator by Scott et al. (2019) and are currently only available at national scale. Although a few cities, sectors and municipalities in South Africa have begun to undertake climate change risk assessments and from these have generated greenhouse gas emission reduction targets, the scale of assessment and disjointed nature of these documents makes them a poor and only partially representative data source choice for this indicator. Tourism is not explicitly mentioned in South Africa's latest NDC document and provincial distribution of emission reduction targets too do not appear. A score of 5 was therefore applied to all study sites to represent the high vulnerability associated with the ambitious emission reduction targets set by South Africa (Marquard et al., 2021) and the well documented flaws and concerns surrounding the possibility of achieving these aims (Cunliffe et al., 2019; Mailula, 2019).

5.4.2.5. TOC5 – Food Costs

This indicator represents the impact that climate change will have on food related variables for the tourism sector such as increased transportation costs, a reduction in food tourism and increased sensitivity to price volatility (Scott et al., 2019). To quantify these considerations, Scott et al. (2019) used a measure of food import dependency. Whilst this is a suitable measure to use when studying global trends, on a country scale it is less useful, particularly in cases where a country is a net exporter of food (Baldos & Hertel, 2015), such as South Africa (Masipa, 2017). This study therefore sought to quantify in-country climate change food impacts through the use of an appropriate proxy measure. According to Baldos and Hertel (2015), the central dependent variable in food security risks as a result of climate change is crop supply and this study therefore first attempted to use the SANBI Climate Change, Agriculture and Biodiversity Assessment (SANBI, 2011) to measure the climate change impact on grain and wheat. A more suitable alternative was, however, sought which would better represent the multifaceted dynamics of agricultural climate change vulnerability across multiple agricultural categories including grains, livestock and fisheries. Gbetibouo and Ringler (2010) quantified the vulnerability of the agricultural sector of South African provinces using the composite Agricultural Vulnerability Index. Scores were linearly distributed and thus suitable for quintile-based classification. Whilst the temporal scale of this dataset is a potential limitation, no more recent alternatives which would be more suitable were available.

5.4.3. Tourism Demand

5.4.3.1. TD1 – Climate Change Influence on International Arrivals

This indicator represents the impact that climate change will have on international tourist arrival patterns as supply side demand changes in response to the relative attractiveness of destinations being altered under different climate change scenarios (Hamilton et all., 2005; Scott et al., 2019).This was quantified by Scott et al. (2019) using country-level scores assessed by Hamilton et al. (2005) that projected a reduction in international tourist arrivals to South Africa of between 25% and 30% under 4^{o}C global warming scenarios. A measure of domestic departures to other countries was also employed by Scott et al. (2019) through TD5. The use of two measures for changes to arrivals and departures as a result of climate change is necessary when conducting intercountry comparisons using the CVIT. When assessing the CVIT for a single country, however, both of these indicators would quantify the impacts of climate change on international tourist arrivals. For example, TD1 may suggest a 25% reduction in net international arrivals to South Africa and would provide a single score for the entire country, whilst TD5 would indicate the proportional reduction in departures from specific source countries such as a 50% reduction in inbound tourist movements from Germany. Because TD5 allows for more spatial granularity to be obtained by being able to assess changes in multiple source markets instead of a single score for the entire country, TD1 was excluded from this study as it is a functional duplicate of TD5. A pro-rated dimension score was applied to other indicators in the tourism demand component to account for the missing TD1 indicator and to ensure CVIT scores still fall within the same range used by Scott et al. (2019).

5.4.3.2. TD2 – Economic Growth in Country's Top Five International Markets

This indicator quantifies the positive or negative impact that climate change will have on country scale GDP in 2100 (Burke et al., 2015) and was used by Scott et al. (2019) as a proxy for the amount of disposable income that will be available for tourists in source countries. The projected economic growth in the top five international markets for each country was aggregated by Scott et al. (2019). Each of the study sites explored in this South African CVIT study has differing proportions of international tourist arrivals from different source markets (table 9). The highest spatial granularity available for international tourist sources was provincial scale, with the most reliable and comprehensive information available from 2018 in the form of the Tourism Performance Report compiled by South African Tourism (2019). The top five international markets for each province (table 9) were applied proportionally according to the number of tourist arrivals to the variable of interest in each of the study sites for TD2, TD3 and TD4. Whilst some studies do not classify neighbouring countries as international tourists, the South African Department of Tourism does include SADC nations in their definition of an international tourist (StatsSA, 2020) and this definition was therefore extended to this study to account for the large amount of regional tourism coming from neighbouring and other SADC nations (South African Tourism, 2019). This data was linearly distributed and quintile-based classification was therefore applied to normalise data.

Table 9. Top five international source markets per province based on tourist arrival numbers (South African Tourism, 2018).

Province	Source 1	Proportion	Source 2	Proportion	Source 3	Proportion	Source 4	Proportion	Source 5	Proportion
Eastern Cape	Germany	35%	UK	27%	USA	16%	Netherlands	12%	France	10%
Free State	Lesotho	97%	Botswana	1%	USA	1%	Germany	1%	UK	1%
Gauteng	Mozambique	32%	Lesotho	22%	Zimbabwe	19%	Eswatini	14%	Botswana	14%
KwaZulu-Natal	Eswatini	61%	UK	10%	Germany	10%	Botswana	10%	Lesotho	9%
Limpopo	Zimbabwe	88%	Botswana	8%	USA	2%	Germany	1%	UK	1%
Mpumalanga	Mozambique	58%	Eswatini	24%	USA	7%	Germany	6%	UK	5%
North West	Botswana	66%	Lesotho	19%	Zimbabwe	6%	Mozambique	5%	Eswatini	4%
Northern Cape	Namibia	70%	Botswana	8%	USA	8%	UK	7%	Germany	8%
Western Cape	USA	22%	UK	29%	Germany	25%	Namibia	12%	France	12%

5.4.3.1. TD 3 – Distance to Country's Top Five International Markets

This indicator represents the increased travel costs likely to be associated with long-haul tourism travel and increased prices caused by emission reduction policies aimed at air travel (Scott et al., 2019). The average travel distance for tourists from the top five source countries was aggregated from the geocentroid point of each country by Scott et al. (2019). For this South African CVIT study there was a notable difference in the arrival methods of international tourists – either by air travel or through land borders (table 9 and 10). This distinction was important to consider when quantifying the impact of distance. For source countries where land borders were used as the main entry point, the distance in km between the source country capital and the study site location as per Google Maps suggested route was used. Once long-haul, air travel international tourists have arrived in South Africa the financial impact of in-country ground travel has been argued to be limited and therefore the distance between the most popular international airport in the source country and the closest international airport to the study site was used (table 10), with distances obtained from a flight distance calculator (flightdistance.com, 2022). For the USA, multiple airports could have been used as the originating point as there are several cities which fly directly to South Africa. Hartsfield-Jackson Atlanta was selected as the originating point as it is the busiest airport in the USA and often serves as a transit airport for tourists leaving the USA from other regions in the country (Henriques & Feiteira, 2018). Proportionally aggregated distances based on the number of travellers from each source location produced data that was skew in nature and Jenks Natural Breaks Optimisation was therefore applied to normalise data.

5.4.3.1. TD4 – % International Leisure Arrivals

This indicator is used to distinguish the impact that climate change will have on different types of tourism travel. Leisure tourists have been argued to be more likely to change their destination choice than travellers whose main purpose of travel is for example business or visiting friends and relatives (Scott et al., 2019). The highest spatial granularity available for purpose of travel was provincial scale from the South African Tourism Dashboard (South African Tourism, 2022). The percentage of leisure tourists in 2018 was aggregated proportionally according to the top five source markets for each province to produce a vulnerability score for each study site. Data were distributed linearly and were therefore suitable for quintile-based classification to obtain a score of 1 to 5.

5.4.3.2. TD5 – Climate Change Influence on Domestic Departures

This indicator was used by Scott et al. (2019) as a measure of the positive or negative impact climate change would potentially have on international travel patterns by focusing on domestic departure trends driven by projected changes to temperatures (Hamilton et al., 2005; Scott et al., 2019). This was measured by Scott et al. (2019) through the modelled percentage change in domestic departures under 4^{o}C global warming scenarios (Hamilton et al., 2005). When assessing the CVIT for local scale, single country contexts domestic departures would not influence destination vulnerability and this variable was therefore used to replace TD1. This is further reinforced by TD6 accounting for domestic travel patterns under climate change scenarios. The proportional change in departures for the top five international source markets per province in South Africa (table 9) was applied to this study using the same source as Scott et al. (2019). A limitation of this data source is the temporal period covered and potentially outdated findings of the Hamilton et al. (2005) study. No suitable recent alternative could be found that justified using a different source to Scott et al. (2019). The results were linearly distributed and therefore suitable for quintile-based classification. A score transformation (table 5) was applied to produce inverse scores to ensure low scores were representative of low vulnerability (least change in departures from source markets), whilst high values represented greatest vulnerability (largest reduction in source market departures).

Table 10. Points used to calculate travel distance from top five international source markets

		Point A	**Point B**
Botswana	Land	Gaborone	Study Site
Eswatini	Land	Mbabane	Study Site
France	Air	Paris Charles de Gaulle Airport	Closest International Airport to Study Site
Germany	Air	Frankfurt Airport	Closest International Airport to Study Site
Lesotho	Land	Maseru	Study Site
Mozambique	Land	Maputo	Study Site
Namibia	Land	Windhoek	Study Site
Netherlands	Air	Amsterdam Airport Schiphol	Closest International Airport to Study Site
UK	Air	London Heathrow	Closest International Airport to Study Site
USA	Air	Hartsfield-Jackson Atlanta	Closest International Airport to Study Site
Zimbabwe	Land	Harare	Study Site

5.4.3.3. TD6 – Economic Growth in Country (Domestic GDP)

This indicator is used to measure the positive or negative impact that climate change would have on domestic GDP (Burke et al., 2015) by 2100, and consequently the income available to spend for domestic tourism (Scott et al., 2019). This indicator is crucial to include in this South African CVIT study as affordability has been cited as a major reason that potential South

African domestic tourists choose not to travel (South African Tourism, 2019). A 60% reduction in GDP was projected for South Africa by Burke et al. (2015). Net domestic tourism spend, however, is not distributed ubiquitously between provinces. A proportional reduction in the total direct domestic spend by destination province as of 2018 (StatsSA, 2019) was therefore used as the data source for this indicator with the assumption that source provinces would be impacted ubiquitously by climate change and those provinces receiving the lowest proportion of tourism income were likely more dependent on tourism income (Rogerson & Rogerson, 2020b). Data were linearly distributed and thus suitable for quintile-based classification. A score transformation (table 5) was applied to produce inverse scores to ensure low scores (highest proportion of total domestic spend) were representative of low vulnerability, whilst high values (lowest proportion of domestic spend) represented greatest vulnerability.

5.4.4. Host Country Deterrents

5.4.4.1. HCD1 – Weather Disasters

This indicator seeks to quantify the substantial impact that extreme weather events and natural disasters have on tourism infrastructure, destination communities and the reputational damage which can act as a deterrent for inbound tourists (Scott et al., 2019). The increased risk of disasters under climate change scenarios was measured by Scott et al. (2019) using the climate risk index score (GermanWatch, 2018). This index quantifies the historical number of disasters that have occurred in each country and is not available with higher spatial granularity. Two potential options were considered to quantify the historical number of natural disasters that have occurred in South Africa – namely Vital and EM-DAT natural hazard databases. Vital produces results at a provincial scale. EM-DAT was chosen as the final data source due to its greater temporal resolution, spatial granularity (district), and comprehensiveness benefits identified by David-Reddy & Hilgart (2021). Quintile based classification based on all districts was used to derive a score per study site. A notable limitation of the data sources used both in this study and by Scott et al. (2019) is that the severity of the natural disasters recorded is not quantified, only the count of disasters. This results in large scale disasters with potentially more impact on tourist perception being equated to smaller disasters with potentially less impact on tourist views and consequent travel decisions.

5.4.4.2. HCD2 – Security Impacts

This indicator seeks to represent the deterrent effects that issues such as conflict, civil unrest and political strife can have on the travel patterns of international tourists (Scott et al., 2019). The data source selected by Scott et al. (2019) to represent this phenomenon was the Fragile State Index Score (Fund for Peace, 2018). This information is only available at national scale and therefore an alternative data source was sought to acquire more spatial granularity. In a South African context, one of the biggest deterrents to travel is crime (Musavengane et al. 2020). This variable affects tourist decision making at various scales – most commonly at local scale, with tourists choosing to avoid specific neighbourhoods or regions such as informal settlements where a high perception of risk exists (Chilli, 2018). Crime statistics were therefore employed as a proxy measure for security impacts within South Africa, despite limiting the impact that political stability may have on tourist safety perceptions of the country. This compromise was deemed acceptable as political stability is often measured at a national scale and thus would impact all study sites equally. Crime statistics at a local or municipal level were behind paywalls, and therefore was not a suitable data source for this study. Recent looting in KwaZulu-Natal spurred some countries to encourage their outbound tourists to avoid the entire province (Smith, 2021), thus justifying the use of provincial level community reported serious crimes statistics acquired from the South African Police Service (SAPS, 2019) as the final selected data source for this indicator. Data were skew in distribution therefore warranting the use of Jenks Natural Breaks Optimisation to normalise data.

5.4.4.3. HCD3 – Health Impacts

This indicator seeks to represent the deterrent effect that the presence of disease vectors and outbreaks can have on the movement decisions of tourists (Scott et al., 2019). Under climate change, the distribution of many organisms including disease vectors is projected to change substantially (Pecl et al., 2017) and Scott et al. (2019) therefore used the change in malaria, a common vector borne disease, under climate change scenarios in 2050 (ND-Gain, 2016) to quantify this factor. This data source was not available at a source with greater spatial granularity than national scale and therefore an alternative source was sought. A study conducted by Tonnang et al. (2010) modelled the potential change in range of *Anopheles arabiensis* – a species of Anopheles, malaria carrying mosquito under various climate change scenarios in Africa. The least conservative model, a 4^{o}C increase in temperature and a 20% reduction in both summer and winter rainfall was used in line with least conservative measures used by Scott et al. (2019). Study sites were mapped using QGIS against the jpeg map produced by Tonnang et al. (2010) to assign a risk score to each study site. Five risk classes were present across South Africa ranging between no prevalence and a 35% increase in prevalence. Scores of 1 to 5 were applied according to the risk interval categories identified by Tonnang et al. (2010).

5.4.5. Tourism Sector Adaptive Capacity

5.4.5.1. TSAC1 – Tourism Competitiveness

This variable seeks to represent the increased adaptive capacity associated with higher multifaceted tourism competitiveness (Scott et al., 2019). Tourism competitiveness is a complex measure calculated by considering variables such as enabling environments, policies, infrastructure and natural resources (WEF, 2019). Scott et al. (2019) used the Travel and Tourism Competitiveness Index produced by The World Economic Forum to represent this variable. This data was only available at national scale. In the 2019 study, South Africa was ranked 61st out of 140 countries. When utilising quintile-based classification to normalise this national dataset, a score of 3 is achieved by South Africa and a score of 3 was therefore applied to all study sites.

5.4.5.2. TSAC2 – Country Image and Brand Attractiveness

This indicator measures the brand strength of a destination and the corresponding increased rebranding capacity the destination would have following adverse climate change impacts or natural disaster impacts to tourism assets (Scott et al., 2019). Scott et al. (2019) used the Bloom Consulting (2018) Country Brand Ranking: Tourism Edition Report to quantify this variable. In the latest 2022/2023 report South Africa is ranked 41st globally and 2nd in Africa behind Egypt. A score of 2 can therefore be applied to South Africa. Some destinations in

South Africa are, however, far more popular and recognisable than others as suggested by the Tourism Sentiment Index (Think! Innovation Inc, 2022). Approaches were therefore sought to account for this brand heterogeneity. Five South African destinations (Cape Town, Hermanus, Pretoria, Knysna and Stellenbosch) were included in the latest Tourism Sentiment Index (Think! Innovation Inc., 2022) and three were included in a study on Destination Awareness and Image conducted by De Klerk and Haarhoff (2019). Study sites therefore had the national score of 2 adjusted up or down as per table 11.

Table 11. Adjustment factor for individual study sites based on brand image nuance

Factor	Adjustment	Net Score
In both TSI and Destination Awareness and Image Study	-1	1
In either TSI or Destination Awareness and Image Study	0	2
In neither TSI nor Destination Awareness and Image Study	+1	3

5.4.5.3. TSAC3 – Outbound Market Size

This indicator quantifies the size of the outbound tourism market from a country as these tourists may convert to domestic tourists as a result of climate change induced impacts such as cost increases and attractiveness changes in typical international destination choices (Scott et al., 2019). These outbound tourists therefore represent a measure of adaptive capacity for the domestic tourism sector of a country (Scott et al., 2019). Evidence for this phenomenon was observed in a South African context during the COVID-19 pandemic whereby the increased costs and inconvenience associated with COVID-19 prevention measures for outbound tourism including PCR testing and limited flights saw a reduction in outbound tourism trips and in many cases a redirection of these tourists to local destinations (Bama & Nyikana, 2021). The popularity of local tourism attractions is however not homogenous and the number of domestic trips taken per destination differs greatly (Tourism South Africa, 2019). This study therefore assumed that converted outbound tourists who chose to travel domestically would likely do so in a pattern mirroring current domestic tourism trends. The number of overnight domestic trips per province undertaken in 2018 for the purpose of leisure or holiday was therefore selected as the final data source for this indicator. The highest spatial resolution available was provincial scale from StatsSA (2019) Tourism and Migration Report. Data points were linearly distributed and therefore suitable for quintile-based classification. Scores were transformed (table 5) to ensure that low scores (high proportion of domestic tourism trips) corresponded to low vulnerability and high scores (low proportion of domestic tourism trips) corresponded with high vulnerability.

5.4.5.4. TSAC4 – Wealth Distribution

Wealth distribution is used as an indicator in the CVIT to represent the amount of potential domestic tourists in a country and the likely potential adaptive capacity of a country which can be degraded by high inequality (Scott et al., 2019). The data source chosen by Scott et al. (2019) for this measure was the latest available Gini index per country (World Bank, 2018). Several data source options were explored for this indicator. The self-reported Gini scores presented in the annual performance reports of municipalities were excluded as an option because the datasets, timescales and methodologies used to quantify Gini were inconsistent across study municipalities. A study by David et al. (2018) sought to estimate the Gini score of each municipality using census data from the 2011 census. These scores were however presented in large ranges (e.g. 0.67-0.70) and were calculated using outdated municipal boundaries no longer representative of current demarcations and dynamics, and this study was therefore excluded as a reliable source. The best source available was the provincial level Gini scores presented in the StatsSA (2019) Inequality Trends of South Africa Report. South Africa has the highest Gini score globally out of 168 countries (World Bank, 2018), scoring 0.63 on a scale of 0 – 1 where 0 is perfect equality and 1 is absolute inequality where all resources in a country belong to one individual. The functional range for provincial scores was between 0.60 and 0.65. Scores were linearly distributed. To ensure differential vulnerability could be quantified given the differences in Gini scores between provinces, study sites were therefore scored either 4 or 5, with 0.61 as the 50th percentile division separator.

5.4.5.5. TSAC5 – Quality of Transport Infrastructure

This indicator is used to represent the greater accessibility which high quality infrastructure affords to destinations within a country, thus allowing for tourists to easily substitute between similar destinations and to limit any impacts that arise due to prolonged disruptions to a single route (Scott et al., 2019). To quantify this variable, Scott et al. (2019) used the Trade and Transport Infrastructure Score form ND-Gain (2016). Because this data was only available at national scale a more suitable substitute dataset was sought. Road condition scores have been calculated by the CSRI (2014) and the South African Council for Industrial Engineering which presents a suitable alternative. More recent priorities for SANRAL have shifted towards traffic and the latest data available for road conditions is from 2013. Road classifications were given scores (Very Poor = 5; Poor = 4; Fair = 3; Good = 2 and Very Good = 1) and destinations were then given net scores calculated using the proportional percentage of each road condition category measured in that province.

5.4.6. Host Country Adaptive Capacity

5.4.6.1. HCAC1 – Socioeconomic Conditions That Support Adaptation

This indicator seeks to represent the increased adaptive capacity to climate change associated with better education, general infrastructure and health care systems within a country. Scott et al. (2019) used the Human Development Index (HDI) to quantify this variable because it has consistently been found to be one of the best measures of social vulnerability to disturbances arising due to climate change (Fussel, 2010). HDI scores theoretically range between 0 and 1, but the functional range thereof is narrower, with global results being classified into four main categories (0.8 – 1.0 = very high development, 0.7 – 0.79 = high development, 0.55 – 0.7 = medium development and < 0.55 = low development). South Africa has a mean HDI of 0.706 and is in position 111th out of 185 countries when ranking best to worst HDI scores. Global Data Lab (2019) provides HDI data at provincial scale for South Africa, the highest spatial granularity reliability available for the country. The functional range for HDI scores within South Africa is between 0.671 (Eastern Cape) and 0.745 (Western Cape). These HDI scores and South Africa's global HDI ranking are relatively low, but do not fall into the "low development" classification. In line with global categorisation classes, a score of 3 (high development) or 4 (medium development) was therefore allocated to provinces with 0.7 being the division separator.

5.4.6.2. HCAC2 – Governance Quality

This indicator seeks to operationalise the impact that stable and high-quality governance systems can have in ensuring enhanced adaptive capacity in the face of climate change (Scott et al., 2019). Of particular focus is the influence of corruption (Scott et al., 2019) which is a known problematic factor generally and with the governance of climate policy within the governance institutional structures of South Africa (Averchenkova et al., 2019). Scott et al. (2019) used a combined rank score comprising six World Governance Indicators compiled by the World Bank (2016). These datasets were not available with higher spatial granularity than national scale and a suitable alternative data source was therefore sought. Good Governance Africa is a non-profit organisation that aims to research and advocate for improved governance across the continent (Good Governance Africa, 2021) and annually publishes a Governance Performance Index (GPI) for the municipalities of South Africa. This comprehensive and multidisciplinary index was a suitable substitute to quantify governance at a high spatial resolution. Scores were provided in an existing scale of 1 to 5 and thus normalisation was not required. Scores were not in integer format, but this was deemed acceptable as the adjusted scores of the tourism demand (TD) component were also decimal values and the use of decimals allowed for increased detail to be observed in the GPI scores between municipalities.

5.4.6.3. HCAC3 – Sustainability Governance and Performance

The final indicator used by Scott et al. (2019) in the CVIT is used to quantify the increased ecosystem associated adaptive capacity that is found in contexts where strong sustainability performance is observed. Scott et al. (2019) used the Environmental Performance Indicator (EPI) score compiled by Yale University (2016) as the data source to quantify this measure. This measure is made up of 32 performance indicators including air quality, sanitation, waste management and pollution to name a few (Wendling et al., 2020). The EPI is only available at national scale and thus an appropriate substitute with higher spatial granularity was sought. The Municipal Green Book (2022) presents a wide variety of measures at municipality scale relating to environmental, socioeconomic and infrastructural climate change vulnerability. The Environmental Vulnerability score is presented to reflect the conflicting priorities of protecting the environment and allowing significant land use changes to occur at the detriment of natural ecosystems, and is comprised of measures of air quality, environmental governance and urban encroachment and thus can be used to represent the increased adaptive capacity associated where stronger environmental performance is observed (Green Book, 2022). Although having EPI measures at local scale would have been ideal, the environmental vulnerability score can serve as an appropriate data source for this indicator as similar variables are considered when calculating both scores. Environmental Vulnerability Scores range between 1 and 10, with 10 being highest vulnerability. These scores were halved to produce a score used in calculating the CVIT at municipality scale.

5.5. Selection Summary

The below table summarises the final data sources selected for each indicator and the spatial scale applied. Three indicators were at national scale, 11 indicators were at provincial scale, one indicator was at district scale, six indicators were at municipality scale and five indicators were at city or study site scale.

Table 12. Summary of indicators used in this study including spatial granularity utilised.

Indicator	Data Source	National	Provincial	District	Municipality	City
TA1	TCI rate of change (Fitchett et al., 2017)					x
TA2	Terrestrial threat status (SANBI-GIS, 2018)				x	
TA3	Marine threat status (SANBI-GIS, 2018)				x	
TA4	Future sea level rise (Allison et al., 2022)					x
TA5	Ski tourism risk (N/A)	x				
TOC1	Current water stress (WRI, 2022)				x	
TOC2	Future water stress (2050)(WRI, 2022)				x	
TOC3	Renewable energy capacity (REDIS, 2022)		x			
TOC4	Nationally Determined Contributions (Marquard et al., 2021)	x				
TOC5	Agricultural Vulnerability Index (Gbetibouo & Ringler, 2010)		x			
TD1	Excluded					
TD2	Future GDP (Burke et al., 2015)		x			
TD3	Distance from source to destination					x
TD4	Percentage leisure arrivals (South African Tourism, 2019)		x			
TD5	Future source market departures (Hamilton et al., 2005)		x			
TD6	Proportion of domestic tourism spend (StatsSA, 2019)		x			
HCD1	Number of disasters (EM-DAT, 2022)			x		
HCD2	Number of serious crimes reported (SAPS, 2019)		x			
HCD3	Future A.arabiensis prevalence (Tonnang et al., 2010)					x
TSAC1	Tourism Competitiveness (WEF, 2019)	x				
TSAC2	Adjusted Country Brand Ranking (Bloom Consulting, 2022)					x
TSAC3	Proportion leisure trips by destination (StatsSA, 2018)		x			
TSAC4	Gini Score (StatsSA, 2019)		x			
TSAC5	Road Infrastructure Score (CSRI, 2014)		x			
HCAC1	HDI Score (Global Data Lab, 2019)		x			
HCAC2	GPI Score (Good Governance Africa, 2021)				x	
HCAC3	Environmental Risk Score (Green Book, 2022)				x	

5.6. Normalisation Summary

Multiple normalisation techniques were employed in this study (table 13). Eight indicators were normalised using quintile-based classification where linear distribution was found in the dataset (table 13). Three indicators were normalised using Jenks Natural Breaks Optimisation (table 13). Eight indicators had existing scales which could be used as is or slightly modified to be used in calculated in the CVIT (table 13). Five indicators required alternative normalisation strategies such as up or down adjustment in order for scores to be representative of local scale dynamics (table 13). Three indicators had a national score for all study sites that was determined using quintile-based classification in relation to international scores (table 13).

Table 13. Summary of normalisation techniques employed for each of the 27 indicators used to calculate the CVIT in this study

Indicator	Quintile Classification	Jenks Natural Breaks	Existing Scale	Alternative or Adjustment	National (single score)
TA1	x				
TA2			x		
TA3			x		
TA4				x	
TA5					x
TOC1			x		
TOC2			x		
TOC3		x			
TOC4					x
TOC5	x				
TD1	-	-	-	-	-
TD2	x				
TD3		x			
TD4	x				
TD5	x				
TD6	x				
HCD1	x				
HCD2		x			
HCD3			x		
TSAC1					x
TSAC2				x	
TSAC3	x			x	
TSAC4				x	
TSAC5			x		
HCAC1				x	
HCAC2			x		
HCAC3			x		

5.7. Conclusion

This chapter outlined the data source selection process used to downscale the CVIT for local scale application to South Africa. Where possible, the same data sources as used by Scott et al. (2019) in the global CVIT assessment were used for local scale application. Many obstacles were encountered in this regard, with the spatial resolution of most datasets only being available at national scale. Suitable alternative data sources or proxy datasets which could be used to represent local scale variables were located for all but three of the indicators.

CHAPTER 6 – RESULTS

6.1. Introduction

This chapter will outline the results of the CVIT calculation for 18 study sites distributed across South Africa. First, scores and trends for each component namely: Tourism Assets (TA), Tourism Operating Costs (TOC), Tourism Demand (TD), Host Country Deterrents (HCD), Tourism Sector Adaptive Capacity (TSAC) and Host Country Adaptive Capacity (HCAC) will be explored based on the standard weighting approach employed by Scott et al. (2019). Study sites are each assessed to determine which variables contribute most to the overall vulnerability of the site. Thereafter, the CVIT results of each of the three different weighting approaches tested in this study (W1, W2 and W3) will be examined and compared. Finally, cumulative CVIT scores for each study site using the standard weighting approach will be explored in detail.

6.2. Indicator Trends

6.2.1. Tourism Assets

Results for the Tourism Assets component range between 17 (highest vulnerability) and 7 (lowest vulnerability). Cape Town is found to be the study site most vulnerable to climate change when considering Tourism Assets with a score of 17. Gqeberha and Durban also have tourism assets highly vulnerable to the impacts of climate change, with scores of 16 and 17 respectively. Ladysmith is the study site with lowest tourism asset vulnerability to climate change with a score of 7.

Table 14. Results of the TA component indicators for each study site, ranked from highest to lowest cumulative TA score

Location	TA1	TA2	TA3	TA4	TA5	Total
Cape Town	4	5	2	5	1	17
Gqeberha	5	3	2	5	1	16
Durban	2	4	4	4	1	15
St Lucia	1	4	3	4	1	13
East London	2	1	2	5	1	11
Port Nolloth	1	1	4	4	1	11
Bethlehem	5	2	1	1	1	10
eMakhazeni	5	2	1	1	1	10
Knysna	1	2	2	4	1	10
Paarl	3	4	1	1	1	10
Pilanesberg	5	1	1	1	1	9
Bloemfontein	3	2	1	1	1	8
Johannesburg	1	4	1	1	1	8
Kimberley	4	1	1	1	1	8
Mbombela	3	2	1	1	1	8
Polokwane	4	1	1	1	1	8
Pretoria	2	3	1	1	1	8
Ladysmith	3	1	1	1	1	7

Highest scores for TA1 of 5 associated with greatest vulnerability as a result of decreases in climatic suitability for tourism are found for Bethlehem, eMakhazeni, Gqeberha and Pilanesberg (table 14). Lowest vulnerability scores for TA1 of 1 where climatic suitability for tourism is projected to improve are found for Johannesburg, Knysna, Port Nolloth and St Lucia (table 14). For TA2, climate change vulnerability associated with terrestrial asset impacts, Cape Town is found to be most vulnerable with a score of 5 (table 14). Vulnerability associated with climate change impacts to marine assets (TA3) are negligible for non-coastal study sites and thus have the lowest score of 1 (table 14). Within coastal study sites, Durban and Port Nolloth have the highest vulnerability scores for TA3, threat to marine assets, with a score of 5 each whilst Knysna, East London, Gqeberha and Cape Town have relatively lower vulnerability scores of 2 (table 14). The threat of climate change induced coastal flooding

(TA4) is greatest for Cape Town, Gqeberha and East London with scores of 5 respectively (table 14). Durban, St Lucia, Port Nolloth and Knysna are also highly vulnerable with scores of 4 (table 14). Inland study sites all have a score of 1 for TA4 and TA5, indicating very low vulnerability to ocean related climate change risks including threats to marine assets and impact from sea level rise (table 14). No study sites were vulnerable to climate change induced impacts to ski tourism and all had the lowest vulnerability score of 1 applied to them (table 14).

6.2.2. Tourism Operating Costs

Results for the Tourism Operating Costs component range between 23 (highest vulnerability) and 13 (lowest vulnerability) (table 15). Pilanesberg is found to be the study site most vulnerable to climate change when considering tourism operating costs with a score of 23 (table 15). Cape Town, Durban, Ladysmith, Paarl, Polokwane and Port Nolloth are also highly vulnerable to the impacts of climate change associated with increased tourism operating costs, with scores of 21 for each study site (table 15). Bethlehem and Kimberley are the study sites with lowest tourism operating cost associated vulnerability to climate change, with scores of 15 and 13 respectively (table 15). The scores for the TOC component are generally higher than the scores for TA with proportionally more scores of 4 or 5 present in the normalised results (table 15).

Table 15. Results of the TOC component indicators for each study site, ranked from highest to lowest cumulative TOC score

Location	TOC1	TOC2	TOC3	TOC4	TOC5	Total
Pilanesberg	4	5	5	5	4	23
Cape Town	5	5	5	5	1	21
Durban	2	5	5	5	4	21
Ladysmith	4	3	5	5	4	21
Paarl	5	5	5	5	1	21
Polokwane	5	1	5	5	5	21
Port Nolloth	5	5	4	5	2	21
eMakhazeni	4	3	5	5	3	20
Gqeberha	1	5	4	5	5	20
Pretoria	4	5	5	5	1	20
East London	1	4	4	5	5	19
Knysna	3	5	5	5	1	19
Mbombela	1	3	5	5	3	17
St Lucia	1	2	5	5	4	17
Bloemfontein	1	3	5	5	2	16
Johannesburg	2	3	5	5	1	16
Bethlehem	1	2	5	5	2	15
Kimberley	1	1	4	5	2	13

With scores of 5 each, Cape Town, Paarl, Polokwane and Port Nolloth are the study sites with the highest vulnerability scores for TOC1, associated with greatest current water stress (table 15). The number of study sites highly vulnerable to future water stress pressures (TOC2) as a result of climate change is double the amount of study sites with current high water stress vulnerability, with eight sites carrying a score of 5 (table 15). Only 2 study sites, Kimberley and Polokwane, do not experience moderate or high vulnerability as a result of future water stress pressures (TOC2) with a score of 1 each (table 15). Most study sites are found to be highly vulnerable to climate change due to a large dependency on fossil fuels (TOC3) with a score of 5 for 14 of the 18 study sites (table 15). Port Nolloth, Gqeberha. East London and Kimberley are slightly less vulnerable as they have some renewable energy capacity installed within their respective provinces and therefore have scores of 4 each for TOC3 (table 15). All study sites are highly vulnerable to climate change due to emission reduction targets associated with TOC4, scoring 5 each (table 15). Agricultural vulnerability (TOC5) is highest in Polokwane, Gqeberha and East London with scores of 5 each, whilst lowest agricultural vulnerability is found for Cape Town, Paarl, Pretoria, Knysna and Johannesburg with scores of 1 each (table 15).

6.2.3. Tourism Demand

Because TD1, climate change induced change to international tourist arrivals, was excluded from this study (see methods), each of the other indicators in the TD component had a pro-rata dimension score applied to them when calculating final CVIT scores. Weighted results for this component range between 21.6 (highest vulnerability) and 12 (lowest vulnerability) (table 16). East London, Gqeberha and Knysna are the study sites with highest vulnerability associated with climate change induced changes to tourism demand, with a weighted TD score of 21.,6 each (table 16). Ladysmith and St Lucia are the study sites with lowest vulnerability associated with climate change induced changes to tourism demand, with a weighted TD score of 12 each (table 16).

Table 16. Results of the TD component indicators for each study site, ranked from highest to lowest cumulative weighted TD score

Location	Standard Indicator Scores						Weighted Scores					Weighted Total
	TD1	TD2	TD3	TD4	TD5	TD6	TD2	TD3	TD4	TD5	TD6	
East London	NA	1	5	5	5	2	1.2	6	6	6	2.4	21.6
Gqeberha	NA	1	5	5	5	2	1.2	6	6	6	2.4	21.6
Knysna	NA	1	5	4	4	4	1.2	6	4.8	4.8	4.8	21.6
Cape Town	NA	1	4	4	4	4	1.2	4.8	4.8	4.8	4.8	20.4
Paarl	NA	1	4	4	4	4	1.2	4.8	4.8	4.8	4.8	20.4
Bethlehem	NA	2	1	5	3	5	2.4	1.2	6	3.6	6	19.2
Bloemfontein	NA	2	1	5	3	5	2.4	1.2	6	3.6	6	19.2
Kimberley	NA	4	3	2	1	5	4.8	3.6	2.4	1.2	6	18
Port Nolloth	NA	4	3	2	1	5	4.8	3.6	2.4	1.2	6	18
eMakhazeni	NA	3	2	4	1	4	3.6	2.4	4.8	1.2	4.8	16.8
Mbombela	NA	3	2	4	1	4	3.6	2.4	4.8	1.2	4.8	16.8
Pilanesberg	NA	5	1	1	3	3	6	1.2	1.2	3.6	3.6	15.6
Polokwane	NA	5	1	1	5	1	6	1.2	1.2	6	1.2	15.6
Johannesburg	NA	4	1	2	3	2	4.8	1.2	2.4	3.6	2.4	14.4
Pretoria	NA	4	1	2	3	2	4.8	1.2	2.4	3.6	2.4	14.4
Durban	NA	2	3	3	2	1	2.4	3.6	3.6	2.4	1.2	13.2
Ladysmith	NA	2	2	3	2	1	2.4	2.4	3.6	2.4	1.2	12
St Lucia	NA	2	2	3	2	1	2.4	2.4	3.6	2.4	1.2	12

Study sites that are most vulnerable to climate change induced changes to GDP at their source markets (TD2) are Pilanesberg and Polokwane with a score of 5 each, whilst East London, Gqeberha, Knysna, Cape Town and Paarl have the lowest vulnerability score of 1 for this indicator (table 16). Study sites that are most vulnerable to tourism demand changes as a result of increased travel costs associated with increased distance from source markets to destinations (TD3) are East London, Gqeberha and Knysna with a score of 5 each (table 16). Bethlehem, Bloemfontein, Pilanesberg, Polokwane, Johannesburg and Pretoria are least vulnerable to distance related tourism demand changes (TD3) as a result of climate change with a score of 1 each (table 16). Study sites which have larger proportions of international leisure tourists are more likely to see reductions in tourist arrivals under climate change contexts have higher vulnerability scores for TD4 and include East London, Gqeberha, Bethlehem and Bloemfontein with a score of 5 each (table 16). Study sites with the lowest proportion of leisure travellers have lower vulnerability scores for TD4 as non-leisure tourists are less likely to change their destination choices under climate change contexts and include Pilanesberg and Polokwane with a score of 1 each (table 16). Study sites that are most vulnerable to reductions in tourist arrival volumes based on climate change induced changes to departure patterns from source destinations include East London, Gqeberha and Polokwane with scores of 5 each (table 16). Study sites least vulnerable to reductions in tourist volumes as a result of climate change driven changes to departure patterns from source destinations are Port Nolloth, Kimberley, Mbombela and eMakhazeni with a score of 1 each (table 16). Study sites currently receiving the lowest proportion of direct domestic tourism spend are most vulnerable to reductions in national GDP and associated money available for tourism spending (TD6), and these include Bethlehem, Bloemfontein, Kimberley and Port Nolloth with a score of 5 each (table 16). Least vulnerable study sites for TD6 are Polokwane, Ladysmith, Durban and St Lucia with a score of 1 each (table 16).

6.2.4. Host Country Deterrents

Results for the Host Country Deterrents component range between 14 (highest vulnerability) and 4 (lowest vulnerability) (table 17). Durban and Ladysmith are most vulnerable to host country deterrent indicators with a score of 14 each (table 17). Johannesburg and St Lucia are slightly less vulnerable with a score of 13 each (table 17). Study sites with the lowest overall vulnerability for the HCD component are Kimberley and Port Nolloth with very low scores of scores of 5 and 4 respectively (table 17).

Table 17. Results of the HCD component indicators for each study site, ranked from highest to lowest cumulative HCD score

Location	HCD1	HCD2	HCD3	Total
Durban	5	4	5	14
Ladysmith	5	4	5	14
Johannesburg	3	5	5	13
St Lucia	5	4	4	13
East London	3	4	5	12
Pretoria	2	5	5	12
Mbombela	3	3	5	11
Cape Town	3	5	2	10
Gqeberha	3	4	3	10
Polokwane	2	3	5	10
eMakhazeni	2	3	4	9
Pilanesberg	1	3	5	9
Knysna	1	5	2	8
Paarl	1	5	2	8
Bloemfontein	2	2	3	7
Bethlehem	2	2	2	6
Kimberley	2	1	2	5
Port Nolloth	2	1	1	4

Study sites most vulnerable to extreme weather and natural disaster impacts based on historical natural disaster prevalence (HCD1) are Durban, Ladysmith and St Lucia with a score of 5 each, whilst the least vulnerable study sites for HCD1 are Pilanesberg, Knysna and Paarl with scores of 1 each (table 17). Security related vulnerability scores (HCD2) are found to be highest for Johannesburg, Pretoria, Cape Town, Knysna and Paarl with a score of 5 each (table 17). Lowest security related vulnerability (HCD2) is associated with Kimberley and Port Nolloth with scores of 1 each (table 17). Eight of the 27 study sites had a large projected climate change induced increase in malaria prevalence and associated health related vulnerability (HCD3) with scores of 5 each (table 17). Only one destination, Port Nolloth, was not projected to have malaria prevalence under climate change scenarios and therefore had the lowest vulnerability score of 1 (table 17).

6.2.5. Tourism Sector Adaptive Capacity

Results for the Tourism Sector Adaptive Capacity component range between 20 (highest vulnerability) and 13 (lowest vulnerability) (table 18). Bethlehem and Bloemfontein are the study sites with the highest TSAC associated vulnerability with scores of 20 each (table 18). The least vulnerable study site for the TSAC component was found to be Cape Town with a score of 13 (table 18).

Table 18. Results of the TSAC component indicators for each study site, ranked from highest to lowest cumulative TSAC score

Location	TSAC1	TSAC2	TSAC3	TSAC4	TSAC5	Total
Bethlehem	3	3	5	4	5	20
Bloemfontein	3	3	5	4	5	20
East London	3	3	2	5	4	17
Gqeberha	3	3	2	5	4	17
Kimberley	3	3	5	4	2	17
Pilanesberg	3	3	4	4	3	17
Port Nolloth	3	3	5	4	2	17
eMakhazeni	3	3	2	5	3	16
Ladysmith	3	3	1	4	5	16
Mbombela	3	3	2	5	3	16
St Lucia	3	3	1	4	5	16
Durban	3	2	1	4	5	15
Paarl	3	3	1	5	3	15
Johannesburg	3	2	4	4	1	14
Knysna	3	2	1	5	3	14
Polokwane	3	3	3	4	1	14
Pretoria	3	2	4	4	1	14
Cape Town	3	1	1	5	3	13

All study sites had a moderate vulnerability score of 3 for tourism competitiveness (TSAC1) (table 18). Results for TSAC2, destination image and brand, were found to be moderate to positive with scores ranging between 1 and 3 (table 18). The study site least vulnerable based on TSAC 2 was Cape Town with a score of 1 (table 18). The TSAC3 indicator represented the proportion of international converted to domestic tourists that a destination would likely receive. Study sites most likely to benefit from these climate change induced tourist movement changes were found to be Ladysmith, St Lucia, Durban, Paarl, Knysna and Cape Town with a score of 1 each (table 18). Study sites that would likely receive the lowest proportion of new domestic tourists and therefore had the highest vulnerability score of 5 were found to be Bethlehem, Bloemfontein, Kimberley and Port Nolloth (table 18). Inequality related socioeconomic vulnerability associated with TSAC4 was found to be high for all study sites, with 11 sites scoring 4 and seven sites scoring 5 (table 18). Infrastructure quality related tourism sector vulnerability (TSAC5) was found to be highest for Bethlehem, Bloemfontein, Ladysmith, St Lucia and Durban with scores of 5 each (table 18). Lowest vulnerability scores for TSAC5 were found for Johannesburg, Polokwane and Pretoria, with scores of 1 each (table 18).

6.2.6. Host Country Adaptive Capacity

Results for the Host Country Adaptive Capacity component range between 9,43 (highest vulnerability) and 6,31 (lowest vulnerability) (table 19). Pilanesberg, Cape Town, Knysna and Johannesburg were found to be most vulnerable for the HCAC component with scores above 9 for each site (table 19). Lowest vulnerability for the HCAC component was found in Kimberley, Bethlehem and Bloemfontein with total HCAC scores below 7 (table 19).

Table 19. Results of the HCAC component indicators for each study site, ranked from highest to lowest cumulative HCAC score

Location	HCAC1	HCAC2	HCAC3	Total
Pilanesberg	4	3,24	2,19	9,43
Cape Town	3	1,17	5,00	9,17
Knysna	3	1,99	4,07	9,06
Johannesburg	3	1,38	4,66	9,04
Port Nolloth	4	2,19	2,48	8,67
Polokwane	3	2,54	3,09	8,63
St Lucia	3	2,74	2,80	8,54
Mbombela	4	2,31	2,20	8,51
Durban	3	2,18	3,13	8,31
eMakhazeni	4	1,97	2,22	8,19
Paarl	3	1,47	3,63	8,10
Ladysmith	3	2,46	2,50	7,96
Gqeberha	4	1,43	2,34	7,77
East London	4	1,89	1,66	7,55
Pretoria	3	1,28	3,07	7,35
Bloemfontein	3	1,87	2,12	6,99
Bethlehem	3	1,77	1,85	6,62
Kimberley	4	1,41	0,90	6,31

Scores for HCAC1 were found to be moderate to high, with 11 study sites having a score of 3 and seven study sites having a score of 4 each (table 19). The study site with the greatest vulnerability associated with governance quality (HCAC2) was found to be Pilanesberg with a score of 3.24 whilst lowest vulnerable associated with governance quality was identified to be Cape Town with a score of 1.17 (table 19). 11 study sites had a moderately low vulnerability score for HCAC3 with scores below 2, with Cape Town, Knysna and Johannesburg emerging as most vulnerable (table 19).

6.3. CVIT Results

6.3.1. Weighting Set 1 – Equal Indicator Weighting

Total CVIT scores range between 92.37 (highest vulnerability) and 67.31 (lowest vulnerability), with an average of 80.44 (standard deviation of 5.94) (table 20). The three study sites with tourism sectors most vulnerable to climate change were found to be Gqeberha (92.37), Cape Town (90.57) and East London (88.15) (table 20). The three study sites with tourism sectors least vulnerable to climate change were found to be Kimberley (67.31), Johannesburg (74.44) and Pretoria (75.75) (table 20).

Table 20. CVIT results including component totals (Weighting Set 1)

Location	TA	TOC	TD	HCD	TSAC	HCAC	Total
Gqeberha	16	20	21.6	10	17	7.77	92.37
Cape Town	17	21	20.4	10	13	9.17	90.57
East London	11	19	21.6	12	17	7.55	88.15
Durban	15	21	13.2	14	15	8.31	86.51
Pilanesberg	9	23	15.6	9	17	9.43	83.03
Paarl	10	21	20.4	8	15	8.10	82.50
Knysna	10	19	21.6	8	14	9.06	81.66
eMakhazeni	10	20	16.8	9	16	8.19	79.99
Port Nolloth	11	21	18	4	17	8.67	79.67
St Lucia	13	17	12	13	16	8.54	79.54
Ladysmith	7	21	12	14	16	7.96	77.96
Mbombela	8	17	16.8	11	16	8.51	77.31
Polokwane	8	21	15.6	10	14	8.63	77.23
Bloemfontein	8	16	19.2	7	20	6.99	77.19
Bethlehem	10	15	19.2	6	20	6.62	76.82
Pretoria	8	20	14.4	12	14	7.35	75.75
Johannesburg	8	16	14.4	13	14	9.04	74.44
Kimberley	8	13	18	5	17	6.31	67.31
Average	10	19	17.3	9.7	16	8.12	80.44
Standard Deviation	3	2.6	3.15	2.9	1.89	0.86	5.94

6.3.2. Weighting Set 2 – Adaptive Capacity Focused Weighting

Weighting set 2 weighs adaptive capacity components TSAC and HCAC proportionally more than in weighting set 1. Total CVIT scores when using weighting set 2 range between 88.12 (highest vulnerability) and 67.06 (lowest vulnerability), with an average of 80,32 (standard deviation 4.85) (table 21). The three study sites with tourism sectors most vulnerable to climate change were found to be Gqeberha (88.12), Cape Town (86.56) and Durban (86.42) (table 21). The three study sites with tourism sectors least vulnerable to climate change were found to be Kimberley (67.06), Pretoria (75.93) and Bethlehem (76.31) (table 21).

Table 21. CVIT results including component totals (Weighting Set 2)

Location	TA	TOC	TD	HCD	TSAC	HCAC	Total
Gqeberha	10.80	13.50	12.15	11.25	22.95	17.47	88.12
Cape Town	11.48	14.18	11.48	11.25	17.55	20.63	86.56
Durban	10.13	14.18	7.43	15.75	20.25	18.70	86.42
East London	7.43	12.83	12.15	13.50	22.95	16.99	85.84
Pilanesberg	6.08	15.53	8.78	10.13	22.95	21.22	84.67
St Lucia	8.78	11.48	6.75	14.63	21.60	19.22	82.44
Ladysmith	4.73	14.18	6.75	15.75	21.60	17.90	80.90
Knysna	6.75	12.83	12.15	9.00	18.90	20.37	80.00
Paarl	6.75	14.18	11.48	9.00	20.25	18.23	79.88
eMakhazeni	6.75	13.50	9.45	10.13	21.60	18.43	79.85
Mbombela	5.40	11.48	9.45	12.38	21.60	19.14	79.44
Port Nolloth	7.43	14.18	10.13	4.50	22.95	19.51	78.68
Johannesburg	5.40	10.80	8.10	14.63	18.90	20.34	78.17
Polokwane	5.40	14.18	8.78	11.25	18.90	19.41	77.91
Bloemfontein	5.40	10.80	10.80	7.88	27.00	15.72	77.59
Bethlehem	6.75	10.13	10.80	6.75	27.00	14.88	76.31
Pretoria	5.40	13.50	8.10	13.50	18.90	16.53	75.93
Kimberley	5.40	8.78	10.13	5.63	22.95	14.19	67.06
Average	7.01	12.79	9.71	10.9	21.6	18.3	80.32
Standard Deviation	1.96	1.75	1.77	3.29	2.55	1.94	4.85

6.3.3. Weighting Set 3 – Tourism Asset Focused Weighting

Weighting set 3 weighs the TA component proportionally than weighting set 1, the standard equal indicator weighting used by Scott et al. (2019). Total CVIT scores when using weighting set 3 range between 90.69 (highest vulnerability) and 56.07 (lowest vulnerability), with an average of 70.75 (standard deviation 9.35) (table 22). The three study sites with tourism sectors most vulnerable to climate change were found to be Cape Town (90.69), Gqeberha (88.89) and Durban (85.96) (table 22). The three study sites with tourism sectors least vulnerable to climate change were found to be Kimberley (56.07), Bloemfontein (62.27) and Pretoria (63.85) (table 22).

Table 22. CVIT results including component totals (Weighting Set 3)

Location	TA	TOC	TD	HCD	TSAC	HCAC	Total
Cape Town	45.90	11.34	9.18	9.00	7.02	8.25	90.69
Gqeberha	43.20	10.80	9.72	9.00	9.18	6.99	88.89
Durban	40.50	11.34	5.94	12.60	8.10	7.48	85.96
St Lucia	35.10	9.18	5.40	11.70	8.64	7.69	77.71
East London	29.70	10.26	9.72	10.80	9.18	6.80	76.46
Paarl	27.00	11.34	9.18	7.20	8.10	7.29	70.11
Knysna	27.00	10.26	9.72	7.20	7.56	8.15	69.89
Port Nolloth	29.70	11.34	8.10	3.60	9.18	7.80	69.72
Pilanesberg	24.30	12.42	7.02	8.10	9.18	8.49	69.51
eMakhazeni	27.00	10.80	7.56	8.10	8.64	7.37	69.47
Bethlehem	27.00	8.10	8.64	5.40	10.80	5.95	65.89
Mbombela	21.60	9.18	7.56	9.90	8.64	7.65	64.53
Polokwane	21.60	11.34	7.02	9.00	7.56	7.76	64.28
Johannesburg	21.60	8.64	6.48	11.70	7.56	8.14	64.12
Ladysmith	18.90	11.34	5.40	12.60	8.64	7.16	64.04
Pretoria	21.60	10.80	6.48	10.80	7.56	6.61	63.85
Bloemfontein	21.60	8.64	8.64	6.30	10.80	6.29	62.27
Kimberley	21.60	7.02	8.10	4.50	9.18	5.67	56.07
Average	28.1	10.2	7.8	8.75	8.64	7.31	70.75
Standard Deviation	7.85	1.4	1.4	2.63	1.02	0.78	9.35

6.3.4. Weighting Set Comparison

The three different CVIT weighting sets explored in this, W1, W2 and W3 study yielded different CVIT scores for each of the 18 study sites (figure 15).

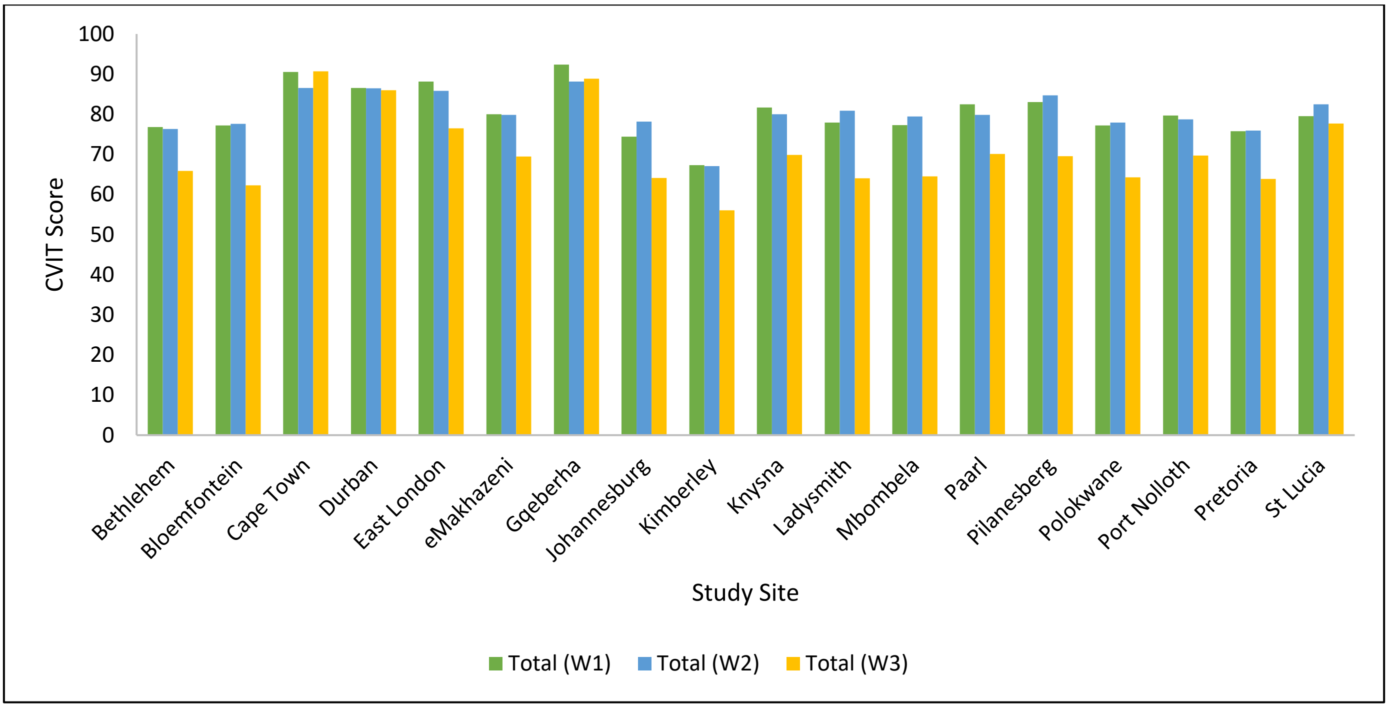


Figure 15. Graph of CVIT scores per study site using weighting set 1, 2 and 3.

Weighting set 2 yielded CVIT scores for each study site that were found to not be significantly different to the standard weighting approach (W1) (table 23), with a dependent t.test value of 0.82 and a correlation coefficient of 0.93 (table 23). This aligns to the findings of Scott et al. (2019) who found a 0.97 correlation between the two weighting approaches and therefore chose to only focus on and present results for weighting set 1. Weighting set 3, however, yielded CVIT scores significantly different to the standard equal indicator weighting approach used by Scott et al. (2019) (W1) and had a lower correlation coefficient of 0.91 (table 23).

Weighting set 3 also yielded CVIT scores with a larger range and variance than weighting set 1 and 2 (table 23).

Table 23. Summary of measures used to determine statistical differences between standard weight (W1) with W2 (adaptive capacity focused weighting) and W3 (tourism asset focused weighting)

Weighting Set	**W1**	**W2**	**W3**
Mean	80.44	80.32	70.75
Standard Deviation	6.12	5.00	9.62
Variance	37.40	24.96	92.42
Sample Size	18	18	18
p value (paired t.test)		0.82	1.27×10^{-7}
W1 comparison		Not significant	Significant
Correlation Coefficient		0.93	0.91

The use of different weighting approaches changes the comparative rank in climate change vulnerability for tourism for each study site (table 24). Gqeberha and Cape Town are consistently the two most vulnerable study sites across the three different weighting sets (table 24). For weighting set 2, the vulnerability rank of St Lucia, Ladysmith and Johannesburg is greatest, moving four positions upwards each and being found to be more vulnerable than when compared to their original ranking in weighting set 1 (table 24). For weighting set 3, the biggest change in rank position is St Lucia, moving six positions from 10th most vulnerable to 4th most vulnerable study site (table 24). Pilanesberg and Ladysmith both move lower in vulnerability ranking, down four positions from the original position with weighting set 1 (table 24).

Table 24. Ranking of study sites from most to least vulnerable using weighting set 1, 2 and 3, showing rank position change in comparison to standard, equal indicator weighting (W1).

Rank	Weighting 1	Weighting 2	Position Change	Weighting 3	Position Change
1st	Gqeberha	Gqeberha	0 →	Cape Town	1 ↑
2nd	Cape Town	Cape Town	0 →	Gqeberha	1 ↓
3rd	East London	Durban	1 ↑	Durban	1 ↑
4th	Durban	East London	1 ↓	St Lucia	6 ↑
5th	Pilanesberg	Pilanesberg	0 →	East London	2 ↓
6th	Paarl	St Lucia	4 ↑	Paarl	0 →
7th	Knysna	Ladysmith	4 ↑	Knysna	0 →
8th	eMakhazeni	Knysna	1 ↓	Port Nolloth	1 ↑
9th	Port Nolloth	Paarl	3 ↓	Pilanesberg	4 ↓
10th	St Lucia	eMakhazeni	2 ↓	eMakhazeni	2 ↓
11th	Ladysmith	Mbombela	1 ↑	Bethlehem	4 ↑
12th	Mbombela	Port Nolloth	3 ↓	Mbombela	0 →
13th	Polokwane	Johannesburg	4 ↑	Polokwane	0 →
14th	Bloemfontein	Polokwane	1 ↓	Johannesburg	3 ↑
15th	Bethlehem	Bloemfontein	1 ↓	Ladysmith	4 ↓
16th	Pretoria	Bethlehem	1 ↓	Pretoria	0 →
17th	Johannesburg	Pretoria	1 ↓	Bloemfontein	3 ↓
18th	Kimberley	Kimberley	0 →	Kimberley	0 →

→	No change in vulnerability rank position from W1
↑	Increased vulnerability ranking compared to W1
↓	Decreased vulnerability ranking compared to W1

Considering the limited differences between weighting set 1 and 2, and the previously untested nature of weighting set 3, the results of weighting set 1 will be the focus of the remainder of this results chapter and will be explored in detail for the 18 study sites within South Africa.

6.4. CVIT Spatial Distribution – Standard Weighting (W1)

Figure 16 presents the final CVIT score of focus for each of the 18 study sites explored within this study and was produced using QGIS software. Spatial heterogeneity within the vulnerability of tourism sectors across the country is confirmed. Coastal regions emerge as regions with generally highest relative vulnerability scores including East London, Gqeberha, Port Nolloth, Cape Town, Durban and Knysna (figure 16). Two inland study sites, Paarl and Pilanesberg, have moderately high relative vulnerability scores (figure 16). Kimberley, Bethlehem, Bloemfontein, Johannesburg and Pretoria emerge as study sites with lowest relative vulnerability scores (figure 16). Polokwane, Mbombela and Ladysmith are found to have moderate vulnerability in comparison to other study sites (figure 16).

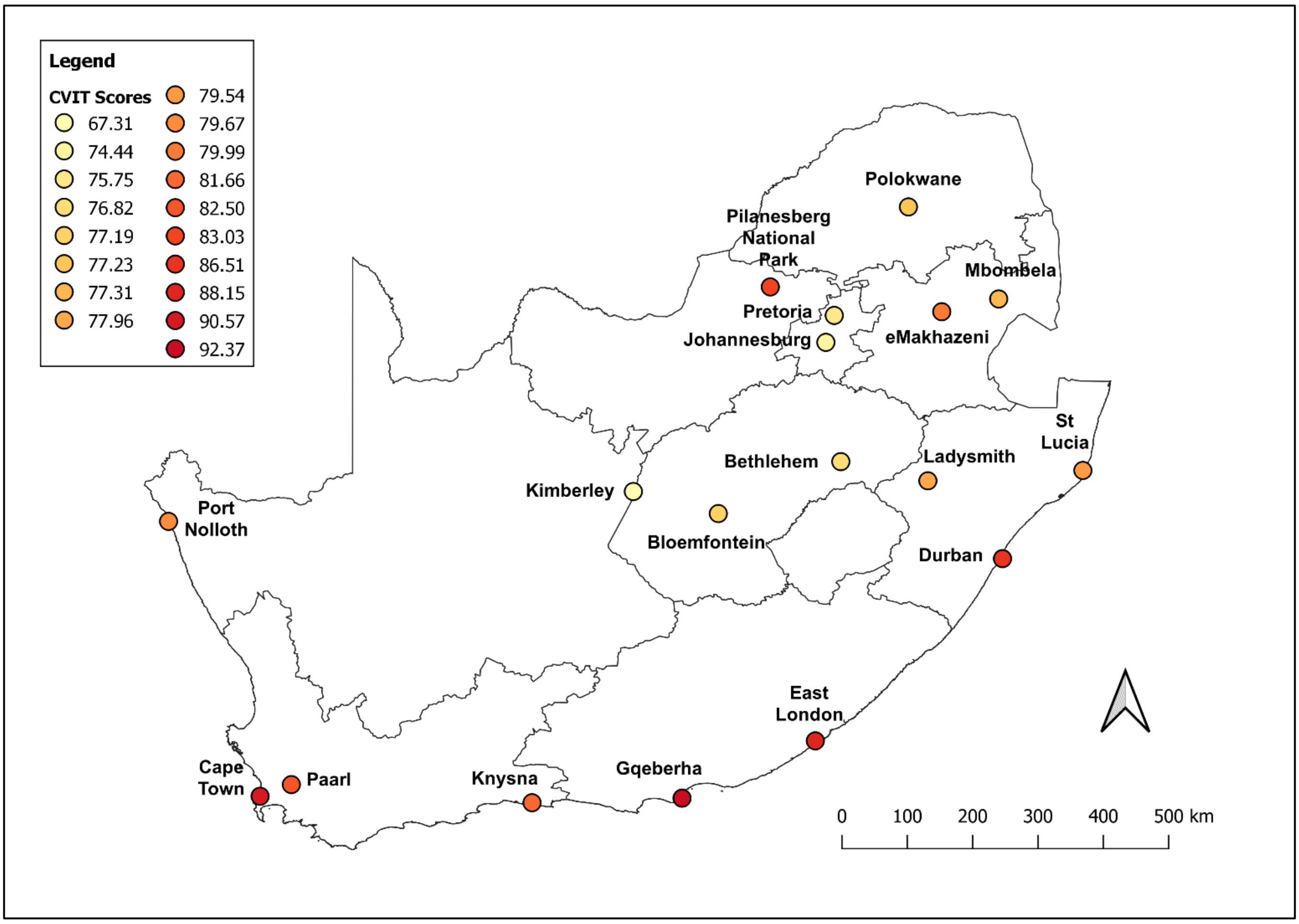


Figure 16. Map of CVIT scores per study site using the standard, equal indicator weighting approach.

Spatial interpolation of CVIT scores across the country are presented in figure 17. Spatial interpolation was undertaken using Inverse Distance Weighted(IDW) interpolation techniques using QGIS software. Whilst the entire country is found to have relatively high vulnerability, in line with the findings of Scott et al. (2019), notable vulnerability hotspots are found (figure 17). These include parts of the north-eastern interior as well as the south-eastern and south-western coastlines (figure 17). Low vulnerability is observed in the central interior of the country (figure 17).

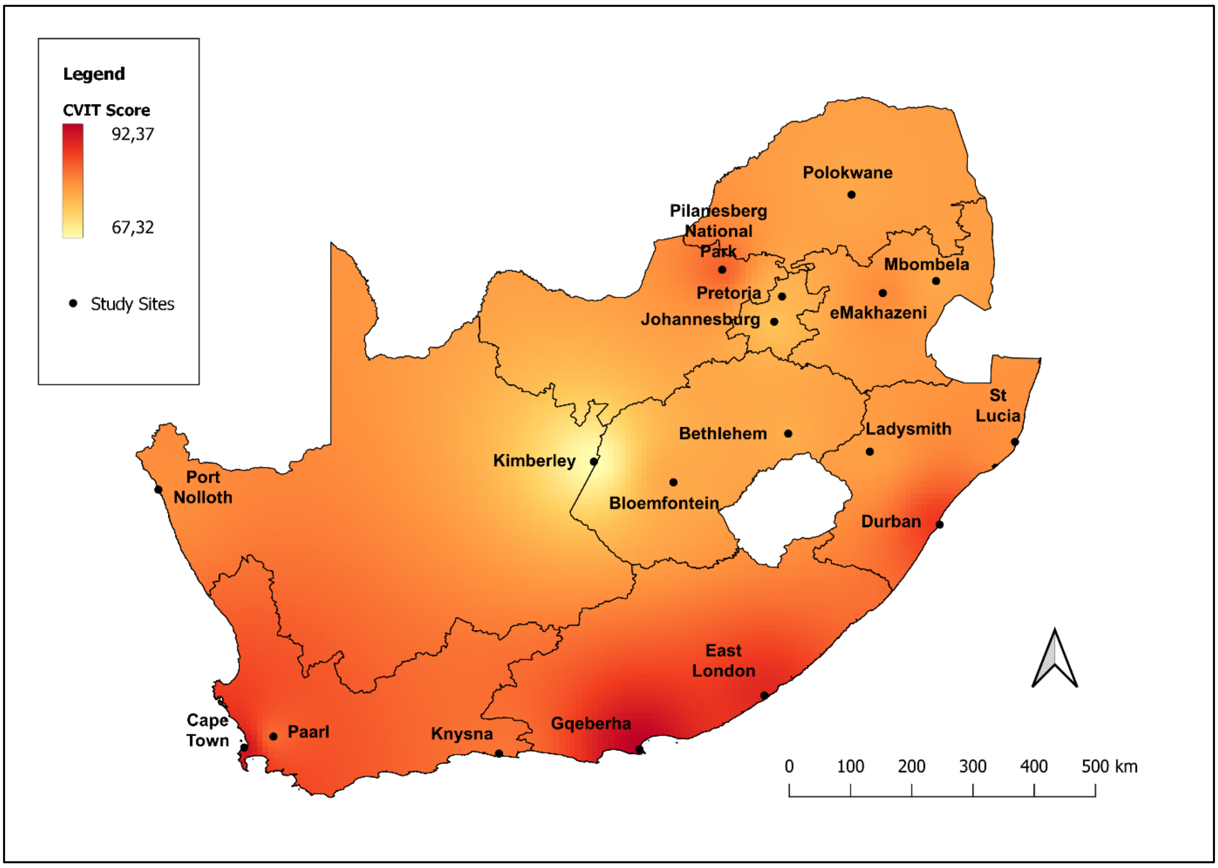


Figure 17. Spatial distribution of standard CVIT scores (W1) across South Africa calculated using IDW approach and QGIS software.

6.5. Vulnerability Quadrant Placement

Figure 18 presents the distribution of study sites across a vulnerability quadrant chart which compares the potential impacts of climate change and obstacles associated with climate change mitigation (x-axis) in comparison to adaptation capacity (y-axis). Mean scores for both dimensions are used to define the quadrants and lie at 24 for the y-axis and 57 for the x-axis (figure 18). Study sites in the upper right-hand quadrant represent study sites with highest potential climate change impacts and lowest adaptive capacity and therefore greatest net vulnerability, and include Pilanesberg, East London and Gqeberha (figure 18). Study sites with moderate vulnerability can be found in the upper left and lower right-hand quadrants (figure 18). Port Nolloth, Bethlehem, Bloemfontein, St Lucia and Mbombela have relatively lower potential climate change impacts but are characterised by a relatively lower adaptive capacity than other study sites and thus are found to be moderately vulnerable (figure 18). Cape Town, Durban, Paarl and Knysna have high relative potential climate change impacts but are also characterised by higher relative adaptive capacity than other sites (figure 18) and can be classified as moderately vulnerable. Study sites within the lower left-hand quadrant have the lowest relative potential impacts in conjunction with relatively high adaptive capacity, and therefore lowest relative vulnerability and include Kimberley, Johannesburg, Ladysmith, Polokwane and eMakhazeni (figure 18).

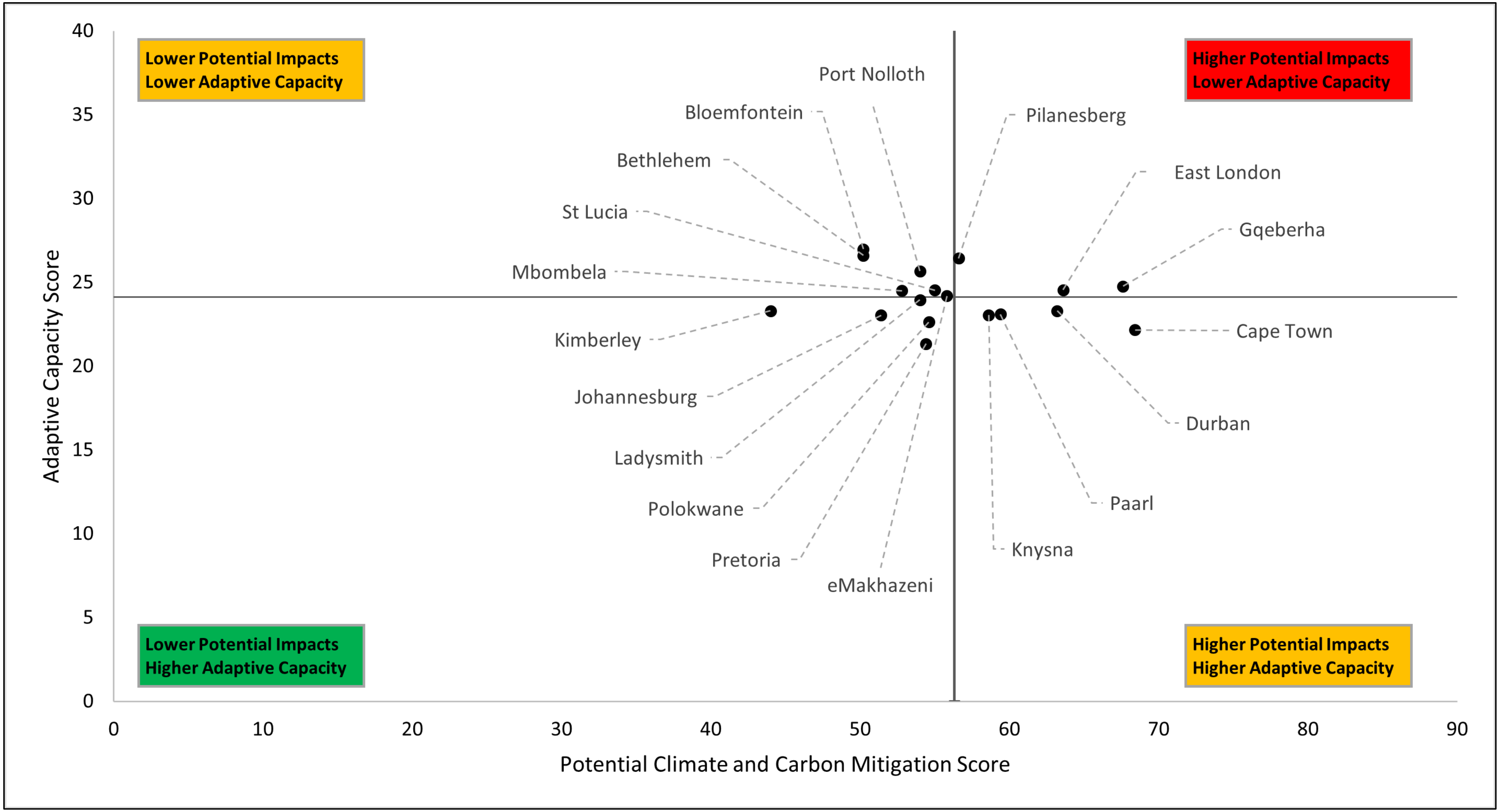


Figure 18. Vulnerability quadrant placement of 18 South African study sites comparing climate change impact and adaptive capacity scores

6.6. Site Level Vulnerability Drivers

Understanding what variables are driving vulnerability most at each study site is important to understand in order to identify where local scale action should be prioritised. Each study site was found to have differing numbers and types of indicator variables contributing to relative vulnerability (table 25). Cape Town and Gqeberha have nine indicators with scores of 5 and therefore have the most variables contributing to overall vulnerability (table 25). Kimberley has only three indicators with a score of 5 including TOC4, TD6 and TSAC3 and therefore has fewer indicators contributing to its vulnerability score (table 25).

Table 25. Indicators with highest vulnerability score (5) per study site

Location	**Indicators with highest vulnerability (5)**								
Cape Town	TA2	TA4	TOC1	TOC2	TOC3	TOC4	HCD2	TSAC4	HCAC3
Gqeberha	TA1	TA4	TOC2	TOC4	TOC5	TD3	TD4	TD5	TSAC4
East London	TA4	TOC4	TOC5	TD3	TD4	TD5	HCD3	TSAC4	
Polokwane	TOC1	TOC3	TOC4	TOC5	TD2	TD5	HCD3		
Bethlehem	TA1	TOC3	TOC4	TD4	TD6	TSAC3	TSAC5		
Pilanesberg	TA1	TOC2	TOC3	TOC4	TD2	HCD3			
Knysna	TOC2	TOC3	TOC4	TD3	HCD2	TSAC4			
Paarl	TOC1	TOC2	TOC3	TOC4	HCD2	TSAC4			
Durban	TOC2	TOC3	TOC4	HCD1	HCD3	TSAC5			
Bloemfontein	TOC3	TOC4	TD4	TD6	TSAC3	TSAC5			
Pretoria	TOC2	TOC3	TOC4	HCD2	HCD3				
Port Nolloth	TOC1	TOC2	TOC4	TD6	TSAC3				
Ladysmith	TOC3	TOC4	HCD1	HCD3	TSAC5				
Johannesburg	TOC3	TOC4	HCD2	HCD3					
eMakhazeni	TA1	TOC3	TOC4	TSAC4					
Mbombela	TOC3	TOC4	HCD3	TSAC4					
St Lucia	TOC3	TOC4	HCD1	TSAC5					
Kimberley	TOC4	TD6	TSAC3						

Understanding which indicators are driving vulnerability most at a national scale is also useful to understand to guide national policy making priorities. This can be demonstrated using a word cloud that reflects the relative frequency of indicators that have the highest score (5) across the study sites (figure 19). Bigger words are indicative of having a score of 5 more frequently, with TOC4, most frequent, followed by TOC3, HCD3, TOC2 and TSAC4 (figure 19).

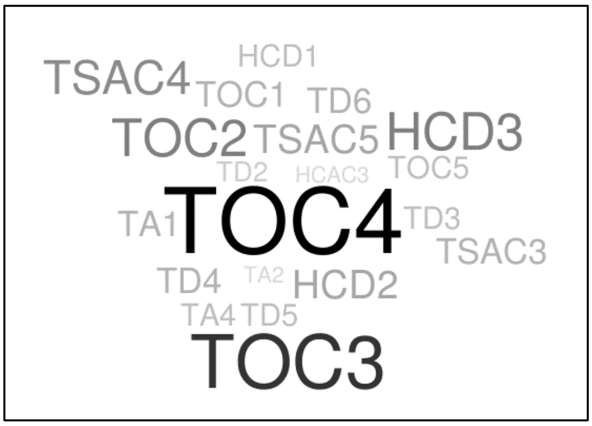


Figure 19. Word cloud showing relative frequency of indicators with a score of 5 per study site.

6.7. Conclusion

This chapter presented the results of this study, including an indicator level assessment for each of the six components making up the CVIT. The CVIT scores for the three different weighting sets explored in this study were then presented. Weighting set 2 was found not to be significantly different to weighting set 1 (standard), whilst weighting set 3 was found to be significantly different to weighting set 1 (standard). The CVIT results of weighting set 1, standard equal indicator weighting, were explored in detail, identifying the spatial distribution of vulnerability across the 18 study sites and the country, as well as an in-depth examination of the drivers of vulnerability at each site and a vulnerability quadrant placement which allowed for the comparison of potential impacts of climate change in comparison to adaptive capacity for each of the study sites. The results serve as a strong warning about the potential high vulnerability of the south African tourism sector to climate change and confirms the hypothesis that heterogeneity in climate change vulnerability at subnational scale for the tourism sector exists.

CHAPTER 7 - DISCUSSION

7.1. Introduction

This study sought to calculate the CVIT for 18 locations across South Africa, the purpose of which was twofold – firstly, to assess whether or not the CVIT methodology introduced by Scott et al. (2019) at a global scale can be downscaled to a subnational level, and secondly, if indeed it can, to determine the spatial distribution of differential climate change vulnerability for tourism across the country. Chapter two of this study (Literature Review) engaged extant research on the relationship between climate change and tourism, reinforcing the need for local scale assessment of climate change vulnerability for tourism in South Africa by highlighting the local scale of climate change impacts and responses. This discussion chapter will reflect on the methodologies and approaches employed in this study across the research journey, and thereafter will engage the results in comparison to existing literature and policy. This will be done in a structured manner, engaging concerns and implications at every step of the research process (figure 20), highlighting the cascading and compounding impact of limitations to output score integrity and validity.

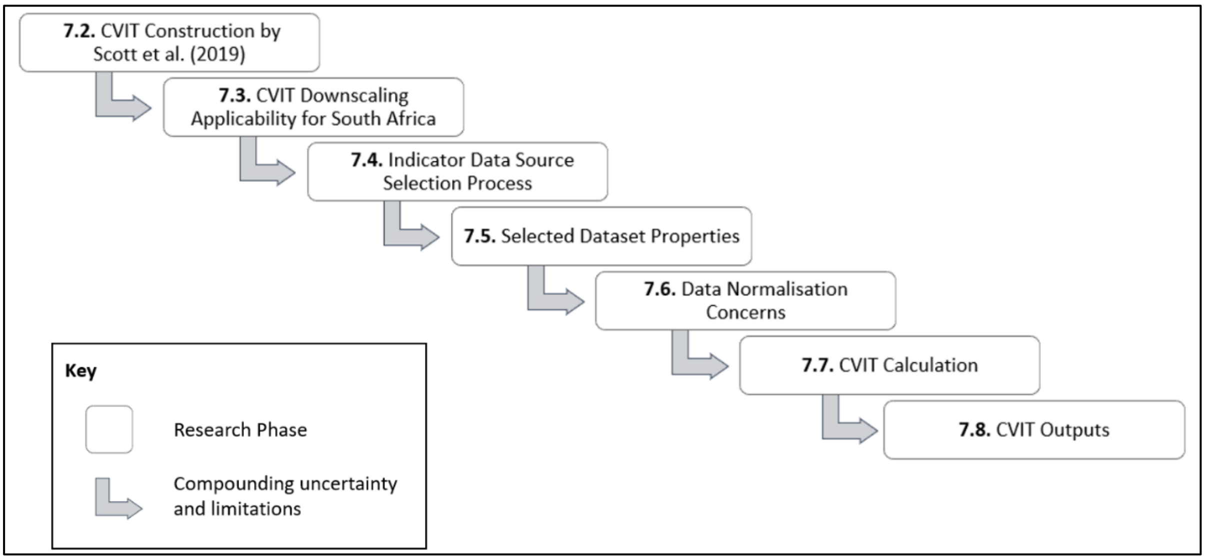


Figure 20. Structure of Discussion Chapter

7.2. CVIT Construction by Scott et al. (2019)

Before one can downscale an index to a local scale, it is important to examine the source of the index and methodologies followed to construct the index by original authors. Chapter 4 of this study summarised and explored the approach employed by Scott et al. (2019), but this discussion will take a more critical look at the index and how it was constructed which has implications for downscaling the CVIT to local scale context.

The information presented by Scott et al. (2019) on how the CVIT is constructed and computed can occasionally be described as high-level in nature or lacking detail. This is understandable given the page limits for academic journal articles, but nonetheless has the effect of making the CVIT difficult to reproduce identically and for other researchers to yield the same scores as Scott et al. (2019), even at a national scale. Examples of areas potentially lacking some detail include mentioning surveys of experts for the indicator related to Ski Tourism Impacts – but no mention of what questions were asked and how scores were aggregated. Several data sources listed by Scott et al. (2019) had multiple possible data sets that Scott et al. (2019) could have chosen between – including results under different climate change scenarios such as future GDP by Burke et al. (2015) and future tourism flows by Hamilton et al. (2005) – but Scott et al. (2019) do not detail which of the potential options were selected. There were instances of the least conservative estimate being used, so it was assumed in this study that that approach was employed throughout. Another example of a small lack of detail in presentation of the CVIT is that Scott et al. (2019) do not indicate where they acquired the information for percentage GDP from tourism that was used to plot CVIT scores in comparison to relative importance of the tourism sector for each country to show where climate change would likely be most impactful (figure 21). Regardless of this omission, similar information could not be found for South Africa at a spatial resolution greater than national scale due to the difficulty of delineating tourism and non-tourism spending at local scale. Having such information would have been a useful addition to this study to understand where climate change impacts would have the greatest impact at city scale for South Africa.

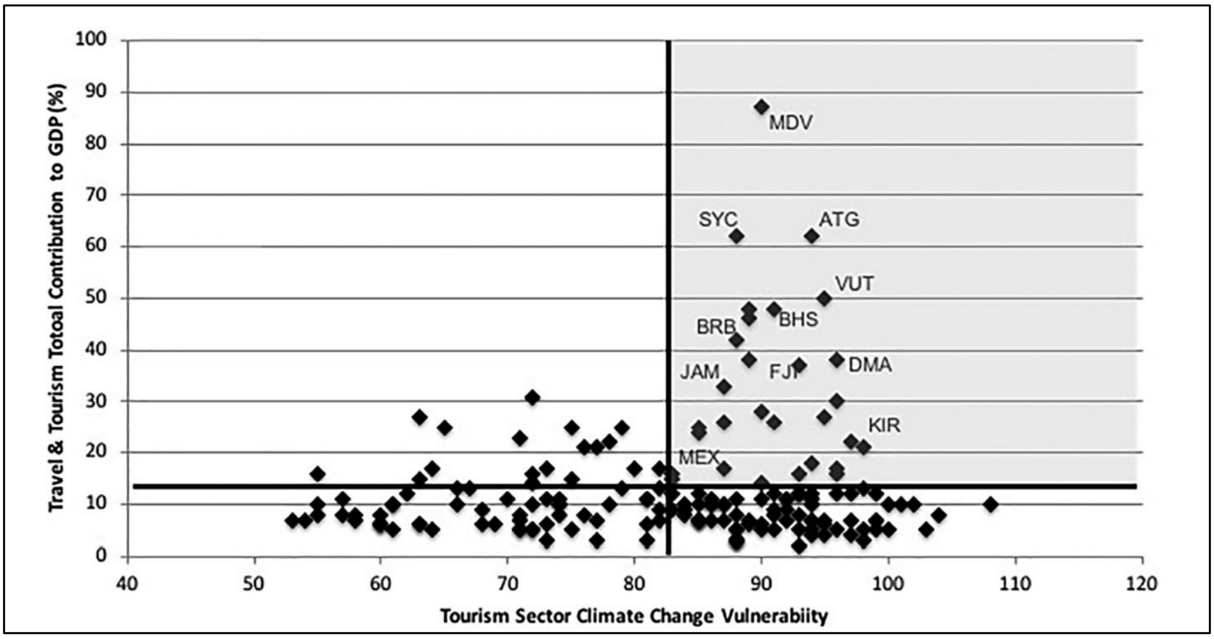


Figure 21. CVIT Scores in comparison to tourism contribution to national economy (Scott et al., 2019)

Next, one can reflect on the suitability of the CVIT for a South African context by reflecting on the assumptions made by Scott et al. (2019) when constructing the CVIT and exploring if they hold true for local contexts. Generally speaking, the making of assumptions and applying a broad brushstroke to all countries when developing an index can be justified given the more important priority of including as many countries as possible (Scott et al., 2019). The use of the TCI by Scott et al. (2019) in favour of the HCI is suitable for a South African context. An underlying assumption of the HCI and the reason for which it was adapted from the TCI, is the presence of air conditioning at destinations to mitigate the impact of night-time thermal comfort concerns. Although some destinations in southern Africa do indeed have air conditioning, the prevalence thereof is not ubiquitous (Mushawemhuka et al., 2020) and even if it were, loadshedding – the phenomenon whereby electricity supply is rationed by electricity producers during demand-supply mismatches – may make the infrastructure redundant. Southern African researchers have reinforced the need to understand applicability of the climate tourism index of interest for the context to which it is being applied and the assumptions of Scott et al. (2019) hold true for South Africa. Another assumption that can be tested in the CVIT is that greater fossil fuel dependency will result in greater renewable transition costs (Scott et al., 2019). Whilst this may hold true at a national scale, at destination scale it is possible that interventions that have already been put in place such as solar power generation and storage which would make individual destinations more resilient to these costs as the capital has already been invested in the technology and the vulnerability associated with this variable may be decreased and improve destination scale resilience in the face of climate change. Despite several examples of assumptions not aligning to local contexts, the majority of assumptions particularly those relating to crime, governance, disease prevalence and socioeconomic conditions do indeed hold true for South Africa and make the CVIT suitable for application to the country. Scott et al. (2019) undertook extensive engagement with policy makers, tourism operators and academic experts when constructing the CVIT, which enhanced validity of the index structure. Following a similar process when attempting the first downscaling attempt of the CVIT may have enhanced robustness of results found in this study.

7.3. CVIT Downscaling Applicability for South Africa

Having understood that the CVIT is indeed suitable for understanding the South African climate-tourism nexus, determining applicability of the index for local scale use is the next consideration which will guide this discussion. Applicability speaks broadly to whether or not we can indeed apply the index to local scale, answering the questions "do we have the necessary data?", and if not, "are there suitable proxies or alternatives that can be used?". Scott et al. (2019) presented a minimum threshold of at least 70% of all indicators being present and no individual component missing half or more of the variables required for calculating the CVIT. This project far surpassed these minimum thresholds, having data or suitable alternatives available for almost all indicators at subnational scale and voluntarily choosing to exclude one indicator to prevent variable duplication at local scale. Several proxies and alternative data sources had to be used as outlined in chapter 4, but in many instances these alternative sources were more representative of local dynamics than the originally desired data source would have been – for example the use of SANBI threat classification for terrestrial tourism assets (SANBI-GIS, 2018) provides more nuance that the future biome distribution score information used by Scott et al. (2019) which was not available at subnational scale for South Africa. Although information was available for all indicators, this study did compromise in several instances on spatial resolution. Ultimately the CVIT is indeed workable for local scale application in a South African context. Future studies attempting to modify the CVIT for better suitability for local scale application may prove fruitful.

7.4. Indicator Data Source Selection Process

Having understood that the CVIT can indeed be applied to local scale for South Africa, this discussion will now reflect on the process followed to downscale the CVIT and how data sources for each indicator were selected. As with all studies, the researcher is subject to bias and positionality which may have influenced the data sources that were selected in subtle or major ways (Perch-Nielsen, 2010; Hoogendoorn & Visser, 2012). An example of this includes varying exposure levels of the researcher to the different study locations which may have guided unconscious choices of data which supported pre-existing conceptions of a location through confirmation bias. Furthermore, this study engaged an incredibly broad range of multidisciplinary variables. Typically, climate tourism indices have far fewer indicators than the 27 employed by Scott et al. (2019) and are typically in one broad theme (e.g. climatology), for example the TCI with five indicators including daytime thermal comfort, average thermal comfort, total rainfall, sunshine hours and wind speed (Fitchett et al., 2017). Although extensive reading through both the literature review and peripheral reading was undertaken in an attempt to both broaden and deepen the researcher's knowledge of the variables of consideration in this study, an expert in these fields may have had a more nuanced understanding of the variable which may have guided different data source selection decisions than made by the researcher in this study. This concern speaks broadly to the issue of reproducibility of the CVIT at local scale and whether or not given the wide range of data options available to choose between, another researcher undertaking the same study would yield the same or similar results independently, speaking to the complexity and subjectivity of data source selection.

Several major obstacles were encountered which limited the data source options available for local scale application of the CVIT. Paywalls were a prevalent example thereof, with accurate and reliable information often only available through private entities at a cost. This does not align with the publicly accessible data requirement outlined by Scott et al. (2019). Other issues encountered included the accuracy of data, with data, such as that acquired from StatsSA, very often only available in pre-processed formats instead of in a raw format where filtering and customising of analysis would have been possible. Beyond the personal selection decisions which were informed by literature, data choice very often was limited by practicality with some sources being too computationally difficult or time consuming to adapt to a finer spatial scale. For example, renewable energy generation capacity is available at plant level with GPS coordinates, but assigning the 133 plants to each of the 18 study sites, along with understanding the distribution grid structure of electricity at local scale would have been incredibly tedious and necessitated a compromise on spatial resolution to provincial scale where the effort of achieving higher spatial resolution would not have notably changed the general conclusion that all study sites are very vulnerable to climate change due to fossil fuel dependency.

This study did not attempt to alter the structure of the CVIT presented by Scott et al. (2019) as it was the first attempt at downscaling the index to subnational scale and doing so would have interfered with understanding downscaling applicability. That being said, there is definitely room for the inclusion of further indicators into the CVIT, including those identified by Scott et al. (2019) and those identified through the downscaling process. Scott et al. (2019) encouraged the inclusion of insurance, wine tourism and attractor species variables in future CVIT assessments. These would all be particularly relevant to the South African context where climate change linked natural hazard insurance costs increases are of concern to tourism operators (Fitchett et al., 2016a), where wine tourism is a major driver of the Western Cape tourism sector (Araujo et al., 2016) and where seeing the “big 5” is a major motivator of tourists decisions to visit South Africa (Dube & Nhamo, 2020). Furthermore, the data selection process highlighted other indicators which could be included in future studies, including inland aquatic and river system threat metrics available from SANBI-GIS which is of importance due to the prevalence of fishing tourism in South Africa (Hoogendoorn, 2014). The inclusion of indigenous knowledge would too be a worthwhile inclusion into the CVIT but may present issues of knowledge quantification and standardisation (Makondo & Thomas, 2018; Apraku et al., 2021; Filho et al., 2022). Addition of these and other indicators may enhance the robustness of CVIT output scores in future studies.

7.5. Selected Dataset Properties

Having understood limitations inherent to the data selection process followed in this study, weaknesses of the final selected data sources can now be examined. Spatial resolution is an issue of major concern, whereby many indicators had different spatial resolutions to one another, varying between city, municipality, district, provincial and national scale. Compromising on spatial resolution was often required due to data availability limitations, but in future acquiring data at finer spatial resolution would enhance the robustness and accuracy of CVIT output scores. Prevalent examples include indicators only available at provincial scale which almost certainly blur heterogeneity at finer spatial resolution. For example, tourist arrival statistics are aggregated at provincial scale by SA Tourism (2019) and StatsSA (2019), however, Mbombela and eMakhazeni which are both in the Mpumalanga province or Cape Town and Knysna which are both in the Western Cape have very different tourist visitation and overnight stay patterns. The same can be said for crime statistics, whereby crime in St Lucia is aggregated with crime in Durban, when Durban has a significantly higher crime proportion (Linda & Nzama, 2020). Gini and HDI scores at municipal scale were historically accessible on the municipal barometer tool, but the platform has been inaccessible for many years and centralised reporting of information no longer exists at municipal or city scale despite differences in these socioeconomic variables being present at finer scales (David et al., 2018).

The use of a single score for all study sites when downscaling the CVIT could occasionally be justified and explained. NDCs for example are not disaggregated to finer spatial resolution or including the tourism sector and would therefore likely impact all provinces ubiquitously until the allocation of emission reduction responsibility is provided by government at a higher spatial resolution. Tourism competitiveness however, which saw a single score applied to all study sites, was a decision forced by a lack of data availability at a finer scale. This would have been incredibly useful and whilst some studies exist which asses the competitiveness of individual South African destinations, these sources were not comprehensive enough to be used in this study (Lubbe et al., 2015; Marin-Gonzalez et al., 2021). This is particularly important because applying a single score to all study sites does not allow for nuanced understanding of the price competitiveness between destinations, a variable which motivates tourism internationally (du Plessis et al., 2017) and domestically (SA Tourism, 2019). Ski tourism was an example of an indicator that was accurate and representative when using a national score due to the lack of ski tourism vulnerability at all study sites allowing for the lowest score of 1 to be applied. This indicator does however flag the importance of including additional study sites in future local scale CVIT applications as examples of destinations which are dependent on ski tourism do exist in South Africa in the form of Tiffindell Ski Resort near Rhodes in the Eastern Cape (Stockigt et al., 2018). This small town has historically struggled to remain financially viable and competes with popular nearby ski tourism destinations such as Afriski in Lesotho (Stockigt et al., 2018). Afriski is particularly good at monitoring its climate, therefore reducing its vulnerability to climate change (Noome & Fitchett, 2019). The inclusion of a site so potentially vulnerable to the impacts of climate change in South Africa due to the dependence of ski tourism on climate dependent snowfall (Hoogendoorn et al., 2020), would enhance the spatial resolution of the CVIT assessment and allow for a more accurate representation of spatial distribution of vulnerability.

Many of the variables assessed and included in this local scale application of the CVIT were subject to notable temporal variation, both interannually and intra annually. Calculating the CVIT for longer time periods would therefore be useful to assess how vulnerability trends are changing over time. Moreover, understanding that vulnerability is dynamic in nature, calculating the CVIT within a year, perhaps at monthly scale, would highlight further granularity and heterogeneity in vulnerability with variables such as climate suitability for tourism, water stress, food costs, tourism arrival patterns, natural disasters and disease prevalence all subject to intra annual seasonality (Dennis & Dennis, 2012; Connel et al., 2015; Fitchett et al., 2017). The internal consistency of temporal features may too have impacted usefulness of output CVIT scores as data did not represent a true snapshot in time – but rather was comprised of a mix of years, with for example TD5 using 2005 data in contrast with HCAC3 using 2022 data. Future studies would benefit from having temporal consistency in dataset properties to give an accurate representation of contextual results.

The final consideration of dataset properties is the relevance thereof to on ground findings. In many instances despite objective metrics being used as indicators when calculating the CVIT, the decisions made by tourists are actually guided by perceptions of variables and not reality. This is true for climate related variables (Wilkins et al., 2018), crime (Ferreira & Harmse, 2000; Chili, 2018), destination image (Bruwer et al., 2014) and deterrents such as malaria, with tourists choosing to travel where they perceive safety to be greatest and interpreting current and future malaria lines in manners different to statistics (Fitchett & Swatton, 2020). This has been seen historically with the Ebola virus whereby the virus was not actually prevalent in South Africa but perceptions by tourists resulted in trip cancelations (Sifilo & Sifilo, 2015). Furthermore, understanding the factors that drive decision making for tourists requires expansion in South African literature, as it is unclear at what scale the decision to visit a destination is made. For example, is a tourist choosing to visit South Africa as a destination or choosing Cape Town? Some other indicators may not have been entirely representative of local dynamics either – with water supply for example not only being limited by water availability and aquifer recharge, but also strongly dependent on infrastructure (DWS, 2022). Crime statistics relating to serious crimes may not have been indicative of the corruption and political instability intended to be represented for by HCD2 as Scott et al. (2019) used the Fragile State Index.

7.6. Data Normalisation Concerns

Beyond the properties of final selected data sources, the techniques employed in this study to normalise the datasets, which all had different units and scales, to scores of 1 to 5 also requires reflection. The two main techniques used were Jenks Natural Breaks optimisation for skew datasets, whilst linearly distributed datasets were normalised using quintile-based classification. Scott et al. (2019) did not provide details on which of the indicators they employed which normalisation approaches with, but these would likely be different at local scale so this was not a limiting factor. The use of quintile-based classification does have the effect of blurring nuance and grouping items which are not necessarily very similar together. Where normalisation was not representative of local scale dynamics, adjusted normalisation techniques were employed. This includes variables where the functional range of variables was not very big (e.g. Gini and HDI metrics), and adjustments of existing scores in relation to external factors such as local sea level rise scores in comparison to global trends, or the up and down rating of tourism image and brand attractiveness based on multiple brand indicator variables. These decisions can be deemed acceptable as the reclassifying and adjusting of weighting for better index validity and alignment is well established (Fitchett et al., 2017) but may influence the reproducibility of the study.

7.7. CVIT Calculation

Once final data sources had been selected and normalisation had been conducted, calculating the CVIT was the next research phase which may have introduced errors or concerns into the output scores of this study. The exclusion of variables where data is limited is a common practise in climate tourism indices, such as Fitchett et al. (2017) who exclude climate variables and reweight TCI variables to account for missing datasets. The exclusion of indicators for other reasons is less well established, and therefore the exclusion of TD1 from this study as a functional duplicate of TD5 is potentially contentious. The use thereof can be justified by the fact that the TD1 score, had it been included, would have been a single score for all study sites and therefore would not change the relative vulnerability between locations. The use of different weighting approaches in climate tourism indices is well established and a common practise to apply indices to local scales (Gan et al., 2017). Scott et al. (2019) tested two weighting approaches – an equal indicator weighting and a weighting which favoured adaptive capacity by providing the eight adaptive capacity indicators a 50% weighting. Having found little difference between the two approaches, only the results of the first weighting set were presented by Scott et al. (2019). This study tested the same two weighting approaches and too found little significant difference between the two approaches. This study also tested a novel tourism asset focused weighting due to the high dependence of the South African tourism sector on natural resources. This weighting approach gave 50% weighting to five indicators in the TA component and was found to be significantly different to standard, equal indicator weighting set 1, which potentially gave more significance than was justified to these indicators. This novel weighting approach produced scores which were lower than the standard and adaptive capacity focused weighting methods, thus potentially suggesting that although the South African tourism sector is very reliant on natural assets, these variables are less vulnerable to the impacts of climate change than other variables in the tourism system. Establishing a methodology to determine the appropriate weighting of variables in the CVIT would greatly enhance the output relevance and validity of scores.

7.8. CVIT Outputs

Having reflected on the process followed to produce the final CVIT scores, this section will now assume the CVIT output scores from the standard equal indicator weighting approach to be correct and explore the implications thereof.

The results of this CVIT downscaling were produced with local scale data applicable to local scale contexts. Using local scale data however comes with a notable weigh up between international comparability and local scale relevance. Although compromising on international comparability was an intentional decision made, it is worth nothing that the mean score from weighting set 1 presented and explored in this study, of 80.44, falls within the CVIT range that South Africa was classified under by Scott et al. (2019) of between 77 and 88. This supports the meaningfulness and validity of the results produced. Moreover, the findings of this research align strongly to existing literature examining the relationship between climate change and tourism in South Africa. The finding of high vulnerability for coastal sites aligns to research by Rogerson (2020) who also flags coastal regions as particularly vulnerable to climate change. There are other factors which may make the vulnerability scores found in this study slightly less meaningful, for example, Debortoli et al. (2019) argue that if community hasn't experienced a hazard before they are more vulnerable to its impacts. Because South Africa is a common victim of drought conditions and flooding events, it may in fact be more resilient to these events as they have been experienced before and therefore recovery times may be reduced (Debortoli et al., 2019). Generally attempting to simplify a complex phenomenon such as vulnerability through the use of indictors comes with risks of oversimplification (Barnet et al., 2008). The results of this study stand in stark contrast to the findings of Ehmer and Heymann (2008) who noted that South Africa was likely to benefit from climate change and was a potential "rising star of tomorrow". This was justified by the diversity of offerings that South African tourism has (Ehmer & Heymann, 2008), however the scale of vulnerability suggests that impacts to the tourism sector at country scale will be harmful. The results of this study align strongly to the findings of Golder Associates (2012) who used a vulnerability framework to assess vulnerability of tourism attractions in South Africa to climate change. Common hotspots between this study and the Golder Associates (2012) study include The Cape Winelands, Garden Route, and Pilanesberg National Park. Finally, the findings of this study will briefly be compared to the district municipality climate change response strategies published on the Let's Respond Toolkit (2022). Concerningly, although 12 districts have flagged decreased income from tourism as a particular priority under climate change scenarios, these do not align strongly with where vulnerability using the CVIT was found to be greatest, with neither Cape Town nor Gqeberha represented at the time of writing. This study therefore recommends study sites most vulnerable to climate change impacts on tourism ought to include tourism as a priority focus area when developing and implementing climate change adaptation and mitigation plans.

Beyond the net CVIT scores for each destination of focus, this study went on to deconstruct the CVIT components making up the cumulative CVIT score and placed these into a vulnerability quadrant matrix (figure 18). This demonstrated the relative contribution of adaptive capacity focused variables and of climate change impact and mitigation focused variables to the total CVIT score. This approach revealed insightful details that are not visible when looking solely at the cumulative CVIT score per destination. This technique is in line with the approach of Perch-Nielsen (2010) who chose to independently consider exposure, sensitivity, adaptive capacity and vulnerability when exploring beach tourism vulnerability to climate change. Perch-Nielsen (2010) found South African beach tourism to have unfavourable sensitivity and low adaptive capacity with generally low exposure to climate change impacts. The vulnerability quadrant placement allows for more spatial granularity when considering these variables and found differences between different coastal locations. Examples emerging include that Cape Town may have a greater adaptive capacity to climate change than Gqeberha, despite facing slightly worse projected impacts. Understanding the nature of the variables that are driving vulnerability is useful to inform ground-based action and provides an element of hope as although potential impacts may be large, adaptive capacity can be controlled and amended by interventions (Adenle et al., 2017). This is important as local environments, policies and vulnerability drivers differ between locations and adaptation measures therefore need to be context specific. The clustering of variables along the Y-axis suggests that adaptive capacity is more similar between South African destinations and that climate impacts are the biggest difference driver in climate change vulnerability for tourism. This indicates the urgency to improve adaptive capacity for South African tourism destinations - particularly in places where impacts are projected to be largest and reinforces the utility of vulnerability assessments (Fussel & Klein, 2006).

7.9. Conclusion

In conducting climate change and tourism research the concept of reflexivity is very important due to the tendency of unconscious biases, belief systems and positions to shape the narratives of research produced (Becken, 2013; Gössling & Scott, 2018). This discussion chapter reflected on each phase of the research process in downscaling the CVIT and it can be concluded that despite data limitations and room for improvement and expansion of the index, the CVIT is indeed suitable for local scale application. When assessing the CVIT output scores, results are not comparable internationally but are however nonetheless useful when viewed with a degree of caution to inform vulnerability hotspots, key vulnerability drivers and differential vulnerability characteristics for tourism in South Africa. Vulnerability is a dynamic property and therefore gaining higher temporal resolution and historical information for CVIT indicators would add great value to understanding the patterns or vulnerability for tourism in South Africa.

CHAPTER 8 – CONCLUSION

8.1. Introduction

The impacts of climate change have begun to be experienced globally and are projected to get worse over coming decades (IPCC, 2021), with particularly severe impacts projected for Africa (Weber et al., 2018). The tourism sector is an economically important component of many economies (Dorgu et al., 2019), particularly developing nations (Scott et al., 2019) such as South Africa (StatsSA, 2021). Understanding vulnerability of the tourism sector to climate change is thus of great importance, particularly because tourism has been flagged as more vulnerable than other sectors to climate change impacts (Dorgu et al., 2019) and is still recovering financially from the COVID-19 pandemic (Rogerson & Rogerson, 2021). This study was the first known subnational scale application of the CVIT. South Africa was chosen as the location for the downscaling due to marked heterogeneity in climatic, tourism, demographic, geographical and ecological variables. This study successfully calculated CVIT scores for 18 study locations. This study found that the CVIT is indeed suitable for local scale application but that the effects of rescaling do impact output scores and require a degree of caution to be taken when assessing results.

8.2. Key Findings and Synthesis

This study found that the South African tourism sector is generally very vulnerable to the impacts of climate change with an average CVIT score of 80.44. Vulnerability for destinations is however not evenly distributed across the country and instead subject to notable heterogeneity, with a CVIT scores ranging between 92.37 (highest vulnerability) and 67.31 (lowest vulnerability). The three study sites with tourism sectors most vulnerable to climate change were found to be Gqeberha (92.37), Cape Town (90.57) and East London (88.15) (table 20). The three study sites with tourism sectors least vulnerable to climate change were found to be Kimberley (67.31), Johannesburg (74.44) and Pretoria (75.75). Different variables were found to be driving vulnerability most at different study site, reinforcing the need for context specific climate change mitigation and adaptation plans.

8.3. Achievement of Study Aims

The main aim of this study was to downscale and calculate the CVIT at a high spatial resolution for South Africa. The extent to which the study aim has been achieved will be examined by examining the three main study objectives.

i. *To scope, gather and standardise appropriate local scale data sources for each of the 27 indicators used in calculating the CVIT for 18 South African locations*

Chapter 5 presents the data selection process followed to downscale the CVIT for South Africa. Suitable datasets were found for each of the 18 study sites for each of the 27 variables belonging to the six core components of the CVIT. The datasets were not all at the same spatial scale, with three indicators at national scale, 11 indicators at provincial scale, one indicator at district scale, six indicators at municipality scale and five indicators at city or study site scale. Instances of the use of proxies and alternative data sources was necessitated due to data available constraints when seeking the same data sources used by Scott et al. (2019) at finer spatial resolution.

ii. *To calculate CVIT scores for each of the 18 study locations using:*

a. *the standard (equal) weighting approach and;*

b. *the adaptive capacity weighted approach*

This study successfully calculated the CVIT using the two waiting approaches tested by Scott et al. (2019) – an equal indicator weighting (W1) and adaptive capacity focused weighting (W2). Guided by evidence within literature that South Africa is highly dependent on natural assets for most of its tourism, this study went beyond the objectives ii a and b and calculated a third weighting approach with focused on tourism assets. There was no significant different found between weighting set 1 and weighting set 2, in line with the findings of Scott et al. (2019). There was however a significant difference between the standard, equal indicator weighting (W1) and the novel weighting set 3 tested.

iii. *To identify tourism climate change vulnerability hotspots and examine spatial variations in CVIT scores and vulnerability drivers across South Africa*

This study used the standard equal indicator weighting presented by Scott et al. (2019) as the weighting approach to explore in detail. Through the use of spatial interpolation, vulnerability distribution across the country was identified, with greatest vulnerability found for coastal regions and the north-eastern parts of the country. Site level drivers of vulnerability were identified, with different indicators responsible for driving vulnerability in varying proportions across study sites. Some study sites such as Cape Town and Gqeberha had up to nine indicators contributing to high vulnerability with scores of 5 for each, whilst other sites such as Johannesburg, eMakahzeni, Mbombela, St Lucia and Kimberley had four or less indicators carrying a score of 5.

8.4. Recommendations

The outputs of this study in the form of cumulative CVIT scores as well as indicator specific results and trends for each study site can be used by policy makers to inform climate change responses. This study recommends to policy makers that local scale focus on sites deemed high risk with high CVIT scores should be closely examined and considered when developing climate change adaptation and mitigation plans. This is particularly important in places which are pivotal to the arrival of tourists to the country generally such as Cape Town where attractiveness changes in such destinations may have ripple effects on other destinations within the country (Dube et al., 2020). Despite uncertainty existing in the results of this study, the concept of agnogenesis whereby uncertainty and doubt in scientific results can be used to justify inaction should not be a limit to implementing urgent action as this can be a major barrier to change towards a low-carbon society (Gössling & Scott, 2018). Climate change vulnerability assessments need to include all sectors, even potentially unintuitive ones like health, and acknowledge the cross boundary and multidisciplinary nature of climate change impacts between sectors (Conway et al., 2015; Chersich & Wright, 2019). This study too recommends alignment between SDG targets and climate change adaptation plans for greatest positive impact (Cohen et al., 2021). Climate change action is no longer a concern that can be postponed in favour of more urgent priorities as (Chiutsi & Saarinen, 2017) as the threats faced are grave. This study encourages action at local scale including regional, city level and business level commitments to adaptation and mitigation practices (Kuramochi et al., 2020).

8.5. Future Research

This study presents the first downscaling of the CVIT for local contexts and can inform the development of future climate change vulnerability metrics for tourism at local scales. Future research stemming from this study ought to include the application of the CVIT to another country at subnational scale to confirm the validity of CVIT downscaling in other locations. This could extend into a regional assessment of the SADC zone where the tourism sectors of neighbouring countries are closely tied and connected (Woyo & Slabbert, 2019). Similarly, the need to get greater temporal resolution in datasets would allow for vulnerability trends over time and within seasons to be assessed. The inclusion of 2022 census data, soon to be released, would ensure up-to-date and relevant socioeconomic data is used. In addition to the additional indicators suggested earlier, the CVIT methodology could also benefit from the use of novel techniques such as social media to assess complex tourism dynamics (da Mota & Pickering, 2020) or by finding unique metrics which better represent the South African tourism context. Finally, climate change too impacts society in nuanced and intersectional ways and therefore examining the CVIT through the lenses of gender and race could too be beneficial (Djoudi et al., 2016; Hardy et al., 2017; Rao et al., 2019). This includes reflecting on the complex and interconnected components that make up the tourism sector Burns & Bibbings, 2009; Moreno & Becken, 2009).

REFERENCES

Abrams, R.W., Abrams, J.F. and Abrams, A.L. 2018. Climate Change Challenges for Africa. *Encyclopedia of the Anthropocene*, 2: 177-194.

Agnew, M.D. and Viner, D. 2001 Potential impacts of climate change on international tourism. *International Journal of Tourism and Hospitality Research,* 3(1): 37-60.

Allison, L.C., Palmer, M.D. and Haigh, I.D. 2022. Projections of 21st century sea level rise for the coast of South Africa. *Environmental Research Communications*. https://doi.org/10.1088/2515-7620/ac4a90

Amelung, B. and Viner, D. 2006. Mediterranean Tourism: Exploring the Future with the Tourism Climatic Index. *Journal of Sustainable Tourism*, 14(4): 349-366.

Amelung, B., Nicholls, S. and Viner, D. 2007. Implications of Global Climate Change for Tourism Flows and Seasonality. *Journal of Travel Research*, 45: 285-296.

Amusan, L. and Olutola, O. 2017. Climate Change and Sustainable Tourism: South Africa caught in-between. *African Journal of Hospitality, Tourism and Leisure*, 6(4): 1-15.

Apraku, A., Morton, J.F. and Gyampoh, B.A. 2021. Climate change and small-scale agriculture in Africa: Does indigenous knowledge matter? *Insights from Kenya and South Africa. Scientific African*, 12, p.e00821.

Araujo, J.A., Abiodun, B.J. and Crespo, O. 2016. Impacts of drought on grape yields in Western Cape, South Africa. *Theoretical and applied climatology*, 123(1): 117-130.

Archer, E.R., Engelbrecht, F., Landman, W., Le Roux, A., Van Huyssteen, E., Fatti, C., Vogel, C., Akoon, I., Maserumule, R., Colvin, C. and Le Maitre, D.C. 2010. South African risk and vulnerability atlas. *Department of Science and Technology*. Pretoria.

Archer, E., Engelbrecht, F., Hänsler, A., Landman, W., Tadross, M. and Helmschrot, J. 2018. Seasonal prediction and regional climate projections for southern Africa. In Revermann, R., Krewenka, K.M., Schmiedel, U., Olwoch, J.M., Helmschrot, J. and Jürgens, N. (eds.). Climate change and adaptive land management in southern Africa – assessments, changes, challenges, and solutions. *Klaus Hess Publishers: Göttingen.*

Averchenkova, A., Gannon, K.E. and Curran, P. 2019. Governance of climate change policy: A case study of South Africa. *Grantham Research Institute on Climate Change and the Environment Policy Report*, 1-39.

Aylen, J., Albertson, K. and Cavan, G. 2014. The impact of weather and climate on tourist demand: the case of Chester Zoo. *Climatic Change*, 127(2): 183-197.

Baker, A.C. 2011. *How can air travel contribute to the costs of adapting to climate change? The feasibility of the International Air Passenger Adaptation Levy (IAPAL) as a market governance mechanism*. International Institute for Environment and Development, London.

Baldos, U.L.C. and Hertel, T.W. 2015. The role of international trade in managing food security risks from climate change. *Food Security*, 7(2): 275-290.

Bama, H.K.N. and Nyikana, S. 2021. The effects of COVID-19 on future domestic travel intentions in South Africa: A stakeholder perspective. *African Journal of Hospitality, Tourism and Leisure*, 10(1): 179-193.

Barnett, J., Lambert, S. and Fry, I. 2008. The hazards of indicators: insights from the environmental vulnerability index. *Annals of the Association of American Geographers*, 98(1): 102-119.

Becken, S. 2013. A review of tourism and climate change as an evolving knowledge domain. *Tourism Management Perspectives*, 6: 53-62.

Becken, S., Zammit, C. and Hendrikx, J. 2014. Developing Climate Change Maps for Tourism. *Journal of Travel Research*, 54(4): 430-441.

Becken, S. 2019. Decarbonising tourism: Mission impossible? *Tourism Recreation Research*, 44(4): 419-433.

Becken, S. and Clapcott, R. 2011. National Tourism Policy for Climate Change. *Journal of Policy Research in Tourism, Leisure and Events*, 3(1): doi: 10.1080/19407963.2011.539378.

Becken, S., Whittlesea, E., Loehr, J. and Scott, D. 2020. Tourism and climate change: evaluating the extent of policy integration. *Journal of Sustainable Tourism*, 20(10): 1603-1624.

Bellard, C., Bertelsmeier, C., Leadley, P., Thuiller, W. and Courchamp, F. 2012. Impacts of climate change on the future of biodiversity. *Ecology Letters*. 15(4): 365-377.

Benzie, M., Hedlund, J. and Carlsen, H., 2016. Introducing the Transnational Climate Impacts Index: indicators of country-level exposure-methodology report. Stockholm Environment Institute.

Berittella, M., Bigano, A., Roson, R. and Tol, R. 2006. A General Equilibrium Analysis of Climate Change Impacts on Tourism. *Tourism Management,* 27(5): 913-924.

Bloom Consulting, 2022. Country Brank Ranking: Tourism Edition 2022/2023. 1-32. Bloom Consulting. Spain.

Buckley, R. 2017. Perceived Resource Quality as a Framework to Analyze Impacts of Climate Change on Adventure Tourism: Snow, Surf, Wind, and Whitewater. *Tourism Review International*, 21(3): 241-254.

Burke, M., Hsiang, S.M. and Miguel, E. 2015. Global non-linear effect of temperature on economic production. *Nature*, 527(7577): 235-239.

Burns, P. and Bibbings, L. 2009. The end of tourism? Climate change and societal challenges. *Twenty-First Century Society*, 4(1): 31-51.

Busby, J.W., Smith, T.G. and Krishnan, N. 2014. Climate security vulnerability in Africa mapping 3.0. *Political Geography*, 43: 51-67.

Caldeira, A. and Kastenholz, E. 2018. It’s so hot: predicting climate change effects on urban tourists’ time–space experience. *Journal of Sustainable Tourism*, 26(9): 1516-1542.

Cevik, S. and Ghazanchyan, M. 2021. Perfect Storm: Climate Change and Tourism. *Journal of Globalization and Development*, 12(1): 47-61.

Chersich, M.F. and Wright, C.Y. 2019. Climate change adaptation in South Africa: a case study on the role of the health sector. *Globalization and health*, 15(1): 1-16.

Chili, N.S. 2018. The impact of safety and security on the behaviour of consumers and tourism demand in South African townships. *African Journal of Hospitality, Tourism and Leisure*, 7(4): 1-14.

Chung, M.G., Dietz, T. and Liu, J., 2018. Global relationships between biodiversity and nature-based tourism in protected areas. *Ecosystem Services*, 34: 11-23.

Cohen, B., Cowie, A., Babiker, M., Leip, A. and Smith, P. 2021. Co-benefits and trade-offs of climate change mitigation actions and the Sustainable Development Goals. *Sustainable Production and Consumption*, 26: 805-813.

Coldrey, K.M. and Turpie, J.K. 2020. Potential impacts of changing climate on nature-based tourism: A case study of South Africa's national parks. *African Protected Areas Conservations Science*, 62(1): 1601-1629.

Committee for the Coordination of Statistical Activities (CCSA). 2021. How COVID-19 is changing the world: a statistical perspective Volume III. World Bank's Development Data Group.

Connolly-Boutin, L. and Smit, B. 2015. Climate change, food security, and livelihoods in sub-Saharan Africa. *Regional Environmental Change*, 16(2): 385-399.

Conway, D., Van Garderen, E.A., Deryng, D., Dorling, S., Krueger, T., Landman, W., Lankford, B., Lebek, K., Osborn, T., Ringler, C. and Thurlow, J. 2015. Climate and southern Africa's water–energy–food nexus. *Nature Climate Change*, 5(9): 837-846.

Craig, C. and Feng, S. 2018. A temporal and spatial analysis of climate change, weather events, and tourism businesses. *Tourism Management*, 67: 351-361.

Crime Stats SA. Crime Statistics South Africa: Municipality. 2022. Available online: https://www.crimestatssa.com/. Accessed 13 June 2022.

Cunliffe, G., Holz, C., Mbeva, K., Pauw, W.P. and Winkler, H. 2019. Comparative Analysis of the NDCs of Canada, the European Union, Kenya and South Africa from an Equity Perspective: a research report funded by the Swedish Energy Agency. Research report series.

Czarnek, G., Kossowska, M. and Szwed, P. 2021. Right-wing ideology reduces the effects of education on climate change beliefs in more developed countries. *Nature Climate Change*, 11(1): 9-13.

da Mota, V.T. and Pickering, C. 2020. Using social media to assess nature-based tourism: Current research and future trends. *Journal of Outdoor Recreation and Tourism*, 30: p.100295.

David, A., Guilbert, N., Hamaguchi, N., Higashi, Y., Hino, H., Leibbrandt, M. and Shifa, M. 2018. Spatial poverty and inequality in South Africa: A municipality level analysis.

Davis-Reddy, C. and Vincent, K. 2017. *Climate Risk and Vulnerability: A Handbook for Southern Africa* (2nd Ed), CSIR, Pretoria, South Africa, 30-46.

Davis-Reddy, C. and Hilgart, A. 2021. Toward an interoperable national hazards events database for South Africa. Frontiers in Climate, 3, p.591020.

de Freitas, C.R., Scott, D. and McBoyle, G. 2008. A second-generation Climate Index for Tourism (CIT): specification and verification*. International Journal of Biometeorology*, 52: 399-407.

de Freitas, C.R. and Grigorieva, E.A. 2015. A comprehensive catalogue and classification of human thermal climate indices. *International Journal of Biometeorology*, 59(1), 109-120.

De Klerk, B. and Haarhoff, R. 2019. Destination South Africa: analysis of destination awareness and image by international visitors.

de Sherbinin, A. 2014. Climate change hotspots mapping: what have we learned? *Climatic change*, 123(1): 23-37.

de Sherbinin, A., Bukvic, A., Rohat, G., Gall, M., McCusker, B., Preston, B., Apotsos, A., Fish, C., Kienberger, S., Muhonda, P. and Wilhelmi, O. 2019. Climate vulnerability mapping: A systematic review and future prospects. *Wiley Interdisciplinary Reviews: Climate Change*, 10(5): p.e600.

Debortoli, N.S., Clark, D.G., Ford, J.D., Sayles, J.S. and Diaconescu, E.P. 2019. An integrative climate change vulnerability index for Arctic aviation and marine transportation. *Nature Communications*, 10: 1-15.

Demiroglu, O.C., Saygili-Araci, F.S., Pacal, A., Hall, C.M. and Kurnaz, M.L. 2020. Future Holiday Climate Index (HCI) Performance of Urban and Beach Destinations in the Mediterranean. *Atmosphere*, 11: 911.

Dennis, I. and Dennis, R. 2012. Climate change vulnerability index for South African aquifers. *Water SA*, 38(3): 417-426.

Department of Energy (DE). 2018. State of Renewable Energy in South Africa, 2017. 1-222.

Department of Environment, Forestry and Fisheries (DEFF). 2019. National Oceans and Coastal Information Management System (OCIMS) for South Africa. Available online: https://www.ocims.gov.za/hazardlines. Accessed 24 May 2022.

Department of Environmental Affairs. (2017). *South Africa's Third National Communication under the United Nations Framework Convention on Climate Change.* Pretoria, South Africa: Department of Environmental Affairs, Republic of South Africa (RSA).

Department of Environmental Affairs and Tourism. (2004). A National Climate Change Response Strategy for South Africa. Pretoria: Department of Environmental Affairs and Tourism.

Department of Mineral Resources and Energy (DMRE). 2021. South African Energy Sector Report. Available online: http://www.energy.gov.za/files/media/explained/2021-South-African-Energy-Sector-Report.pdf. Accessed 09 June 2022.

Department of Mineral Resources and Energy. 2022. Renewable Energy Data and Information Service: Location and Contracted Capacities. Available online: http://redis.energy.gov.za/power-producers/. Accessed 26 June 2022.

Department of Tourism. 2011. National Tourism Sector Strategy. Pretoria: Department of Tourism of the Republic of South Africa.

Department of Tourism. 2012. The South African National Tourism and Climate Change Response Programme and Action Plan. Pretoria: Department of Tourism of the Republic of South Africa.

Department of Tourism 2017. National Tourism Sector Strategy. Pretoria: Department of Tourism.

Department of Tourism. 2019. Department of Tourism of the Republic of South Africa Annual Report: 2018-2019. Pretoria: Department of Tourism.

Department of Tourism. 2020a. Strategic Plan 202/21 – 2024/25. Pretoria: Department of Tourism. Pretoria: Department of Tourism.

Department of Tourism. 2020b. Annual Performance Plan, 2020-2021 - 2022/2023.Pretoria: Department of Tourism.

Department of Tourism. 2021a. Tourism Environmental Implementation Plan (TEIP), Second Edition. Pretoria: Department of Tourism.

Department of Tourism. 2021b. Annual Performance Plan, 2021-2022 - 2023/2024. Pretoria: Department of Tourism.

Department of Tourism. 2021c. Bojanala: Edition 02. Pretoria: Department of Tourism.

Department of Water and Sanitation (DWS). 2022. Integrated Regulatory Information System: South Africa's Tap Water Map. Available Online: https://ws.dws.gov.za/IRIS/mywater.aspx?c2VvcD0xJnNlYXJjaD1wb3J0IG5vbGxvdGgmc3lzdGVtX2lkPTM3NSZzdWJfcGxhY2VfaWQ9MzYzMDExMDAx . Accessed 14 June 2022.

Deser, C., Phillips, A., Bourdette, V. and Teng, H. 2012. Uncertainty in climate change projections: the role of internal variability. *Climate dynamics*, 38(3): 527-546.

Dickinson, J., Lumsdon, L. and Robbins, D. 2011. Slow travel: Issues for tourism and climate change. *Journal of Sustainable Tourism*, 19(3): 281-300.

Dieke, P.U. 2010. 11 From Apartheid to 'Managed Revolution': Tourism Development and the Transition in South Africa. *Tourism and political change*, 120.

Djoudi, H., Locatelli, B., Vaast, C., Asher, K., Brockhaus, M. and Basnett Sijapati, B. 2016. Beyond dichotomies: Gender and intersecting inequalities in climate change studies. *Ambio*, 45(3): 248-262.

Dorgu, T., Marchio, E.A., Bulut, U. and Suess, C. 2019. Climate change: Vulnerability and resilience of tourism and the entire economy. *Tourism Management,* 72: 292-305.

du Plessis, E., Saayman, M. and van der Merwe, A. 2015. What makes South African Tourism competitive? *African Journal of Hospitality, Tourism and Leisure*, 4(2): 1-14.

du Plessis, E., Van der Merwe, A. and Saayman, M. 2017. Explore changes in the aspects fundamental to the competitiveness of South Africa as a preferred tourist destination. *South African journal of economic and management sciences*, 20(1): 1-11.

Dube, K. and Nhamo, G. 2019. Climate change and potential impacts on tourism evidence from the Zimbabwean side of the Victoria Falls. *Environment, Development and Sustainability*, 21(4): 2025-2041.

Dube, K., Nhamo, G. and Chikodzi, D. 2020. Climate change-induced droughts and tourism: Impacts and responses of Western Cape province, South Africa. *Journal of Outdoor Recreation and Tourism*, https://doi.org/10.1016/j.jort.2020.100319.

Dube, K. and Nhamo, G. 2020. Evidence and impact of climate change on South African national parks. Potential implications for tourism in the Kruger National Park. *Environmental Development*, 33, (100485).

Dube, K. 2020. Tourism and sustainable development goals in the African context. *International Journal of Economics and Finance Studies*, 12(1): 88-102.

Dube, K., Nhamo, G. and Chikodzi, D. 2021. Rising sea level and its implications on coastal tourism development in Cape Town, South Africa. *Journal of Outdoor Recreation and Tourism*, 33, p.100346.

Dubois, G., Ceron, J.P., Gössling, S. and Hall C.M. 2016. Weather preferences of French tourists lessons for climate change impact assessment. *Climatic Change,* 136: 339-351.

Duro, J.A., Perez-Laborda, A., Turrion-Prats, J. and Fernández-Fernández, M. 2021. Covid-19 and tourism vulnerability. *Tourism Management Perspectives*, 38, p.100819.

Ehmer, P. and Heymann, E. 2008. Climate change and tourism: Where will the journey lead? *Deutsche Bank Research, Frankfurt*.

Fang, Y., Yin, J. and Wu, B. 2018. Climate change and tourism: a scientometric analysis using CiteSpace, *Journal of Sustainable Tourism*, 26(1): 108-126.

Ferreira, S.L.A. and Harmse, A.C. 2000. Crime and tourism in South Africa: International tourists perception and risk. *South African Geographical Journal*, 82(2): 80-85.

Filho, W.L., Barbir, J., Gwenzi, J., Ayal, D., Simpson, N.P., Adeleke, L., Tilahun, B., Chirisa, I., Gbedemah, S.F., Nzengya, D.M. and Sharifi, A. 2022. The role of indigenous knowledge in climate change adaptation in Africa. *Environmental Science & Policy*, 136: 250-260.

Finch, J.M. and Meadows, M.E. 2019. South African biomes and their changes over time. In *The Geography of South Africa*, 57-69. Springer, Cham.

Fitchett, J.M. and Hoogendoorn, G. 2018a. An analysis of factors affecting tourists' accounts of weather in South Africa. *International Journal of Biometeorology,* 62: 1261-2172.

Fitchett, J.M. and Hoogendoorn, G. 2018b. Exploring the climate sensitivity of tourists to South Africa through TripAdvisor reviews. *South African Geographical Journal*, 101(1): 91-109.

Fitchett, J.M. and Swatton, D.A. 2020. Exploring public awareness of the current and future malaria risk zones in South Africa under climate change: a pilot study. *International Journal of Biometeorology*, 1-11.

Fitchett, J.M., Hoogendoorn, G. and Swemmer, A.M. 2016a. Economic costs of the 2012 floods on tourism in the Mopani District Municipality, South Africa. *Transactions of the Royal Society of South Africa*, 71(2): 187-194.

Fitchett, J.M., Grant, B. and Hoogendoorn, G. 2016b. Climate change threats to two low-lying South African coastal towns: Risks and perceptions. *South African Journal of Science*, 112(5-6): 1-9.

Fitchett, J.M., Hoogendoorn, G. and Robinson, D. 2016c. Data challenges and solutions in the calculation of Tourism Climatic Index (TCI) *scores* in South Africa. *Tourism*, 64(4): 359-370.

Fitchett, J.M., Robinson, D. and Hoogendoorn, G. 2017. Climate suitability for tourism in South Africa. *Journal of Sustainable Tourism*, 25(6): 851-867.

Fitchett, J.M. and Roshan, G. 2020. Climate change threats to cultural and heritage tourism in Iran. In Cultural and Heritage Tourism in the Middle East and North Africa 218-238. Routledge.

Ford, J., Berrang-Ford, L., Bunce, A., McKay, C., Irwin, M. and Pearce, T. 2014. The status of climate change adaptation in Africa and Asia. *Regional Environmental Change*, 15(5): 801-814.

Fourie, J., Rosselló-Nadal, J. and Santana-Gallego, M. 2020. Fatal attraction: How security threats hurt tourism. *Journal of Travel Research*, 59(2): 209-219.

Friedrich, J., Stahl, J., Hoogendoorn, G. and Fitchett, J.M. 2020. Exploring Climate Change Threats to Beach Tourism Destinations: Application of the Hazard–Activity Pairs Methodology to South Africa. *American Meteorological Society*, 12(3): 529-544.

Fussel, H.M. and Klein, R.J.T. 2006. Climate change vulnerability assessments: An evolution of conceptual thinking. *Climatic Change,* 75(3): 301-329.

Füssel, H.M. 2010. How inequitable is the global distribution of responsibility, capability, and vulnerability to climate change: A comprehensive indicator-based assessment. *Global environmental change*, 20(4): 597-611.

Gan, X., Fernandez, I.C., Guo, J., Wilson, M., Zhao, Y., Zhou, B. and Wu, J. 2017. When to use what: Methods for weighting and aggregating sustainability indicators. *Ecological Indicators*, 81: 491-502.

Gbetibouo, G.A., Ringler, C. and Hassan, R. 2010. Vulnerability of the South African farming sector to climate change and variability: An indicator approach. In Natural resources forum (Vol. 34, No. 3, pp. 175-187). Oxford, UK: Blackwell Publishing Ltd.

Gemeda, D.O. and Sima, A.D. 2015. The impacts of climate change on African continent and the way forward. *Journal of Ecology and the Natural environment*, 7(10): 256-262.

George, R. and Swart, K. 2012. International tourists' perceptions of crime–risk and their future travel intentions during the 2010 FIFA World Cup™ in South Africa. *Journal of Sport & Tourism*, 17(3): 201-223.

Giampiccoli, A., Lee, S.S. and Nauright, J. 2015. Destination South Africa: Comparing global sports mega-events and recurring localised sports events in South Africa for tourism and economic development. *Current issues in tourism*, 18(3): 229-248.

Giddy, J.K., Fitchett, J.M. and Hoogendoorn, G. 2017. Insights into American Tourists' experiences with weather in South Africa. *Bulletin of Geography. Socio-economic Series*, 38: 57-71.

Giddy, J.K. and Rogerson, C.M. 2018. Tracking SCUBA Diving Adventure Tourism in South Africa. *EuroEconomica*, *37*(2): 47-62.

Golder Associates. 2012. Baseline Assessment: Vulnerability and Impact of Climate Change on Major Tourism Attractions and Activities. Kloof: Golder Associates Africa (Pty) Ltd.

Gössling, S. and Arnell, N.W. 2016. A global assessment of the impact of climate change on water scarcity. Climatic Change, 134(3): 371-385.

Gössling, S. and Scott, D. 2018. The decarbonisation impasse: global tourism leaders' views on climate change mitigation. *Journal of Sustainable Tourism*, 26(12): 2071-2086.

Gössling, S., Hall, C.M. and Scott, D. 2009. The challenges of tourism as a development strategy in an era of global climate change. Rethinking development in a carbon-constrained *world*. *Development Cooperation and Climate change*, 100-119.

Gössling, S., Scott, D., Hall., C.M., Ceron, J.P. and Dubois, G. 2012. Consumer behaviour and demand response of tourists to Climate Change. *Annals of Tourism Research,* 39: 36-58.

Gössling, S., Scott, D. and Hall, C.M. 2018. Global trends in length of stay: implications for destination management and climate change. *Journal of sustainable tourism*, 26(12): 2087-2101.

Gössling, S., Scott, D. and Hall, C.M. 2020. Pandemics, tourism and global change: a rapid assessment of COVID-19. *Journal of sustainable tourism*, 29(1): 1-20.

Government Communication and Information System. (GCIS) 2015. Fact Sheet: South Africa's competitiveness at a glance. 25th AU Summit.

Grünewald, C., Schleuning, M. and Böhning-Gaese, K. 2016. Biodiversity, scenery and infrastructure: Factors driving wildlife tourism in an African savannah national park. *Biological conservation*, 201: 60-68.

Gu, L., Chen, J., Xu., C.X., Kim, J., Chen, H., Xia, J. and Zhang, L. 2019. The contribution of internal climate variability to climate change impacts on droughts. *Science of the Total Environment*, 684: 229-246.

Gutiérrez, J.M., R.G. Jones, G.T. Narisma, L.M. Alves, M. Amjad, I.V. Gorodetskaya, M. Grose, N.A.B. Klutse, S. Krakovska, J. Li, D. Martínez-Castro, L.O. Mearns, S.H. Mernild, T. Ngo-Duc, B. van den Hurk, and J.-H. Yoon. 2021: Atlas. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L.Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K.Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press. In Press. Interactive Atlas available from Available from http://interactive-atlas.ipcc.ch/

Hall, C.M. et al. 2014. Denying bogus scepticism in climate change and tourism research. *Tourism Management*, http://dx.doi.org/10.1016/j.tourman.2014.08.009.

Hall, C.M. 2016. Heritage, heritage tourism and climate change. *Journal of Heritage Tourism*, 11(1): 1-9.

Hall, C.M. 2019. Constructing sustainable tourism development: The 2030 agenda and the managerial ecology of sustainable tourism. *Journal of Sustainable Tourism*, 27(7): 1044-1060.

Hall, C.M., Baird, T., James, M. and Ram, Y. 2016. Climate change and cultural heritage: conservation and heritage tourism in the Anthropocene. *Journal of Heritage Tourism*, 11(1): 10-24.

Hambira, W.L., Saarinen, J., Manwa, H. and Atlhopheng, J.R. 2013. Climate change adaptation practices in nature-based tourism in Maun in the Okavango Delta area, Botswana: How prepared are the tourism businesses?. *Tourism Review International*, 17(1): 19-29.

Hambira, W.L. and Saarinen, J. 2015. Policy-makers' perceptions of the tourism–climate change nexus: Policy needs and constraints in Botswana. *Development Southern Africa,* 32(3): 350-362.

Hamilton, J.M., Maddison, D.J. and Tol, R.S.J. 2003 Climate change and international tourism: A simulation study. Working Paper FNU-31, Research Unit Sustainability and Global Change, Centre for Marine and Climate Research, University of Hamburg.

Hardy, R.D., Milligan, R.A. and Heynen, N. 2017. Racial coastal formation: The environmental injustice of colorblind adaptation planning for sea-level rise. *Geoforum*, 87: 62-72.

Hedlund, J., Fick, S., Carlsen, H. and Benzie, M. 2018. Quantifying transnational climate impact exposure: New perspectives on the global distribution of climate risk. *Global environmental change*, 52: 75-85.

Hewer, M. and Gough, W. 2018. Thirty years of assessing the impacts of climate change on outdoor recreation and tourism in Canada. *Tourism Management Perspectives*, 26: 179-192.

Hinkel, J. 2011. "Indicators of vulnerability and adaptive capacity": towards a clarification of the science–policy interface. *Global environmental change*, 21(1): 198-208.

Hoogendoorn, G. 2014. Mapping fly-fishing tourism in Southern Africa. *African Journal of Hospitality, Tourism and Leisure*, 3(2): 1-13.

Hoogendoorn, G. 2021. Last Chance Tourism in South Africa: Future Research Potential? *Tourism: An International Interdisciplinary Journal*, 69(1): 73-82.

Hoogendoorn, G. and Fitchett, J.M. 2018a Tourism and climate change: a review of threats and adaptation strategies for Africa. *Current Issues in Tourism*, 21(7): 742-759.

Hoogendoorn, G. and Fitchett, J.M. 2018b. Climate change and tourism research in South Africa: prospects and obstacles for mixed-method approaches. In Nunkoo, R. (Ed.) *Handbook of*

Research Methods in Tourism and Hospitality Management. Northampton: Edward Elgar, 441-449.

Hoogendoorn, G., Mellett, R. and Visser, G. 2017. Second homes tourism in Africa: Reflections on the South African experience. In Urban tourism in the developing world (pp. 127-166). Routledge.

Hoogendoorn, G. and Fitchett, J.M. 2020. *Fourteen years of tourism and climate change research in southern Africa: Lessons on sustainability under conditions of global change.* In *Natural Resources, Tourism and Community Livelihoods in Southern Africa: Challenges of Sustainable Development*, M. Stone, M. Lenao, and N. Moswete, Eds. London: Routledge, 78–89.

Hoogendoorn, G. and Rogerson, C.M. 2015 Tourism geography in the global South: new South African perspectives. *South African Geographical Journal*, 97(2): 101-110.

Hoogendoorn, G. and Rogerson, C.M. 2016. New perspectives on Southern African tourism research. *Tourism: An International Interdisciplinary Journal*, 64(4): 355-357.

Hoogendoorn, G., Grant, B. and Fitchett, J.M. 2016. Disjunct perceptions? Climate change threats in two low-lying South African coastal towns. *Bulletin of Geography. Socio–economic Series*, 31: 59-71.

Hoogendoorn, G., Stockigt, L., Saarinen, J. and Fitchett, J.M. 2021. Adapting to climate change: The case of snow-based tourism in Afriski, Lesotho. *African Geographical Review*, 40(1): 92-104.

Hoogendoorn, G. and Visser, G. 2012. Stumbling over researcher positionality and political-temporal contingency in South African second-home tourism research. *Critical Arts*, 26(3): 254-271.

IHS Markit. 2018. South Africa Regional eXplorer: municipal level insights at your fingertips.

International Society of Biometeorology (ISB, 2021). International Society of Biometeorology: About. Available Online at https://uwm.edu/biometeorology/about/. Accessed 18 December 2021.

IPCC. 2001. Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC. 2021. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press. InPress.

IPCC. 2022. Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. In Press.

Jiricka-Pürrer, A., Brandenburg, C. and Probstl-Haider, U. 2020. Jiricka-Pürrer, A., Brandenburg, C. and Probstl-Haider, U. (2020). City tourism pre-and post-covid-19 pandemic–Messages to take home for climate change adaptation and mitigation? *Journal of Outdoor Recreation and*

Tourism, 31, DOI: 10.1016/j.jort.2020.100329. *Journal of Outdoor Recreation and Tourism*, 31, DOI: 10.1016/j.jort.2020.100329.

Kajan, E. and Saarinen, J. 2013 Tourism, climate change and adaptation: a review, *Current Issues in Tourism*, 16(2): 167-195.

Kilungu, H., Leemans, R., Munishi, P., Nicholls, S. and Amelung, B. 2019. Forty Years of Climate and Land-Cover Change and its Effects on Tourism Resources in Kilimanjaro National Park. *Tourism Planning & Development*, 16(2): 235-253.

Kim, Y., Ratnam, J.V., Morioka, Y., Behera, S., Tsuzuki, A., Minakawa, N., Sweijd, N., Kruger, P., Maharaj, R., Imai, C.C. and Ng, C.F.S. 2019. Malaria predictions based on seasonal climate forecasts in South Africa: A time series distributed lag nonlinear model. *Scientific reports*, 9(1): 1-10.

Klein, R.J. 2009. Identifying countries that are particularly vulnerable to the adverse effects of climate change: an academic or political challenge. *Carbon & Climate L. Rev.*, 284.

Knight, J. and Fitchett, J.M. 2022. Issues of measuring and interpreting wind direction. *South African Geographical Journal*, 104(1): 35-52.

Knutson, T., Landsea, C. and Emanuel, K. 2010. Tropical cyclones and climate change: A review. *Global perspectives on tropical cyclones: from science to mitigation*, 243-284.

Kuramochi, T., Roelfsema, M., Hsu, A., Lui, S., Weinfurter, A., Chan, S., Hale, T., Clapper, A., Chang, A. and Höhne, N. 2020. Beyond national climate action: the impact of region, city, and business commitments on global greenhouse gas emissions. *Climate Policy*, 20(3): 275-291.

Kusangaya, S., Warburton, M., Archer van Garderen, E. and Jewitt, G. 2014. Impacts of climate change on water resources in southern Africa: A review. *Physics and Chemistry of the Earth, Parts A/B/C*, 67: 47-54.

Le Roux, A., van Niekerk, W., Arnold, K., Pieterse, A., Ludick, C., Forsyth, G., Le Maitre, D., Lötter, D., du Plessis, P. & Mans, G. 2019. Green Book Risk Profile Tool: Municiapl Risk Profiles. Pretoria: CSIR. Available at: riskprofiles.greenbook.co.za. Accessed 02 July 2022.

Leiper, N. 1979. The Framework of Tourism: Towards a Definition of Tourism, Tourist, and the Tourist Industry. *Annals of Tourism Research*, 6(4): 390-407.

Lenzen, M., Sun, Y.Y., Faturay, F., Ting, Y.P., Geschke, A. and Malik, A. 2018. The carbon footprint of global tourism. *Nature Climate Change*, 8(6): 522-528.

Lets Respond Toolkit, 2022. Municipal Climate Change Response Plans. Available Online: https://letsrespondtoolkit.org/. Accessed 28 April 2022.

Li, H., Goh, C., Hung, K. and Chen, J.L. 2018. Relative climate index and its effect on seasonal tourism demand. *Journal of Travel Research*, 57(2): 178-192.

Linda, N. and Nzama, A.T. 2020. Tourism crime, safety and security issues: The case of a local South African municipality. *African Journal of Hospitality, Tourism and Leisure*, 9(3): 372-381.

Loehr, J. and Becken, S. 2021. The Tourism Climate Change Knowledge System. Annals of Tourism Research 86, https://doi.org/10.1016/j.annals.2020.103073.

Lötter, D. 2019. Green Book – Climate change impacts on agriculture, forestry and fisheries. Technical report, Pretoria: CSIR

Lubbe, B.A., Douglas, A., Fairer-Wessels, F. and Kruger, E. 2015. Measuring the competitiveness of South Africa as a tourist destination. Tourism travel and research association: advancing tourism research globally.

Ma, S., Craig, C.A. and Feng, S. 2020. The Camping Climate Index (CCI): The development, validation, and application of a camping-sector tourism climate index. *Tourism Management*, 80: https://doi.org/10.1016/j.tourman.2020.104105.

MacKellar, N., New, M. and Jack, C. 2014. Observed and modelled trends in rainfall and temperature for South Africa: 1960-2010. South African Journal of Science, 110. doi: 10.1590/ sajs.2014/20130353.

Magadza, C.H.D. 1994. Climate change: some likely multiple impacts in Southern Africa. *Food Policy*, 19(2): 165-191.

Magnan, A.K., Schipper, E.L.F., Burkett, M., Bharwani, S., Burton, I., Eriksen, S., Gemenne, F., Schaar, J. and Ziervogel, G. 2016. Addressing the risk of maladaptation to climate change. *Wiley Interdisciplinary Reviews: Climate Change*, 7(5): 646-665.

Mailula,T. 2019. South Africa's GHG Emissions Data Lacks Consistency and Timeliness. Climate Scorecard. Available Online: https://www.climatescorecard.org/2019/06/south-africas-ghg-emissions-data-lacks-consistency-and-timeliness/. Accessed 12 December 209.

Makondo, C.C. and Thomas, D.S. 2018. Climate change adaptation: Linking indigenous knowledge with western science for effective adaptation. *Environmental science & policy*, 88: 83-91.

Martín-González, R., Swart, K. and Luque-Gil, A.M. 2021. Tourism competitiveness and sustainability indicators in the context of surf tourism: The *case of Cape Town. Sustainability*, 13(13): p.7238.

Masipa, T.S. 2017. The impact of climate change on food security in South Africa: current realities and challenges ahead. *Journal of Disaster and Risk Studies*, 9(1): 411-429.

Mather, S., Viner, D. and Todd, G. 2005 Climate and policy changes: Their implications for international tourism. In C.M. Hall and J. Higham (eds). Tourism, Recreation and Climate Change: International Perspectives (63–85). Clevedon: Channel View Publications.

Mckay, T., McEwan, L. and Baker, M. 2019. The rise of trail running in South Africa: Possibilities for small-scale sports tourism. *Geo Journal of Tourism and Geosites*, 26(3): 930-942.

Midgley, S.J.E., Davies, R.A.G. and Chesterman, S. 2011. Climate risk and vulnerability mapping in southern Africa: Status quo (2008) and future (2050). For the Regional Climate Change Programme for Southern Africa (RCCP).

Mieczkowski, Z. 1985. The tourism climatic index: A method of evaluating world climates for tourism. *Canadian Geographer*, 29(3): 220-33.

Mihalic, T. 2016. Sustainable-responsible tourism discourse – Towards 'responsustable' tourism. *Journal of Cleaner Production*, 111: 461-470.

Molina, J. and Font, X. 2015. Mixed methods in sustainable tourism research: an analysis of prevalence, designs and application in JOST (2005-2014). *Journal of Sustainable Tourism*, 24(4): 549-573.

Mora, C., Spirandelli, D., Franklin, E. C., Lynham, J., Kantar, M. B., Miles, W., & Barba, E. W. 2018. Broad threat to humanity from cumulative climate hazards intensified by greenhouse gas emissions. *Nature Climate Change*, 8(12): 1062.

Moran, D., Kanemoto, K.; Jiborn, M., Wood, R., Többen, J. and Seto, K.C. 2018 Carbon footprints of 13,000 cities. Environmental Research Letters doi: 10.1088/1748-9326/aac72a.

Moreno, A., and Becken, S. 2009. A climate change vulnerability assessment methodology for coastal tourism. *Journal of Sustainable Tourism*,17(4): 473-488.

Mtapuri, O. and Tinarwo, P. 2021. From Apartheid to Democracy: Patterns and Trends of inequality in South Africa. *Southern African Journal of Demography*, 21(1): 104-133.

Musavengane, R., Siakwah, P. and Leonard, L. 2020. The nexus between tourism and urban risk: Towards inclusive, safe, resilient and sustainable outdoor tourism in African cities. *Journal of Outdoor Recreation and Tourism*, 29, doi: 10.1016/j.jort.2019.100254

Mushawemhuka, W.J., Fitchett, J.M. and Hoogendoorn, G. 2020. Towards quantifying climate suitability for Zimbabwean nature-based tourism. *South African Geographical Journal*, doi: 10.1080/03736245.2020.1835703.

Njoroge, J. 2015. Climate change and tourism adaptation: Literature Review. *Tourism and Hospitality Management*, 21(1): 95-108.

Noome, K. and Fitchett, J.M. 2019. An assessment of the climatic suitability of Afriski Mountain Resort for outdoor tourism using the Tourism Climate Index (TCI). *Journal of Mountain Science*, 16(11): 2453-2469.

Noome, K. and Fitchett, J.M. 2021. Quantifying the climatic suitability for tourism in Namibia using the Tourism Climate Index (TCI). *Environment, Development and Sustainability*, doi:10.1007/s10668-021-01651-2.

ND-Gain, 2016 .Notre Dame Global Adaptation Initiative: Download Data. Available Online: https://gain.nd.edu/our-work/country-index/download-data/. (Accessed 19 June 2022).

Odimegwu, F. and Francis, O.C. 2018. The interconnectedness between climate change and tourism. *J Contemp Sociol Res*, 1(1): 48-58.

Pandy, W.R. 2017. Tourism enterprises and climate change: some research imperatives. *African Journal of Hospitality, Tourism and Leisure*, 6(4): 1-18.

Pandy, W.R. and Rogerson, C.M. 2018. Tourism and climate change: Stakeholder perceptions of at risk tourism segments in South Africa. *Euroeconomica – Special Issue on Tourism in Africa*, 37(2): 104-118.

Pandy, W.R. and Rogerson, C.M. 2019. Urban tourism and climate change: Risk perceptions of business tourism stakeholders in Johannesburg, South Africa. *Urbani Izziv* 30: 225-243.

Pandy, W.R. and Rogerson, C.M. 2021. Climate change risks and tourism in south Africa: Projections and policy. *Geo Journal of Tourism and Geosites*, 35(2): 445-455.

Pang, S., McKercher, B. and Prideaux, B. 2013. Climate Change and Tourism: An Overview. *Asia Pacific Journal of Tourism Research*, 18(1-2): 4-20.

Pecl, G.T., Araújo, M.B., Bell, J.D., Blanchard, J., Bonebrake, T.C., Chen, I.C., Clark, T.D., Colwell, R.K., Danielsen, F., Evengård, B. and Falconi, L. 2017. Biodiversity redistribution under climate change: Impacts on ecosystems and human well-being. Science, 355(6332), doi: 10.1126/science.aai9214.

Perch-Nielsen, S.L. 2010. The vulnerability of beach tourism to climate change—an index approach. Climatic Change, 100(3), 579-606.

Perch-Nielsen, S.L., Amelung, B. and Knutti, R. 2010. Future climate resources for tourism in Europe based on the daily Tourism Climatic Index. *Climatic Change*, 103(3): 363-381.

Perkins, K., Munguia, N., Moure-Eraso, R., Delakowitz, B., Giannetti, B., Liu, G., Nurunnabi, M., Will, M. and Velazquez, L. 2018. International perspectives on the pedagogy of climate change. *Journal of Cleaner Production*, 200: 1043-1052.

Preston-Whyte, R. and Watson, H. 2005. Chapter 8: Nature tourism and Climatic Change in southern Africa. In: C. Hall and J. Higham, ed., *Tourism, Recreation, and Climate Change*. Bristol; UK: Channel View Publications, 130-142.

Proenca, V., Martin, L.J., Pereira, H.M., Fernandez, M., McRae, L., Belnap, J., Böhm, M., Brummitt, N., García-Moreno, J., Gregory, R.D. and Honrado, J.P. 2017. Global biodiversity monitoring: from data sources to essential biodiversity variables. *Biological Conservation*, 213: 256-263.

Rao, N., Lawson, E.T., Raditloaneng, W.N., Solomon, D. and Angula, M.N. 2019. Gendered vulnerabilities to climate change: insights from the semi-arid regions of Africa and Asia. *Climate and Development*, 11(1): 14-26.

Republic of South Africa. 2021a. Climate Change Bill: Notice of Introduction published in Government Gazette No. 45299 of 2021). Pretoria: Department of Forestry, Fisheries and the Environment.

Republic of South Africa. 2021b. South Africa: First Nationally Determined Contribution Under the Paris Agreement. Pretoria: Republic of South Africa.

Roffe, S.J., Fitchett, J.M. and Curtis, C.J. 2019. Classifying and mapping rainfall seasonality in South Africa: a review. *South African Geographical Journal*, 101(2): 158-174.

Rogerson, C.M. 2014. Rethinking slum tourism: Tourism in South Africa's rural slumlands. *Bulletin of Geography. Socio-economic Series*, (26): 19-34.

Rogerson, C.M. 2015. Restructuring the geography of domestic tourism in South Africa. *Bulletin of Geography. Socio-economic Series*, (29): 119-135.

Rogerson, C.M. 2016. Climate change, tourism and local economic development in South Africa. *Local Economy*, 31(1-2): 322-331.

Rogerson, J.M. 2016. Hotel chains of the global South: The internationalization of South African hotel brands. Tourism: *An International Interdisciplinary Journal*, 64(4): 445-450.

Rogerson, C.M. 2017a. Less visited tourism spaces in South Africa. *African Journal of Hospitality, Tourism and Leisure*, 6(3): 1-17.

Rogerson, C.M. 2017b. Unpacking directions and spatial patterns of VFR travel mobilities in the global South: Insights from South Africa. *International Journal of Tourism Research*, 19(4): 466-475.

Rogerson, C.M. and Baum, T. 2020 COVID-19 and African tourism research agendas*, Development Southern Africa*, 37(5): 727-741.

Rogerson, C.M. and Hoogendoorn, G. 2014. VFR travel and second home tourism: The missing link? The case of South Africa. *Tourism Review International*, 18(3): 167-178.

Rogerson, C.M. and Rogerson, J.M. 2019. Tourism in South Africa's borderland regions: a spatial view. *Geo Journal of Tourism and Geosites*, 24(1): 175-188.

Rogerson, C.M. and Rogerson, J.M. 2021. Niche Tourism in South Africa: A Renewed Policy Focus in the COVID-19 Environment. *Geo Journal of Tourism and Geosites*, 39: 1379-1387.

Rogerson, C.M. and Collins, K.J. 2015. Beer tourism in South Africa: Emergence and contemporary directions. Nordic Journal of African Studies, 24(3&4): 18-18.

Rogerson, C.M. and Rogerson, J.M. 2019. Emergent planning for South Africa's blue economy. *Urbani izziv*, 30: 24-36.

Rogerson, C.M. and Rogerson, J.M. (2020). COVID-19 tourism impacts in South Africa: government and industry responses. *GeoJournal of Tourism and Geosites,* 31(3), 1083-1091.

Rogerson, C.M. and Rogerson, J.M. 2020. COVID-19 and tourism spaces of vulnerability in South Africa. *African Journal of Hospitality, Tourism and Leisure*, 9(4): 382-401.

Rogerson, C.M. and Rogerson, J.M. 2021. COVID-19 and changing tourism demand: Research review and policy implications for South Africa. *African Journal of Hospitality, Tourism and Leisure*, 10(1): 1-21.

Rogerson, C.M. and Visser, G. 2007. International tourist flows and urban tourism in South Africa. In Urban Tourism in the Developing World (pp.41-56). Routledge.

Rossello-Nadal, J. 2014. How to evaluate the effects of climate change on tourism. *Tourism Management*, 42: 334-340.

Rossello, J., Becken, S. and Santana-Gallego, M. 2020. The effects of natural disasters on international tourism: a global analysis. *Tourism Management*, 79, doi: 10.1016/j.tourman.2020.104080.

Rutty, M., Scott, D., Matthews, L., Burrowes, R., Trotman, A., Mahon, R. and Charles, A. 2020a. An inter-comparison of the Holiday Climate Index (HCI: Beach) and the Tourism Climate Index (TCI) to explain Canadian tourism arrivals to the Caribbean. *Atmosphere*, 11(4): 412.

Rutty, M., Steiger, R., Demiroglu, O.C. and Perkins, D.R. 2020b. Tourism climatology: past, present, and future. *International Journal of Biometeorology*, doi: 10.1007/s00484-020-02070-0.

Santos-Lacueva, R., Clavé, S.A. and Saladié, Ò. (2017). The vulnerability of coastal tourism destinations to climate change: The usefulness of policy analysis. *Sustainability*, 9(11): 2062, https://doi.org/10.3390/su9112062.

Scheyvens, R. and Hughes, E. 2019. Can tourism help to "end poverty in all its forms everywhere"? The challenge of tourism addressing SDG1. *Journal of Sustainable Tourism*, doi: 10.1080/09669582.2018.1551404.

Schlosser, C.A., Strzepek, K., Gao, X., Fant, C., Blanc, É., Paltsev, S., Jacoby, H., Reilly, J. and Gueneau, A. 2014. The future of global water stress: An integrated assessment. *Earth's Future*, 2(8): 341-361.

Scott, D. and Becken, S. 2010. Adapting to climate change and climate policy: Progress, problems and potentials. *Journal of Sustainable tourism*, 18(3): 283-295.

Scott, D. and McBoyle, G. 2001, December. Using a 'tourism climate index'to examine the implications of climate change for climate as a tourism resource. In First International Workshop on Climate, Tourism and Recreation (pp. 69-88). Porto Carras: International Society of Biometeorology.

Scott, D., Gössling, S. and Hall, C.M. 2012. International tourism and climate change. *Wiley Interdisciplinary Reviews: Climate Change*, 3(3): 213-232.

Scott, D., Hall, C.M. and Gössling, S. 2019. Global tourism vulnerability to climate change. *Annals of Tourism Research*, 77: 49-61.

Scott, D., Rutty, M., Amelung, B. and Tang, M. 2016. An Inter-Comparison of the Holiday Climate Index (HCI) and the Tourism Climate Index (TCI) in Europe. *Atmosphere*, 80(7), doi:10.3390/atmos7060080.

Scott, D., Gössling, S., Hall, C.M. and Peeters, P., 2016. Can tourism be part of the decarbonized global economy? The costs and risks of alternate carbon reduction policy pathways. Journal of Sustainable Tourism, 24(1), pp.52-72.

Scott, D., Hall, C.M. and Gössling, S. 2016. A review of the IPCC Fifth Assessment and implications for tourism sector climate resilience and decarbonization. *Journal of Sustainable Tourism*, 24(1): 8-30.

Scott, D. and Lemieux, C. 2010. Weather and climate information for tourism. *Procedia Environmental Sciences,* 1: 146-183.

Scott, D. 2021. Sustainable tourism and the grand challenge of climate change. Sustainability, 13(4): p.1966.

Serdeczny, O., Adams, S., Baarsch, F., Coumou, D., Robinson, A., Hare, W., Schaeffer, M., Perrette, M. and Reinhardt, J. 2017. Climate change impacts in Sub-Saharan Africa: from physical changes to their social repercussions. *Regional Environmental Change*, 17(6): 1585-1600.

Shackleton, S., Ziervogel, G., Sallu, S., Gill, T. and Tschakert, P. 2015. Why is socially-just climate change adaptation in sub-Saharan Africa so challenging? A review of barriers identified from empirical cases. *Wiley Interdisciplinary Reviews: Climate Change*, 6(3): 321-344.

Sifilo, P.P.S. and Henama, U.S. 2017. Implications of climate change for tourism in Africa. *GeoJournal of Tourism and Geosites*, 20(2): 191-198.

Sifolo, N. and Sifolo, P.P.S. 2015. The tourism inconvenience of the Ebola epidemic: lessons for the South African tourism sector. *African Journal of Hospitality, Tourism and Leisure*, 4(1): 1-11.

Smith, T. and Fitchett, J.M. 2020. Drought challenges for nature tourism in the Sabi Sands region of South Africa. *African Journal of Range and Forage Science*, 37(1): 107-117.

South African National Parks. CCAB - High Risk Scenarios - Biome Delineations 2011 [vector geospatial dataset] 2011. Available from the Biodiversity GIS website, downloaded on 27 August 2022.

South African Tourism. 2022. Tourist Arrivals Dashboard. Available Online: https://www.southafrica.net/gl/en/corporate/page/provincial-tourist-arrivals-report. (Accessed 18 June 2022).

South African Tourism. 2022. Opportunities to Increase Positive Sentiment for South Africa: Infographic.

South African Tourism. 2021. The Road To Recovery Report.

South African Tourism. 2019. Tourism Performance Report: January - December 2018.

South African Weather Services. (2017). A Climate change reference Atlas. Available at: http://www.weathersa.co.za/Documents/Climate/SAWS_CC_REFERENCE_ATLAS_PAGES.pdf (Accessed: 24 June 2019).

Southon, M.P. and van der Merwe, C.D. 2018. Flooded with risks or opportunities: Exploring flooding impacts on tourist accommodation. *African Journal of Hospitality, Tourism and Leisure*, 7(1): 1-27.

Stanton, E.A., Cegan, J., Bueno, R. and Ackerman, F. 2012. Estimating regions' relative vulnerability to climate damages in the CRED model. Working Paper, Stockholm Environment Institute.

StatsSA, 2018. Electricity, gas and water supply industry, 2016. Available Online: https://www.statssa.gov.za/publications/Report-41-01-02/Report-41-01-022016.pdf. Accessed 11 June 2022.

StatsSA. 2019. Inequality Trends in South Africa: A multidimensional diagnostic of inequality / Statistics South Africa. Pretoria: Statistics South Africa.

StatsSA. 2018. Tourism. Statistics South Africa, Pretoria.

StatsSA. 2019. Tourism and Migration. Statistics South Africa, Pretoria.

StatsSA. 2020. Tourism. Statistics South Africa, Pretoria

StatsSA, 2021. Tourism in South Africa: a pre-COVID-19 benchmark. Available online: https://www.statssa.gov.za/?p=14992. Accessed 28 May 2022.

StatsSA. 2021. Tourism Satellite Account for South Africa. Statistics South Africa, Pretoria.

Steyn, J.N. and Spencer, J.P. 2012. Climate change and tourism: Implications for South Africa. *African Journal for Physical, Health Education, Recreation and Dance*, 18: 1-19.

Stockigt, L., Hoogendoorn, G., Fitchett, J.M. and Saarinen, J. 2018. Climatic sensitivity and snow-based tourism in Africa: an investigation of TripAdvisor reviews on Afriski, Lesotho. Proceedings of Biennial Conference of the Society of South African Geographers, Bloemfontein.

The World Bank Group. 2021. Climate Risk Profile: South Africa.

Tonnang, H.E., Kangalawe, R.Y. and Yanda, P.Z. 2010. Predicting and mapping malaria under climate change scenarios: the potential redistribution of malaria vectors in Africa. *Malaria journal*, 9(1): 1-10.

Think! X Innovations Inc. 2022. Tourism Sentiment Index: Destination Spotlight: South Africa. Available Online: https://www.sentiment-index.com/spotlight-south-africa. Accessed 14 April 2022.

Trisos, C.H., Merow, C. and Pigot, A.L. 2020. The projected timing of abrupt ecological disruption from climate change. *Nature*, 580(7804): 496-501.

USAid, 2015. Greenhouse Gas Emissions in Southern Africa.

van der Walt, A.J. and Fitchett, J.M. 2020a. Exploring extreme warm temperature trends in South Africa: 1960–2016. Theoretical and Applied Climatology, doi: 10.1007/s00704-020-03479-8.

van der Walt, A.J. and Fitchett, J.M. 2020b. Statistical classification of South African seasonal divisions on the basis of daily temperature data. South African Journal of Science, 116(9), doi: 10.17159/sajs.2020/7614.

van der Walt, A.J. and Fitchett, J.M. 2022. Extreme Temperature Events (ETEs) in South Africa: a review. *South African Geographical Journal*, 104(1): 70-88.

Wall, G. and Badke, C. 1994, Tourism and climate change: An international perspective, *Journal of Sustainable Tourism*, 2(4): 193-203.

Warren, R., Price, J., Graham, E., Forstenhaeusler, N. and VanDerWal, J. 2018. The projected effect on insects, vertebrates, and plants of limiting global warming to 1.5°C rather than 2°C. *Science, 360* (6390): 791-795.Climate ch

Weber, T., Haensler, A., Rechid, D., Pfeifer, S., Eggert, B., and Jacob, D. 2018. Analyzing regional climate change in Africa in a 1.5, 2, and 3°C global warming world. *Earth's Future*, 6: 643-655.

Weir, B. 2017. Climate change and tourism – Are we forgetting lessons from the past? *Journal of Hospitality and Tourism Management*, 32: 108-114.

Wheeler, D. 2011. Quantifying vulnerability to climate change: implications for adaptation assistance. *Center for Global Development Working Paper*, (240).

World Bank,, 2018. Gini Index: All Countries and Economies. Available Online https://data.worldbank.org/indicator/SI.POV.GINI?end=2021&start=2021&view=bar. Accessed 17 May 2022.

World Economic Forum, 2019. The Travel & Tourism Competitiveness Report 2019. Travel and Tourism at a Tipping Point, 1-129.

World Resources Institute. WRI. 2019. Aqueduct Food. Available Online: https://www.wri.org/applications/aqueduct/water-risk-atlas/#/?advanced=false&basemap=hydro&indicator=bws_cat&lat=-29.779636262261494&lng=25.51464602351189&mapMode=view&month=1&opacity=0.5&ponderation=DEF&predefined=false&projection=absolute&scenario=optimistic&scope=baseline&timeScale=annual&year=baseline&zoom=6. Accessed 12 June 2022.

World Resources Institute. WRI. 2019. Aqueduct Water Risk Atlas. Available Online: https://www.wri.org/applications/aqueduct/food/#/?basemap=hydro&crop=all&food=none&indicator=6f339b41-ea2f-4502-a454-d03bb22b540b&irrigation=all&lat=-28.83&lng=18.44&opacity=1&period=year&period_value=baseline&scope=global&subscope&threshold=40&type=absolute&year=2030&zoom=6 Accessed 12 June 2022.

Woyo, E. and Slabbert, E. 2019. Cross-border destination marketing of attractions between borders: the case of Victoria Falls. *Journal of Hospitality and Tourism Insights*, 2(2): 145-165.

Wozniak, A., Lück, J. and Wessler, H. 2015. Frames, stories, and images: The advantages of a multimodal approach in comparative media content research on climate change. *Environmental Communication*, 9(4): 469-490.

Yu, D.D., Rutty. M., Scott, D. and Li, S. 2020. A comparison of the holiday climate index: beach and the tourism climate index across coastal 283 destinations in China. *International Journal of Biometeorology,* doi:10.1007/s00484-020-01979-w.

Zanetti, V.B., de Sousa Junior, W.C. and De Freitas, D.M. 2016. A climate change vulnerability index and case study in a Brazilian coastal city. *Sustainability,* 8(8): 811. doi:10.3390/su8080811.

Ziervogel, G., New, M., Archer van Garderen, E., Midgley, G., Taylor, A., Hamann, R., Stuart-Hill, S., Myers, J. and Warburton, M. 2014. Climate change impacts and adaptation in South Africa. *Wiley Interdisciplinary Reviews: Climate Change*, 5(5): 605-620.

APPENDICES

APPENDIX A - Tourism Assets Raw Data

A1. TA1 - TCI Rate of Change including Normalised Score (adapted from Robinson, 2016).

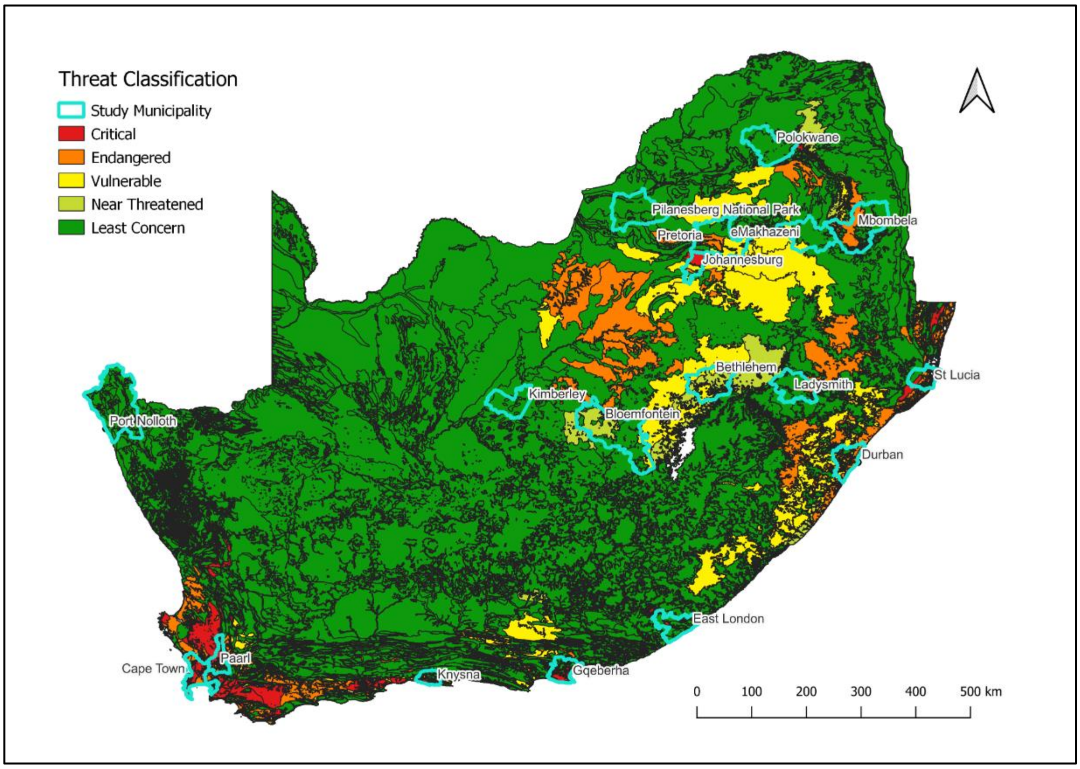
Location	Rate of Change (TCI / Year)	Mathematically Adapted	Normalised Score
Bethlehem	-0.54	No	5
Bloemfontein	0.08	No	3
Cape Town	-0.18	No	4
Durban	0.28	Yes	2
East London	0.15	No	2
eMakhazeni	-0.42	Yes	5
Gqeberha	-0.51	No	5
Johannesburg	0.35	No	1
Kimberley	-0.28	No	4
Knysna	0.76	Yes	1
Ladysmith	0.11	Yes	3
Mbombela	0.10	Yes	3
Paarl	-0.11	Yes	3
Pilanesberg	-0.29	Yes	5
Polokwane	-0.18	No	4
Port Nolloth	0.93	No	1
Pretoria	0.26	Yes	2
St Lucia	0.50	Yes	1

A2. TA2 and TA3 - Threat Classification Normalisation Key

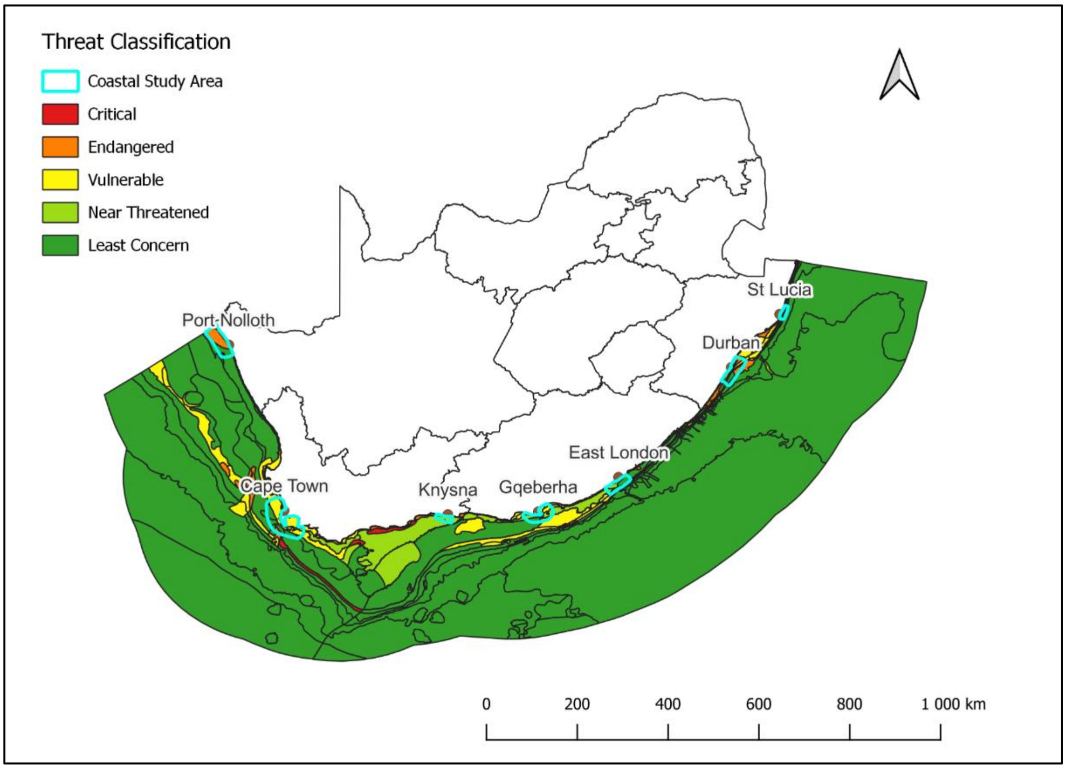
Threat Classification	Score
Critical	5
Endangered	4
Vulnerable	3
Near Threatened	2
Least Concern	1

A3. TA4 - Sea Level Rise Including Normalised Score (adapted from Allison et al., 2022)

Location	RCP8.5 SLR (m)	Score
Cape Town	0.86	5
Durban	0.84	4
East London	0.89	5
Gqeberha	0.87	5
Knysna	0.84	4
Port Nolloth	0.84	4
St Lucia	0.84	4
Global Mean	0.78	3

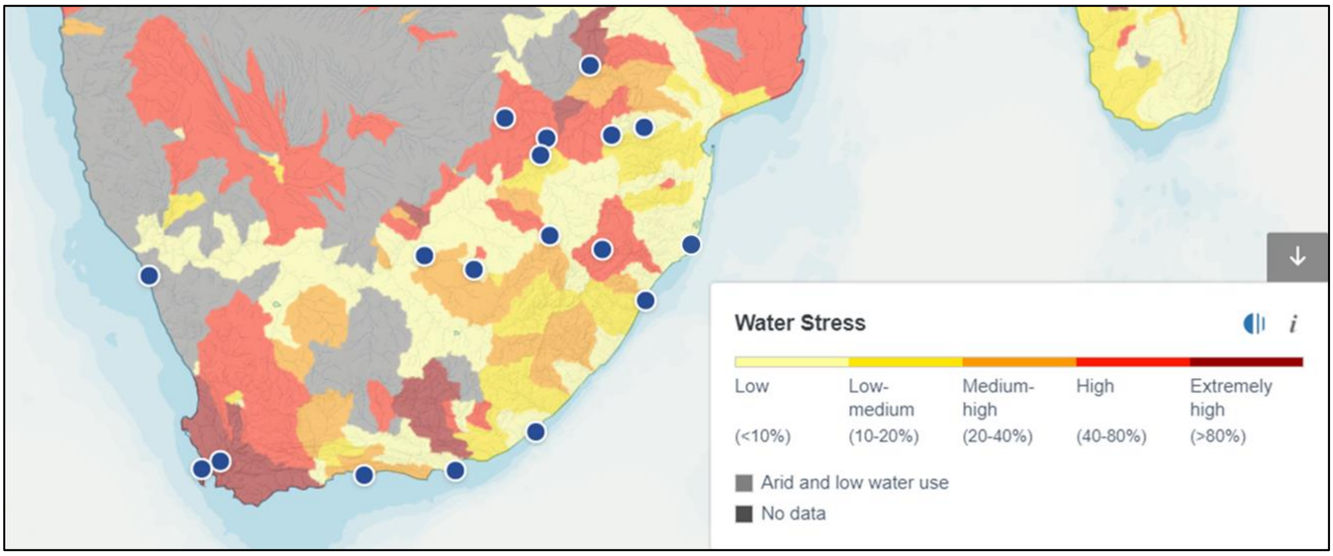


A4. TA2 - Threat Classification - Terrestrial (SANBI-GIS, 2018)

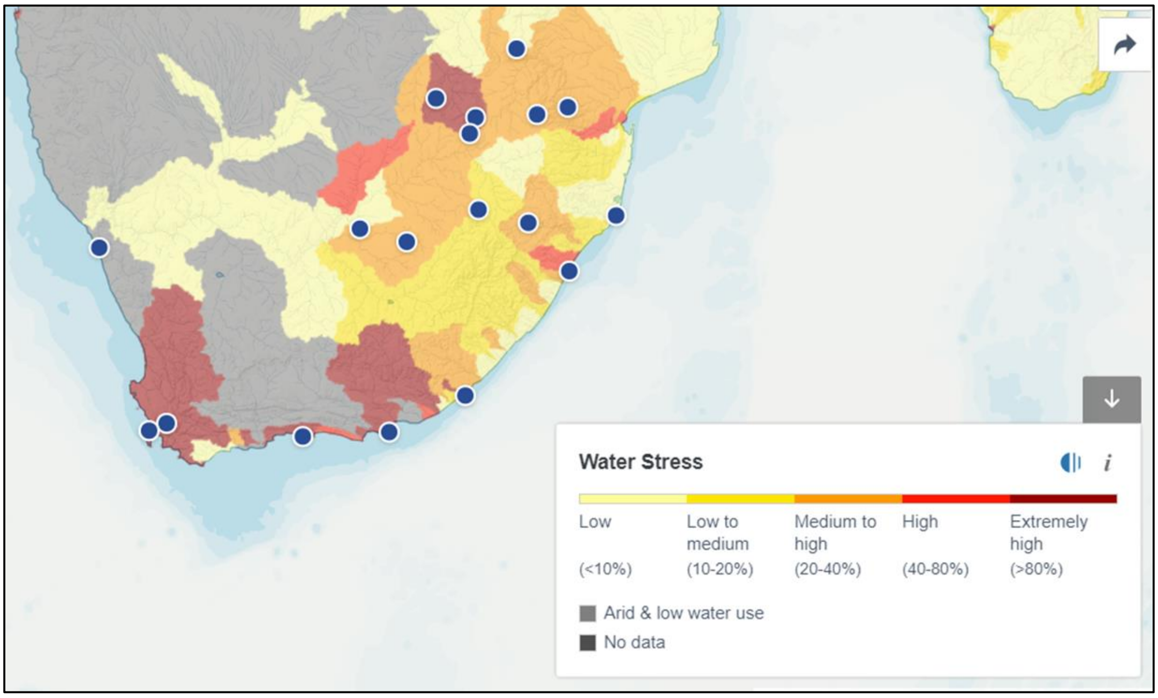


A5. TA3 - Threat Classification - Marine (SANBI-GIS, 2018)

APPENDIX B – Tourism Operating Costs Raw Data



A6. TOC1 - Current Water Stress (WRI, 2022)



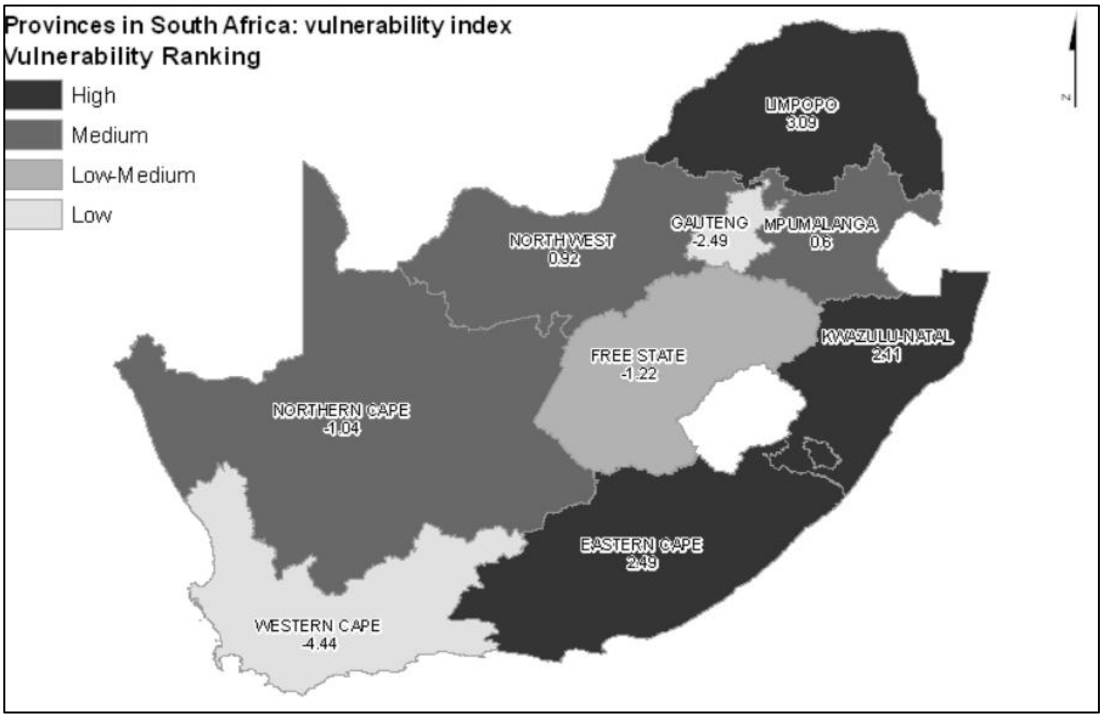
A7. TOC2 - Future Water Stress (2050; WRI, 2022)

A8. TOC1 and TOC2 - Water Stress Normalisation Key

Water Stress Rating	Score
Low (<10%)	1
Low - Medium (10-20%)	2
Medium - High (20-40%)	3
High (40-80%)	4
Extremely High (>80%)	5
Arid and Low Water Use	5

A9. TOC3 - Contracted Renewable Energy Capacity Including Normalised Score (adapted from REDIS, 2022)

Row Labels	Sum of Capacity (MWp)	Score
Gauteng	18.35	5
KwaZulu-Natal	37	5
Mpumalanga	44.6	5
Limpopo	118	5
Free State	235.1	5
North West	279.83	5
Western Cape	708.53	5
Eastern Cape	1570.23	4
Northern Cape	3619.99	4
Grand Total	6631.63	-

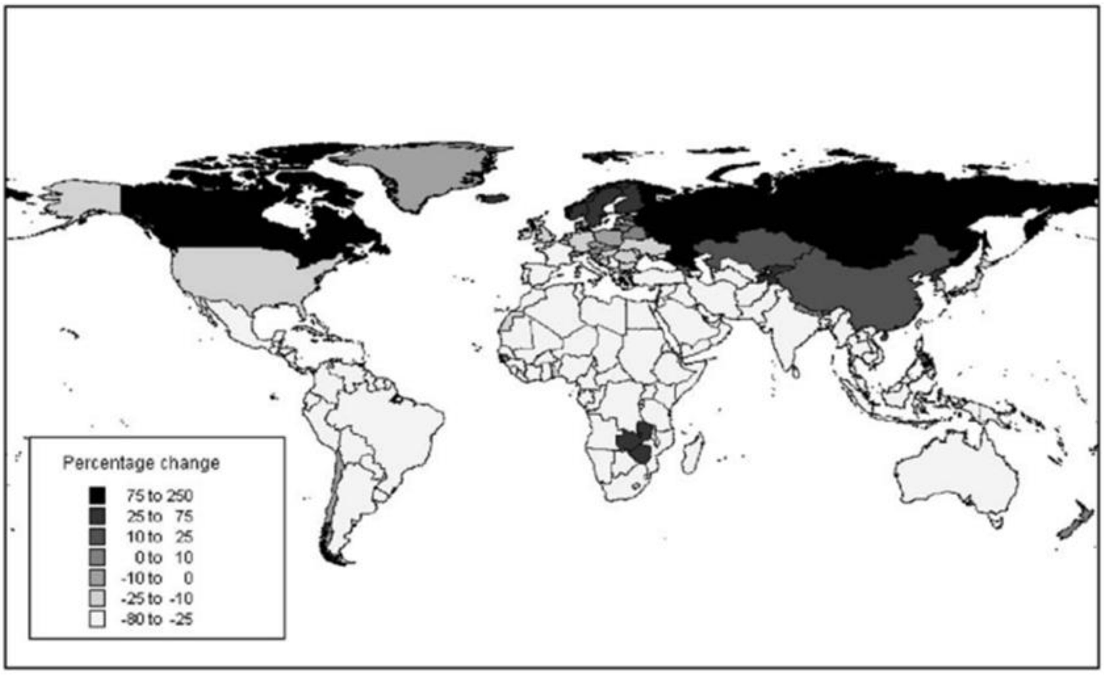


A10. TOC5 - Farming Sector Vulnerability Index (Gbetibouo & Ringler, 2009)

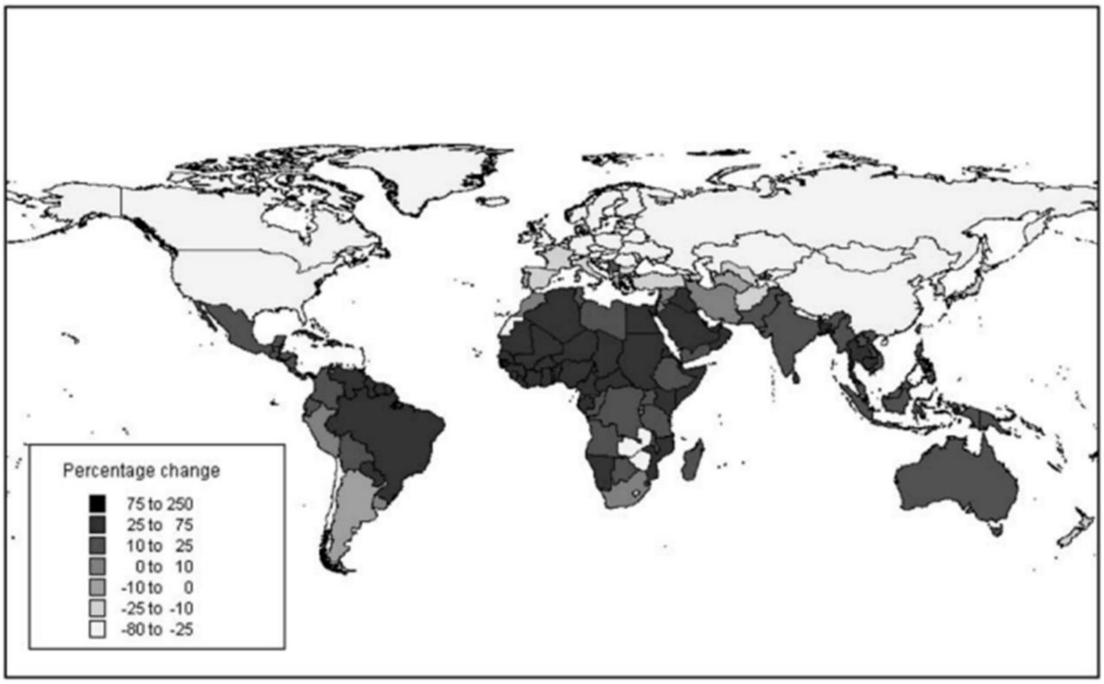
A11. TOC5 - Farming Sector Vulnerability Index Normalisation Key

Province	Vulnerability Index	Score
Western Cape	-4.44	1
Gauteng	-2.49	1
Free State	-1.22	2
Northern Cape	-1.04	2
Mpumalanga	0.6	3
North West	0.92	4
KwaZulu-Natal	2.11	4
Eastern Cape	2.49	5
Limpopo	3.09	5

APPENDIX C – Tourism Demand Raw Data



A12. TD1 - Percentage change in arrivals due to global warming (Hamilton et al., 2005)



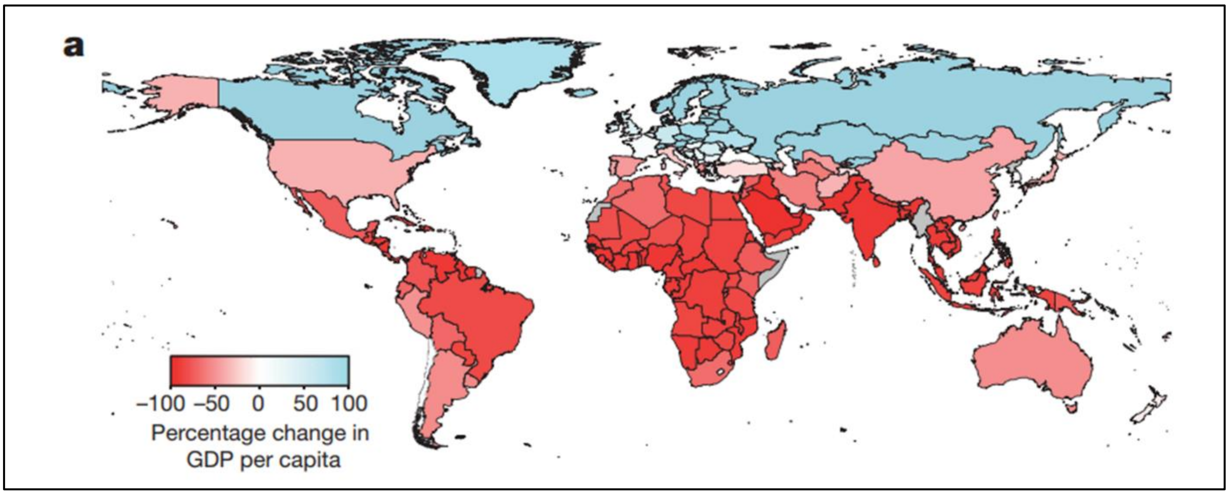
A13. TD5 - Percentage Change in Departures as a Result of Global Warming (Hamilton et al., 2005)

A14. TD2, TD3 and TD4 - Top five international source markets per province including number of visitors per year (South African Tourism, 2019)

Province	Source 1	Tourists	Source 2	Tourists	Source 3	Tourists	Source 4	Tourists	Source 5	Tourists	Sum
FS	Lesotho	1188010	Botswana	12897	USA	9238	Germany	8354	UK	8154	1226653
WC	USA	192629	UK	250429	Germany	213054	Namibia	105817	France	102007	863936
KZN	Eswatini	297163	UK	50464	Germany	48385	Botswana	48159	Lesotho	44796	488967
EC	Germany	81699	UK	61749	USA	36628	Netherlands	26980	France	23622	230678
MP	Mozambique	724129	Eswatini	303119	USA	84544	Germany	78346	UK	58958	1249096
GP	Mozambique	676530	Lesotho	474546	Zimbabwe	408054	Eswatini	292564	Botswana	291667	2143361
NC	Namibia	48033	Botswana	5575	USA	5448	UK	4684	Germany	5268	69008
NW	Botswana	348976	Lesotho	101028	Zimbabwe	33683	Mozambique	27717	Eswatini	19521	530925
L	Zimbabwe	1796473	Botswana	155250	USA	40903	Germany	22161	UK	21295	2036082

A15. TD2 - Percentage net GDP per capita change per top five international source markets per province (extracted from Burke et al., 2015; South African Tourism, 2019)

Province	Source 1	Change	Source 2	Change	Source 3	Change	Source 4	Change	Source 5	Change	Net Change	Score
FS	Lesotho	0	Botswana	-100	USA	-40	Germany	70	UK	40	-0.61	2
WC	USA	-40	UK	40	Germany	70	Namibia	-100	France	0	7.69	1
KZN	Eswatini	-70	UK	40	Germany	70	Botswana	-100	Lesotho	0	-41.34	2
EC	Germany	70	UK	40	USA	-40	Netherlands	0	France	0	29.15	1
MP	Mozambique	-100	Eswatini	-70	USA	-40	Germany	70	UK	40	-71.39	3
GP	Mozambique	-100	Lesotho	0	Zimbabwe	-90	Eswatini	-70	Botswana	-100	-71.86	4
NC	Namibia	-100	Botswana	-100	USA	-40	UK	40	Germany	70	-72.78	4
NW	Botswana	-100	Lesotho	0	Zimbabwe	-90	Mozambique	-100	Eswatini	-70	-79.23	5
L	Zimbabwe	-90	Botswana	-100	USA	-40	Germany	70	UK	40	-86.66	5



A16. TD2 and TD6 - Percentage Change in GDP per capita as a result of climate change (2050) (Burke et al., 2015)

A17. TD3 - Transportation type classification per international source market

Source Market	Transportation Type	Point A	Point B
Botswana	Land	Gaborone	Study Site
Eswatini	Land	Mbabane	Study Site
France	Air	Paris Charles de Gaulle Airport	Closest International Airport to Study Site
Germany	Air	Frankfurt Airport	Closest International Airport to Study Site
Lesotho	Land	Maseru	Study Site
Mozambique	Land	Maputo	Study Site
Namibia	Land	Windhoek	Study Site
Netherlands	Air	Amsterdam Airport Schiphol	Closest International Airport to Study Site
UK	Air	London Heathrow	Closest International Airport to Study Site
USA	Air	Hartsfield-Jackson Atlanta	Closest International Airport to Study Site
Zimbabwe	Land	Harare	Study Site

A18. TD3 - Major International Airports in South Africa

A19. TD4 - Percentage International Leisure Arrivals (South African Tourism Dashboard, 2018)

Location	**Province**	**Leisure %**	**Score**
Bethlehem	Free State	63.9	5
Bloemfontein	Free State	63.9	5
Cape Town	Western Cape	60.7	4
Durban	KwaZulu-Natal	32.6	3
East London	Eastern Cape	61.7	5
eMakhazeni	Mpumalanga	35	4
Gqeberha	Eastern Cape	61.7	5
Johannesburg	Gauteng	21.7	2
Kimberley	Northern Cape	29.1	2
Knysna	Western Cape	60.7	4
Ladysmith	KwaZulu-Natal	32.6	3
Mbombela	Mpumalanga	35	4
Paarl	Western Cape	60.7	4
Pilanesberg	North West	18	1
Polokwane	Limpopo	8	1
Port Nolloth	Northern Cape	29.1	2
Pretoria	Gauteng	21.7	2
St Lucia	KwaZulu-Natal	32.6	3

A20. TD3 - Distance between study site and top five international markets including average weighted distance and normalised score

Location	Source 1	Distance (km)	Source 2	Distance (km)	Source 3	Distance (km)	Source 4	Distance (km)	Source 5	Distance (km)	Weighted Average (km)	Score
Bethlehem	Lesotho	179	Botswana	566	USA	13582	Germany	8689	UK	9075	401.10	1
Bloemfontein	Lesotho	151	Botswana	588	USA	13582	Germany	8689	UK	9075	374.21	1
Cape Town	USA	13089	UK	9681	Germany	9391	Namibia	1479	France	9362	9327.09	4
Durban	Eswatini	538	UK	9563	Germany	9166	Botswana	936	Lesotho	553	2363.77	3
East London	Germany	9391	UK	9681	USA	13089	Netherlands	9687	France	9362	10087.46	5
eMakhazeni	Mozambique	330	Eswatini	174	USA	13582	Germany	8689	UK	9075	2126.16	2
Gqeberha	Germany	9391	UK	9681	USA	13089	Netherlands	9687	France	9362	10087.46	5
Johannesburg	Mozambique	550	Lesotho	419	Zimbabwe	1129	Eswatini	367	Botswana	374	582.30	1
Kimberley	Namibia	1361	Botswana	516	USA	13582	UK	13582	Germany	8689	3646.48	3
Knysna	USA	13089	UK	9681	Germany	9391	Namibia	1840	France	9362	9371.30	5
Ladysmith	Eswatini	358	UK	9563	Germany	9166	Botswana	722	Lesotho	338	2213.61	2
Mbombela	Mozambique	204	Eswatini	183	USA	13582	Germany	8689	UK	9075	2055.30	2
Paarl	USA	13089	UK	9681	Germany	9391	Namibia	1447	France	9362	9323.17	4
Pilanesberg	Botswana	192	Lesotho	564	Zimbabwe	1158	Mozambique	704	Eswatini	521	362.90	1
Polokwane	Zimbabwe	805	Botswana	540	USA	13582	Germany	8689	UK	9075	1213.78	1
Port Nolloth	Namibia	958	Botswana	1227	USA	13089	UK	9681	Germany	9391	3173.29	3
Pretoria	Mozambique	518	Lesotho	489	Zimbabwe	1069	Eswatini	336	Botswana	379	572.72	1
St Lucia	Eswatini	339	UK	9563	Germany	9166	Botswana	985	Lesotho	783	2268.73	2

A21. TD5 - Percentage change in departures from top five international source markets per study site (adapted Hamilton et al., 2005).

Location	**Source 1**	**Change**	**Source 2**	**Change**	**Source 3**	**Change**	**Source 4**	**Change**	**Source 5**	**Change**	**Net Change**	**Score**
Bethlehem	Lesotho	-17.5	Botswana	17.5	USA	-17.5	Germany	-52.5	UK	-52.5	-17.60	3
Bloemfontein	Lesotho	-17.5	Botswana	17.5	USA	-17.5	Germany	-52.5	UK	-52.5	-17.60	3
Cape Town	USA	-17.5	UK	-52.5	Germany	-52.5	Namibia	50	France	-17.5	-28.01	4
Durban	Eswatini	50	UK	-52.5	Germany	-52.5	Botswana	17.5	Lesotho	-17.5	19.89	2
East London	Germany	-52.5	UK	-52.5	USA	-17.5	Netherlands	-5	France	-17.5	-37.80	5
eMakhazeni	Mozambique	50	Eswatini	50	USA	-17.5	Germany	-52.5	UK	-52.5	34.16	1
Gqeberha	Germany	-52.5	UK	-52.5	USA	-17.5	Netherlands	-5	France	-17.5	-37.80	5
Johannesburg	Mozambique	50	Lesotho	-17.5	Zimbabwe	-52.5	Eswatini	50	Botswana	17.5	11.12	3
Kimberley	Namibia	50	Botswana	17.5	USA	-17.5	UK	-52.5	Germany	-52.5	27.26	1
Knysna	USA	-17.5	UK	-52.5	Germany	-52.5	Namibia	50	France	-17.5	-28.01	4
Ladysmith	Eswatini	50	UK	-52.5	Germany	-52.5	Botswana	17.5	Lesotho	-17.5	19.89	2
Mbombela	Mozambique	50	Eswatini	50	USA	-17.5	Germany	-52.5	UK	-52.5	34.16	1
Paarl	USA	-17.5	UK	-52.5	Germany	-52.5	Namibia	50	France	-17.5	-28.01	4
Pilanesberg	Botswana	17.5	Lesotho	-17.5	Zimbabwe	-52.5	Mozambique	50	Eswatini	50	9.29	3
Polokwane	Zimbabwe	-52.5	Botswana	17.5	USA	-17.5	Germany	-52.5	UK	-52.5	-46.46	5
Port Nolloth	Namibia	50	Botswana	17.5	USA	-17.5	UK	-52.5	Germany	-52.5	27.26	1
Pretoria	Mozambique	50	Lesotho	-17.5	Zimbabwe	-52.5	Eswatini	50	Botswana	17.5	11.12	3
St Lucia	Eswatini	50	UK	-52.5	Germany	-52.5	Botswana	17.5	Lesotho	-17.5	19.89	2

A22. TD6 - Total direct domestic spend per province including normalised score

Province	Proportion	Tourism Spend	Inverse Score
Free State	0.06	R 1 584 000 000,00	5
Western Cape	0.07	R 1 848 000 000,00	4
KwaZulu-Natal	0.19	R 5 016 000 000,00	1
Eastern Cape	0.15	R 3 960 000 000,00	2
Mpumalanga	0.09	R 2 376 000 000,00	4
Gauteng	0.12	R 3 168 000 000,00	2
Northern Cape	0.03	R 792 000 000,00	5
North West	0.10	R 2 640 000 000,00	3
Limpopo	0.18	R 4 752 000 000,00	1

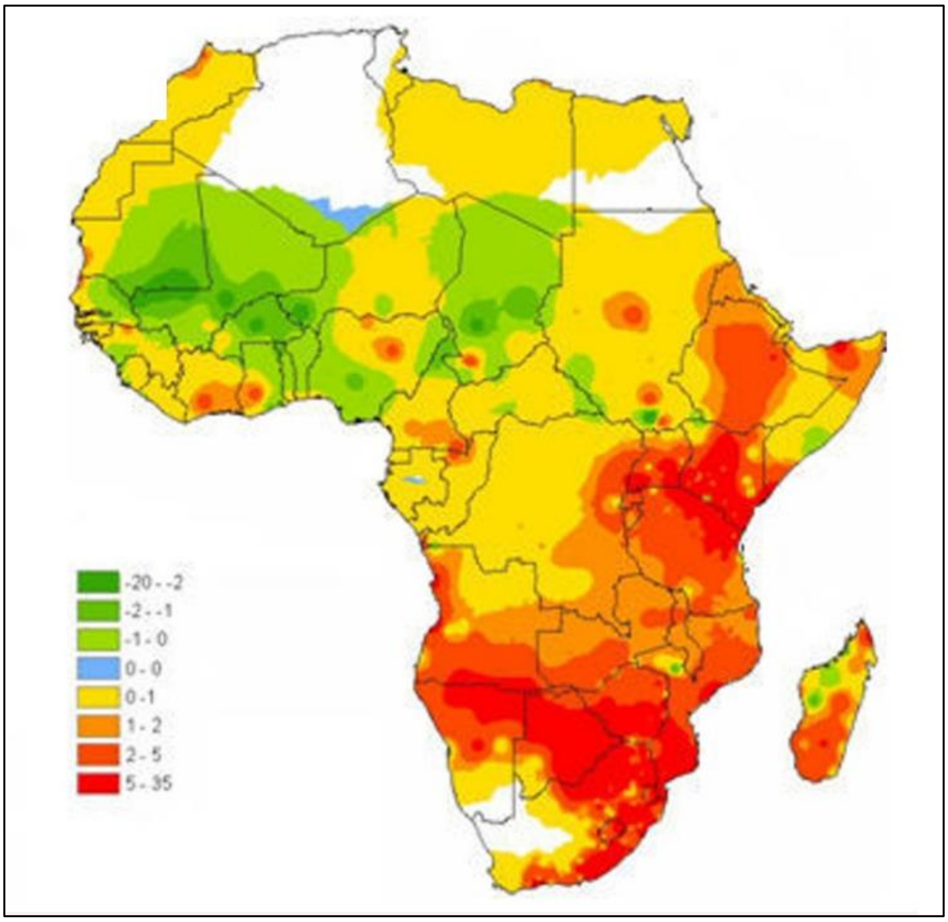
APPENDIX D – Host Country Deterrents Data

A23. HCD1 - Number of natural disasters per district (2000 - 2022) (EM-DAT, 2022)

Location	District	Disasters	Score
Bethlehem	Thabo Mofutsanyane	10	2
Bloemfontein	Mangaung	8	2
Cape Town	City of Cape Town	12	3
Durban	eThekwini	30	5
East London	Buffalo City	15	3
eMakhazeni	Nkangala District	11	2
Gqeberha	Nelson Mandela Bay	12	3
Johannesburg	City of Johannesburg	13	3
Kimberley	Frances Baard	6	2
Knysna	Eden	5	1
Ladysmith	Umgungundlovu	25	5
Mbombela	Ehlanzeni	12	3
Paarl	Cape Winelands	5	1
Pilanesberg	Bojanala Platinum	5	1
Polokwane	Capricorn	9	2
Port Nolloth	Namakwa	6	2
Pretoria	City of Tshwane	11	2
St Lucia	Umkhanyakude	26	5

A24. HCD2 - Number of serious crimes reported per province (2018/2019) (Crime Stats, 2022)

Province	Serious Crimes	Score
Mpumalanga	101 159	3
Free State	93 779	2
Western Cape	339 205	5
KwaZulu-Natal	256 928	4
Eastern Cape	169 300	4
Gauteng	474 005	5
Northern Cape	44 640	1
North West	98 998	3
Limpopo	95 975	3
Total	1 673 989	



A25. HCD3 – Distribution of A. arabiensis illustrating species ranges shifts under climate change (Tonnang et al., 2010).

APPENDIX E – Tourism Sector Adaptive Capacity Data

A26. TSCA2 – Country Image and Brand Attractiveness Score per Study Site

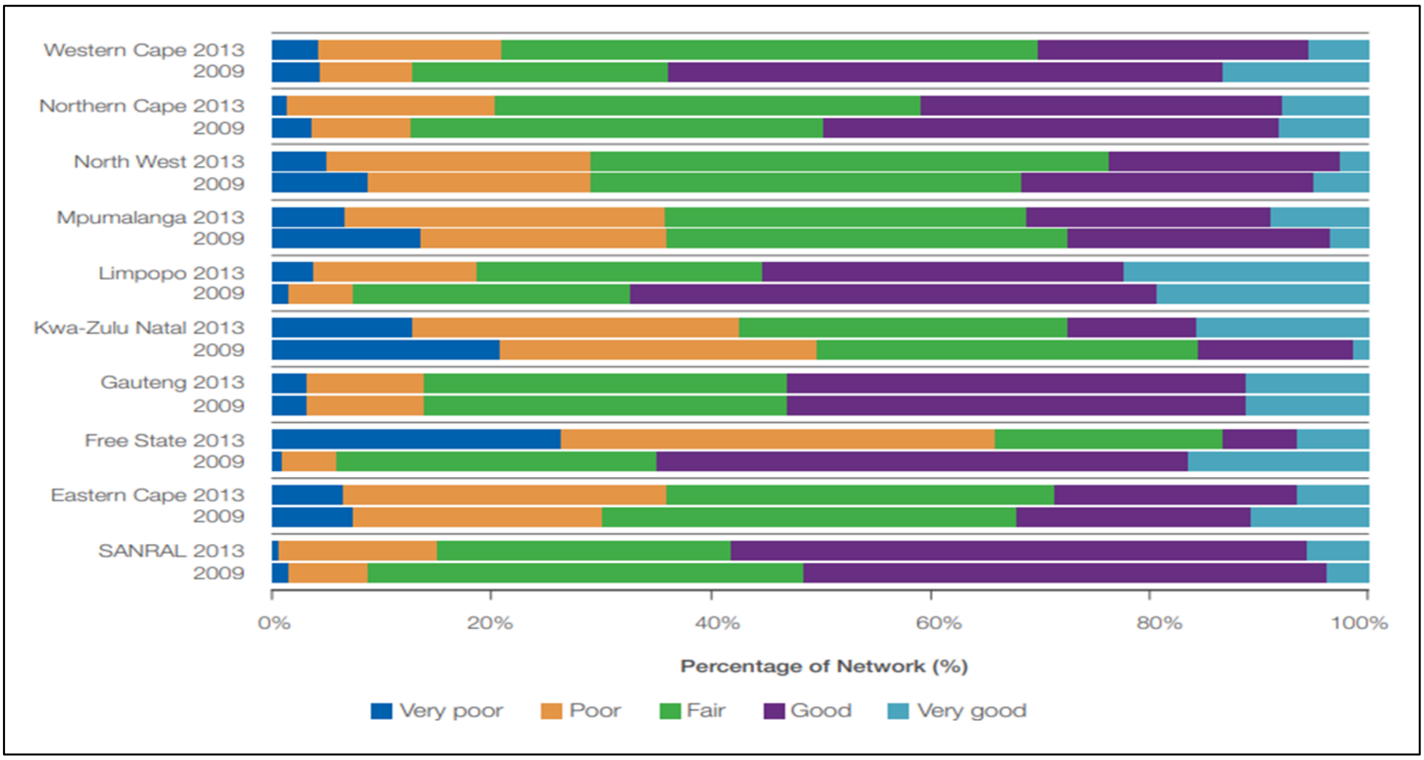
Location	Tourism Sentiment Index (Bloom Consulting, 2022)	Destination Awareness & Image (%) (De Klerk & Haarhoff)	Score
Bethlehem	-	-	3
Bloemfontein	-	-	3
Cape Town	54	89	1
Durban	-	78.5	2
East London	-	-	3
eMakhazeni	-	-	3
Gqeberha	-	-	3
Johannesburg	-	77.4	2
Kimberley	-	-	3
Knysna	19	-	2
Ladysmith	-	-	3
Mbombela	-	-	3
Paarl	-	-	3
Pilanesberg	-	-	3
Polokwane	-	-	3
Port Nolloth	-	-	3
Pretoria	73	-	2
St Lucia	-	-	3

A27. TSAC3 – Purpose of domestic trip by destination province (2018) (StatsSA, 2019)

Province	Trips (million)	Proportion (Leisure)	Score
Mpumalanga	687 000	0.10	2
Free State	349 000	0.05	5
Western Cape	2 178 000	0.32	1
KwaZulu-Natal	1 172 000	0.17	1
Eastern Cape	946 000	0.14	2
Gauteng	432 000	0.06	4
Northern Cape	54 000	0.01	5
North West	456 000	0.07	4
Limpopo	469 000	0.07	3

*A28.	TSAC4 – Gini Coefficient per Province Including Score (StatsSA, 2019)*

Province	Gini Score (2015)	Score
Free State	0.60	4
Western Cape	0.62	5
KwaZulu-Natal	0.61	4
Eastern Cape	0.65	5
Mpumalanga	0.62	5
Gauteng	0.61	4
Northern Cape	0.60	4
North West	0.61	4
Limpopo	0.61	4



*A29.	TSAC5 - Quality of Transport Infrastructure (CSRI, 2014).*

A30. TSAC5 - Quality of Transport Infrastructure per Province (CSRI, 2013)

Province	Road Quality Weighted Score					Net Score
	Very Poor (5)	**Poor (4)**	**Fair (3)**	**Good (2)**	**Very Good (1)**	
Western Cape	0.25	0.64	1.47	0.48	0.06	2.9
Northern Cape	0.1	0.76	1.14	0.66	0.08	2.74
North West	0.3	0.92	1.41	0.42	0.03	3.08
Mpumalanga	0.35	1.16	0.96	0.46	0.09	3.02
Limpopo	0.2	0.6	0.78	0.64	0.23	2.45
KwaZulu-Natal	0.65	1.2	0.87	0.24	0.16	3.12
Gauteng	0.15	0.44	0.96	0.84	0.12	2.51
Free State	1.35	1.56	0.6	0.14	0.07	3.72
Eastern Cape	0.4	1.12	1.08	0.42	0.07	3.09

APPENDIX F – Host Country Adaptive Capacity Data

A31. HCAC1 - HDI Scores Per Province

Province	HDI	Score
Eastern Cape	0.671	4
North West	0.672	4
Mpumalanga	0.675	4
Northern Cape	0.697	4
KwaZulu-Natal	0.706	3
Free State	0.708	3
Limpopo	0.710	3
Gauteng	0.730	3
Western Cape	0.745	3

A32. HCAC2 - GPI Score per Municipality (Good Governance Africa, 2021)

Location	Municipality	GPI Score
Bethlehem	Dihlabeng Local Municipality	1.77
Bloemfontein	Mangaung Metropolitan Municipality	1.87
Cape Town	City of Cape Town Metropolitan Municipality	1.17
Durban	eThekwini Metropolitan Municipality	2.18
East London	Buffalo City Metropolitan Municipality	1.89
eMakhazeni	eMakhazeni Local Municipality	1.97
Gqeberha	Nelson Mandela Bay Metropolitan Municipality	1.43
Johannesburg	City of Johannesburg Metropolitan Municipality	1.38
Kimberley	Sol Plaatje Local Municipality	1.41
Knysna	Knysna Local Municipality	1.99
Ladysmith	Alfred Duma Local Municipality	2.46
Mbombela	City of Mbombela Local Municipality	2.31
Paarl	Drakenstein Local Municipality	1.47
Pilanesberg	Moses Kotane Local Municipality	3.24
Polokwane	Polokwane Local Municipality	2.54
Port Nolloth	Richtersveld Local Municipality	2.19
Pretoria	City of Tshwane Metropolitan Municipality	1.28
St Lucia	Mtubatuba Local Municipality	2.74

A33. HCAC3 - Environmental Risk Score (Green Book, 2022)

Location	**Municipality**	**Environmental Risk Score**	**Score**
Bethlehem	Dihlabeng Local Municipality	3.69	1.85
Bloemfontein	Mangaung Metropolitan Municipality	4.23	2.12
Cape Town	City of Cape Town Metropolitan Municipality	10	5.00
Durban	eThekwini Metropolitan Municipality	6.26	3.13
East London	Buffalo City Metropolitan Municipality	3.32	1.66
eMakhazeni	eMakhazeni Local Municipality	4.44	2.22
Gqeberha	Nelson Mandela Bay Metropolitan Municipality	4.67	2.34
Johannesburg	City of Johannesburg Metropolitan Municipality	9.32	4.66
Kimberley	Sol Plaatje Local Municipality	1.79	0.90
Knysna	Knysna Local Municipality	8.13	4.07
Ladysmith	Alfred Duma Local Municipality	4.99	2.50
Mbombela	City of Mbombela Local Municipality	4.39	2.20
Paarl	Drakenstein Local Municipality	7.26	3.63
Pilanesberg	Moses Kotane Local Municipality	4.38	2.19
Polokwane	Polokwane Local Municipality	6.17	3.09
Port Nolloth	Richtersveld Local Municipality	4.96	2.48
Pretoria	City of Tshwane Metropolitan Municipality	6.13	3.07
St Lucia	Mtubatuba Local Municipality	5.6	2.80

APPENDIX G – Indicator Score Summary

A34. Summary table of normalised scores per indicator

Location	**TA1**	**TA2**	**TA3**	**TA4**	**TA5**	**TOC1**	**TOC2**	**TOC3**	**TOC4**	**TOC5**	**TD1**	**TD2**	**TD3**	**TD4**	**TD5**	**TD6**	**HCD1**	**HCD2**	**HCD3**	**TSAC1**	**TSAC2**	**TSAC3**	**TSAC4**	**TSAC5**	**HCAC1**	**HCAC2**	**HCAC3**	**Sum (W1)**
Bethlehem	5	2	1	1	1	1	2	5	5	2	-	2.4	1.2	6	3.6	6	2	2	2	3	3	5	4	5	3	1.77	1.85	76.82
Bloemfontein	3	2	1	1	1	1	3	5	5	2	-	2.4	1.2	6	3.6	6	2	2	3	3	3	5	4	5	3	1.87	2.12	77.19
Cape Town	4	5	2	5	1	5	5	5	5	1	-	1.2	4.8	4.8	4.8	4.8	3	5	2	3	1	1	5	3	3	1.17	5.00	90.57
Durban	2	4	4	4	1	2	5	5	5	4	-	2.4	3.6	3.6	2.4	1.2	5	4	5	3	2	1	4	5	3	2.18	3.13	86.51
East London	2	1	2	5	1	1	4	4	5	5	-	1.2	6	6	6	2.4	3	4	5	3	3	2	5	4	4	1.89	1.66	88.15
eMakhazeni	5	2	1	1	1	4	3	5	5	3	-	3.6	2.4	4.8	1.2	4.8	2	3	4	3	3	2	5	3	4	1.97	2.22	79.99
Gqeberha	5	3	2	5	1	1	5	4	5	5	-	1.2	6	6	6	2.4	3	4	3	3	3	2	5	4	4	1.43	2.34	92.37
Johannesburg	1	4	1	1	1	2	3	5	5	1	-	4.8	1.2	2.4	3.6	2.4	3	5	5	3	2	4	4	1	3	1.38	4.66	74.44
Kimberley	4	1	1	1	1	1	1	4	5	2	-	4.8	3.6	2.4	1.2	6	2	1	2	3	3	5	4	2	4	1.41	0.90	67.31
Knysna	1	2	2	4	1	3	5	5	5	1	-	1.2	6	4.8	4.8	4.8	1	5	2	3	2	1	5	3	3	1.99	4.07	81.66
Ladysmith	3	1	1	1	1	4	3	5	5	4	-	2.4	2.4	3.6	2.4	1.2	5	4	5	3	3	1	4	5	3	2.46	2.50	77.96
Mbombela	3	2	1	1	1	1	3	5	5	3	-	3.6	2.4	4.8	1.2	4.8	3	3	5	3	3	2	5	3	4	2.31	2.20	77.31
Paarl	3	4	1	1	1	5	5	5	5	1	-	1.2	4.8	4.8	4.8	4.8	1	5	2	3	3	1	5	3	3	1.47	3.63	82.50
Pilanesberg	5	1	1	1	1	4	5	5	5	4	-	6	1.2	1.2	3.6	3.6	1	3	5	3	3	4	4	3	4	3.24	2.19	83.03
Polokwane	4	1	1	1	1	5	1	5	5	5	-	6	1.2	1.2	6	1.2	2	3	5	3	3	3	4	1	3	2.54	3.09	77.23
Port Nolloth	1	1	4	4	1	5	5	4	5	2	-	4.8	3.6	2.4	1.2	6	2	1	1	3	3	5	4	2	4	2.19	2.48	79.67
Pretoria	2	3	1	1	1	4	5	5	5	1	-	4.8	1.2	2.4	3.6	2.4	2	5	5	3	2	4	4	1	3	1.28	3.07	75.75
St Lucia	1	4	3	4	1	1	2	5	5	4	-	2.4	2.4	3.6	2.4	1.2	5	4	4	3	3	1	4	5	3	2.74	2.80	79.54