School of Geography, Archaeology and Environmental Science

THE HOLIDAY CLIMATE INDEX: APPLICABILITY AND SUITABILITY FOR THE SOUTH AFRICAN CONTEXT

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DECLARATION

I hereby declare this research is my own, unaided work, except where acknowledged otherwise. This thesis is being submitted to the School of Geography, Archaeology and Environmental Studies at the University of the Witwatersrand for the fulfilment of a MSc degree. It has not been submitted in part or full towards any other degrees at this or any other institutions.

Signed at Rivonia on this day, 4th April of 2024.

Daniella Kristensen

ABSTRACT

Tourism is one of the largest economic sectors and continues to grow at a rapid pace. This sector is under threat by climate change, with Africa deemed to be most vulnerable to these changes. The projected climatic changes and increase in occurrence and intensity of extreme events over South Africa has an impact on overall tourism comfortability. Quantifying the climatic suitability of tourist destinations has been achieved through tourism climate indices. Some of these indices cover all tourism activities and some are specific to a tourism type (e.g., snow tourism). The Holiday Climate Index (HCI) was developed to determine climactic comfortability of beach and urban destinations and to address the limitations of previous indices. This study will provide the first determination of the appropriateness of the HCI for the South African context and calculations of the HCI for destinations across South Africa.

The mean annual HCI_{urban} and HCI_{beach} scores for the longest continuous period of each destination reveal that the majority of destinations demonstrate HCI_{urban} and HCI_{beach} scores between 70 and 79 and are considered to have 'very good' climatic conditions for tourism. An exception is the HCI_{urban} result for Durban which is scored as 'good'. Generally, the highest HCI scores were calculated for Cape Town on the west coast, while the lowest HCI scores were calculated for Durban on the east coast. It was determined that McBoyle's (2001) winter season peak distribution is applicable to seven of the 13 HCI_{urban} and three of the five HCI_{beach} destinations. This indicates that the winter season is most suitable for tourism for most destinations. In comparing the results of destinations where both the HCI_{urban} and HCI_{beach} are applicable, it was determined that all destinations, with the exception of Durban, have a minimal difference in the average annual HCI scores. Durban recorded a notable difference which demonstrated that the destination would be more suitable for beach tourism. The results of this study can be used to quantify the impacts of climate change on the tourism sector and assist tourism stakeholders in developing the capacity to adapt to the projected changes.

ACKNOWLEDGEMENTS

I would like to sincerely thank my supervisor, Professor Jennifer Fitchett, for her invaluable guidance and patience during the compilation of this thesis. Beyond this thesis, I truly appreciate the interest you took in my personal and professional development, as without you, I would not be where I am today. Your passion for your field is like no other and has inspired me throughout our time working together. Starting out as a research assistant during my Honours year where I assisted you with certain aspects of research into tourism climate indices, to writing a thesis on one of these indices has been a wonderful journey!

I am profoundly grateful to my mom, who has shaped me into the person I am today, and whom without, I would definitely not be here. Your unwavering support has pushed me to do many things in life, of which this thesis (a big milestone!) is one. Thank you for always encouraging me through life's struggles and for making it possible for me to pursue anything I put my heart into. Your sacrifices, whether big or small, mean the world to me. I love you. As I am sure you will agree, Mormor and Morfar also played a pivotal role in my life. I would like to dedicate this thesis to both of my grandparents, who are now together once again, and who continue to watch over me and provide their guidance from afar. To my uncle Niels, thank you for your patience and guidance on the trickiest aspects of this research. Your knowledge greatly assisted in allowing me to work through my data and produce this thesis!

To the family I have not explicitly mentioned, friends and colleagues, thank you for consistently questioning how my thesis was going, that extra bit of pressure and support made the world of difference!

Lastly, I would like to thank the South African Weather Service for providing the climate data from 13 weather stations across South Africa to allow me to complete my thesis. I am profoundly grateful to the University of the Witwatersrand for bestowing upon me the Postgraduate Merit Award and providing full funding for my years of study.

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LIST OF ACRONYMS

AAO	Antarctic Oscillation
CCI	Camping Climate Index
CCTR	Commission on Climate, Tourism and Recreation (International Society of Biometeorology)
CIT	Climate Index for Tourism
CoL	Cut-off Low
DoT	Department of Tourism
ENSO	El Niño/Southern Oscillation
HCI	Holiday Climate Index
IPCC	Intergovernmental Panel on Climate Change
IOD	Indian Ocean Dipole
SAM	Southern Annual Mode
SCI	Ski Climate Index
SST	Sea Surface Temperature
TCI	Tourism Climate Index
TGSCA	Tourism Grading Council of South Africa
UNWTO	United Nations World Tourism Organization
UTCI	Universal Thermal Comfort Index

CHAPTER 1. INTRODUCTION

1.1. Background

Tourism is one of the most rapidly growing and largest sectors of the global economy, and includes segments such as sun and beach tourism, sports tourism, adventure tourism, nature-based tourism, cultural tourism, urban tourism, health and wellness tourism, cruises, theme parks, visiting friends and relatives, and meetings and conferences (Scott & Lemieux, 2010; Scott & Gössling, 2015; Thams *et al.*, 2020; UNWTO, 2021). The nexus between climate change and tourism is a relatively new research area that has increased considerably over the last two decades (Becken, 2013; Scott & Gössling, 2022). The initial research phase occurred in the 1970s, with significant growth taking place towards the end of the 2000s and an increase of a factor of five taking place between 2010 and 2020 (Becken, 2013; Scott & Gossling, 2022). Research areas have typically included the impact of climate on tourism, destination adaptations, the role of tourism in greenhouse gas emissions and the mitigation of these emissions (Becken, 2013; de Freitas, 2017; Scott & Gössling, 2022). Over the last decade, the use of integrative indices to assess the climatic potential of destinations and the assessment of adaptation and mitigation measures have been deemed more relevant in research (Lopes *et al.*, 2021). Research on the climatic preferences of tourists began around 2010, which differed from previous objective assumptions used to establish indices by researchers (Lopes *et al.*, 2021). Research has however been focused on western tourist destinations, contributing to widening of the gap in tourism and climate change research (Becken, 2013; Hoogendoorn & Fitchett, 2018b; Rutty *et al.*, 2021; Scott & Gössling, 2022). In South Africa, research into the climate-tourism nexus is spread across the country and prominent research themes are varied when compared to international research. However, there are overlaps in terms of the use of indices, sustainability and tourist perception evaluation (Saarinen *et al.*, 2022). Research is focused on tourist perceptions of climate, tourist behaviours, specific climatic component impacts on perceptions and behaviours and the changes in climate across the country. International methodologies have been used to identify the links between tourism and climate change in South Africa with a focus on comparing results and the validity of these methodologies (Saarinen *et al.*, 2022). Research in South Africa has been done to validate the TCI by comparing climatic suitability results to tourists self-reported suitability using review platforms such as TripAdvisor (Fitchett & Hoogendoorn, 2019). The outcome of this research indicated that the tourist reviews analysed were largely in agreement with the TCI (Fitchett & Hoogendoorn, 2019).

Africa is deemed to be most vulnerable to the threats posed by climate change (Scott *et al.*, 2019). Climate resources in South Africa are an attraction for tourism, with conditions perceived as ‘good’ enhancing willingness of tourists to travel and satisfaction of their travel experience (Fitchett *et al.*, 2016b; Saarinen *et al.*, 2022).One of the key threats to tourism in South Africa is the change to suitability of weather for outdoor tourist activities and the aesthetic quality of natural settings (Gössling & Hall, 2006; Scott *et al.*, 2015; Tervo-Kankare *et al.*, 2017; Hall, 2018; Dube & Nhamo, 2020a). A second threat identified is that of weather extremes which may deter tourists from visiting destinations where these extremes are common (Gössling & Hall, 2006). The main changes to climate projected to occur in South Africa include widespread drought, increased temperatures, increased rainfall, intensification and increased occurrence of extreme climatic events and sea level rise along the coastline (Fitchett *et al.*, 2016a; Fitchett & Hoogendoorn, 2018; Hoogendoorn *et al.*, 2021; IPCC, 2021; Smith & Fitchett, 2022). These changes have a direct impact on outdoor activities planned and performed by tourists.

The HCI was developed for the purpose of sightseeing and to address the deficiencies of the TCI (Tang, 2013; Scott *et al*. 2016b). This included the introduction of a climatic variable weighting scale and a component (i.e., thermal comfort, physical and aesthetic) weighting system that is based on a decade of established tourist climate preferences (Scott *et al*. 2016b). However, there are limitations to this index too, including the assumption that tourist accommodation in developed countries and in major tourism destinations make use of air conditioning (Scott *et al.*, 2016b). Limited air conditioning availability within tourism accommodation establishments has been discussed in the literature and confirmed within this study (Mushawemhuka, 2021). Night-time temperatures may affect tourist comfortability while sleeping or during night-time activities such as animal viewings (Mushawemhuka, 2021).

1.2. Rationale

With the literature applying the HCI being predominantly focused on western destinations, there is a large gap in terms of research conducted within the southern hemisphere, with only one publication being available for Africa (Hoogendoorn and Fitchett, 2018b). This research will be the first to apply the HCI in South Africa and will be one of two studies to apply the HCI in Africa. The length of the tourism season and peak arrivals are impacted upon by climate (Gössling *et al*., 2018). Climate change threats projected for South Africa including rising temperatures, decreasing relative humidity and resultant decrease in cloud cover and an increase in rainfall over the central interior and east coast of South Africa may have a negative impact on tourist satisfaction (Engelbrecht *et al*., 2015; Engelbrecht, 2019; Noome, 2020; IPCC, 2021). In order to mitigate against these threats, it is essential that planning and adaptation strategies are considered and implemented by potentially affected stakeholders, such as tourism accommodation establishments.

1.3. Aims and Objectives

The primary aim of this research is to contribute to the existing southern African and international literature on the nexus between climate and tourism. More specifically, the aim is to contribute to knowledge on the nature and extent of climate change within South Africa in the last 30 years. This includes an exploration of how this change has influenced the suitability of selected destinations for tourists according to the HCI model.

The research objectives are:

1. To identify the availability of air conditioning in tourism accommodation establishments.
2. To calculate the HCI_{urban} and HCI_{beach} for 13 destinations across South Africa over a 30 year period, where possible, to:
    a. Determine the climactic suitability of each destination.
    b. Determine the annual spatial distribution of the HCI scores.
    c. Determine the seasonal distribution of the HCI scores.
3. To determine the direction and magnitude of the changes in the HCI scores over the study period to:
    a. Determine which locations are becoming more or less suitable for tourists climatically.
    b. Explore spatial patterns of the changes.

1.4. Structure

This thesis comprises seven chapters. This introductory chapter is followed by a review of relevant existing literature in Chapter 2. This includes climate change and tourism internationally and locally, quantitative and qualitative evaluations of climatic suitability for tourism, and the history of the HCI along with its limitations and potential within South Africa.

The study site is presented in Chapter 3 and provides the climatic and tourism background of South Africa. A description of the methods used to determine the applicability and suitability of the HCI and to determine the HCI scores for each destination is provided in Chapter 4. Results determined by following the methods provided are given in Chapter 5. Chapter 6 critically analyses the findings presented in Chapter 5 through a discussion that delves into the appropriateness of the HCI within South Africa, an analysis of the HCI_{urban} and HCI_{beach} results, a comparison to the calculated TCI results for shared destinations, tourist comfortability under a changing climate, a comparison of the HCI results to TripAdvisor reviews and limitations of the study. Lastly, a synopsis of the research conducted is provided in Chapter 7.

CHAPTER 2. LITERATURE REVIEW

2.1. Introduction

This literature review will start by providing background on the history of tourism and climate change research on a global scale, followed by an analysis of the South African portion of this research. The focus will be on key themes in the literature, methods utilised and the geographical spread of tourism and climate change research. Following this, an analysis of quantitative evaluations of climate suitability in South Africa will be conducted. This section will look at how climate suitability for tourism is modelled using tourism climate indices. An analysis of tourist perceptions on the suitability of the South African climate for tourist activities will be conducted to validate the claims of the calculated index ratings. The HCI will be critically discussed by focusing on the reason for its development and the methodology behind the equation. An in-depth analysis of publications utilising the HCI globally and at the South African scale and analysis of publication authorship will be undertaken. Lastly, the appropriateness of the HCI in comparison to the TCI, identified limitations and the potential to utilise the HCI in the South African context will be explored.

2.2. History of tourism and climate change research

Tourism has continued to expand over the past decades, becoming one of the most rapidly growing and largest sectors of the global economy (Scott & Gössling, 2015; Thams *et al.*, 2020; UNWTO, 2021). Major tourism segments include sun and beach tourism, sports tourism, adventure tourism, nature-based tourism, cultural tourism, urban tourism, health and wellness tourism, cruises, theme parks, visiting friends and relatives, and meetings and conferences (Scott & Lemieux, 2010). As with the global economy, the growing tourism industry contributes greatly to the South African economy (Scott & Lemieux, 2010; Fitchett *et al.*, 2016b). In 2019, the tourism sector contributed R209 billion (3.7%) to the country's Gross

Domestic Product (Organisation for Economic Co-operation and Development (OECD), 2022). In the same year, 773 532 direct jobs were associated with the tourism sector, which accounts for 4.7% of employment (OECD, 2022). Further analysis of tourism within South Africa is provided in Chapter 3 (*3.4 Tourism Attractions in South* Africa). Climate is defined as the long-term average of prevailing climatic conditions observed at a destination (Gómez Martín, 2005). At global and regional scales, it has been reported that climate plays a role in influencing the decision making of tourists during travel planning, as well as the satisfaction of the travel experience itself (Scott & Lemieux, 2010; Fitchett *et al.*, 2016).

This section will make use of reviews of tourism climatology literature by Matzarakis *et al.* (2004), Becken (2013), de Freitas (2017) and Scott and Gössling (2022) to assist in forming a timeline of this research globally, starting a few decades ago. These papers are useful as a starting point to aid in establishing the prominent research themes and spatial nature of the literature through their synthesis of papers within the tourism climatology field. The focus of this section will then shift from global literature to an analysis of tourism climatology research in South Africa.

2.2.1. Tourism climatology research globally

The nexus between climate change and tourism is a relatively new research area which has only, in the last two decades, begun to increase significantly (Becken, 2013; Scott & Gössling, 2022). De Freitas (2017) explains that the tourism climatology field arose in the 1960s and 1970s, where focus was initially placed on the effect of climate on a range of economic activities, inclusive of the tourism sector (Matzarakis *et al.*, 2004). Research into the link between economic activities and climatology information was encouraged through investments by governments into this area (de Freitas, 2017; Rutty *et al.*, 2021. This was due to the assistance it could provide governments in terms of planning for tourism and recreation (de Freitas, 2017; Rutty *et al.*, 2021). A peak in the initial development phase research into climate, tourism and recreation occurred in the 1970s and 1980s with papers from Danilova (1974), Crowe *et al*. (1977), Singh (1977) and Besancenot *et al*. (1978). Following this initial focus on tourism, climate and weather, a shift towards tourism and climate change occurred in 1985 (Wall *et al*., 1986, 1988; McBoyle & Wall, 1987). However, one dominant author, namely Wall, is present throughout these articles. Following the introduction of this research area, a new growth phase began in the 1990s due to the expected change to the climate globally (de Freitas, 2017). Matzarakis *et al*. (2004) indicated that the volume of articles published increased threefold between 1990-1994 and 1995-1999. Towards the end of the 2000s, significant growth in the tourism and climate change field was recorded, followed by an increase of a factor of five between 2010 and 2020 (Becken, 2013; Scott & Gossling, 2022). Expanding on the review conducted by Becken (2013), a search of the terms "tourism" and "climate change" on the Scopus platform was conducted to provide an estimate on the number of publications globally from the year 2012 to 2022 (Figure 2.1). It should be noted that a more stringent method of identifying papers was used by Becken (2013) and therefore the publication numbers from 2012 shown in Figure 2.1 may be inflated.

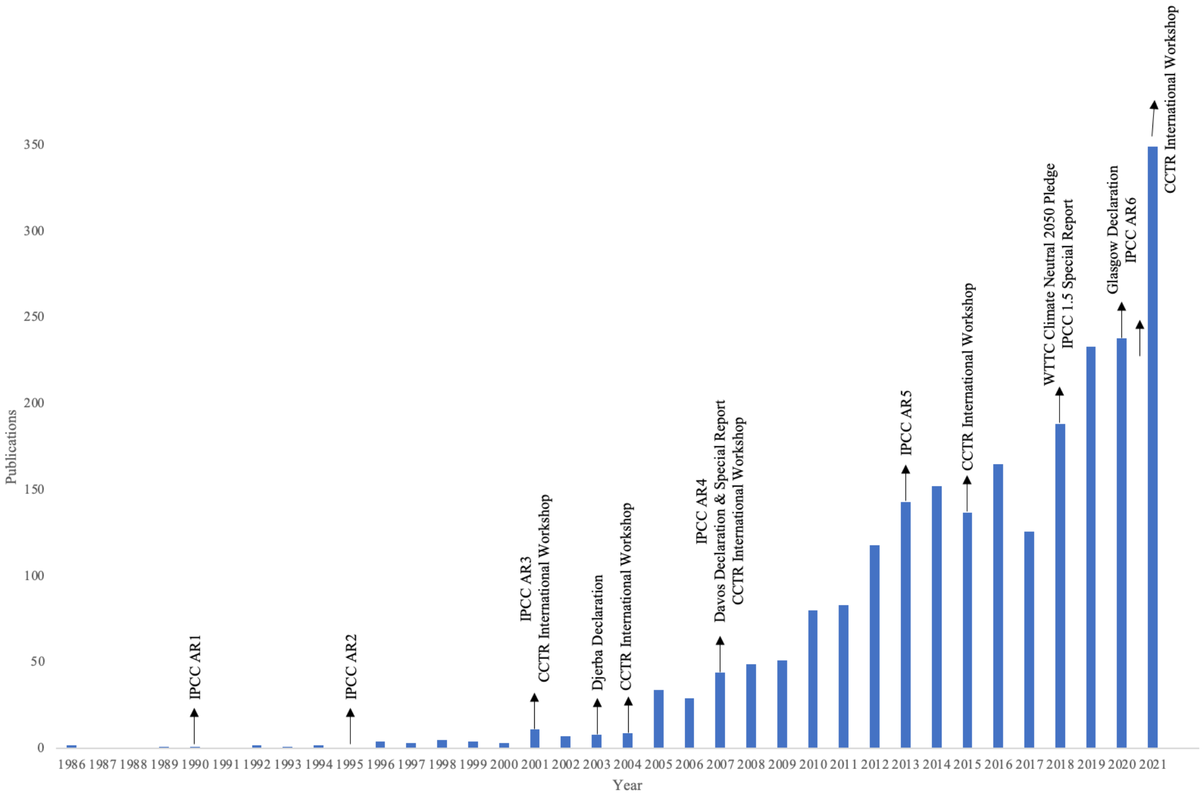

Figure 2.1: Number of climate change and tourism publications beginning in 1986 and the milestones that played a role in periods of explosion of tourism and climatology publications (adapted from Becken, 2013, de Freitas, 2017 and Scott & Gössling, 2022)

There is importance in recognising the potential drivers of publication growth. Specific milestones have been noted to have had a potential impact on this growth (Figure 2.1). The first milestone identified was the release of the Intergovernmental Panel on Climate Change's (IPCC) First Assessment Report (1990), however no noticeable change in publication numbers was observed following this event (Gössling *et al*., 2022). This was followed by the release of the Third Assessment Report in 1995, which may have played a role in the increased publications in the following years (1996-2000) (Gössling *et al*., 2022). A slight uptick in publications is noticeable in 2001, which ties into the release of the IPCC's Third Assessment Report and the first International Society of Biometeorology Commission on Climate, Tourism and Recreation (CCTR) International Conference (de Freitas, 2017; Gössling *et al*., 2022; Rutty *et al*., 2021). The CCTR was established in 1999 due to the recognition of the need for an organisation that would assist researchers with their ideas centred on tourism climatology (de Freitas, 2017). De Freitas (2017) and Rutty *et al*. (2021) noted the importance of the CCTR in expanding the research into climate change and tourism through its initiatives, activities, setting of research priorities, identification of knowledge gaps and promotion of collaboration. A rapid increase in publications is evident from around 2005, which may have been spurred by the Djerba Declaration in 2003 (Gössling *et al*., 2022), coupled with the second CCTR International Workshop in 2004. Three milestones were identified in 2007 including the third CCTR International Workshop, the UNWTO commission of the special report titled *Climate Change and Tourism: Responding to Global Challenges* for the Davos Declaration and the IPCC's Fourth Assessment Report (de Freitas, 2017; Scott & Gössling, 2022). These milestones could explain the increase from 29 publications in 2006 to 44 publications in 2007 (Figure 2.1). A continued increase, with slight drops in 2015 and 2017, took place leading up to 2021, where a dramatic increase of around 349 publications occurred (Figure 2.1). This could be attributed to the Glasgow Declaration, the IPCC's Sixth Assessment Report in 2020 and the CCTR's fifth international workshop in 2021 (Gössling *et al*., 2022; Figure 2.1).

The initial focus of tourism and climate research was motivated by the usefulness of information on climate and how to plan for tourism and recreation, taking this information into account (de Freitas, 2017). The release of the UNWTO special report in 2008 encouraged researchers to pay particular attention to climate change impacts, adaptation and mitigation in the context of tourism (Rutty *et al*., 2021). In Becken's (2013) review of published literature in the tourism climatology field, research focus areas identified included the impact of climate on tourism, destination adaptations, the role of tourism in greenhouse gas emissions and the mitigation of these emissions. Scott and Gössling (2022) identified two major themes in their review. As in Becken's (2013) review, the first theme looks at research on the estimation of tourism-related greenhouse gas emissions and mitigation of these emissions. Notable literature looked at global tourism emissions (e.g., Lenzen *et al*., 2018), national tourism emissions (e.g., Becken & Patterson, 2006), destination emissions (e.g., Sun, 2014) and mitigation measures to decrease emissions and decarbonisation of the tourism sector (e.g., Gössling *et al*., 2007, 2013; Peeters & Dubois, 2010; Scott *et al*., 2011; Scott, Hall, *et al*., 2016; Jacob *et al*., 2018). Similar to both Becken (2013) and de Freitas (2017), the second major theme identified is physical climate risk, which focuses on understanding climate change impacts on environmental and socio-economic systems (with both impacting on or being an impact of tourism) and adaptation strategies of the tourism sector (Scott & Gössling, 2022). Under this major theme, specific focus areas include cumulative global risks (e.g., Scott *et al*., 2019), change in resources for tourism (e.g. Gómez Martín, 2005; Amelung *et al*., 2007), changes to tourism demand (e.g., Lise & Tol, 2002; Peeters & Dubois, 2010), behavioural responses of tourists to climate change (e.g., Gössling *et al*., 2012), adaptation options for tourists and the tourism industry itself (e.g., Scott *et al*., 2012) and specific subsectors such as snow tourism (e.g. Noome & Fitchett, 2019; Steiger *et al*., 2019, 2020; Demiroglu *et al*., 2020; Falk & Lin, 2021). Between the two identified major themes, a larger percentage of focus has been on physical climate impacts and adaptation measures (Scott & Gössling, 2022). Prominent literature on climate changes impacts on tourism identified by Lopes *et al*. (2021) includes Koenig and Abegg (1997), Maddison (2001), Hamilton *et al*. (2005), Amelung *et al*. (2007), Becken and Hay (2012), Gössling *et al*. (2012), Gössling and Buckley (2016) and Jacob *et al*. (2018). Aside from the two identified major themes, other smaller key themes included climate change impacts for the tourism economy and stakeholder perceptions of climate responses in tourism and policy governance (Scott & Gössling, 2022). While not key themes, destination image and climate justice featured in Scott and Gössling's (2022) review. In the review of literature conducted by Lopes *et al*. (2021), issues deemed most relevant in the last decade were the use of integrative indices to assess climatic potential of destinations and assessing the adaptation and mitigation measures for climate change. Lopes *et al*. (2021) also identified that research done on actual tourist climatic preferences began around 2010, which differs from the objective assumptions previously made by researchers when establishing indices (Frew & Winter, 2010; Gössling *et al*., 2012; Demiroglu *et al*., 2018; Hewer & Gough, 2018). As can be seen through the themes identified in each review, the field of tourism climatology is multidisciplinary.

Having an understanding of temporal spread, major themes and key focus areas of tourism climatology research, it is now important to establish where this research has been taking place. Becken (2013) and Rutty *et al*. (2021) found that research has been primarily focused on western tourist destinations such as Canada, Australia, New Zealand, North America, United Kingdom and the broader European area. Rutty *et al*. (2021) and Scott and Gössling (2022) emphasise that there are obvious geographical knowledge gaps in tourism and climate change research. The concentration on developed country destinations or perspectives of tourists from developing countries outweighs research done in the global south (inclusive of Africa, Asia and South America) (Rutty *et al*., 2021; Scott and Gössling, 2022). While research has been done on global tourist flows (e.g., Amelung *et al*., 2007) and integration of different case studies, this has not filled the knowledge gap. From approximately 2012, there has been an increase in contributions to research from regions such as East Asia, Middle East and southern Africa (Becken, 2013; Scott & Gössling, 2022). This ties in to the review of Becken (2013) where it was determined that there is an increase in publications focused on climate change of developing country destinations, with researchers from these countries contributing to filling the knowledge gap. Not only has there been a gap in terms of research in developed versus developing countries, but also surrounding destination/tourist activity type. Scott and Gössling (2022) identified the major destination types from most researched to least being mountain (ski and glacier tourism), nature-based, coastal, cultural, urban, polar and island tourism. Furthermore, Rutty *et al*. (2021) found that snow sports tourism forms one of the most-studied areas due to the reliance of this tourism on climatic resources.

Tourism and climate change research globally has demonstrated a couple of key findings. These findings can be split into key threats on the tourism industry and tourists themselves and regions found to be at the greatest risk for negative impacts caused by these threats. One of the key threats for the tourism industry as a result of climate change is the change to the suitability of weather for tourist activities, specifically outdoor activities such as beach or ski tourism, and the aesthetic quality of natural settings (such as the flow of the Victoria Falls in Zimbabwe as a result of adequate rainfall) (Gössling & Hall, 2006; Scott *et al*., 2015; Tervo-Kankare *et al*., 2017; Hall, 2018; Dube & Nhamo, 2020a). Another threat identified is that of weather extremes, such as intensified and more frequent tropical storms linked to a changing climate (Gössling & Hall, 2006). This may deter tourists from visiting destinations where extremes are known to occur (Gössling & Hall, 2006). Regions that are expected to be most vulnerable to the threats posed by climate change are shown in Figure 2.2 below and include Africa, most countries within South America, Central America, Middle East, parts of southern Europe, South Asia, parts of East Asia and the Pacific (Scott *et al*., 2019).

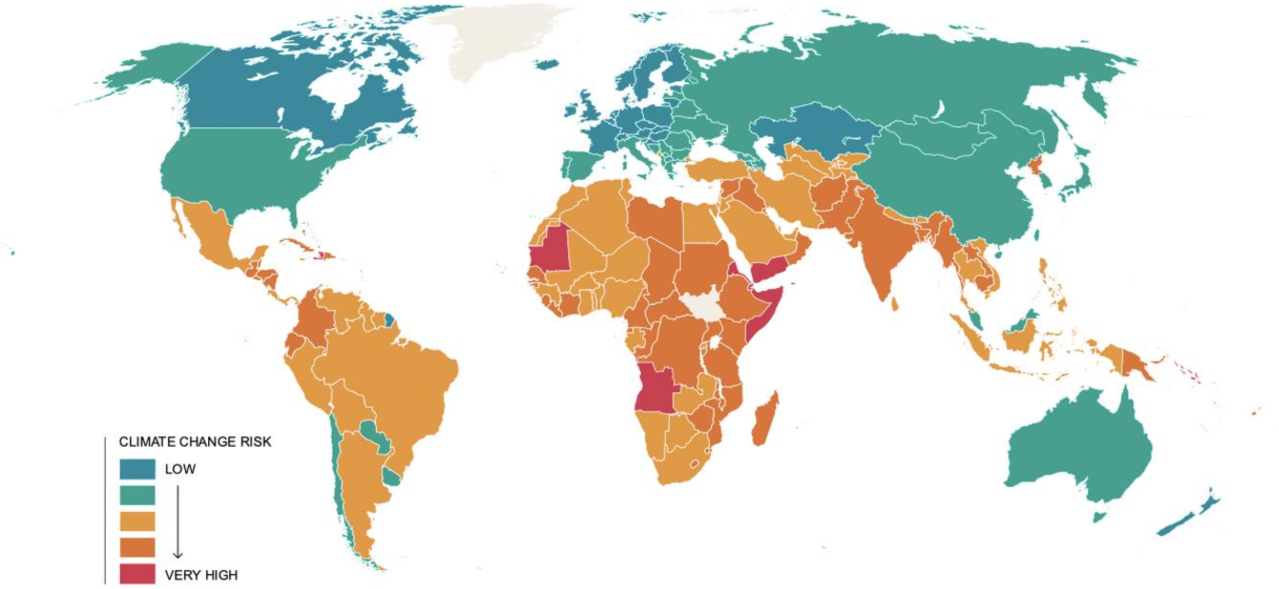

Figure 2.2: Map showing global distribution of climate change risk (adapted from Scott *et al*., 2019)

2.2.2. South African tourism climatology research

The first research into the link between climate change and tourism in South Africa began with a theoretical perspective published by Preston-Whyte and Watson (2005) in Hall and Higham's (2005) book *Tourism, Recreation and Climate Change* (Hoogendoorn & Fitchett, 2018, 2019). This research discussed the potential impact that climate change may have on tourism in South Africa (Preston-Whyte and Watson, 2005). Following this, research into the climate change and tourism nexus began to grow, with a considerable uptick experienced from 2016 (Figure 2.3).

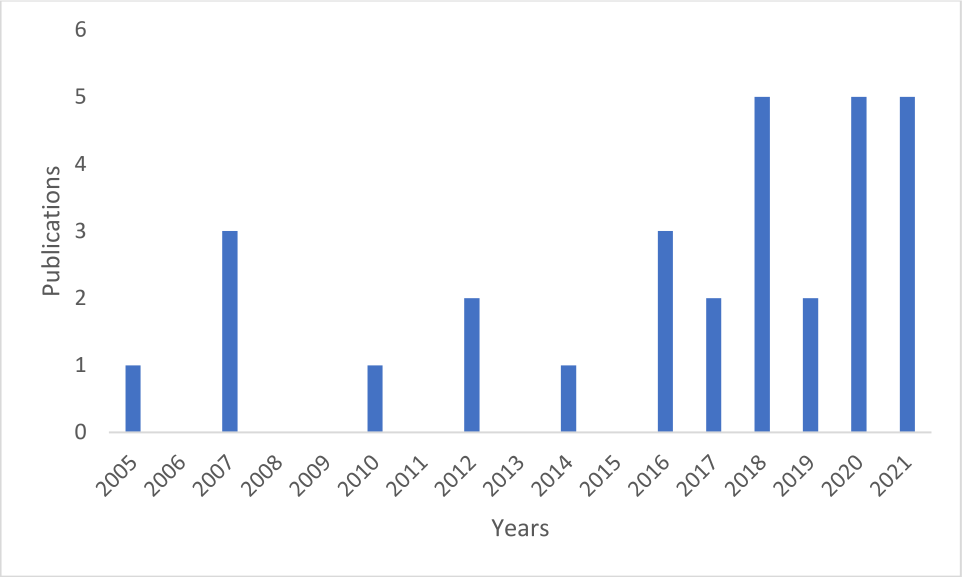

Figure 2.3: Climate change and tourism research publications in South Africa

The predominant themes identified during the course of this research, along with authors who have contributed to this literature, identified in South African tourism and climate change research are presented in Table 2.1. The most common theme is the impact of climate change on tourism, inclusive of perception-based studies of this threat (e.g., Hoogendoorn & Fitchett, 2018b; Friedrich *et al*., 2020a; Fitchett, 2021; Pandy & Rogerson, 2021b; Saarinen *et al*., 2022). Following this, research into mitigation and adaptation (e.g., Hoogendoorn & Fitchett, 2018b; Pandy & Rogerson, 2019, 2021a; Dube *et al*., 2020a,b) was identified as a prominent theme. Minor thematic areas identified include policy recommendations, methodological developments, climatic suitability assessments and economic analyses (Saarinen *et al*., 2022). While prominent themes within South Africa vary from global research themes, overlaps such as the use of indices, sustainability and evaluation of tourist perceptions exist (Saarinen *et al*., 2022). From a geographical perspective, tourism and climate change research has been spread across South Africa (Table 2.1)

Table 2.1: Geographical distribution of tourism and climate change studies in South Africa

Publications	**Geographical area**
Reddy, 2012; Ziervogel *et al*., 2014; Hoogendoorn and Fitchett, 2018b; Odeku, 2018; Pandy & Rogerson, 2021a; Rogerson, 2016; Pandy & Rogerson, 2018; Friedrich *et al*., 2020b	South Africa
Steyn, 2012	Western Cape
Pandy & Rogerson, 2019; Fitchett, 2021	Johannesburg
Pandy & Rogerson, 2021b, Coldrey & Turpie, 2020	Garden Route
Fitchett *et al*., 2016a; Hoogendoorn & Fitchett, 2018a	St Francis Bay and Cape St Francis, Eastern Cape
Hoogendoorn & Fitchett, 2018a; Dube *et al*., 2021; Coldrey & Turpie, 2020; Fitchett, 2021	Cape Town
Hoogendoorn & Fitchett, 2018a	Rhodes Village, Eastern Cape
	Nieu Bethesda, Eastern Cape
	Clarens, FS
	Greyton, WC
	Hartebeespoort, NW
	Dullstroom, MP
	Zinkwazi, KZN
Smith & Fitchett, 2020	Sabi Sands Game Reserve
Coldrey & Turpie, 2020	National Parks: Kruger, Mapungubwe, Marakele, Golden Gate Highlands, Mokala, Kalahari Gemsbok, Augrabies Falls, Richtersveld, Namaqua, West Coast, Agulhus, Bontebok, Kargo, Tankwa Karoo, Addo Elephant, Mountain Zebra
Fitchett, 2021	Polokwane
	Pretoria
	Nelspruit
	Durban
	Bloemfontein
	Kimberley
	East London
	Gqeberha

As with global research into the tourism and climate change nexus, a shift from theoretical work to empirical work has taken place in South African research. Looking into Preston-Whyte and Watson's (2005) publication, the link between nature-based tourism and climate was theoretically explored. Their research identified that nature-based tourism requires temperatures that do not exceed human comfort levels and a large amount of sunshine hours (Preston-Whyte & Watson, 2005). Statements were also given on cooler temperatures improving animal siting opportunities (Preston-Whyte & Watson, 2005). Analysis of research published from 2016 onwards demonstrates that a shift to empirical research has occurred. Research has become focused on determining tourist perceptions of climate, tourist behaviours, the climatic components that influence tourist perceptions and behaviours the most and the changing climate in South Africa (e.g., Giddy *et al.,* 2017; Fitchett & Hoogendoorn, 2018, 2019; Friedrich *et al*., 2020a, 2020b; Ngxongo, 2021). Methods that have been used to identify the links between tourism and climate change in South Africa have foundations in international methodologies that were developed in the years prior to the acknowledgement of this research area in South Africa (Saarinen *et al*., 2022). Although there is a limitation in relying on methodologies developed for different regions, research in South Africa has a focus on comparing results and the validity of these methodologies (Saarinen *et al*., 2022). Some of the methodologies identified included the use of questionnaires and interviews (Giddy *et al*., 2017; Dube & Nhamo, 2020a; Friedrich *et al*., 2020; Hoogendoorn *et al*., 2021; Ngxongo, 2021; Mosia *et al*., 2022). A unique methodology developed in South Africa is that of utilising TripAdvisor reviews to collect tourist reviews of weather and climate (Fitchett & Hoogendoorn, 2019; Dube & Nhamo, 2020a). As with international methodologies, a shift towards utilising globally applicable models, such as the TCI, to analyse the relationship between tourism and climate has taken place through works from Fitchett *et al*. (2016a, 2016b, 2017).

Some of the key findings identified in South African research that focused on tourism and climate change includes the climate resources that are part of the attractiveness of South Africa as a destination, the major threats of climate change on tourism and the sectors that are at risk as a result of climate change. The climate resources of South Africa have been determined to be an attraction for tourism in itself, with research demonstrating that climate conditions, such as temperature, perceived as ‘good’ by tourists will enhance their willingness to travel and their satisfaction with their travel experience (Fitchett *et al*., 2016b; Saarinen *et al*., 2022). Different tourism types in South Africa will be impacted by the changing climate in different ways. The main threats projected to occur in the literature include widespread drought, increased temperatures (which will have a specific effect on snow tourism), increased rainfall, intensification and increased occurrence of extreme climatic events and sea level rise along the coastline (Fitchett *et al*., 2016a; Fitchett & Hoogendoorn, 2018; Hoogendoorn *et al*., 2021; IPCC, 2021; Smith & Fitchett, 2022). Specific sectors that have been determined to be at risk are nature tourism, cultural and heritage tourism, beach tourism, business tourism, golf tourism and cruise tourism (Pandy & Rogerson, 2018).

2.3. Quantitative evaluations of climate suitability in South Africa

Tourism comfortability and satisfaction is greatly influenced by the climate of the destination (Scott & Lemieux, 2010; Fitchett *et al*., 2016b). Attempts to quantify this relationship have been conducted globally over the last four decades, and within southern Africa in the last few years. This section will analyse the climate sensitivity of tourists in South Africa, and the calculated climactic suitability of South African destinations.

2.3.1. Modelling of tourist comfortability in South Africa

To quantify the climatic suitability of a destination, tourism climate indices have been developed. Mieczkowski (1985) explains that due to the multifaceted nature of climate and its influence on tourism, an index approach is essential. Thermal, physical and aesthetic components of climate are important for tourist comfortability (Mieczkowski, 1985). The first index developed was that of the TCI, which was based on the opinions of experts in the field (Mieczkowski, 1985). The variables included in this index are temperature, relative humidity, precipitation, sunshine hours, and wind speed (Table 2.2). A limitation of the tourism climate indices identified in Table 2.2 (especially relevant to the TCI) by many authors is that of the rating schemes for climate variables and the weighting of these climate variables being developed based on subjective opinion of researchers, and not based on tourist opinion (de Freitas *et al*., 2004; Tang, 2013; Scott *et al*., 2016b). However, it is important to note that tourist opinions do not offer an idea of overall tourist sensitivity to weather experienced (Fitchett *et al*., 2016b). A concern noted by Scott *et al*. (2016), is the emphasis on thermal comfort, which represents half of the index weight. However, the South African climate setting, where temperatures are often warmer than that of Europe, should be considered here as this does not support Scott *et al*.'s (2016) concern.

Table 2.2: Tourism Climate Indices and their calculations

Tourism Climate Index	**Formula**	**Variable description**
TCI	$TCI = 2(4Cid + Cia + 2R + 2S + W)$	Cid = Daytime comfort index, composed of maximum daily temperature (°C) and minimum daily relative humidity Cia = daily comfort index, composed of mean daily temperature and mean daily RH R = Precipitation in mm of rain S = Daily hours of bright sunshine W = Wind speed in m/s or km/h
CIT	$CIT = f[(T, A) * P]$	T = Thermal sensation using ASHRAE scale A = Aesthetic appeal of the sky condition P = Physical thresholds of high wind and rain
HCI	$HCI\!: Urban = T * 4 + A * 2 + (R * 3 + W * 1)$ $HCI\!: Beach = 2(T) + 4(A) + [3(P) + W]$	T = Thermal comfort determined using Humidex A = Aesthetic (cloud cover) R = Rainfall W = Wind
CCI	$CCI = 0.5 * TC + 0.5 * S$ min(CCI, 3) if $Tmin<(8^{\circ}C$, or $Tmax)>34^{\circ}C$, or $P>10mm$, or $W>23km/h$	TC = Thermal comfort S = Daily hours of bright sunshine Tmin = Minimum temperature Tmax = Maximum temperature P = Precipitation W = Wind speed
SCI	$SCI = (10(1 - SR) * (1 - AC))^{G} * (SR * AC)^{1-G}$	SR and AC = Facets of snow reliability and aesthetics and comfort G = GAMMA factor

De Freitas *et al*. (2004, 2008) add that no overriding effects of physical facets were identified, further explaining that strong rain or wind could override suitable thermal and/or aesthetic factors. Another limitation is that of varying results based on the choice/availability of monthly, daily, or hourly data (Scott *et al*., 2004; de Freitas *et al*., 2008; Dubois *et al*., 2016). These limitations resulted in modifications to the TCI being pursued, such as that of Perch-Nielsen *et al*. (2010) who altered the TCI in three ways, with the first being the inclusion of daily, instead of monthly meteorological data (Perch-Nielsen *et al*., 2010). The remaining modifications were performed to reflect current knowledge on thermal comfort and to address the shortcomings of the original ‘wind chill index’ by replacing it with the wind chill equivalent temperature (Perch-Nielsen *et al*., 2010). Another adaptation to the TCI was developed by Fitchett *et al*. (2016b) to compensate for a lack of sunshine hour data or proxy data for this variable in South Africa. Fitchett *et al*. (2016b) removed the aesthetic variable from the TCI calculation and distributed the weighting across the remaining variables, however this omission serves as the largest limitation of the adapted calculation.

Many tourism climate indices have been developed, following the release of the TCI (Table 2.2). This includes updated indices that address the limitation of subjectivity in the rating scale and weighting of variables such as the Climate Index for Tourism (CIT). Indices have also been tailored to specific tourism attractions such as the HCI for Urban and Beach settings (Scott *et al*., 2016; Rutty *et al*., 2020), the Camping Climate Index (CCI) (Ma *et al*., 2020) and the Ski Climate Index (SCI; Demiroglu *et al*., 2021). Looking at the CIT, modifications to resolve the limitation of not addressing specific tourism types were implemented to focus on sun, sea and sand tourism (de Freitas *et al*., 2008; Saarinen *et al*., 2022). These modifications were based on the examination of actual tourist climate preferences and tourist-determined thresholds of temperature, sunshine, wind speed and rainfall (de Freitas *et al*., 2008). It should be noted that the use of actual tourist climatic preferences to select and weight climatic variables, determined through questionnaire responses rather than expert opinions, may in fact limit the indices to the specific regions from which tourists’ perceptions were surveyed (Scott *et al*., 2016; Saarinen *et al*., 2022).

In South Africa, research has been conducted into the validation of the TCI by comparing the climatic suitability results to tourists’ self-reported suitability reported on review platforms such as TripAdvisor (Fitchett & Hoogendoorn, 2019). The outcome of this research indicated that the tourist's reviews analysed were largely in agreement with the TCI, however modifications to the rating of wind speed were recommended (Fitchett & Hoogendoorn, 2019). This can be interpreted as an acknowledgement of the limitation of the TCI not being applicable to specific tourism types. Saarinen *et al*. (2022) explain that to adequately calculate climactic suitability of a destination, the purpose of the research and the selected region to be assessed needs to be considered when selecting the tourism climate index. An example was given for using the CCI for camping destination comparison, while using a widely applicable index such as the TCI for tourism types that do not have an exclusively developed index, such as adventure tourism (Saarinen *et al*., 2022). These index calculations all produce a maximum score of 100, excluding the CCI with a maximum score of 10 (Saarinen *et al*., 2022). These scores classify the climatic suitability (usually from unsuitable to ideal) of destinations for tourism using a rating scale (Saarinen *et al*., 2022). To determine the peak seasonal climatic suitability of these destinations, the determined scores can be calculated to a monthly resolution. The scores can then be analysed using Scott and McBoyles' (2001) distribution classes: Poor, Optimal, Summer Peak, Winter Peak, Bimodal-Shoulder Peaks and Dry Season Peak.

Changes in mean annual, seasonal and monthly scores calculated using the initial TCI or adapted versions have been assessed over a period of time for 18 destinations across South Africa from 2005 to 2014 and 1995 to 2015 (Fitchett *et al*., 2016b; 2017). Calculations using this index have also been completed for the Port Elizabeth area, representing St Francis Bay and Cape St Francis region, from 1978 to 2014 (Fitchett *et al*., 2016a). It is important to acknowledge and discuss other notable studies in the southern African regions due to the similarities shared between the study areas in terms of climate. These studies include calculations of the TCI for Afriski in Lesotho from 2012 to 2017 (Noome & Fitchett, 2019), for eight destinations across Zimbabwe from 1989 to 2014 (Mushawemhuka, 2021) and for seven destinations across Namibia from 2008 to 2018 (Noome & Fitchett, 2021). The findings of these studies in terms of use of the TCI in the southern African context will be discussed to highlight its limitations.

Studies that have calculated the TCI for multiple South African destinations were conducted by Fitchett *et al*. (2016b, 2017). Adaptations developed by Fitchett *et al*. (2016b) and by Perch-Nielsen *et al*. (2010) for the Fitchett *et al*. (2017) index calculation were used to allow for comparison with the global North while addressing the limited sunshine hours, humidity and wind speed data availability (Fitchett *et al*., 2017). Following these studies, Fitchett *et al*. (2016a) focused on calculating the TCI for the St Francis Bay and Cape St Francis region using the Perch-Nielsen *et al*. (2010) adaptation. In this study, it was found that a small range of scores were produced, potentially due to the TCI being an international model that does not account for climates recognised as ideal in comparison to the northern hemisphere (Fitchett *et al*., 2016a). In 2019, the first study calculating the TCI outside of South Africa, but within the southern African region, was conducted for Afriski in Lesotho (Noome & Fitchett, 2019). In agreement with Fitchett *et al*. (2016a, 2016b, 2017), the availability and quality of meteorological data for Afriski was limited and therefore hindered the accuracy of the TCI calculation (Noome & Fitchett, 2019). It was acknowledged that an index suited for this destination should be developed to substitute the TCI (Noome & Fitchett, 2019). A potential index to address the shortcomings of the TCI in this environment may be the SCI. This index is tailored towards ski tourism and focuses on the climate variables required for tourist satisfaction in this particular climate (Demiroglu *et al*., 2021). Mushawemhuka (2021) also identified gaps in climate data, especially cloud cover and sunshine hour data which hindered their TCI calculations. In this case, the TCI was identified as the most suitable index for

Zimbabwe based on confirmation of the broad weightings of climatic components in the TCI for similar destinations in South Africa that are dominated by nature tourism, such as Polokwane. It was also suitable based on the assumptions of other indices being unapplicable to Zimbabwe due to the lack of air conditioning, eliminating the usability of the HCI. Once again, poor availability of uninterrupted, continuous data was also identified as a limitation for TCI calculations done for Namibia by Noome and Fitchett (2021). It was acknowledged that an index more suited to the arid climate of the desert should be developed to address the shortcomings of the TCI for this destination type.

When analysing South African tourism destinations, it can be seen that there is a great variety, from beaches to urban locations to mountains. Therefore while the TCI may have been determined to be acceptable for use in the southern African region in most cases, calculations of the SCI or CCI (depending on the destination type and tourism type) may be better suited for certain destinations. This is due to their ability to more effectively rate the climate acceptability of tourism destinations for which they were developed. For example, the CCI may be more effective for camping destinations due to its acknowledgement of overriding effects of rain, wind and temperature (Ma *et al*., 2020).

2.3.2. Tourist perceptions of climate

While calculating tourism index scores for a destination is important, an understanding of the perceptions of tourists visiting the area through means such as TripAdvisor reviews should be created (Fitchett *et al.*, 2019). Fitchett and Hoogendoorn (2018) explained that the determination of tourist comfortability solely using indices ignores the role of tourist country origin, anticipated climatic conditions and the role of infrastructure (accommodation and attractions). This section will discuss studies of tourist perceptions of climate in South Africa, then shift the focus onto studies that compared these perceptions to calculated TCI scores.

Giddy *et al*. (2017) analysed the climate experiences of tourists visiting South Africa based on their country of origin, North America. By analysing the surveys, it was found that while climate was not deemed to be important when deciding to visit South Africa, daily weather experienced did impact on tourist comfortability (Giddy *et al*., 2017). This was due to the ability of weather to impact on participation in outdoor activities (Giddy *et al*., 2017). In agreement with Giddy *et al.* (2017), Friedrich *et al*.'s (2020a) analysis of beach tourist perceptions in South Africa found that 'good' weather leads to increased outdoor activity participation. Other publications that analysed tourist perceptions did not identify specific tourist origins when analysing tourist reviews. Fitchett and Hoogendoorn's (2019) results across nineteen South African destinations agreed with Giddy *et al*. (2017) in terms of weather variations such as cold and hot temperatures (specifically in the autumn and spring periods where temperatures varied from what was expected by tourists), rain (more rain than was expected by tourists) and sunshine (less sunshine than was expected by tourists). Dube and Nhamo (2020a) also found that increasingly high temperatures influence tourist comfort levels and outdoor activity participation at the Victoria Falls World Heritage Site. Ngxongo (2021) identified that the most significant parameter for tourists in the Drakensberg region of South Africa was pleasant and warm temperatures. This is consistent with the findings of Fitchett and Hoogendoorn (2019) and Dube and Nhamo (2020a), with identification of temperatures outside of these parameters having a negative influence on tourist comfort. Friedrich *et al*. (2020a) identified that domestic tourists showed more concern over weather factors, in agreement with that of the American tourists surveyed in Giddy *et al*.'s (2017) study. In agreement with these studies, Hoogendoorn *et al*. (2021) identified a positive trend in perceptions to snow at the

Afriski resort, highlighting the importance of the weather conditions and overall climate of a destination for a specific tourism type, in this case, snow tourism. Mosia *et al*. (2022) also noted that climatic conditions influence the decision of tourists to visit the Walter Sisulu and Pretoria National Botanical Gardens. This is due to the potential impact on specific tourist activities such as picnicking, bird watching, flower and waterfall viewing, and hiking (Mosia *et al*., 2022). The research conducted into tourist sensitivities and experiences should be used to analyse the results of calculated tourism climate indices to determine if tourist comfortability is in fact being accounted for. The results of these studies should be incorporated into tourism climate indices to adequately reflect the sensitivities of tourists.

2.4. Holiday Climate Index

The HCI was first developed in a dissertation by Tang (2013) and later published by Scott *et al*. (2016), with the term 'holiday' better addressing what the index is designed for, which is specifically for sightseeing. The HCI was developed to address the identified deficiencies of the TCI (Scott *et al*., 2016). The most important limitation of the TCI (and applicable to most other tourism climate indices) identified by a range of authors is the subjectivity of the rating schemes for climatic variables and the weighting of these variables in the index (de Freitas, 2003; Scott *et al.*, 2004, 2016; de Freitas *et al.*, 2008; Tang, 2013). The variable weightings were based on expert opinion and availability of biometeorological literature, with no empirical testing done on actual tourist perceptions (de Freitas, 2003; Scott *et al.*, 2004, 2016; de Freitas *et al.*, 2008; Tang, 2013). Other key limitations identified include neglecting the overriding influence that physical climatic variables such as rain or wind may have on tourist comfortability, low temporal and spatial resolution of climate data, and not considering the varying climatic conditions that are required for different tourist activities and destination types (e.g., beach destinations, ski-tourism) (de Freitas *et al.*, 2008; Scott *et al.*, 2008, 2016). In addressing these, the HCI was developed with the guidance of the essential requirements of a comprehensive index identified by de Freitas *et al*. (2008). Firstly, these requirements include incorporating results of recent tourism and climate change research into the development of indices (de Freitas *et al*., 2008). Tourist comfortability is influenced by various climatic facets and therefore de Freitas *et al*. (2008) proposed the variables under the physical facet that should ideally be incorporated into a tourism climate index. Examples of this include temperature, humidity, wind speed and level of activity (de Freitas *et al*., 2008). The thermal facet should be based on sound physiological research on the effect of thermal variables on people and on the relationship between this physical state and the condition of the mind (de Freitas *et al*., 2008). De Freitas *et al*. (2008) recommended the use of the ASHRAE thermal sensation scale, however the HCI incorporated the more easily calculated Humidex measure of effective temperature into its calculation. The aesthetic facet should include climatic variables such as sunshine or cloud cover of which the HCI includes cloud cover. De Freitas *et al*. (2008) advised that an index should be made up of a rating system with five to seven classes, be simple to calculate, allow for the use of standard, daily data and be easy to interpret by those in the tourism sector. The HCI has followed these recommendations. Certain conditions and thresholds exist whereby the physical facet overrides the thermal and aesthetic facets, such as heavy rains or high winds influencing overall tourist comfortability which should be recognised and incorporated into indices (de Freitas *et al*., 2008). The HCI has attempted to incorporate this recommendation by weighting the physical facet equally to the thermal comfort facet (Tang, 2013). This ensures that a high HCI score cannot be achieved should an increase in rainfall, temperature (high or low) or wind speed occur (Tang, 2013). The wind and precipitation schemes particularly decline rapidly and have weightings that do not allow a high score to be calculated (Tang, 2013). However, if we compare the attempt of the HCI to the CCI, for example, it can be seen that the HCI does not address the overriding effect of physical conditions effectively. The CCI integrates temperature, wind and rainfall thresholds independently to the index score calculation which truly allows for the overriding effects of physical conditions to dominate the CCI score (Ma *et al*., 2020). Lastly, tourism climate index performance should be tested and thresholds should be validated against actual tourist satisfaction. The $\text{HCI}_{\text{urban}}$ was compared with mean monthly visitation data for Paris to test the index performance (Tang, 2013). Self-reported tourist satisfaction has been recommended by de Freitas *et al*. (2008) as a reliable source to validate indices. It is explained that cross-cultural validation should be considered as tourists from different geographical areas will display different perceptions of climate.

With these requirements in mind during development, Scott *et al*. (2016) state that the HCI has a major advancement in comparison to the TCI, including a climatic variable weighting scale and a component (i.e., thermal comfort, physical and aesthetic) weighting system that is based on a decade of established tourist climate preferences. Surveys conducted in Canada, New Zealand, Sweden, Europe. Germany, China and France were consulted during the development of the HCI. It is important to note that the majority of these surveys were in the form of questionnaires conducted in European cities. This indicates that a large tourist population is not accounted for and therefore that their perceptions are not considered. Other indices, such as the CCI, made use of tourism visitation data (camping occupancy data in the case of the CCI) to run a regression analysis to determine the significance of individual weather variables (Ma *et al*., 2020). Another example is that of the CTI, which was developed similarly to the HCI in that it made use of questionnaires, with the initial questionnaire being conducted with beach tourists (de Freitas *et al*., 2008). However, following this, a survey demonstrating a range of hypothetical atmospheric conditions was administered in a controlled indoor setting to determine satisfaction in these situations (de Freitas *et al*., 2008). The final survey used to inform the index development was also undertaken in a controlled setting to students at the University of Waterloo. It is important to consider that the participants may not have experienced a beach holiday prior to the survey being administered, which could hinder their ability to respond accurately. Another potential limitation of this method is that this does not represent those outside of the student's age group.

2.4.1. Application of the HCI

The weight of the thermal comfort facet is decreased in comparison to the TCI and made equal to the physical facet, taking into account leisure tourists tolerance for higher temperatures and the assumption of availability of air conditioning in accommodation establishments (Tang, 2013; Scott *et al.*, 2016). However, it should be noted that this assumption has been refuted as many developing country accommodation establishments do not provide air conditioning and tourists partake in activities during the night-time (Mushawemhuka, 2021). The HCI makes use of maximum daily temperature and excludes evening temperatures due to the representation of threshold climate conditions experienced during the day (Tang, 2013; Scott *et al.*, 2016). This is based on the assumption that tourist activities are at their highest when maximum temperature is experienced, and the availability of air conditioning (Tang, 2013; Scott *et al.*, 2016). The thermal comfort facet makes use of effective temperature which combines air temperature and relative humidity (Scott *et al.*, 2016). Differing from the TCI, the aesthetic facet is calculated using cloud cover percentage due to increased availability of this data in comparison to sunshine hours as used in the TCI (Scott *et al.*, 2016). Precipitation, under the physical facet, is calculated using daily measurements (Scott *et al.*, 2016). The wind speed variable is rated using one rating system in contrast to that of the TCI, as tourist comfortability is based on the physical impacts of wind instead of its impact on thermal comfort (e.g., blowing of clothing/hair/sand). This assumption could be a limitation of the HCI due to the cooling effect that wind can bring, known as the wind chill factor (Ahmad *et al.*, 2016). Following the initial HCI publication by Scott *et al*. (2016), a slow uptick in publications utilising the HCI has occurred with three publications in 2018 (Arbabi *et al.*, 2018; Mahtabi & Taran, 2018; Öztürk & Göral, 2018), one in 2019 (Hejazizadeh *et al.*, 2019), three in 2020 (Amiranashvili *et al.*, 2020; Demiroglu *et al.*, 2020; Hasanah *et al.*, 2020), four in 2021 (Amiranashvili & Kartvelishvili, 2021; Amiranashvili *et al.*, 2021; Mushawemhuka, 2021; Yu *et al.*, 2021), two in 2022 (Carrillo *et al.*, 2022; Zajch *et al.*, 2022) and five in 2023 (Jong *et al*., 2023; Putra *et al*., 2023; Samarasinghe *et al*., 2023; Sudiar & Gautama, 2023; Yu *et al*., 2023; (Figure 2.4). In total, 20 papers have calculated the HCI (Figure 2.4).

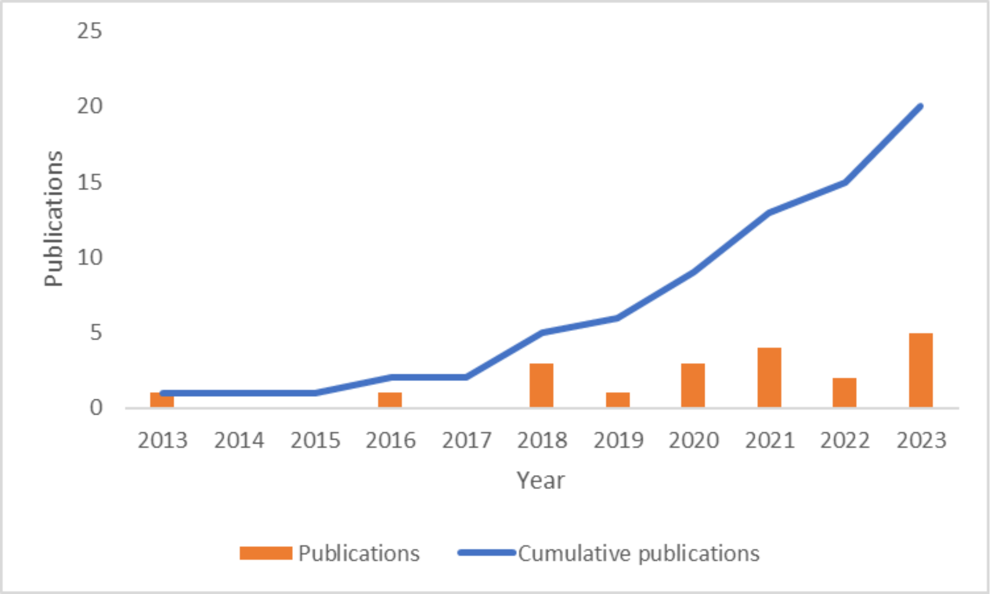

Figure 2.4: Number of publications utilising the Holiday Climate Index from its establishment until present

Geographically, the HCI_{urban} has been used to measure climatic suitability across locations in the Caribbean (Rutty *et al*., 2020) , Europe (Scott *et al*., 2016), Turkey (Scott *et al*., 2016), Iran (Arbabi *et al.*, 2018; Mahtabi & Taran, 2018; Öztürk & Göral, 2018; Hejazizadeh *et al.*, 2019), the greater Mediterranean region (Demiroglu *et al.*, 2020), Indonesia (Hasanah *et al.*, 2020; Putra *et al*., 2023; Sudiar & Gautama, 2023), Georgia (Amiranashvili *et al.*, 2020, 2021;

Amiranashvili & Kartvelishvili, 2021), China (Yu *et al.*, 2021, 2023), Malaysia (Jong *et al.*, 2023), Sri Lanka (Samarasinghe *et al.*, 2023) and the Canary Islands (Carrillo *et al.*, 2022) (Figure 2.5). To shift the HCI from a focus on 'urban' destinations, Rutty *et al.* (2020) developed the $\mathrm{HCI}_{\mathrm{beach}}$ index for beach destinations. The index is based on a decade of tourist perceptions of climatic preferences in this environment, specifically acknowledging the preference of beach tourists for warmer conditions (Rutty *et al.*, 2020). Surveys from literature included Canada, New Zealand, Sweden, Belgium, greater Europe area, Germany, the Caribbean, United States, Greece, and the larger temperate and tropical regions were consulted during the development of the $\mathrm{HCI}_{\mathrm{beach}}$.

Rutty *et al.* (2020) explained that cloud cover (under the aesthetic facet) is the most important climatic variable, as discovered in a survey from the Caribbean state. It was also found that thermal comfort was rated as third, with a score of 20%, and as with the $\mathrm{HCI}_{\mathrm{urban}}$, evening comfort is not included in the equation due to the assumption of air conditioning availability in accommodation establishments (Rutty *et al.*, 2020). The $\mathrm{HCI}_{\mathrm{beach}}$ index has been calculated for the greater Mediterranean region (Demiroglu *et al.*, 2020), the Caribbean (Rutty *et al.*, 2020), China (Yu *et al.*, 2021), the Canary Islands (Carrillo *et al.*, 2022), Indonesia (Putra *et al.*, 2023; Sudiar & Gautama, 2023), Sri Lanka (Samarasinghe *et al.*, 2023) and Japan (Zajch *et al.*, 2022) (Figure 2.5). While the HCI was developed using tourist perceptions from predominantly developed countries, it is interesting to note that the majority of HCI studies have been conducted in developing countries.

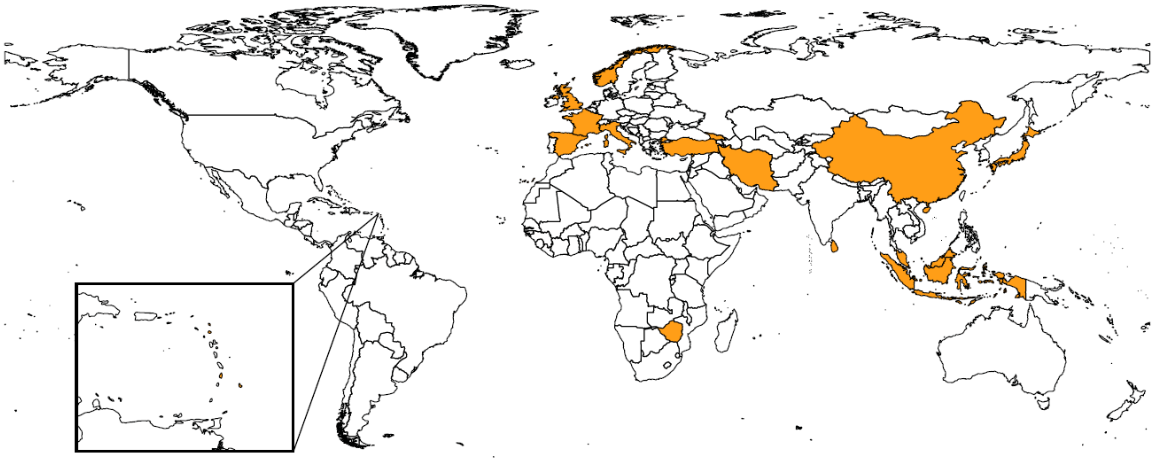

Figure 2.5: Countries where the HCI has been calculated (highlighted in orange)

From the 20 published papers that utilised the HCI, 12 compared the HCI to the TCI with 50% of publications concluding that the HCI was a more suitable index in their specific case studies, 17% concluding that the TCI was a more suitable index in their specific case studies and 33% indicating that neither index is particularly better (Table 2.3). A variety of methods were used in these publications to guide the selection of the most appropriate index. This included comparison to TCI scores, tourist arrival and demand data, and comparison to results from questionnaires and interviews with tourists (Table 2.3). Scott *et al.* (2016) explained that the $\text{HCI}_{\text{urban}}$ is a more suitable index for the European cities selected as urban tourist perspectives were incorporated in its design. Complementing this, the HCI ratings calculated for the selected European destinations were observed to be more consistent with the observed visitation patterns than that of the TCI (Scott *et al.*, 2016). The $\text{HCI}_{\text{beach}}$, designed by Rutty *et al.* (2020) was stated to perform better than the $\text{HCI}_{\text{urban}}$ and TCI by more accurately demonstrating the relationship between the calculated scores and actual tourist arrivals to the Caribbean. Mahtabi and Taran (2018) did not explicitly verify which index is better suited in their case study. It was stated that the HCI scores were in line with those given by the TCI for their selected sites in most cases, however calculations for July demonstrated that the HCI score is closer to 'reality' (Mahtabi and Taran, 2018). No comparison to tourist arrivals/demand or questionnaires and interviews took place in the Mahtabi and Taran (2018) publication. Therefore, the accuracy of comparison to 'reality' can be questioned. Publications from Amiranashvili *et al*. (2020, 2021) for Georgia made statements that the HCI more adequately determines the bioclimate of the environment for specific tourism types. However, no comparison to real-world findings such as interviews and questionnaires or tourism arrivals was conducted. Hasanah *et al.* (2020) determined the HCI to be the most accurate index for application in tropical areas such as that of the Borobudur Temple in Indonesia. This was determined through comparison of the HCI ratings to monthly visitation data. In the Sistan and Baluchesten Province in Iran, Arbabi *et al*. (2018) found that the HCI was more consistent with the province's climates. However, to adapt the index to the geographical conditions of Iran, a modified version of the HCI was developed (Arbabi *et al*., 2018). It should be noted that no comparisons to real-world findings were conducted in this study. Publications that deemed the TCI to be more appropriate than the HCI to their specific destinations included Hejazizadeh *et al*. (2019) and Mushawemhuka (2021). For Iran, the HCI displayed less variability and oscillation, thereby deeming the TCI more suitable especially for the east and southwest regions (Hejazizadeh *et al.*, 2019). However, this publication did not utilise real-world data to compare the calculated ratings to actual tourist arrivals/demand or results from questionnaires and interviews. In the case of Zimbabwe, tourist activities are not limited to the daytime (night-time temperatures are thus important to consider), air conditioning is not always available in tourist accommodation establishments and perspectives of climate in Zimbabwe most likely differs to that of the European city climate perspectives used in the HCI's development (Mushawemhuka, 2021). The ratings were triangulated with questionnaire results from tourists and interviews with tourism stakeholders which indicated that the TCI ratings were more appropriate for Zimbabwe. Samarasinghe *et al*. (2023) determined that the HCI was more suitable for Sri Lanka than the TCI through a comparison of calculated monthly HCI scores to monthly tourist arrivals by country and guest nights. Lastly, using the same method as Samarasinghe *et al*. (2023), Jong *et al*. (2023) found that neither of the indices was more suitable for Malaysia. It is interesting to note that while designed for urban or beach destinations, the HCI has been deemed more suitable in destinations that do not fall into either of these categories, such as mountainous regions of Georgia (Amiranashvili *et al.*, 2021) and the Borobudur Temple in tropical Indonesia (Hasanah *et al.*, 2020).

Table 2.3: Comparison study conclusions on suitability of HCI vs TCI

Publication	**Location**	**Method of comparison to real-world tourism situation**	**HCI**	**TCI**	**Neither**
Scott *et al.*, 2016	Istanbul, Rome, Barcelona, Athens, Venice, Madrid, London, Dublin, Stockholm, Paris, Amsterdam, Vienna, Berlin, Munich, Warsaw.	Ratings examined against available tourism demand data to evaluate validity	X		
Rutty *et al.*, 2020	Caribbean	Daily climate ratings were correlated with monthly arrivals data from Canada at an island destination scale	X		
Mahtabi & Taran, 2018	Isfahan and Rasht, Iran	No comparison to real-world tourism situation			X
Hejazizadeh *et al.*, 2019	Sistan-Balouchestan, Hormozgan, Kerman, Yazd, South Khorasan, Qom, Khorasan Razavi, Isfahan, and Semnan provinces, Iran.	No comparison to real-world tourism situation		X	
Amiranashvili & Kartvelishvili, 2021	Kakheti, Georgia	No comparison to real-world tourism situation			X
Amiranashvili *et al.*, 2020	Tbilisi, Georgia	No comparison to real-world tourism situation			X
Hasanah *et al.*, 2020	Borobudur Temple Compounds, Indonesia.	Monthly ratings evaluated in view of the monthly visitation data	X		
Arbabi *et al.*, 2018	Sistan and Baluchesten Province, Iran.	No comparison to real-world tourism situation	X		
Amiranashvili *et al.*, 2021	Georgia - Bakhmaro, Bakuriani, Borjomi, Goderdzi, Gudauri, Khaishi, Khulo, Lentekhi, Mestia , Pasanauri, Shovi, Stepantsminda and Tianeti.	No comparison to real-world tourism situation	X		
Mushawemhuka, 2021	Zimbabwe - Buffalo Range Airport, Chipinge, Hwange National Park, Kariba, Karoi, Masvingo, Rusape, Victoria Falls Airport.	Ratings were triangulated with questionnaire results from tourists and interviews with tourism stakeholders.		X	
Samarasinghe *et al.*, 2023	Sri Lanka – Ancient cities, Columbo Suburbs, Southern Region, Northern Region, Central Hills and Eastern Region.	Monthly ratings evaluated in view of the monthly tourist arrivals by country and guest nights.	X		
Jong *et al.*, 2023	Malaysia	Monthly ratings evaluated in view of the monthly tourist arrivals.			X

Authorship of publications utilising the HCI should be scrutinised to identify whether the HCI is gaining popularity due to its effectiveness as a tourism climate index or if the developer of the index remains the prominent author utilising the HCI. Becken (2013) explains that reoccurring authors could inflate the field, in this case the utilisation of the HCI as a tourism climate index, without adding new information or ‘fresh thinking’. The developers of the HCI, namely Tang, Scott, Amelung and Rutty, have only authored or co-authored two, three, one and two papers respectively out of the 20 publications utilising the HCI (Table 2.4). It is important to note that these publications all include the design of the HCI_{urban} and HCI_{beach}, other than Yu *et al.* (2021), which only Scott co-authored.

Table 2.4: Number of publications utilising the HCI per author

Number of publications utilising the HCI	**Authors**
1	Amelung, Arbabi, Arip, Burrowes, Carrillo, Charles, Chen, Demiroglu, Diaz, Dwiridal, Edelweis, Exposito, Fauzi, Gautama, Gonzalez, Goral, Gough, Gunathilake, Hasanah, Hejazizadeh, Hewer, Hosseini, Indriyani, Jong, Karbalaee, Khosravi, Kurnaz, Mahon, Mahtabi, Makumbura, Maryetnowati, Matzarakis, Meddage, Mushawemhuka, Muttil, Nugrahayu, Ozturk, Pacal, Payedar, Perez, Puah, Putra, Rathnayake, Samarasinghe, Saygili-Araci, Tabarabaei, Taran, Trotman, Udo, Wickramarachchi, Zajch
2	Amiranshvili, Guo, Hall, Kartvelishvili, Li, Matthews, Rutty, Sudiar, Tang, Yu
3	Scott

2.4.2. Limitations of the HCI

While publication limitations, with regards to authorship, were not found, technical limitations have been identified. One of the main limitations of the HCI is the use of surveys to inform the rating scales and weighting system based on tertiary student perceptions. These surveys were undertaken in Canada, New Zealand, Sweden, Austria, Germany, Netherlands, and Switzerland (Tang, 2013; Scott *et al.*, 2016). A survey based on air traveller perceptions in the Belgian and Dutch airports was also used (Tang, 2013; Scott *et al.*, 2016). Tang (2013) explains that optimal climate conditions will be different for each person, and perceptions of climate change at different destinations (i.e. urban and beach). The integration of these sparse surveys as well as the differences in climate perception indicates that researchers still make expert judgements when it comes to rating scales and weighting systems, as there is no harmonised international survey available at this point (Dubois *et al*., 2016).

Another potential limitation of the HCI is the assumption that tourist accommodation in developed countries and in major tourism destinations make use of air conditioning (Scott *et al.*, 2016). Mushawemhuka (2021) discussed limited air conditioning availability in tourist accommodation establishments within developing countries such as Zimbabwe, thus contesting this assumption. South Africa, the focus of this study, as a developing country may experience the same air conditioning availability as Zimbabwe, thus making the HCI less suitable than other tourism climate indices. As with Zimbabwe, night-time temperatures may affect tourist comfortability while sleeping or during night-time activities (e.g. animal viewings). Therefore it may be a significant limitation of the HCI to exclude night-time temperatures from its calculation (Mushawemhuka, 2021). Lastly, the assumption that all countries, especially developing countries, have daily, high resolution climatic data available is a limitation of the HCI (Nicholson *et al.*, 2012). With a focus on southern Africa, temperature and precipitation data are readily available for many tourism destinations, however variables such as humidity and sunshine hours are not as readily available (Fitchett *et al.*, 2016b).

2.4.3. Potential for the HCI in the South African context

The identified limitations of the HCI in the South African context must be considered, however the suitability of the HCI for South Africa specifically should be acknowledged. A large part of South Africa is classified as warm temperate, which is similar to the conditions experienced across Europe, therefore increasing the probability that the HCI will be suitable for most tourism destinations across the country (Conradie, 2012; Figure 2.6). Another way in which the HCI may be applicable to certain destinations in South Africa, specifically for cities such as Cape Town, is through city design. Wessels and Bosman (2014) explained that South African cities have been influenced by European architecture, which was introduced in the 1920s. To address the assumption of air conditioning in accommodation establishment, a review of a limited number of accommodation establishments at popular tourism destinations within South Africa indicates that some establishments do provide air conditioning, while others do not.

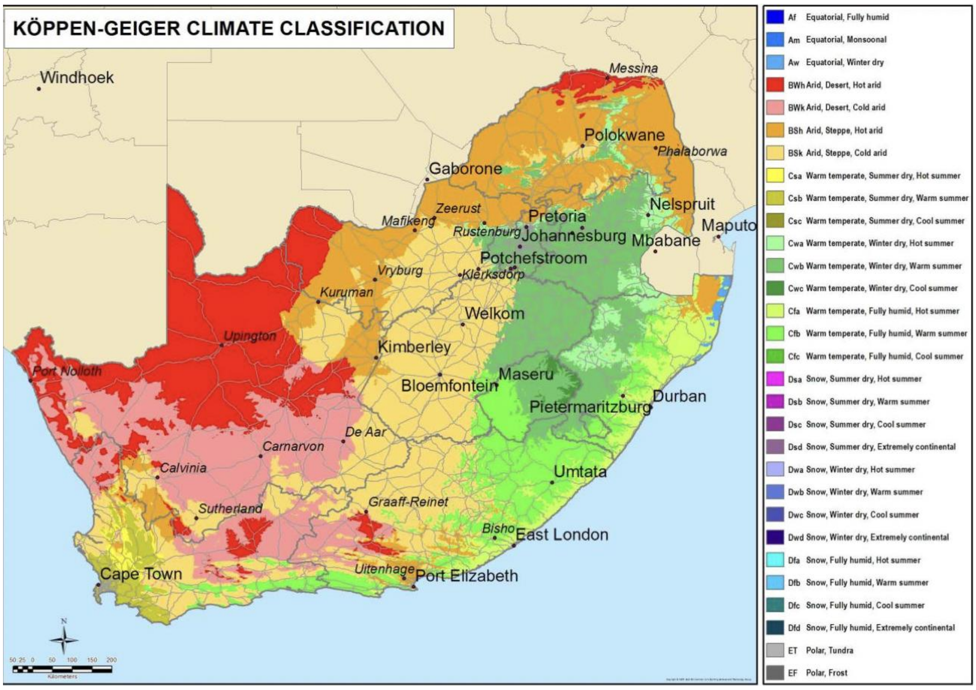

Figure 2.6: Koppen-Geiger map of South Africa based on data from 1985 to 2005 (Conradie, 2012)

2.5. Conclusion

An analysis of the history of tourism and climate change literature, followed by a discussion on quantitative evaluations of South African climate suitability for tourism and an in-depth look at the HCI was conducted in this literature review. Through this process, the gap in the literature has been identified. The HCI claims to address shortcomings of the TCI at a global scale, while at the same time making assumptions on air conditioning availability in all tourist destination accommodation establishments and being developed based on predominantly European city tourist preferences. Therefore, towards obtaining the most accurate measure of climatic suitability for tourism in South Africa, it is imperative to determine if the HCI is indeed applicable and suitable for use in South Africa and if it is, to calculate the HCI ratings.

CHAPTER 3. STUDY SITE

3.1. Introduction

This study is situated in South Africa. South Africa was selected as the focus area from which to choose specific tourism destinations based on the diverse climatic conditions across the country, the availability of the required climate data for the desired time period, the paucity of literature on the HCI and the effects of climate on tourism in South Africa. The choice to base this study in South Africa was also influenced by the variation in types of tourism across the country and overall success of the tourism sectors. This chapter will provide a description of the climate in South Africa followed by a background of the tourism sectors within the country. At each destination, the types of tourism activities have also been provided.

3.2. Study Location Selection

The selection of specific study locations was primarily informed by the availability of the requisite input data for the calculation of the HCI, with further considerations for spatial coverage across the country. A total of 13 meteorological stations were selected, each of which measured all of the requisite variables, and spanned the nine Provinces (Figure 3.1). Of these stations, TCI scores have previously been calculated for nine of the locations, namely Bethlehem, Bloemfontein, Cape Town, Durban, East London, Gqeberha, Johannesburg, Kimberley and Polokwane. For the remaining five locations, this will represent the first calculation of any tourism climate index scores.

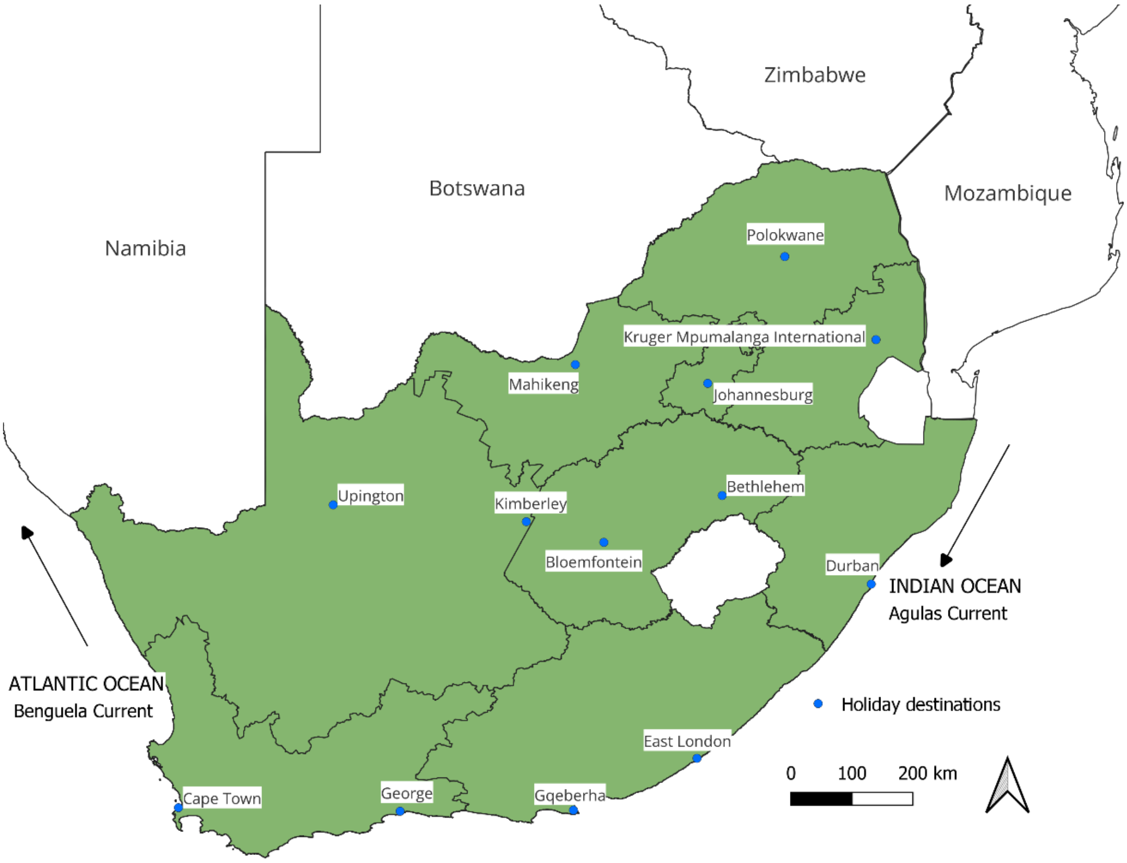

Figure 3.1: Tourism destinations with required climate variables and period available

3.3. South African Climate

The climate of South Africa, although variable, has been identified as suitable for tourism, and is a defining feature of the country (Fitchett *et al*., 2016a). This section will delve into South Africa's climate heterogeneity, temperatures, rainfall, cloud cover, synoptic systems and inter-annual drivers of the climate variability.

3.3.1. Climatic Heterogeneity

The heterogenous nature of climate across South Africa is caused by the latitude in which the country is located, the topography across the country and the Indian and Atlantic Ocean currents. Climate is influenced by the latitude of a country with tropical climates experienced between 23.5° North and South, temperate climates between 23.5° and 66.5° North and South and polar climates between 66.5° and 90° North and South (Lennard, 2019). South Africa is located within the coordinates 22-35°S and 17-33°E, spanning the subtropics to the mid-latitudes (Roffe *et al*., 2021). South Africa experiences both temperate and tropical climates. Landman *et al*. (2017) explains that the South African climate is also influenced by various topographical environments across the country. A decrease in temperature is felt over the mountainous escarpment separating the low-lying coastal regions from the high-lying interior plateau of South Africa (Landman *et al*., 2017). During the summer and winter seasons, a low-pressure trough is formed as a result of descending air over the escarpment, termed the westerly trough and easterly wave respectively (Cook *et al*., 2004). Lennard (2019) explains that the westerly trough formed in winter results in surface convergence, uplift, cloud formation and rainfall in the western region of South Africa, while subsidence, surface divergence and clear skies are experienced in the interior and eastern regions of the country. In contrast, the easterly wave experienced during summer results in surface convergence, uplift, cloud formation and rainfall across the interior and eastern regions of the country, and subsidence, surface divergence and clear skies over the western region of the country (Lennard, 2019). The Hadley cell descends over South Africa resulting in a subtropical high-pressure system over the interior of the country associated with clear skies (Saarinen *et al*., 2022). Lennard (2019) explains that the base of this high-pressure system is situated above the escarpment during summer, allowing for warm, moist air to reach the interior of South Africa. During winter, the base is located below the escarpment which prevents moisture from reaching the interior (Lennard, 2019).

The warm Agulhas Current flows southward just off the east coast (Indian Ocean), and the cold Benguela Current flows northward just off the west coast (Atlantic Ocean; Jury *et al.*, 1993). Both currents play a role in the diverse climate found across South Africa, inducing a decrease of rainfall from the east to the west of the country (Jury *et al.*, 1993). These ocean currents result in the temperatures on the eastern coast being approximately 5°C warmer than along the western coast (Karmalkar *et al*., 2012). Lennard (2019) explains that onshore flow from the Agulhus current brings moist, warm air over the escarpment into the interior of South Africa during the summer months. The effect of the cold Benguela Current on the western coast, along with the descending Hadley cell, is a dry arid and semi-arid climate along the western region of South Africa (South African Government, 2015b).

3.3.2. Temperature and Thermal Comfort

Temperatures across coastal areas are generally moderate, while temperatures exceed 30°C during summer days and can drop to below 0°C during winter nights across the interior of South Africa (Fitchett & Hoogendoorn, 2018). A large proportion of South Africa experiences average annual temperatures above 17°C (Engelbrecht & Landman, 2010; Figure 3.2). Engelbrecht and Landman (2010) explain that the lowest temperatures are found over the southern and eastern escarpment due to decreasing temperatures with increasing altitude. The warmest temperatures are found across the coastal areas in the eastern regions, the Lowveld and the interior of the Northern Cape (Engelbrecht and Landman, 2010). The influence of the Agulhus and Benguela ocean currents play a role in the temperature variation across the country. Karmalkar *et al*. (2012) adds that the inland plateau causes a temperature variation between night and day over the interior, and a temperature variation from south to north of South Africa. Moving from the east to the west of the country, the climate becomes hotter and drier (Lennard, 2019).

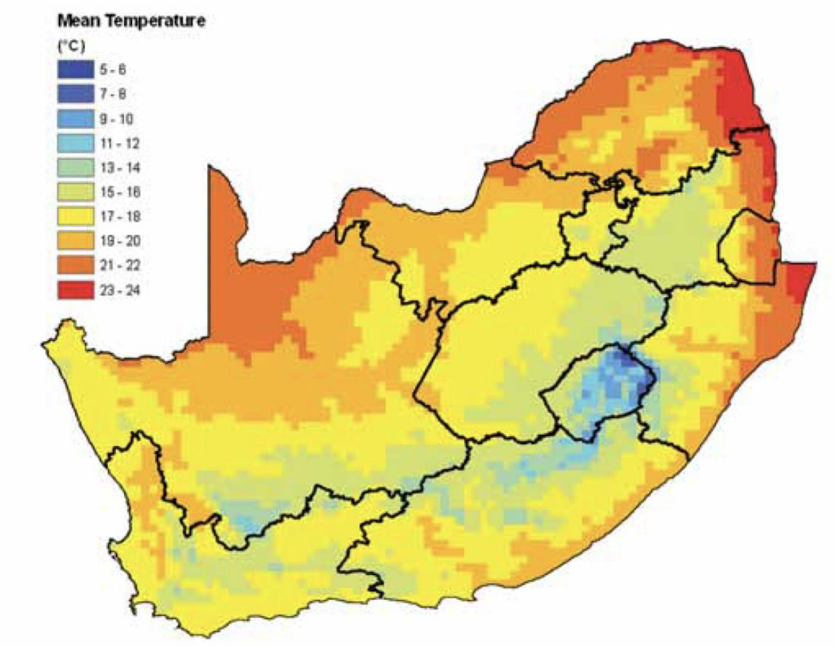

Figure 3.2: Average annual temperatures over South Africa (Engelbrecht & Landman, 2010)

In terms of thermal comfort, Roffe *et al*. (2023) demonstrate that southern Africa experiences four of the Universal Thermal Comfort Index (UTCI) thermal stress categories, namely moderate cold stress, slight cold stress, no thermal stress and moderate heat stress (Figure 3.3). On average, annual heat stress is minimal to none across South Africa, with slight cold stress experienced in isolated areas over the escarpment (Figure 3.3). This stress increases in the autumn months and during the winter months, with the majority of the country experiencing slight cold stress and the escarpment experiencing moderate cold stress (Figure 3.3). The north-western point of the country, at the border of Namibia and Botswana, experiences moderate heat stress during the summer months (Figure 3.3).

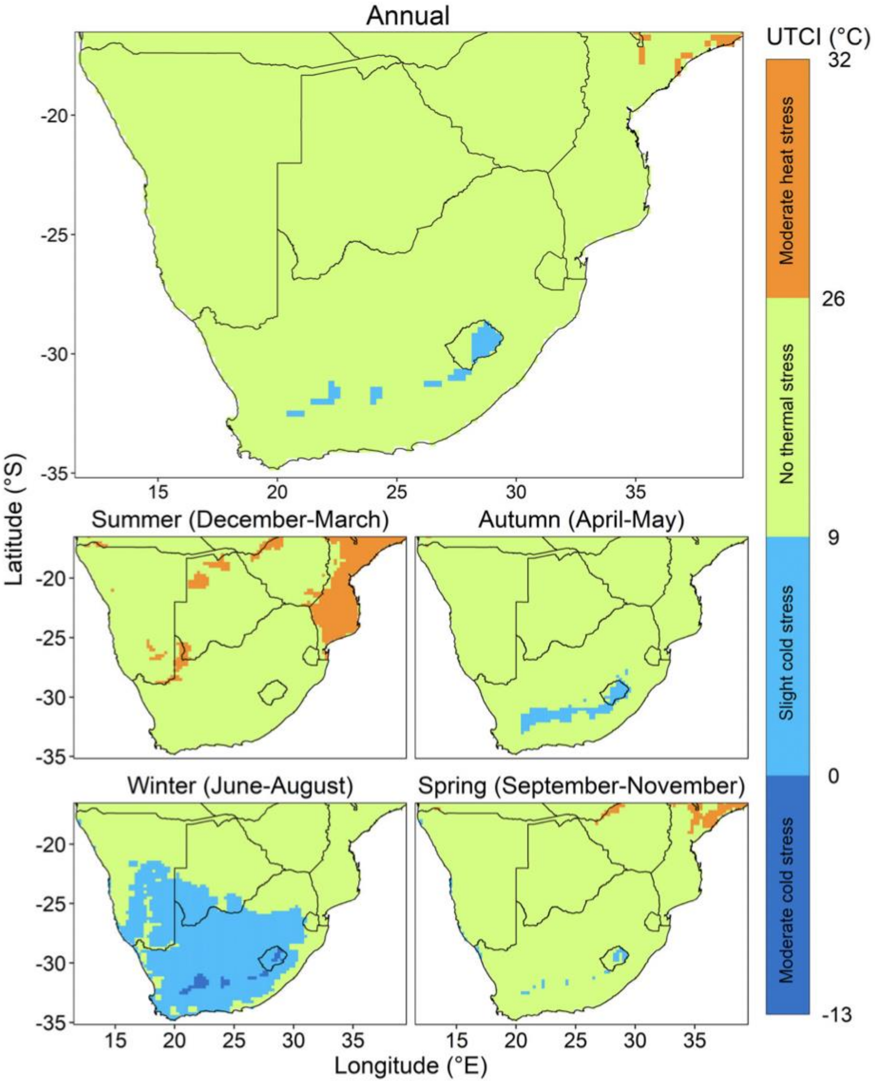

Figure 3.3: Daily mean annual and seasonal UTCI thermal stress categories across southern Africa (1979 – 2021) (Roffe *et al*., 2023)

3.3.3. Rainfall

South Africa receives a mean annual rainfall of approximately 464mm, classing the country as semi-arid (South African Government, 2015). Engelbrecht and Landman (2010) describe a west-east gradient in rainfall totals (Figure 3.4). Characteristic rainfall of South Africa includes winter rain in the south-western region, year-round rain in the southern region and summer rain in the central and northern interior regions (Tyson & Preston-Whyte, 2000; Roffe *et al*., 2021). Over the Eastern regions of South Africa, precipitation takes place from October to April, (Favre *et al*., 2012). Along the Atlantic coast, precipitation takes place in June and July as a result of mid-latitude cyclones and extra-tropical storms in the westerlies (Favre *et al*., 2012; Jawtusch, 2014). Orographic forcing is present along the eastern escarpment, south-western Cape and Cape south coast regions which results in increased precipitation (Engelbrecht & Landman, 2010).

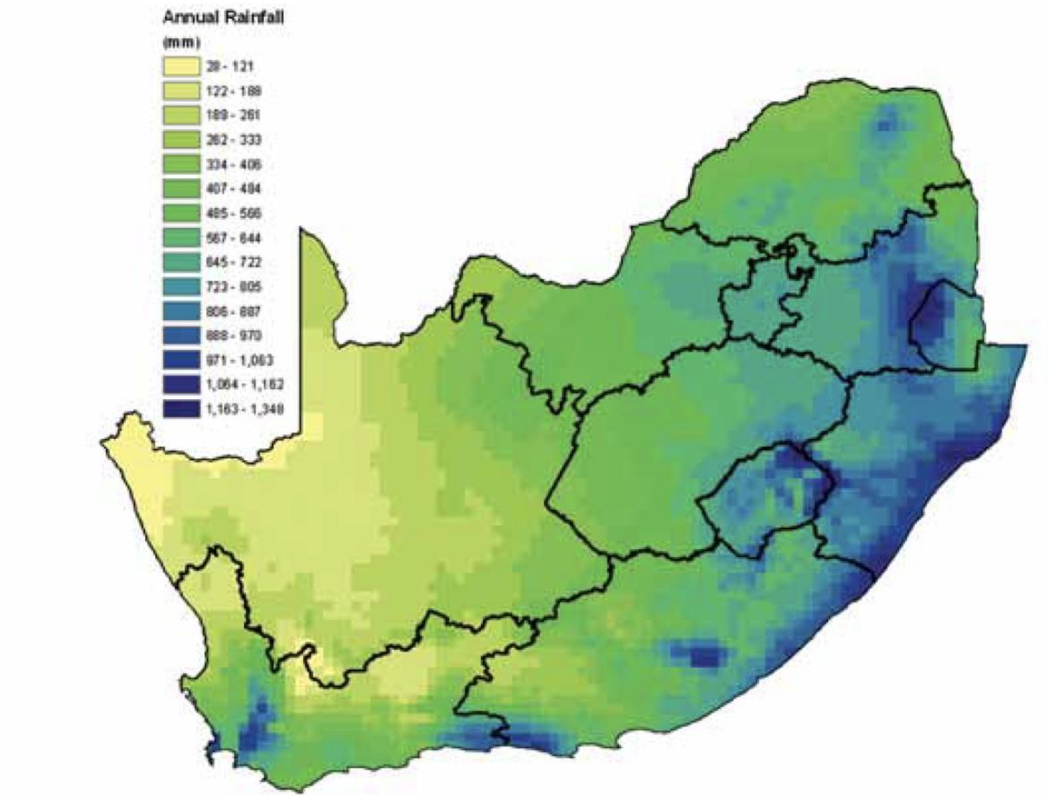

Figure 3.4: Average annual rainfall across South Africa (Engelbrecht & Landman, 2010)

3.3.4. Cloud cover

Cloud properties such as height, thickness, extent, water content, phase, droplet and crystal sizes influence the climate of an area through radiation and precipitation (Warren & Hahn, 2002). The different types of clouds are classified by their height and form and include high level (cirrus, cirrocumulus and cirrostratus), middle-level (altocumulus and altostratus) and low-level clouds (stratocumulus, stratus, cumulus, cumulonimbus and nimbostratus). The cirrus, cirrocumulus and cirrostratus clouds form above 6km and consist of ice crystals but are not associated with precipitation (Warren & Hahn, 2002; Houze, 2014). The mid-level clouds altocumulus and altostratus can form between 2-6km above the ground and are usually quite thin, with precipitation being rare (Warren & Hahn, 2002; Houze, 2014). The remaining low-level clouds form below 2km and have many different characteristics. Stratocumulus and stratus are horizontally extensive and are associated with drizzle (Warren & Hahn, 2002; Houze, 2014). Cumulus clouds are non-precipitating and small, developing from a few hours before daybreak and lasting until sundown, however they may develop into cumulonimbus which are associated with thunder and rain showers (Warren & Hahn, 2002; Pretor-Pinney, 2009; Houze, 2014). Lastly, nimbostratus is a thick vertically extending cloud that is associated with rain and snow (Warren & Hahn, 2002; Houze, 2014). Barth (2010) explains that stratus, stratocumulus, cumulus and cumulonimbus clouds can be forced, triggered or enhanced by hilly or mountainous terrain. Orographic features may also form a different species of cloud known as a lenticular cloud, which is formed when air flows over a mountain, however this can also form downwind of the peak (Barth. 2010; Houze, 2014). Downslope violent winds may result in a rotor cloud which is associated with turbulent air motions (Barth, 2010).

3.3.5. Synoptic systems

Synoptic systems determine the weather and climate of South Africa. Synoptic features that influence the climate of South Africa include the subtropical south Atlantic and subtropical south Indian high, coastal lows, cold fronts, westerly waves, mid-latitude cyclones and easterly wave lows (Lennard, 2019; Figure 3.5). Mid-latitude cyclones, known locally as cold fronts, are cold, low pressure systems that move in an easterly direction associated with rainfall and north-westerly winds (Lennard, 2019). During the winter months, mid-latitude cyclones primarily affect the south-western and southern regions of South Africa (Lennard, 2019).

However, these systems may move into the interior resulting in cold conditions with snow occurring over the Drakensberg Mountain range (Lennard, 2019).

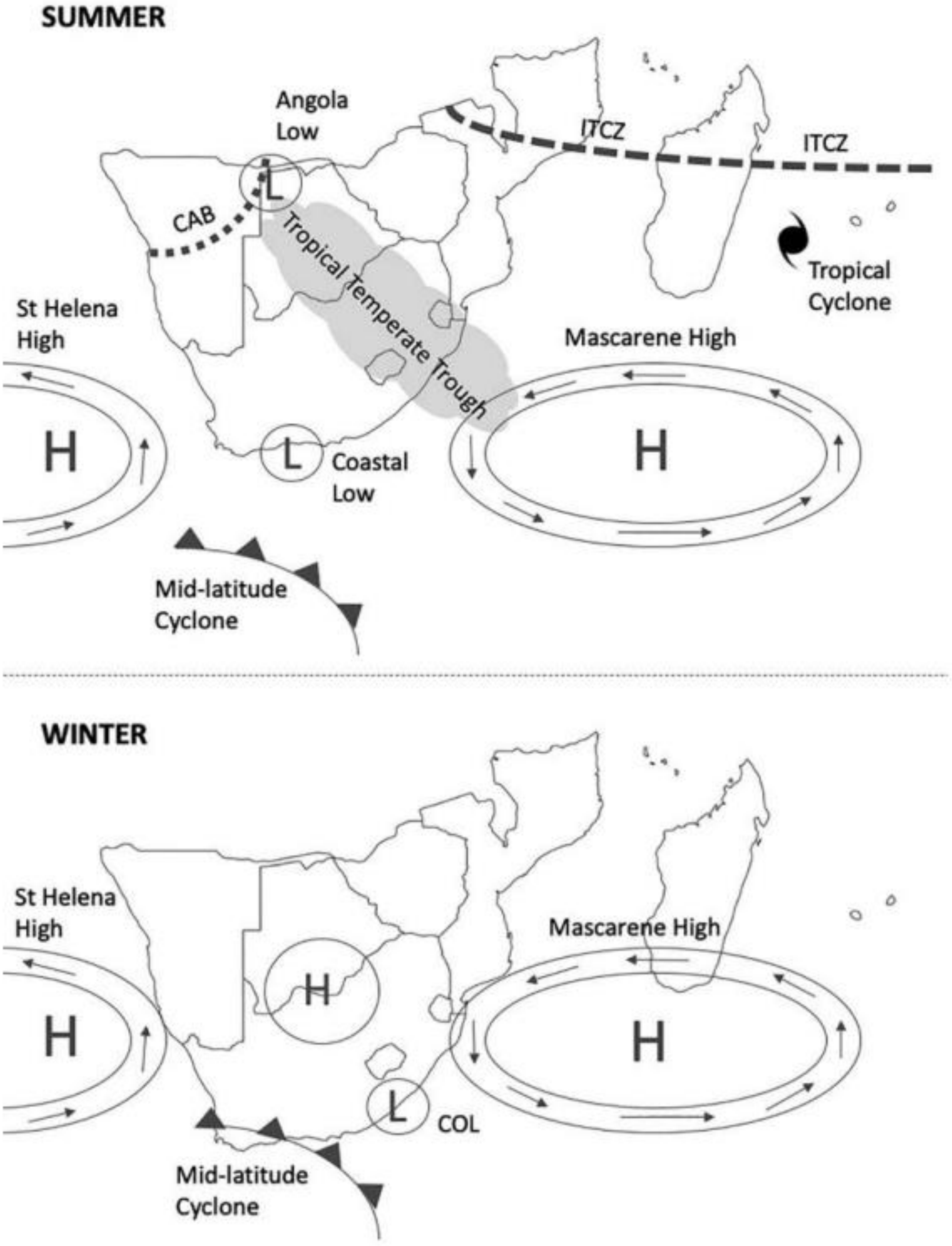

Figure 3.5: Surface synoptic features that influence the South African climate (Saarinen *et al*, 2022)

Cut-off Lows (CoLs) are formed after detaching from a mid-latitude cyclone in the middle and upper troposphere (Favre *et al*., 2012; Lennard, 2019). CoLs move in a south-westerly to north-easterly direction with rainfall occurring on the eastern side of the system (Lennard, 2019). Favre *et al*. (2012) and Lennard (2019) further explain that CoLs occur throughout the year and generally are located over the south coast, east coast and interior of South Africa. Favre *et al*. (2012) do however note that the strongest contribution of CoLs to annual precipitation is during the spring season. Cold fronts approaching the western coast of South Africa assist in the creation of an offshore wind flow, from the interior (relatively low pressure) of the country to the coast (relatively higher pressure; Kraaij *et al*., 2018). As the wind, known as the Berg wind, travels down the escarpment, it is warmed adiabatically resulting in warm temperatures over the Western Cape (Kraaij *et al*., 2018). The Berg Winds may be associated with a shallow coastal low pressure system which is trapped between the escarpment and the cold front approaching the west coast (Lennard, 2019).

Tropical cyclones are warm systems that can grow to 1000km in diameter which usually form over warm ocean currents of the Indian Ocean with a westerly movement towards southern Africa, with a possibility of formation over the Mozambique Channel (Fitchett & Grab, 2014; Lennard, 2019; Saarinen *et al*., 2022). Tropical cyclones may influence the north-eastern regions of South Africa with strong winds and heavy rainfall due to the scale of the system (Lennard, 2019). However, it is a rare occurrence for these tropical cyclones to extend beyond the escarpment to the interior regions (Lennard, 2019). Subtropical high-pressure systems, which bring clear weather, are formed as a result of the sinking Hadley cell (Saarinen *et al*., 2022). This system brings mild days and cold nights over the interior of South Africa during the winter months (Lennard, 2019). In summer, this system is present over the south-western and southern parts of the country, resulting in a south-easterly wind blowing along the western coast (Lennard, 2019). In the summer months, a semi-permanent trough, known as the easterly wave low, is formed over the interior of South Africa creating an east to west wind flow that brings warm, moist air from the Agulhus region to the interior of the country (Cook *et al*., 2004). Lennard (2019) explains that this flow results in the well-known summer rainfall associated with this low pressure system. A tropical temperate trough is a low-pressure system occurring from November to March that extends from the tropics to the mid-latitudes with a northwest-southeast orientation (Rapolaki *et al*., 2019). Thunderstorms form within these systems and bring rainfall to the country's interior region (Cook *et al*., 2004; Rapolaki *et al*., 2019).

3.3.6. Inter-annual drivers of variability

Climate in South Africa is influenced by large-scale teleconnections, which refers to the climate links between different geographic regions (Nigam & Baxter, 2015; Lennard, 2019). These teleconnections include the El Niño/Southern Oscillation (ENSO), Southern Annual Mode (SAM), Indian Ocean Dipole (IOD) and Antarctic Oscillation (AAO). ENSO has an approximate seven year cyclicity, as a result of sea surface temperatures (SST) in the Pacific Ocean being warmer or cooler than normal (Trenberth, K.E., 2013; Lennard, 2019). During the El Niño phase of ENSO, the majority of South Africa experiences drier than normal conditions (van Heerdan *et al*., 1988). During the La Niña phase, the summer rainfall zone regions of South Africa experience wetter than normal conditions (van Heerdan *et al*., 1988). Lennard (2019) explains that during the summer months, the effect of El Niño or La Niña is most noticeable, however this is not always the case. When there is no significant deviation from SSTs, a neutral phase of ENSO is experienced (Lennard, 2019). The SAM, powered by its position amongst the mid-latitude westerly winds and the subtropical jet stream, results in a poleward shift of storm tracks during its positive phase and an equatorward shift of storm tracks and weaking of the westerly winds during the negative phase (King *et al*., 2023). During the positive state, droughts are known to occur in the winter rainfall regions of South Africa, such as Cape Town (King *et al*., 2023). Warmer SSTs off the east African coast, paired with cooler SSTs of the eastern Indian Ocean, result in the occurrence of the IOD (Lennard, 2019). If SSTs are warmer off the east African coast, rainfall may be above normal in the summer rainfall region of South Africa, while cooler SSTs off the east African coast may result in decreased summer rainfall (Reason & Smart, 2015). Lennard (2019) emphasizes that a neutral phase of IOD exists, as with ENSO. The AAO occurs between the Antarctic and mid-latitude zonal band (MacKellar *et a*l., 2014). Lennard (2019) explains that when the geopotential height anomaly over the mid-latitudes is positive and negative over the Antarctic, storm tracks shift towards the poles resulting in less rainfall over the South African winter rainfall region. Should the positive and negative geopotential height anomalies switch, increased rainfall will occur in this region (Lennard, 2019).

3.4. Tourism Attractions in South Africa

The tourism sector is a great source of income for developing countries, with South Africa's growing tourism sector, influenced by the attractive climate, contributing greatly to the local economy (Scott & Lemieux, 2010; Fitchett *et al*., 2016b). From 2016 to 2019, more than 10 million international tourist arrivals were recorded annually (DoT, 2020). The main reasons that international tourists visited South Africa in 2019 include visiting friends and relatives (41.4%), holiday (20.9%), shopping (22.9%), business (6.4%) and 'other' (8.3%; Figure 3.6).

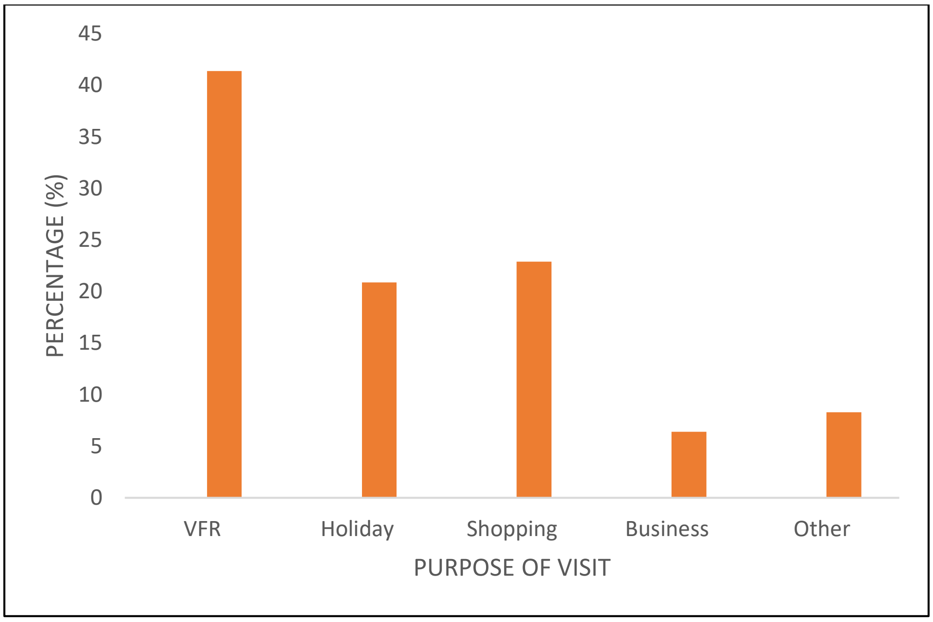

Figure 3.6: Main purpose of visit for international tourist arrivals in 2019 (adapted from DoT, 2020)

While focus has primarily been placed on international tourism in research, domestic tourism contributes to the economic and socio-cultural environments of South Africa (Rogerson, 2015). The DoT (2020) reported the number of domestic trips taken from 2015-2019 (Figure 3.7). It can be observed that a decrease in both day and overnight trips occurred from 2016 to 2018, however a large uptick is noted in day trips from 2018 to 2019 (115 to 225 respectively; Figure 3.7). Overnight trips remain low at 28 in 2019 (Figure 3.7).

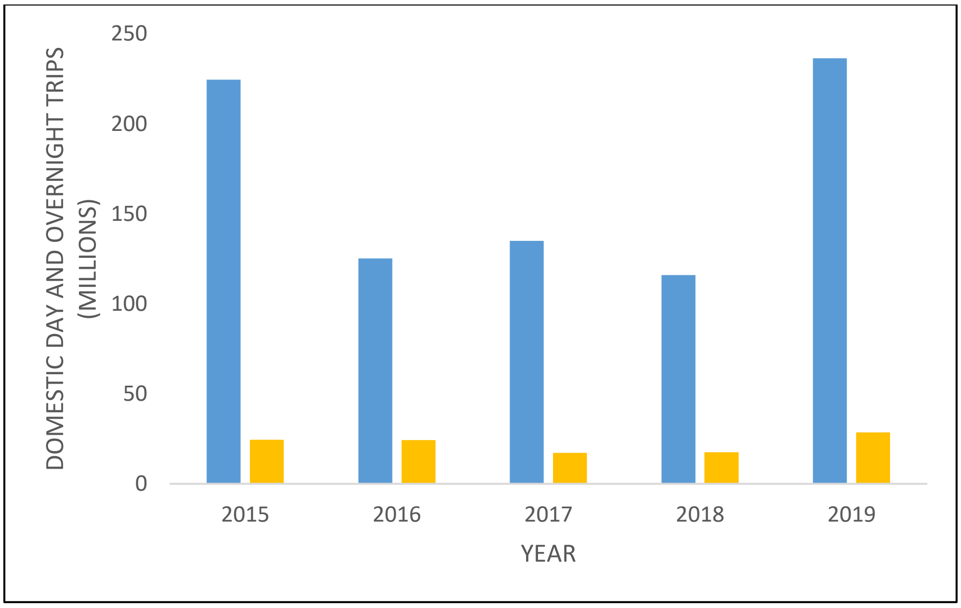

Figure 3.7: Number of domestic trips taken from 2015-2019 in South Africa (DoT, 2020). Day trips and overnight trips are represented by the blue and yellow bars respectively.

The DoT (2020) also reported the reasons for domestic trips in South Africa (Figure 3.8). Overnight trips remain low at 28 in 2019 (Figure 3.7). The main purpose for the day and overnight domestic trips includes visiting family and relatives (60.3%), holiday (28.4%), shopping (6%), business (3%) and other (1.7%; Figure 3.8).

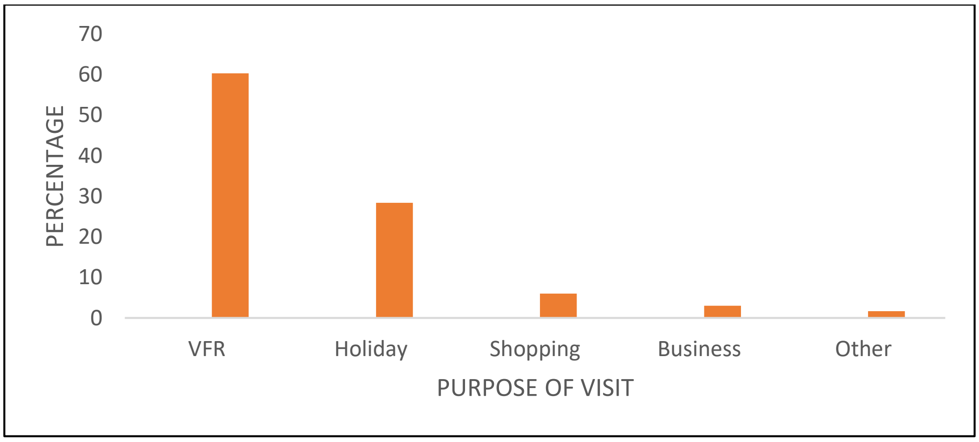

Figure 3.8: Main purpose of visit for domestic tourism in 2019 (adapted from DoT, 2020)

The DoT (2020) represented the provincial share of tourist arrivals (Figure 3.9), with the largest number of visits occurring in Gauteng (32.1%), Limpopo (21.9%) and Western Cape (19.6%). These provinces are followed by Mpumalanga and Free State with 16.7% and 10.1% respectively (Figure 3.9). The provinces with the lowest amount of tourist arrivals includes Northern Cape (1.2%), Eastern Cape (4.1%), North West Province (6%) and KwaZulu-Natal (7.8%; Figure 3.9).

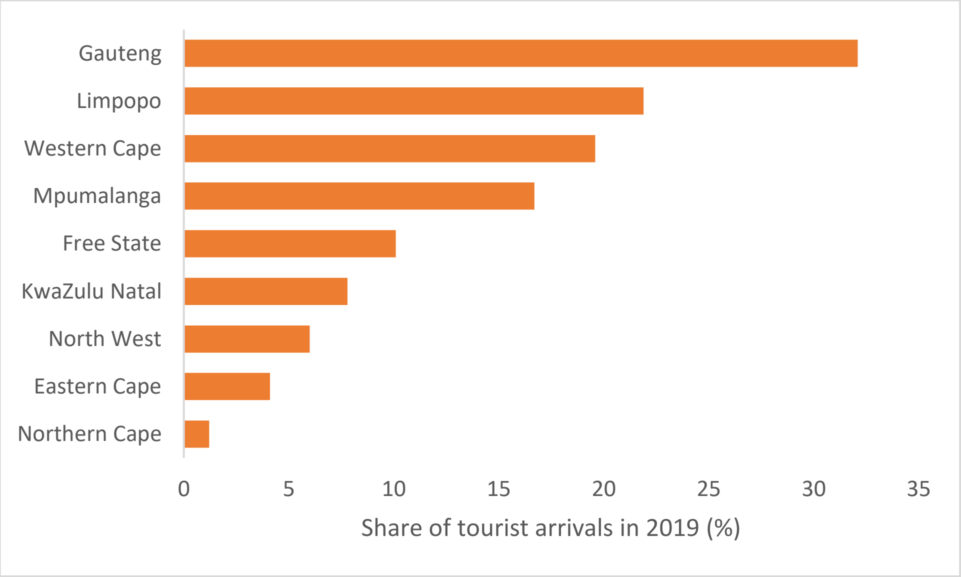

Figure 3.9: Provincial share of tourist arrivals in 2019 (DoT, 2020)

3.4.1. Nature-based tourism

Nature-based tourism includes travelling to natural areas to study, appreciate and enjoy the scenery and wildlife (Valentine, 1992). South Africa consists of a number of protected areas including 19 national parks which contribute to biodiversity conservation and nature-based tourism (Coldrey & Turpie, 2020). Coldrey and Turpie (2020) elaborated that national parks are found throughout South Africa and contain a wide range of vegetation and species that are conserved and act as a tourist offering (Figure 3.10). Dube & Nhamo (2020b) and Smith and Fitchett (2020) determined that nature-based tourism is under threat from a changing climate and that biodiversity may be negatively impacted upon, followed by tourist activities and the attractiveness of tourist destinations. Giddy (2016) emphasizes that a satisfactory environment plays a key role in enjoyment of nature-based adventure tourism.

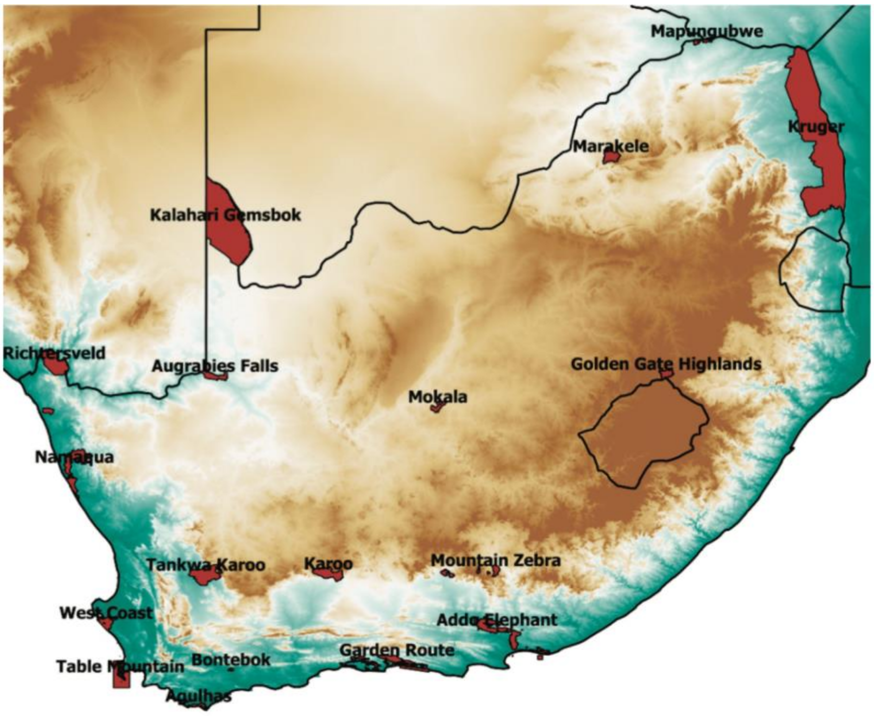

Figure 3.10: Map showing the 19 national parks in South Africa (Coldrey & Turpie, 2020)

3.4.2. Adventure tourism

Adventure tourism has been described as an extension of outdoor recreation that is not typically associated with beach or nature-based tourism experiences (Weber, 2001). McKay (2016) and Giddy (2016) add that adventure tourism involves some risk, uncertainty and challenge, and typically take place in outdoor natural environments. McKay (2016) determined that the Western Cape has the largest number of adventure tourism operators, followed by KwaZulu-Natal and Gauteng (Figure 3.11).

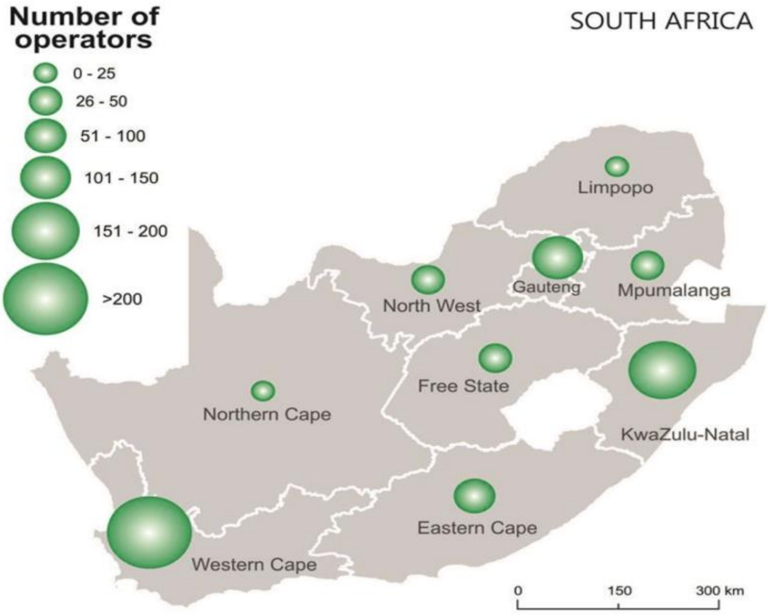

Figure 3.11: Number of tourism operators per province in South Africa (McKay, 2016)

3.4.3. Heritage tourism

Khumalo *et al*. (2014) describes heritage tourism as involving the appreciation of culture and heritage in a specific country, encompassing both industrial and liberation/struggle heritage. Heritage includes innate culture, traditions, customs, monuments and historical items (Khumalo *et al.*, 2014). Nine World Heritage Sites are located within South Africa, however many more sites can be found across South Africa, such as the Hector Pieterson Memorial and Museum and Robben Island which are located in Johannesburg and Cape Town respectively (van der Merwe, 2018; Figure 3.12). van der Merwe (2018) adds that there is a total of 51 911 heritage sites within South Africa.

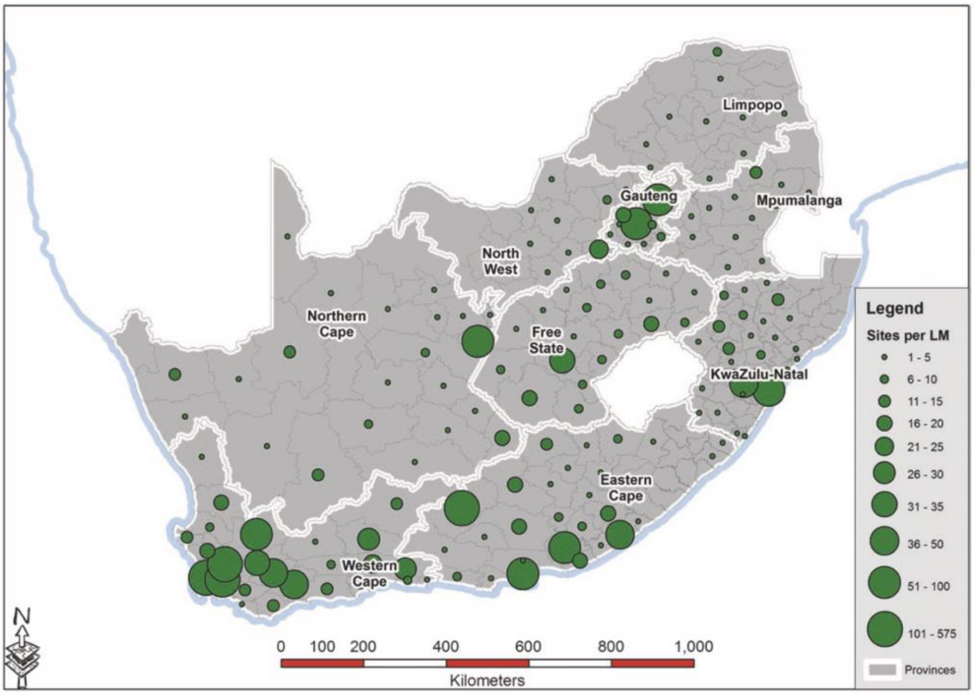

Figure 3.12: Number of heritage sites per local municipality in South Africa (van der Merwe, 2018).

3.4.4. Coastal tourism

Coastal tourism involves leisure and recreational activities that take place in the coastal zone including swimming, surfing, snorkeling, fishing and cruises (Hall, 2001). Slater and Mearns (2018) discussed the use of Blue Flag awards to indicate the quality of beaches, boats and marinas across the world, with South Africa having 45 Blue Flag beaches as of 2017/2018 (Figure 3.13). A clean and safe beach, as indicated by the Blue Flag status, will attract tourists to those specific beaches with this status (Slater & Mearns, 2018).

Figure 3.13: Blue Flag beaches along the South African coastline (Slater & Mearns, 2018)

3.4.5. Urban tourism

Urban tourism can simply be defined as tourism that occurs within towns and cities (Selby, 2004). The eight metropolitan areas in South Africa are located within five Provinces including Gauteng, KwaZulu-Natal, Eastern Cape, Western Cape and the Free State (Figure 3.14). The majority of the metropolitan areas are located on the coastline, with only two areas located inland (Rogerson & Rogerson, 2014; Figure 3.14).

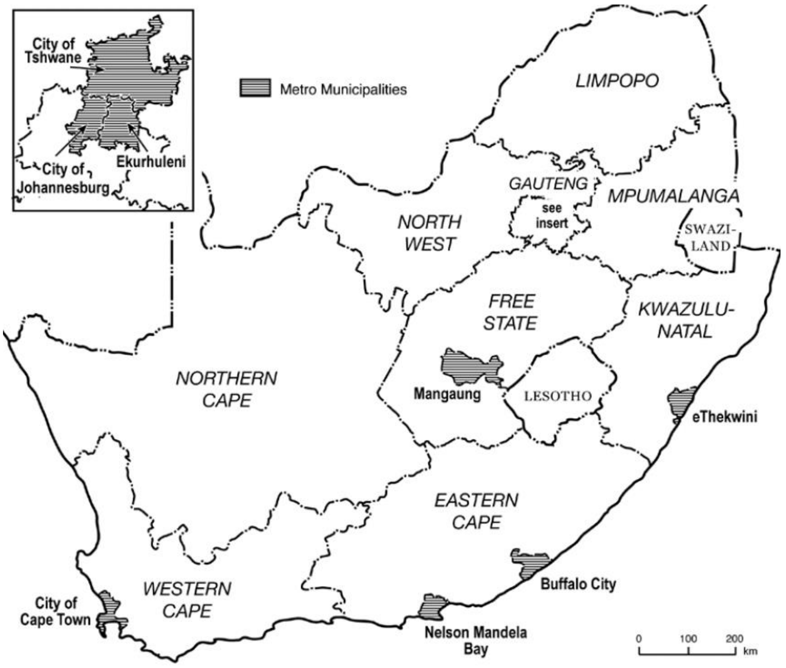

Figure 3.14: Metropolitan Municipal areas across South Africa (Rogerson & Rogerson, 2014)

The tourism destinations selected for this study include locations that have distinct climates and tourist attractions (Table 3.1). These destinations also have the required climate variables available from the South African Weather Service (SAWS) for the desired measurement period. These sites are ideal for the exploration of the climate suitability of destinations labelled as attractive for tourists. As many tourism activities take place outdoors, it can be said that these attractions are dependent on the climate of the area. Therefore, climate change can impact on tourism in these areas in the future.

Table 3.1: Tourist attractions surrounding chosen destinations

Destination	Annual Mean Temperature (°C)	Annual Mean Rainfall (mm)	Köppen Geiger Zone	Tourism attractions
Cape Town	16.4	621	Csb (Warm-summer Mediterranean climate)	Table Mountain National Park Kirstenbosch National Botanical Gardens Beaches (Clifton, Camps Bay, Boulders, Muizenburg) Victoria and Alfred Waterfront Robben Island Canal Walk Museums (Zeitz MOCAA, The Heart of Cape Town Museum, Iziko South African Museum) Two Oceans Aquarium Bo-Kaap Whale watching Wind surfing/Surfing/Diving Wine routes
Durban	20.9	893	Cfa (Humid subtropical climate)	uShaka Marine World Durban Botanical Gardens Golden Mile Indian Quarter Moses Mabhida Stadium Umgeni River Bird Park Beaches (North Beach, Addington Beach, uMhlanga Rocks, Bay of Plenty) Surfing/Snorkelling/Fishing/Diving
East London	19.4	843	Cfb (Temperate oceanic climate)	Beaches (Orient, Eastern, Nahoon, Gonubie) East London Museum Ann Bryant Art Gallery Khaya La Bantu Cultural Village Morgan Bay Cliffs Inkwenkwezi Nature Reserve Mpongo Private Game Reserve Esplanade dolphin watching Adventure trails/rock climbing Beach horseback riding Surfing
Johannesburg	15.9	784	Cwb (Subtropical highland climate)	Vilakazi Street Mandela House Soweto Towers Gold Reef City Maboneng Precinct Lion and Safari Park Cradle of Humankind Walter Sisulu National Botanical Gardens Market Theatre Museums (Apartheid, Hector Pieterson, Constitution Hill Human Rights Precinct, Wits Art Museum, Origins Centre, SciBono, Museum Africa)
Kruger National Park	22.5	540	Cwa (Monsoon-influenced humid subtropical climate)	Safari Luxury hotels Guided walking trails Archaelogical sites Hot air balloon rides

Destination	Annual Mean Temperature (°C)	Annual Mean Rainfall (mm)	Köppen Geiger Zone	Tourism attractions
Gqeberha	18.1	563	Cfb (Temperate oceanic climate)	Addo Elephant Park Beaches (Wells Estate, Humewood, Kings, Hobie, Sardinia Bay) The Boardwalk Kragga Kamma Game Park Route 67 Van Stadens Wildflower Reserve Cape Recife Nature Reserve South End Museum Storms River Bridge Whale/dolphin/penguin watching Wind surfing/Surfing/Snorkelling/Diving/Angling
Kimberley	18	283	BSk (Cold semi-arid (steppe) climate)	The Big Hole Complex Kimberley tram ride McGregor Museum Cathedral Church of St Cyprian the Martyr Wildebeest Kuil Rock Art Centre Kamfers Dam (flamingo watching) Mokala National Park
George	17.1	715	Cfb (Temperate oceanic climate)	Garden Route Botanical Gardens Herold Wine Estate Robertson Brewing Co. Outeniqua Transport Museum Outeniqua Pass Surfing Hiking Safari
Nieuwoudtville	11.7	114	BSk (Cold semi-arid (steppe) climate) / BWk (Cold desert climate)	Namaqualand daisies Neo-Gothic Sandstone Church Historical Sandstone Ruins Glacial Pavement Rock art Nieuwoudtville Wild Flower Reserve Hantam National Botanical Garden Oorlogskloof Nature Reserve Nieuwoudtville Waterfall Reserve Hiking/cycling/4X4 routes/stargazing
Upington	21.6	219	BWh (Hot desert climate)	Orange River Cellars Bezalel Wine & Brandy Estate Kgakagadi Transfrontier Park Sakkie se Arkie (river cruise) Kalahari-Oranje Museum Kalahari Safaris
Bethlehem	14.7	845	Cwa (Monsoon-influenced humid subtropical climate)	LIONSROCK Big Cat Sanctuary Basotho Cultural Village Maluti Mountain Adventures De Wild Adventures Bethlehem Museum Clarens Golden Gate National Park Hiking trails/River rafting
Mafikeng	18.5	571	BSh (Hot semi-arid (steppe) climate)	Mafikeng Game Reserve Botsalano Game Reserve Mafikeng Museum Horse trails Adventure tourism (river rafting) River cruises Wondergat Diving

Destination	Annual Mean Temperature (°C)	Annual Mean Rainfall (mm)	Köppen Geiger Zone	Tourism attractions
Polokwane	18	661	BSk (Cold semi-arid (steppe) climate) / Cwb (Subtropical highland climate	Polokwane Game Reserve Bakone Malapa Open-Air Museum Polokwane Art Museum Magoebaskloof Canopy Tour Polokwane Bird and Reptile Park
Sutherland	13.7	333	BWk (Cold desert climate) / BSk (Cold semi-arid (steppe) climate	Southern Africa Large Telescope Sutherland Planetarium Sutherland NG Kerk Sutherland museum Bird watching Adventure tourism (hiking, biking, 4X4, horse riding) Fossil exhibition (Sterland)
Bloemfontein	17.1	545	BSk (Cold semi-arid (steppe) climate	Free State National Botanical Garden Museums (Oliewenhuis Art, National Museum Bloemfontein, War Museum of the Boer Republics Bloemfontein) Bagamoya Wildlife Estate Franklin Nature Reserve Naval Hill Planetarium

3.5.Conclusion

All destinations include some form of outdoor tourism (Table 3.1) and therefore all destinations selected for this study are influenced by outdoor climatic conditions. While tourism attractions were considered, a balance between coastal and inland tourism destinations and an even distribution through the provinces was attempted.

CHAPTER 4. METHODS

4.1. Introduction

To achieve the aim of determining if the HCI_{urban} and HCI_{beach} are suitable for the South African context, secondary data on air conditioning availability for accommodation establishments across South Africa was obtained and further analysed. Following this, the calculation of the HCI for 13 destinations across South Africa was facilitated by meteorological data sets acquired from the SAWS. HCI calculations were performed using the collected and cleaned data for each destination to obtain the HCI scores over the longest period, common period and monthly. Statistical analyses were then performed for the changes over time. This chapter outlines the above in more detail by explaining the process followed for determination of the suitability of the HCI_{urban} and HCI_{beach}, data collection, calculation of the HCI_{urban} and HCI_{beach} scores and the statistical analyses used to analyse trends and changes in the HCI scores over time.

4.2. Determining air conditioning availability across South Africa

Using the Tourism Grading Council of South Africa's (TGCSA) website, accommodation establishments located within popular tourism destinations across South Africa were identified. The types of accommodation establishments that are listed on the TGSCA website are formal accommodation (hotel, apartment hotel, boutique hotel and small hotel), guest accommodation (bed & breakfasts, country houses and guest houses), self-catering accommodation (exclusive and shared), game lodge, nature lodge, backpackers and hotels, caravan and camping sites and venues. As this research is focused on tourist comfortability, all accommodation types were considered, with the exception of venues. Using the accommodation booking website, Booking.com, the availability of air conditioning at each accommodation establishment listed on the TGCSA website was identified. This information was used to determine the percentage of air conditioning availability in tourist accommodation establishments across South Africa. It was then determined if the HCI is applicable for the South African context based on the key assumption that all accommodation establishments have air conditioning.

4.3. Climate Data Acquisition

To calculate the longest period, common period and monthly HCI scores for South Africa, climate data for each location was sourced from SAWS (Table 4.1). The climate data required to calculate the HCI_{urban} and HCI_{beach} input variables are selected based on the work of Scott *et al*. (2016) and Rutty *et al*. (2020) respectively, which includes the daily maximum temperature, daily average humidity, daily average rainfall, daily average wind speed and daily cloud cover.

Table 4.1: Data available from SAWS for the destinations used in this study

Destination	**TMax**	**Humidity**	**Rainfall**	**Wind speed**	**Cloud cover**
Cape Town	1991 - 2021	1991 - 2021	1991 - 2021	1991 - 2021	1992 - 2021
Durban	1991 – 2021	1991 – 2021	1991 – 2021	1991 – 2021	1991 – 2021
East London	1991 – 2021	1991 – 2021	1991 – 2021	1991 – 2021	1997 - 2021
Johannesburg	1991 – 2021	1991 – 2021	1991 – 2021	1991 – 2021	1991 – 2021
Kruger National Park	2008 - 2021	2008 - 2021	2008 - 2021	2008 - 2021	2008 - 2021
Gqeberha	1991 – 2021	1991 – 2021	1991 – 2021	1991 – 2021	1992-2021
Kimberley	1992 - 2021	1991 - 2021	1992 - 2021	1991 - 2021	1992 - 2021
George	1991 – 2021	1991 – 2021	1991 – 2021	1991 – 2021	1992-2021
Upington	1991 - 2021	1991 - 2021	1991 - 2021	1991 - 2021	1991 - 2021
Bethlehem	1991 - 2021	1991 - 2021	1991 - 2021	1991 - 2021	1991 - 2021
Mafikeng	1991 - 2021	1991 - 2021	1991 - 2021	1991 - 2021	1991 - 2021
Polokwane	1991 – 2021	1991 – 2021	1991 – 2021	1991 – 2021	1991 – 2021
Bloemfontein	1991-2021	1991-2021	1991-2021	1991-2021	1992 – 2021

4.3.1. Cloud Cover Data

The cloud cover data supplied by SAWS is recorded in oktas. Oktas is a unit of measure for cloudiness and is measured on a scale from 0 to 8 (Doorenbos & Pruitt, 1977). The HCI requires cloud cover as a percentage and therefore the common conversion of 12.5% for 1 okta was used to calculate this percentage (Silva & Souza-Echer, 2016). Daily cloud cover measurements were provided for 08:00, 14:00 and 20:00. Due to the HCI being developed predominantly for daytime activities of tourists, and based on the assumption that tourists are indoors with air conditioning at night, the 14:00 cloud cover measurements were used as the input variable for cloud cover.

4.4. HCI Calculation

The $\text{HCI}_{\text{urban}}$ used in this study was originally developed in a dissertation by Tang (2013) and later published by Scott *et al.* (2016). The HCI was formulated to include the three aspects of climate that are most relevant to tourism: thermal comfort, physical and aesthetic components (de Freitas, 2008). Rutty *et al.* (2020) subsequently developed the $\text{HCI}_{\text{beach}}$, also calculated in this study, to compensate for different tourist preferences when visiting beach destinations. The HCI makes use of five daily climate variables that fall under the thermal comfort, physical and aesthetic aspects including: maximum air temperature and relative humidity (thermal comfort), cloud cover (aesthetic), and precipitation and wind speed (physical) (Tang, 2013; Scott *et al.*, 2016). The original $\text{HCI}_{\text{urban}}$ developed by Tang (2013) and Scott *et al.* (2016) is given as $HCI_{urban} = 4(\text{TC}) + 2(\text{A}) + (3(\text{P}) + \text{W})$, and the $\text{HCI}_{\text{beach}}$ developed by Rutty *et al.* (2020) is given as $HCI_{beach} = 2(TC) + 4(A) + (3(P) + W)$ where TC is thermal comfort, A is aesthetic, P is precipitation and W is wind.

Both HCI calculations make use of maximum daily temperature due to the representation of threshold climate conditions experienced during the day, when tourist activities are at their highest (Tang, 2013; Scott *et al.*, 2016). The thermal comfort facet makes use of effective temperature which combines maximum daily air temperature and relative humidity (Scott *et al.*, 2016). The aesthetic facet is calculated using daily cloud cover percentage due to increased availability of this data (Scott *et al.*, 2016). Precipitation and wind, under the physical facet, is calculated using daily measurements (Scott *et al.*, 2016). These four components are assigned weights according to their perceived importance in terms of tourism, indicated by the number preceding the components of the calculations. Each climate component is rated in terms of Table 4.2 prior to being inserted in the calculations.

Table 4.2: Ratings of TC, P, W and C components of the $\text{HCI}_{\text{urban}}$ and $\text{HCI}_{\text{beach}}$ (Scott *et al.*, 2016 & Rutty *et al.*, 2020)

Rating	**$\text{HCI}_{\text{urban}}$**				**$\text{HCI}_{\text{beach}}$**			
	Thermal Comfort	**Precipitation**	**Wind**	**Cloud Cover**	**Thermal Comfort**	**Precipitation**	**Wind**	**Cloud Cover**
-10			>70		≤9.9		70.0	
-5					10.0-14.9			
-1		>25.00				25.00		
0	≥39	>12.00	50-70		≥39.0 15.0-16.9	12.00-24.99	50.0-69.9	
1	≤-6			100	17.0-17.9			
2	37-39 -1 - -5	9.00-12.00		90-99	38.0-38.9 18.0-18.9			≥96.0
3	0-6		40-49	81-90	19.0-19.9		40.0-49.9	86.0-95.9
4	35-36 7-10			71-80	37.0-37.9 20.0-20.9	9.00-11.99		76.0-85.9
5	33-34 11-14	6.0-8.99		61-70	36.0-36.9 21.0-21.9			66.0-75.9
6	31-32 15-17		30-39	51-60	35.0-35.9 22.0-22.9	6.00-8.99	30.0-39.9	56.0-65.9

Rating	**HCI_{urban}**				**HCI_{beach}**			
	Thermal Comfort	**Precipitation**	**Wind**	**Cloud Cover**	**Thermal Comfort**	**Precipitation**	**Wind**	**Cloud Cover**
7	29-30 18-19			41-50	34.0-34.9 23.0-25.9			46.0-55.9
8	27-28	3.00 - 5.99	0 20-29	0 31-40	33.0-33.9	3.00-5.99	0-0.5 20.0-29.9	0-0.9 36.0-45.9
9	26 20-22	<3.00	10-19	1-10 21-30	31.0-32.0 26.0-27.9	0.01-2.99	10.0-19.9	1.0-14.9 26.0-35.9
10	23-25	0.00	1-9	11-20	28.0-30.9	0	0.6-9.99	15.0-25.9

Once the HCI calculations have been determined, a descriptive category can be assigned to the result (Table 4.3). These categories indicate the conditions most preferred by the majority of tourists, from ideal (scores closer to 100) where all 3 facets are within the preferred range, to scores of less than 40 which are deemed unacceptable by the majority of tourists (Scott *et al.*, 2016). It is important to note that no index score is assigned the category of ‘impossible’ as adverse weather conditions may be what tourists seek, however the category of ‘dangerous’ is assigned.

Table 4.3: HCI descriptive category scheme (Scott et al., 2016 & Rutty et al., 2020)

HCI Score	**Descriptive category**
90-100	Ideal
80-89	Excellent
70-79	Very good
60-69	Good
50-59	Acceptable
40-49	Marginal
30-39	Unacceptable
20-29	Unacceptable
10-19	Unacceptable
0-9	Dangerous

4.5. Spatial distribution of the HCI

Scott and McBoyle's (2001) annual climatic typology distributions were used to classify the ideal time of year for tourism across the destinations in South Africa selected for this study. The six typologies include year-round optimal, summer peak, winter peak, bi-modal shoulder peak and dry season peak (Scott & McBoyle, 2001; Figure 4.1). The typologies were originally developed for the northern hemisphere, and therefore the timing and thus visual appearance of the summer and winter peak curves differ for the southern hemisphere. Mean monthly HCI scores were averaged to produce an annual score that was used to determine the classification of each destination.

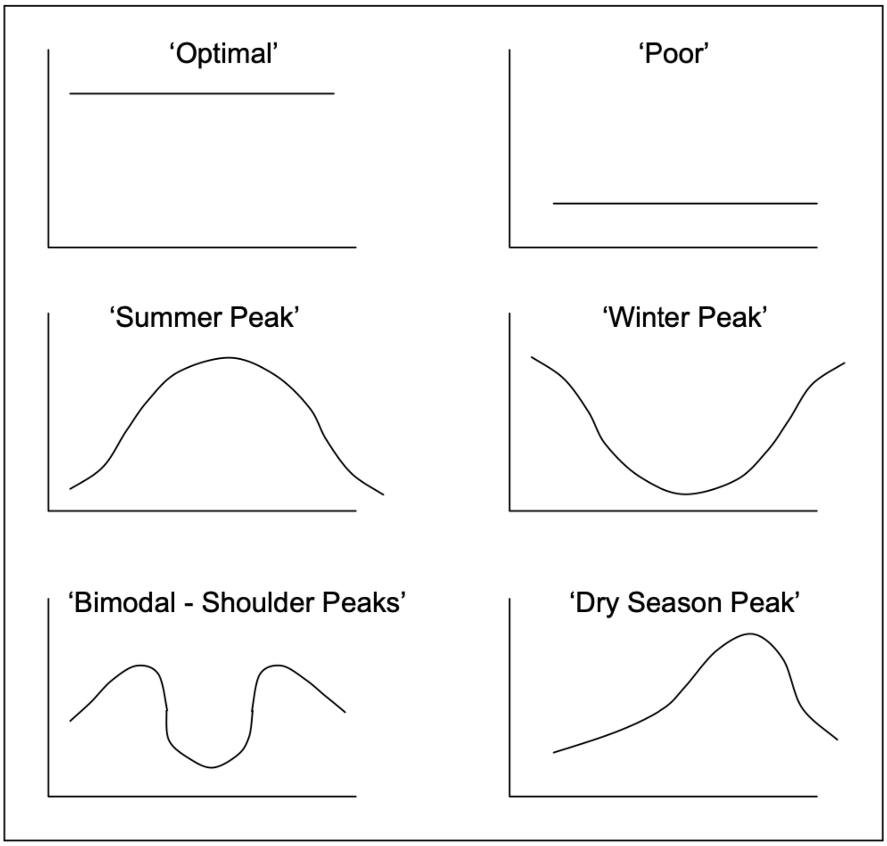

Figure 4.1: Climate typology distributions of Scott and McBoyle (2001)

4.6. Statistical analyses of trends in the HCI values

To determine if climate variability and/or climate change has an effect on the climate suitability of a destination for tourism, a change in HCI scores would be observed for the study period. Correlation analysis was used to identify the direction and strength of these changes in the HCI scores (Fitchett, 2013). Manly (2009) explains that correlation analysis assists in identifying a relationship between an independent (in this case time) and dependent variable (in this case HCI scores). For this study, correlation analysis was performed for the longest continuous period and for each month for each destination to determine the direction of the trends and magnitude. The Pearson correlation coefficients were calculated using the following formula (Underhill and Bradfield, 2009):

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}}$$

Once the trends were identified for each destination over the longest continuous period and for each month, the rate of change of the HCI scores was determined using linear regression analyses:

$$y = ax + b$$

The results of this analysis were presented as changes in the HCI scores per year, and for each month per year. The percentage by which changes in time account for changes in the HCI scores was determined by calculating the coefficient of determination (R_2; Underhill & Bradfield, 2009):

$$R^2 = \frac{b(\Sigma XY - \frac{\Sigma X \Sigma Y}{N})}{(\Sigma Y^2 - \frac{(\Sigma Y)^2}{2}}$$

The result of this formula is between 0 and 1 with values closer to 1 representing the majority of the change in the HCI results as a result of changes in time (Underhill & Bradfield, 2009).

4.7. Conclusion

The following Results chapter presents the outcomes of following the methodology detailed in this chapter. A look into the applicability of the HCI for the South African context is followed by calculations of the HCI_{urban} and $HCI_{beach.}$ Further analysis into the trends over the longest continuous period of data availability is then completed. Based on the HCI results, the annual climatic typology distributions will also be explored in the following chapter.

CHAPTER 5. RESULTS

5.1. Introduction

The findings of this study are presented in this chapter. This study made use of daily-resolution meteorological data including maximum temperature, minimum temperature, rainfall, relative humidity, wind speed and cloud cover from 13 weather stations distributed across South Africa. This data was used to calculate the climatic suitability for tourism at these destinations. This chapter begins with an analysis of the prevalence of air conditioning across South Africa to evaluate the suitability of the HCI. This is followed by the results of the HCI_{urban} and HCI_{beach} calculations through an annual mean, monthly mean and seasonal distribution of the HCI scores. The factors that influence the HCI were determined through identification of the components of the HCI that increase or decrease the final HCI score.

5.2. Air conditioning availability across South Africa

A key assumption of the HCI is the ubiquity of air conditioning, which led to the exclusion of night-time thermal comfort from the index. Challenges in this assumption are clear for research in Zimbabwe, and so therefore it is important to first evaluate the prevalence of air conditioning in South Africa before applying the index. An analysis of the accommodation listings on TGCSA with air conditioning reveals that average air conditioning availability across all destinations is 58% (Table 5.1). This is likely the result of the wide range of climatic conditions across the country. It can be observed that destinations with a warmer climate such as Durban, Pilanesberg and Kimberley have a higher percentage of air conditioning availability (Table 5.1). The lowest percentage of air conditioning availability in accommodation establishments was determined to be 8% in Port Nolloth, while the highest was 93% in St Lucia (Table 5.1). Nine of the 18 destinations have air conditioning availability above 50% (Table 5.1). Based on the average across all destinations, air conditioning in tourism accommodation across South

Africa is prevalent. Therefore, the HCI can be used to determine climatic suitability for tourism in South Africa. However, caution should be maintained when applying and interpreting the HCI in South Africa, as not all accommodation establishments have air conditioning available, and as there is a considerable diurnal temperature range across all of the South African climate zones.

Table 5.1: Air conditioning availability at accommodation establishments across South Africa

Destination	Accommodation Establishments listed on TGCSA	Air conditioning available	Percentage of establishments with air conditioning
Johannesburg	1536	613	40%
Cape Town	4275	2017	47%
Durban	1131	884	78%
Polokwane	177	108	61%
Pilanesburg	16	14	88%
Kimberley	147	121	82%
Port Nolloth	12	1	8%
Paarl	120	104	87%
Knysna	514	181	35%
Gqeberha	401	162	40%
East London	458	181	40%
Bloemfontein	344	261	76%
Bethlehem	58	28	48%
Ladysmith	29	26	90%
St Lucia	180	167	93%
Mbombela	222	167	75%
Ermelo	50	6	12%
Pretoria	1088	501	46%

5.3. HCI_{urban}

5.3.1. Mean annual HCI scores

The mean annual HCI_{urban} scores for the study sites range from 67 ('good') for Durban (HCI_{urban}) to 79 ('very good') for Cape Town (HCI_{urban}; Table 5.2). All of the remaining destinations fall within the 'very good' climate rating. In the years 1994, 2001, 2011, 2014, 2015 and 2018, the highest scores of 79, 78, 78, 79, 79 and 78 respectively were calculated for both Cape Town and Johannesburg. Polokwane recorded the same scores in 2014 (79) and 2015 (79). Mahikeng and George experienced the same scores in 2015 (79) and 2001 (78) respectively. The highest scores of 79, 78, 78, 79, 79, 79 and 79 for the years 1991, 1999, 2002, 2005, 2007, 2012 and 2013 respectively were calculated for Johannesburg. Bethlehem recorded the same scores in 1991 (78) and 1999 (78). The highest score for 2021 of 79 was also calculated for Bethlehem, and additionally Cape Town. It was calculated that Cape Town had the highest scores for the years 1991 (82), 1993 (79), 1996 (78), 1997 (79), 1998 (78), 2000 (80), 2001 (79), 2003 (79), 2004 (79), 2006 (79), 2010 (79), 2016 (78), 2019 (80) and 2020 (79). Mahikeng recorded the same scores as recorded in 2016 (78) and 2019 (80). George recorded the same scores as recorded for Cape Town in 1998 (78) and 2001 (78). The highest score for 2009 (79), was also calculated in George. Gqeberha recorded the highest score for 1995 of 79. Lastly, Polokwane and Kruger Mpumalanga recorded the highest scores for the years 2017 (80) and 2008 (84) respectively. The lowest scores for the years 1991 (68), 1992 (65), 1993 (67), 1994 (70), 1995 (69), 1996 (68), 1997 (67), 1998 (67), 1999 (66), 2000 (67), 2001 (69), 2002 (68), 2003 (68), 2004 (68), 2005 (68), 2006 (67), 2008 (69), 2008 (69), 2009 (68), 2010 (64), 2011 (66), 2012 (65), 2013 (67), 2014 (69), 2015 (67), 2016 (68), 2018 (63), 2020 (66) and 2021 (56) were calculated for Durban. Additionally, Bloemfontein experienced the lowest score for 2002 (68). Kruger Mpumalanga recorded the lowest scores of 68, 70 and 65 for the years 2009, 2017 and 2019 respectively.

Table 5.2: Mean annual HCI_{urban} score for each destination from 1991 to 2021

Destination	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	**Average**
Bethlehem	79	77	78	78	75	75	76	77	78	76	76	75	75	76	77	75	76	76	74	76	76	76	77	78	77	74	79	77	77	77	79	**77**
Bloemfontein		77	71	72	72	69	70	69	70	72	71	68	72	73	73	71	71	70	70	69	71	72	74	71	72	70	73	73	72	70	71	**71**
Cape Town (HCI_{urban})		83	79	79	77	78	79	78	77	80	78	77	79	79	78	79	77	78	78	79	78	78	78	79	79	78	79	78	80	79	79	**79**
Durban (HCI_{urban})	68	65	67	70	69	68	67	67	66	67	69	68	68	68	68	67	69	69	69	64	66	65	67	69	67	68	71	63	69	66	56	**67**
East London (HCI_{urban})							76	73	73	73	74	73	74	74	76	72	74	74	75	72	73	74	77	75	74	73	74	74	74	74	74	**74**
George (HCI_{urban})		77	76	77	77	77	78	78	76	79	78	77	78	77	77	76	77	78	79	77	77	76	78	77	75	76	78	77	78	76	77	**77**
Gqeberha (HCI_{urban})					79	75	78	76	75	77	77	76	75	75	77	75	76	76	76	75	76	75	77	75	76	75	76	75	76	75	76	**76**
Johannesburg	79	77	78	79	78	76	75	77	78	77	78	78	78	77	79	77	79	77	76	76	78	79	79	79	79	77	78	78	78	77	78	**78**
Kimberley		81	74	74	74	72	73	72	73	73	71	74	77	73	75	73	75	74	74	73	71	73	76	74	74	74	74	75	72	70	73	**74**
Kruger Mpumalanga																		84	68	66	69	71	70	70	72	71	70	67	65	67	67	**70**
Mahikeng	76	77	77	76	74	74	76	76	74	75	75	76	78	76	76	74	76	75	75	76	76	78	77	77	79	78	77	77	80	78	76	**76**
Polokwane	76	79	77	77	74	73	73	74	76	76	74	76	75	76	76	75	76	76	74	73	74	77	76	79	79	75	80	76	76	76	76	**76**
Upington	71	82	73	74	73	75	76	75	73	74	73	73	73	72	74	74	75	75	75	73	72	73	77	75	75	75	75	76	76	75	75	**74**

Score	90-100	80-89	70-79	60-69	50-59	40-49	30-39	20-29	10-19	9-0
Descriptive rating	Ideal	Excellent	Very good	Good	Acceptable	Marginal	Unacceptable	Unacceptable	Unacceptable	Dangerous

Gqeberha (HCI_{urban}) for the longest continuous period (1992-2021) experienced a negative trend of 0.05 units per year (r=0.39, p=0.0400; Table 5.3). Should this trend continue, the classification would change from ‘very good’ (76 in 2021) to ‘good’ (69) in 140 years (2161). It is important to note that the time period analysed is slightly shorter than the study period due to cloud data only being available from 1992-2021. This trend is predominately controlled by fluctuations in wind speed (km/h) and daytime thermal comfort, which incorporate the maximum daily temperature (°C) and mean daily humidity (%) to calculate Humidex which is used to run the HCI model.

Table 5.3: Time trends for annual HCI scores for the longest continuous period, and over the common period (2008–2021) for the selected destinations across South Africa

Destination	**Period**	**Rate of Change (HCI Score/per year)**	**r-value**	**p-value**
Bethlehem	1991-2021	0.01	0.05	0.7848
	2008-2021	0.20	0.57	0.0332
Bloemfontein	1992-2021	-0.00	0.01	0.9587
	2008-2021	0.11	0.31	0.2856
Cape Town (HCI_{urban})	1992-2021	-0.01	0.07	0.7043
	2008-2021	0.08	0.54	0.0459
Durban (HCI_{urban})	1991-2021	-0.09	0.30	0.1076
	2008-2021	-0.32	0.36	0.2007
East London (HCI_{urban})	1997-2021	0.01	0.08	0.6963
	2008-2021	0.00	8.06E-03	0.9782
George (HCI_{urban})	1992-2021	-0.01	0.12	0.5379
	2008-2021	-0.08	0.30	0.2969
Gqeberha (HCI_{urban})	1992-2021	-0.05	0.39	0.0424
	2008-2021	-0.02	0.13	0.6562
Johannesburg	1991-2021	0.02	0.14	0.4625
	2008-2021	0.07	0.27	0.3483
Kimberley	1992-2021	-0.06	0.24	0.1984
	2008-2021	-0.09	0.23	0.426

Destination	**Period**	**Rate of Change (HCI Score/per year)**	**r-value**	**p-value**
Kruger Mpumalanga	2008-2021	-0.56	0.51	0.0622
Mahikeng	1991-2021	0.08	0.52	0.0030
	2008-2021	0.20	0.57	0.0339
Polokwane	1991-2021	0.04	0.22	0.2467
	2008-2021	0.17	0.34	0.229
Upington	1991-2021	0.03	0.13	0.4959
	2008-2021	0.13	0.41	0.1415

By contrast, Mahikeng experienced a positive trend of 0.08 units per year over the longest continuous period (1991-2021) and 0.03 units per year over the common study period (2008-2021; Table 5.3). Should this trend continue, the classification would change from ‘very good’ (76 in 2021) to ‘excellent’ (80) in approximately 50 years (2071). As with Gqeberha, this trend is predominately controlled by fluctuations in daytime thermal comfort. Cape Town (HCI_{urban}) experienced a positive trend of 0.08 units per year associated with fluctuations in cloud cover, thermal comfort and rainfall for the common period (r=0.54, p=0.0500; Table 5.3). Should this trend continue, the classification would change from ‘very good’ (79 in 2021) to ‘excellent’ (80) in 12.5 years (2033). Lastly, a positive trend of 0.20 units per year is noted for the common period for Bethlehem (r= 0.57, p=0.0300; Table 5.3). Should this trend continue, the classification would change from ‘very good’ (79 in 2021) to ‘excellent’ (80) in five years (2026). This is predominantly affected by thermal comfort and cloud cover.

5.3.2. Mean monthly HCI scores

The highest mean monthly HCI scores are predominantly recorded in June and include ‘excellent’ ratings for Bloemfontein (86), East London (84), George (82), Gqeberha (81), Kruger Mpumalanga (86), Polokwane (90) and Upington (88; Table 5.4). The same ‘excellent’ scores were calculated for Bloemfontein, East London, Kruger Mpumalanga and Upington in July. Durban also recorded the highest score in July (83; ‘excellent’; Table 5.4). ‘Excellent’ ratings were recorded in October for Cape Town (83) and Mahikeng (80; Table 5.4). The same ‘excellent’ rating was calculated for Mahikeng in May. The highest score for Kimberley (86; ‘excellent’) was also calculated in May (Table 5.4). The same score for Kimberley was calculated in April. Gqeberha (81) and Johannesburg (87) recorded ‘excellent’ ratings in September (Table 5.4).

Table 5.4: Mean monthly HCI scores for the selected destinations across South Africa for the longest continuous period

Study Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Bethlehem	64	66	73	83	86	80	80	85	85	78	72	66
Bloemfontein	53	54	58	72	82	86	86	85	81	72	65	57
Cape Town (HCI$_{urban}$)	74	72	75	79	82	78	79	78	81	83	82	78
Durban (HCI$_{urban}$)	53	52	57	66	75	82	83	80	74	68	62	57
East London (HCI$_{urban}$)	63	62	65	73	80	84	84	81	80	76	73	68
George (HCI$_{urban}$)	71	70	72	77	81	82	81	80	80	79	78	76
Gqeberha (HCI$_{urban}$)	68	66	70	76	79	81	80	80	81	79	77	73
Johannesburg	67	69	75	84	85	79	79	85	87	79	73	68
Kimberley	55	55	62	76	86	86	85	86	83	75	68	60
Kruger Mpumalanga	54	54	57	69	80	86	86	81	72	66	60	55
Mahikeng	72	70	75	79	80	76	76	75	77	80	79	76
Polokwane	61	61	66	77	87	90	89	88	82	75	67	62
Upington	57	57	61	74	84	88	88	86	84	77	71	63

90-100	Ideal
80-89	Excellent
70-79	Very good
60-69	Good
50-59	Acceptable
40-49	Marginal
30-39	Unacceptable
20-29	Unacceptable
10-19	Unacceptable
9-0	Dangerous

The lowest HCI scores are predominantly recorded in February for Cape Town (72; ‘very good’), Durban (52; ‘acceptable’), East London (62; ‘good’), George (70; ‘very good’), Gqeberha (66; ‘good’), Kimberley (55; ‘acceptable’), Kruger Mpumalanga (54; ‘acceptable’), Mahikeng (70; ‘very good’), Polokwane (61; ‘good’) and Upington (57; ‘acceptable’ Table 5.4). The same scores were also calculated for January for Kimberley, Kruger Mpumalanga, Polokwane and Upington. The lowest HCI scores for Bethlehem (64; ‘good’), Bloemfontein (53; ‘acceptable’) and Johannesburg (67; ‘good’) were calculated for January (Table 5.4). Positive trends of 0.52, 0.45 and 0.58 units per year are calculated for the period 2008-2021 for the months of January, May and June in Bethlehem (r=0.58, p=0.0300; r=0.62, p=0.0200; r=0.58, p=0.0300 respectively). Located within the same province and within relative proximity to Bethlehem, is Bloemfontein, which experienced a similar positive trend of 0.52 units per year for the month of June (r=0.56, p=0.3600).

George, located along the south coast in the Western Cape, experienced a positive trend of 0.42 units per year for the common period (2008-2021) in the monthly HCI score for June (r=0.70, p=0.0050). These trends are interesting to note as this is usually not part of the typical tourist season due to it being winter. In the Eastern Cape, East London and Gqeberha experienced a positive trend of 0.29 and 0.37 units per year for the month of June over the common period (r=0.55, p=0.0400; r=0.61, p=0.0200 respectively). These trends may be predominantly driven by an increasing Humidex and decreasing wind speed and cloud cover. Kimberley, located within the Northern Cape experienced a positive trend of 0.65 units per year for the month of June over the common period (2008-2021; r=0.74, p=0.0030). In the same period, negative trends of 1.19 and 0.51 units per year were calculated for April and December (r=0.69, p=0.0060; r=0.54, p=0.0500) respectively. This is concerning as December falls within the most popular tourism season. The predominant factor affecting the HCI scores in April and

December is the increase in Humidex. Upington, located further west in the province, demonstrates a positive trend of 0.27 units per year for the month of June over the common period (r=0.67, p=0.0100).

In the North West Province, Mahikeng experienced positive trends of 0.8 and 0.47 units per year for March and May over the common period (2008-2021; r=0.65, p=0.0100; r=0.66, p=0.0100 respectively). Polokwane, located in Limpopo, experienced a positive trend of 0.12 units per year in the month of May for the common period (2008-2021; r=0.65, p=0.0100). In Mpumalanga, Kruger Mpumalanga experienced a negative trend of 0.45 units per year for August over the common period (r=0.56, p=0.0400). The negative trend is predominantly driven by the increase in thermal comfort and cloud cover.

5.3.3. Seasonal tourism climate typologies

Based on Scott and McBoyle’s (2001) seasonal classifications of climatic suitability for tourism, none of the selected destinations across South Africa fall into the year-round poor conditions or year round optimal conditions category.The bi-modal shoulder peak distribution is observed for four of 13 destinations for which HCI_{urban} was calculated (Figure 5.1). These destinations experience climatic conditions that are more suitable during spring or autumn.

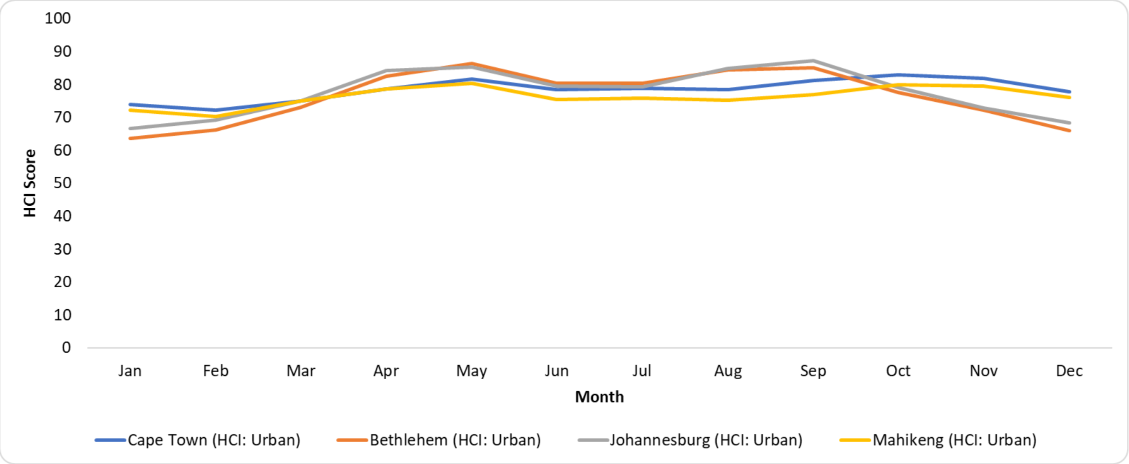

Figure 5.1: Destinations categorised as having a bi-modal shoulder peak tourism climate distribution

The winter season peak distribution is observed for seven of the 13 destinations for which HCI_{urban} was calculated (Figure 5.2). This distribution indicates that climate conditions are most suitable for tourism during winter. Durban and East London are included in this distribution, which is a result of these destinations being located on the eastern coast of South Africa where the warm ocean current regulates the temperature during winter. The occurrence of the majority of the HCI_{urban} inland destinations in this category could be explained by the minimal rainfall experienced during winter, which adds to the suitability for tourism during this time. The temperatures experienced in summer at these destinations can be very hot and these destinations also experience summer rainfall which reduces the suitability for tourism activities.

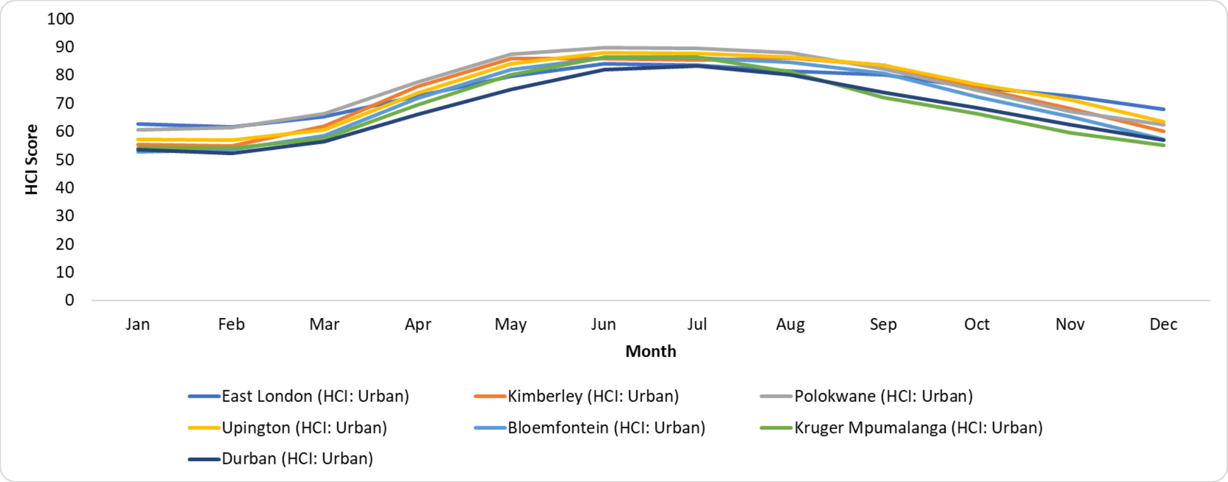

Figure 5.2: Destinations categorised as having a winter peak tourism climate distribution

Two of the 13 destinations for which HCI$_{\text{urban}}$ was calculated do not have distinct classifications (Figure 5.3) and therefore climate conditions that are most suitable for tourism cannot be assigned to any specific season. Notably these two destinations are both located on the southern coast of South Africa, although East London, located in close proximity to Gqeberha has a distinct winter peak. This could be the result of the position of the boundary of the year-round rainfall zone.

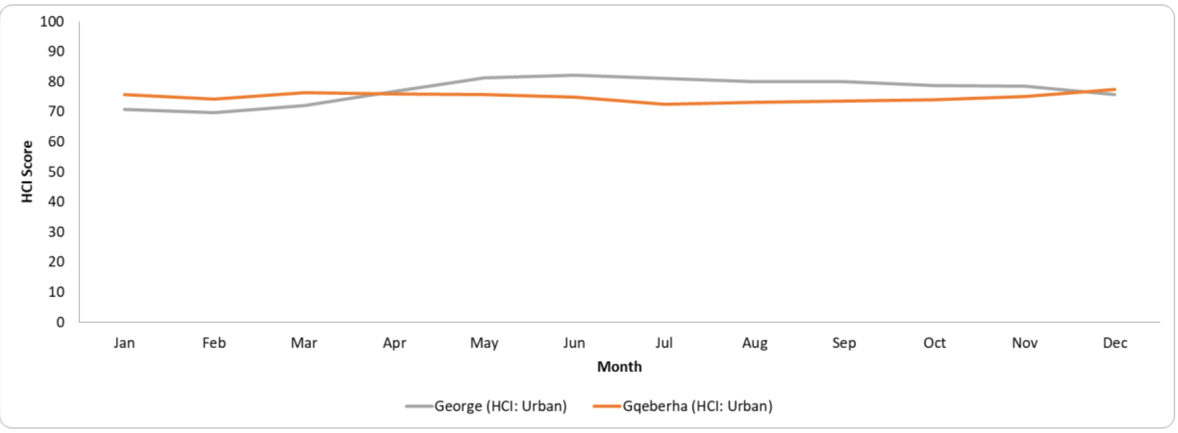

Figure 5.3: Destinations without a distinct seasonal tourism climate typology

5.3.4. Factors influencing the HCI$_{urban}$ score

The most frequently highest rated HCI$_{urban}$ components, according to the results from the HCI$_{urban}$ calculation, that increase the score are wind and rainfall. Thermal comfort (consisting of relative humidity and temperature) and cloud cover decreases the HCI$_{urban}$ score (Figure 5.4). Wind speed is a positive factor for the HCI$_{urban}$ for all destinations, with majority of the average destination scores being above 9 for wind speed, which means that the study areas experience wind speeds that range from 10-19km/h. Average scores just below 9 were assigned to East London and Gqeberha (8.7 and 8.3 respectively), which means that these destinations experience wind speeds of 0km/h or speeds that range from 20-29km/h. The majority of average destination scores were rated as 9 (Figure 5.4).

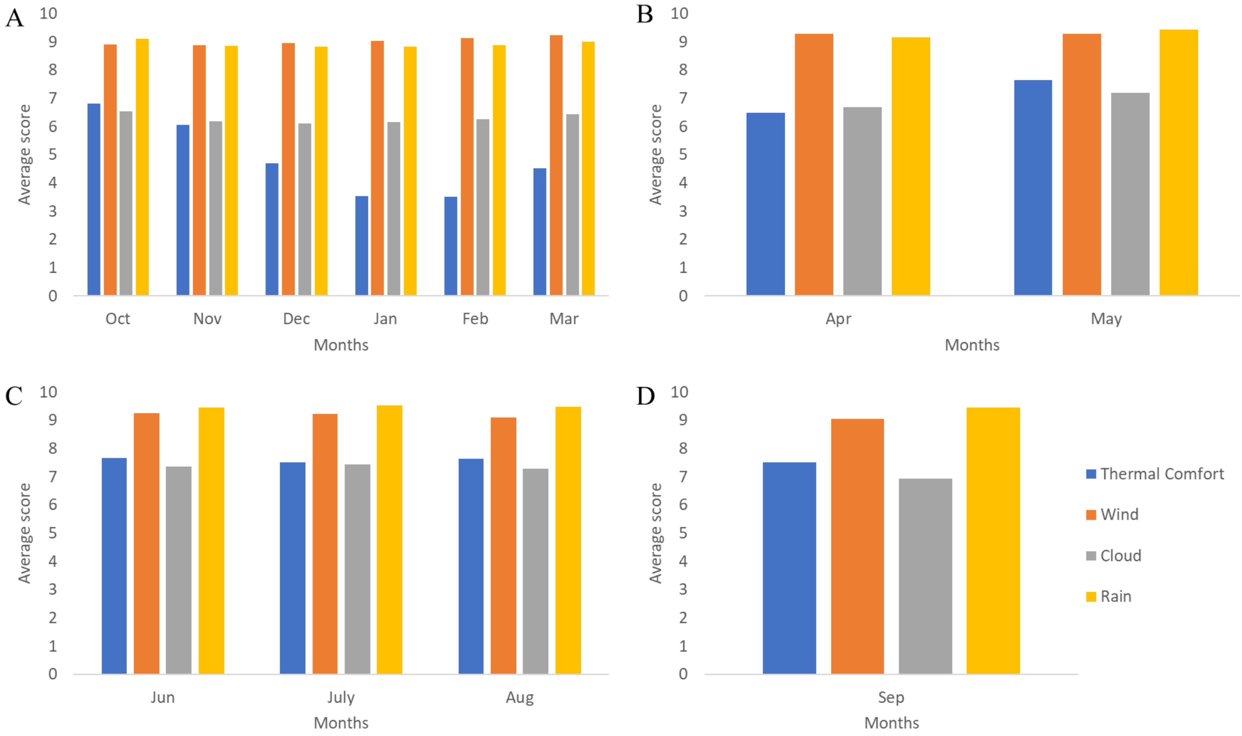

Figure 5.4: Factors that influence the HCI$_{urban}$ scores for the study destinations. From top left: a) summer, b) autumn, c) winter and d) spring.

The relatively low rainfall across South Africa, by international standards, is a positive factor for the HCI$_{urban}$ for all destinations, with the majority of the destinations average scores being above 9 for rainfall. This means that the study areas experience rainfall that ranges from 0.01-2.99mm. Average scores just below 9 were assigned to East London and Durban (8.9 and 8.8 respectively), which means that these destinations experience rainfall of 3.00-5.99mm. The majority of average destination scores were rated as 9 (Figure 5.4). The rating systems used for each climatic factor differs mostly with thermal comfort and cloud cover, which have shown a more negative impact on the HCI_{urban} scores. Thermal comfort is a negative factor for the HCI_{urban} scores, with the majority of the destinations experiencing average scores below 7 for thermal comfort. This means that the study areas experience thermal comfort that ranges from 7-17 or 31°C-36°C. The majority of average destination scores were rated as 9 (Figure 5.4). Half of the average destination scores were rated as 6 or below (Figure 5.4). Cloud cover, although not having as much of a negative influence on the HCI_{urban} scores, is still a negative factor for the HCI_{urban} scores, with the majority of destinations recording scores below 7 for cloud cover. This means that the study areas experience thermal comfort that ranges from 51-60°C. The majority of average destination scores were however rated as 7 (Figure 5.4).

5.4. HCI_{beach}

5.4.1. Mean annual HCI scores

The mean HCI_{beach} scores for the study sites range from 72 for Durban (HCI_{beach}) to 78 good' for Cape Town (Table 5.5). The majority of the highest scores, ranging from 'very good' to 'excellent' were recorded in Cape Town including the years 1992 (82), 1993 (77), 1994 (79), 1995 (75), 1996 (76), 1997 (77, shared with Gqeberha), 1998 (77), 1999 (78), 2000 (80), 2001 (76; shared with George), 2002 (77), 2003 (79), 2004 (79), 2005 (77), 2006 (78), 2007 (76; shared with Gqeberha), 2008 (77), 2009 (77), 2010 (78), 2011 (78), 2012 (76), 2013 (76; shared with George and East London), 2014 (79), 2015 (79), 2016 (78), 2017 (79), 2018 (78), 2019 (80), 2020 (78) and 2021 (78). The majority of the lowest scores were recorded in Durban including the years 1992 (69), 1996 (72), 1997 (71), 1998 (73), 1999 (74), 2000 (73), 2001 (75; shared with East London and Gqeberha), 2002 (73), 2003 (74; shared with Gqeberha), 2004 (74), 2005 (74), 2007 (74), 2008 (73), 2009 (73), 2010 (71), 2011 (71), 2012 (69), 2013 (72), 2014 (73), 2015 (72), 2016 (71), 2017 (73), 2018 (71), 2019 (72), 2020 (71) and 2021 (65). The highest scores for 1993 and 1994, 73 and 74 respectively, were recorded in George. In 2006, the highest score of 71 was calculated for East London. The highest and lowest scores for 1991 cannot be analysed due to a full set of climate data only being available for Durban.

Table 5.5: Mean yearly HCI_{beach} score for each destination from 1991 to 2021

Destination	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	**Average**
Cape Town (HCI_{beach})		82	77	79	75	76	77	77	78	80	76	77	79	79	77	78	76	77	77	78	78	76	76	79	79	78	79	78	80	78	78	**78**
Durban (HCI_{beach})	73	69	74	76	74	72	71	73	74	73	75	73	74	74	74	72	74	73	73	71	71	69	72	73	72	71	73	71	72	71	65	**72**
East London (HCI_{beach})							75	74	75	75	75	74	75	76	76	71	75	74	75	73	72	73	76	77	74	75	74	76	76	76	75	**75**
George (HCI_{beach})		71	73	74	73	74	76	75	75	77	76	75	76	76	76	72	75	75	76	74	74	73	76	74	73	74	76	75	76	74	73	**75**
Gqeberha (HCI_{beach})					73	74	77	75	76	76	75	74	74	76	76	73	76	76	75	75	73	72	75	74	74	75	75	75	76	75	75	**75**

Score	90-100	80-89	70-79	60-69	50-59	40-49	30-39	20-29	10-19	9-0
Descriptive rating	Ideal	Excellent	Very good	Good	Acceptable	Marginal	Unacceptable	Unacceptable	Unacceptable	Dangerous

All of the destinations fall within the ‘very good’ climate rating. Tourists visiting all selected destinations are likely to have good conditions for beach visits. Only one destination, Durban (HCI_{beach}), demonstrates a significant negative trend for the longest continuous period (1991-2021; r=0.29, p=0.1200; Table 5.6). This trend equates to a decrease in the HCI score of 0.09 units per year. Should this trend continue, the classification would change from ‘good’ (65 in 2021) to ‘acceptable’ (59) in 67 years (2088). This trend is predominantly controlled by fluctuations in cloud cover (%) and daytime thermal comfort.

Table 5.6: Statistical values representing time trends for the longest continuous period and over the common period (2008-2021) for the selected destinations across South Africa

Destination	**Period**	**Rate of Change (HCI Score/per year)**	**r-value**	**p-value**
Cape Town (HCI_{beach})	1992-2021	0.02	0.10	0.6103
	2008-2021	0.14	0.51	0.0639
Durban (HCI_{beach})	1991-2021	-0.11	0.46	0.0095
	2008-2021	-0.22	0.44	0.117
East London (HCI_{beach})	1997-2021	0.03	0.16	04555
	2008-2021	0.17	0.50	0.0693
George (HCI_{beach})	1992-2021	0.02	0.09	0.6298
	2008-2021	-0.03	0.12	0.6857
Gqeberha (HCI_{beach})	1992-2021	-0.01	0.06	0.7754
	2008-2021	0.06	0.21	0.4658
	2008-2021	0.13	0.41	0.1415

5.4.2. Mean monthly HCI scores

The highest HCI scores are predominantly recorded in December for Cape Town (84; ‘excellent’), George (77; ‘very good’) and Gqeberha (77; ‘very good’; Table 5.7). The same scores were calculated for Cape Town and George in January and May respectively. East

London also recorded the highest score in May, and also in June (80;' excellent'). The highest score for Durban (84;' excellent') is calculated for June.

Table 5.7: Mean monthly $\text{HCI}_{\text{beach}}$ scores for the selected destinations across South Africa

Study Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Cape Town ($\text{HCI}_{\text{beach}}$)	84	83	83	81	75	69	69	69	74	80	83	84
Durban ($\text{HCI}_{\text{beach}}$)	63	63	67	74	81	84	83	81	75	69	66	64
East London ($\text{HCI}_{\text{beach}}$)	70	70	72	75	80	80	78	77	76	72	72	72
George ($\text{HCI}_{\text{beach}}$)	75	76	76	76	77	74	73	72	72	72	74	77
Gqeberha ($\text{HCI}_{\text{beach}}$)	76	74	76	76	76	75	73	73	73	74	75	77

90-100	Ideal	50-59	Acceptable	10-19	Unacceptable
80-89	Excellent	40-49	Marginal	9-0	Dangerous
70-79	Very good	30-39	Unacceptable		
60-69	Good	20-29	Unacceptable		

The lowest scores for Durban (63; 'good') and East London (60; 'good') are calculated for both January and February. The lowest scores are predominantly recorded in August for Cape Town (69; 'good'), George (72; 'very good') and Gqeberha (73; 'very good'). The same scores for Cape Town, George and Gqeberha are calculated for June and July, September and October and July and September respectively. A positive trend of 0.71 units per year was calculated for Cape Town over the common period (2008-2021) in the monthly HCI score for September, which is a month that falls outside of the typical tourist season ($r=0.56$, $p=0.0400$). George, located in the same province, experienced a positive trend of 0.87 units per year in June ($r=0.87$, $p=<0.0001$). This trend is interesting to note as this is usually not part of the typical tourist season due to it being winter. In contrast, a negative trend of 0.45 units per year ($r=0.64$, $p=0.0100$) was calculated for the month of March for George ($\text{HCI}_{\text{beach}}$) in the common period. An increase in cloud cover and rainfall are the predominant factors affecting the HCI score for these months. In the Eastern Cape, East London and Gqeberha experienced a positive trend of

0.82 and 0.94 units per year for the month of June over the common period (r=0.83, p=0.0003; r=0.76, p=0.0020) respectively. These trends may be predominantly driven by an increasing Humidex and decreasing wind speed and cloud cover.

5.4.3. Seasonal tourism climate typologies

None of the selected destinations for which HCI_{beach} was calculated across South Africa fall into the year-round poor conditions or year-round optimal conditions category. The summer season peak distribution is observed for one of five destinations for which HCI_{beach} was calculated (Figure 5.5). This destination does not have favourable conditions for tourism in winter, however, the climatic conditions during summer are more suitable for tourism. Cape Town may be situated within the summer season peak due to its location within a winter rainfall zone which experiences cold temperatures and wet weather simultaneously.

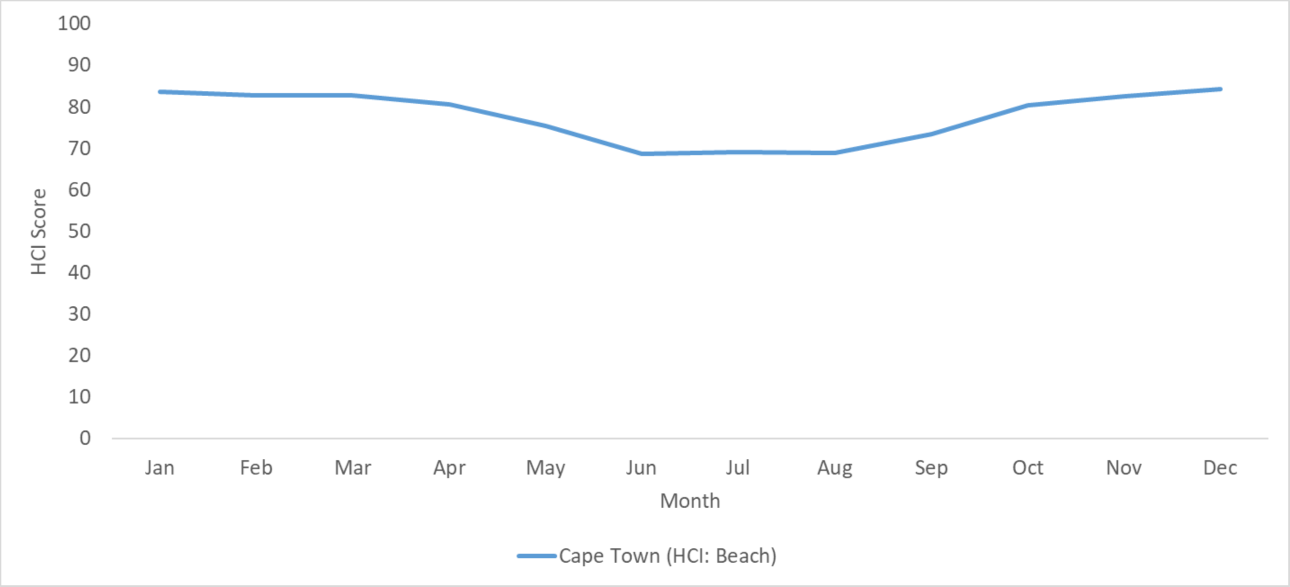

Figure 5.5: Destinations categorised as having a summer peak tourism climate distribution

The winter season peak distribution is observed for three of the five HCI_{beach} destinations for which the HCI_{beach} was calculated (Figure 5.6). This distribution indicates that climate conditions are the most suitable for tourism during winter. All coastal destinations other than Cape Town and George are reflected in this distribution, which is a result of these destinations being located mostly on the eastern coast of South Africa where the warm ocean current regulates the temperature during winter.

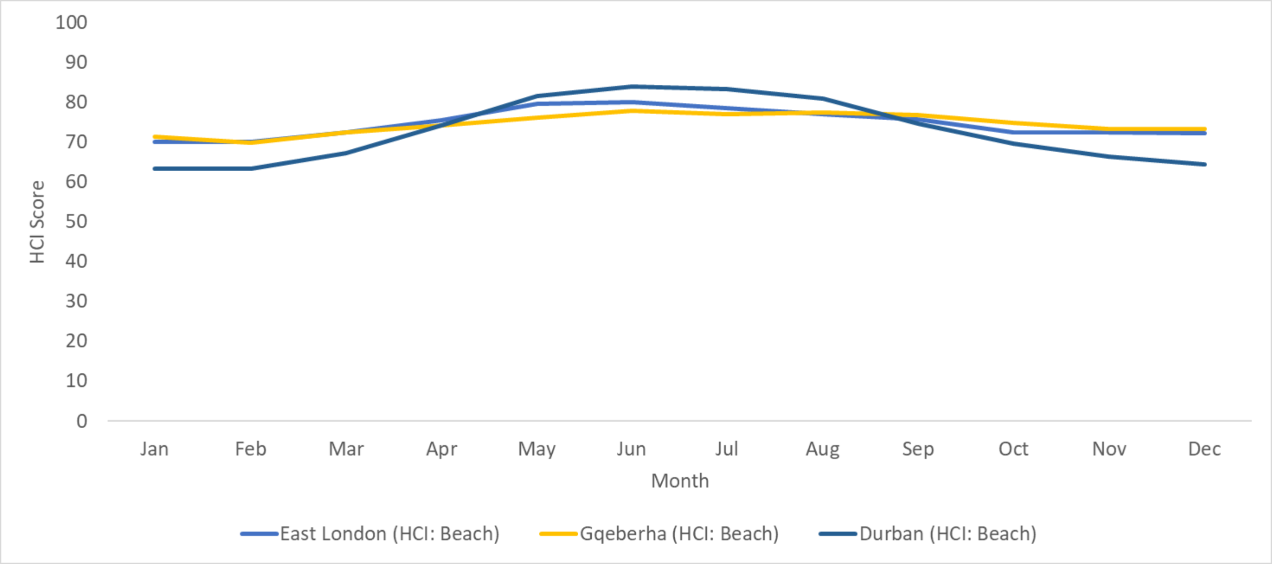

Figure 5.6: Destinations categorised as having a winter peak tourism climate distribution

One of the five HCI_{beach} destinations for which HCI_{beach} was calculated, George, does not have a distinct classification (Figure 5.7), with monthly scores ranging from 72-77, and therefore climate conditions that are most suitable for tourism cannot be assigned to any specific season. Notably, George did not have a clear seasonal distribution in HCI_{urban} scores either.

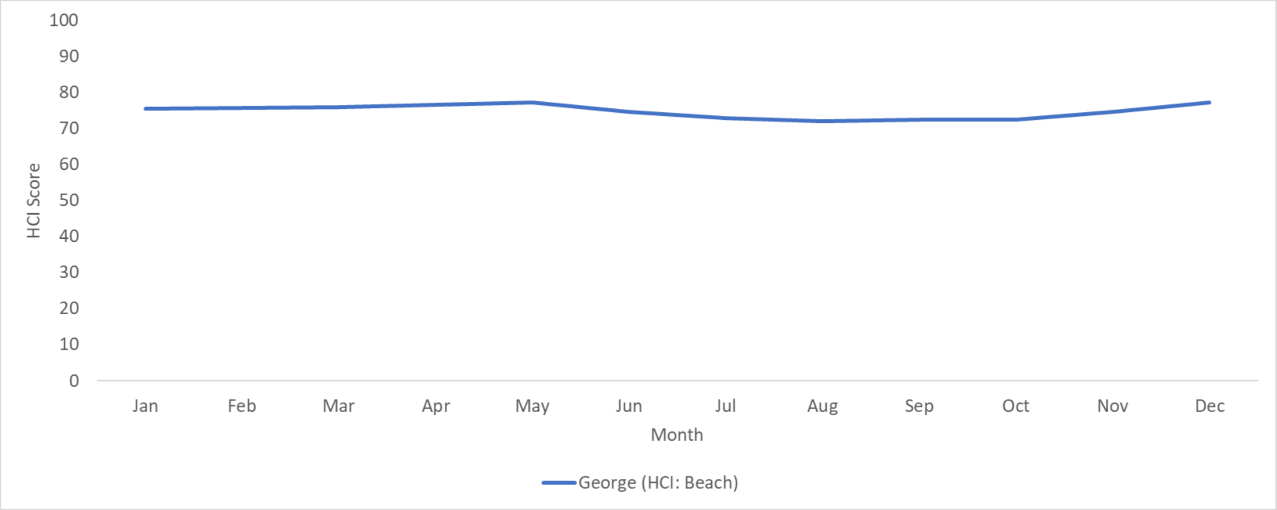

Figure 5.7: Destinations without a distinct seasonal tourism climate typology

5.4.4. Factors influencing the $\mathrm{HCI}_{\mathrm{beach}}$ score

The most frequently highest rated $\mathrm{HCI}_{\mathrm{beach}}$ components that increase the score are wind and rainfall. Thermal comfort and cloud cover decreases the $\mathrm{HCI}_{\mathrm{beach}}$ score (Figure 5.8). Wind speed is a positive factor for the $\mathrm{HCI}_{\mathrm{beach}}$ scores for all destinations, with majority of the average destination scores being above 9 for wind speed. This means that the study areas experience wind speeds that range from 10-19km/h. Average scores just below 9 were assigned to East London and Gqeberha (8.7 and 8.3 respectively), which means that these destinations experience wind speeds of 0km/h or speeds that range from 20-29km/h. The majority of average grouped monthly scores were rated as 9 (Figure 5.8).

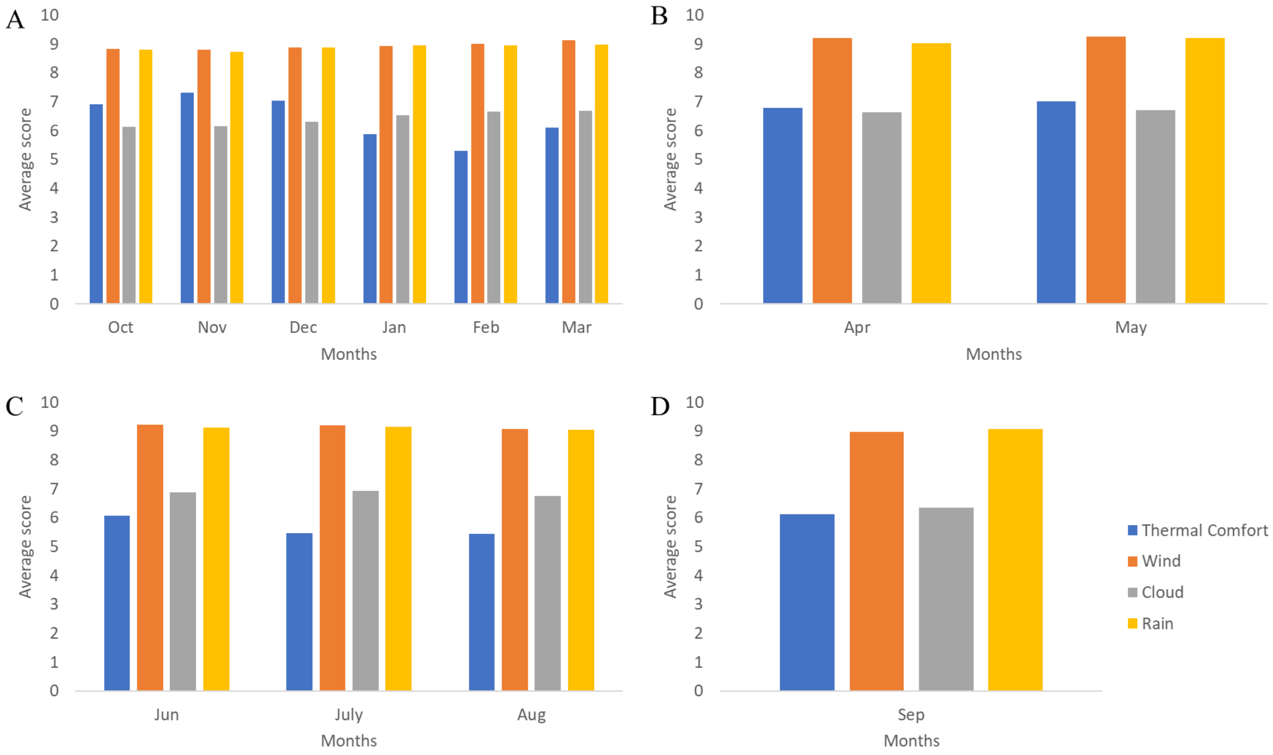

Figure 5.8: Factors that influence the HCI_{beach} scores for the destinations. From top left: a) summer, b) autumn, c) winter and d) spring.

Rainfall is a positive factor for the HCI_{beach} scores of all destinations, with the majority of the destinations average scores being above 9 for rainfall. This means that the study areas experience rainfall that ranges from 0.01-2.99mm. Average scores just below 9 were assigned to East London and Durban (8.9 and 8.8 respectively), which means that these destinations experience rainfall of 3.00-5.99mm. The majority of average destination scores were rated as 9 (Figure 5.8). Thermal comfort is a negative factor for the HCI_{beach} scores, with the majority of the destinations recording average scores below 7 for thermal comfort. This means that the study areas experience thermal comfort that ranges from 21-22.9°C or 35-36.9°C. The majority of average destination scores were rated as 9 (Figure 5.8). Just over half of the scores for HCI_{urban} had ratings of 6 or below (Figure 5.8). Cloud cover, although not having much of a negative influence on the HCI_{beach} scores, is still a negative factor for the HCI_{beach} scores. The majority of destinations recorded scores below 7 for cloud cover, which means that the study areas experience thermal comfort that ranges from 56-65.9%. The majority of average destination scores were however rated as 7 (Figure 5.8).

5.5. Coastal cities

A comparison can be made of the climatic suitability calculated from the HCI_{beach} and HCI_{urban} for those destinations that are located along the coastline with beach attractions, but which also have an urban centre namely Cape Town, Durban, East London, George and Gqeberha. For all destinations, except Durban, the difference in average annual HCI scores is minimal, with Cape Town (HCI_{beach}: 78, HCI_{urban}: 79), East London (HCI_{beach}: 75, HCI_{urban}: 74), George (HCI_{beach}: 75, HCI_{urban}: 77) and Gqeberha (HCI_{beach}: 75, HCI_{urban}: 76) falling into the ‘very good’ category for both calculations. Durban (HCI_{beach}: 72, HCI_{urban}: 67) recorded a notable difference with the rating for HCI_{urban} falling into the ‘good’ category, demonstrating that the climate is more suitable for beach tourism.

In terms of monthly average HCI scores, Durban is calculated to have the highest scores for both HCI_{beach} (84) and HCI_{urban} (83) in the winter months (June/July). The HCI_{beach} (80) and HCI_{urban} (84) for East London are highest in the late autumn/winter (May/June) and winter months (June/July) respectively. A similar trend is recorded for George with the highest scores for both HCI_{beach} (77) and HCI_{urban} (82) in late autumn (May) and winter (June) respectively. However, the highest score for HCI_{beach} is also recorded in summer (December). Cape Town and Gqeberha have the greatest variability in the highest scores throughout the year. The highest scores for HCI_{beach} (84) and HCI_{urban} (83) in Cape Town are however both recorded in summer (December and January for HCI_{beach} and October for HCI_{urban}). The highest scores for HCI_{beach} (77) and HCI_{urban} (81) in Gqeberha are recorded in summer (December), winter (June) and spring (September) respectively.

5.6. Conclusion

The results present a picture that all the selected tourist destinations fall within the ‘very good’ category, with the exception of Durban (HCI_{urban}), which sits at a ‘good’ rating. Based on McBoyle’s (2001) seasonal classification, the seasons with the highest scores observed are winter or spring and autumn. The factors that influence the HCI_{urban} and HCI_{beach} scores positively are wind and rainfall due to the low wind speeds and decreased rainfall for the destinations. The factors that influence the HCI_{urban} and HCI_{beach} scores negatively are thermal comfort and cloud cover due to the higher temperatures and humidity, and the increased cloud cover for the destinations. In terms of the destinations that function as both an urban and beach destination, the average difference in the HCI_{urban} and HCI_{beach} scores is minimal. The exception is Durban on the east coast, which is observed to have a climate more suitable to beach tourism. The following chapter will dive into a discussion behind the results presented here.

CHAPTER 6. DISCUSSION

6.1. Introduction

The aim of this study was to determine the applicability and suitability of the HCI across South Africa, followed by calculating the current suitability of the climate for tourism based on climate data obtained from 1991-2021 for 13 destinations. This facilitates an understanding of the potential changes in climate suitability for tourism under a changing climate in South Africa. The results of this study are presented in Chapter 5 (Results). This chapter will reflect on the results of this study in the context of global literature. This chapter comprises five sections starting with the appropriateness of the HCI for South Africa. This section examines air conditioning availability in tourism establishments across the country, compares the HCI results to the TCI results calculated for 18 destinations in South Africa and analyses TripAdvisor reviews mentioning climatic variables. This is followed by a look into the climatic suitability for tourism across the country, split into an analysis of the HCI_{urban} and HCI_{beach} results across the year and seasonally. Lastly, climatic suitability for tourism in South Africa under a changing climate has been analysed in terms of the potential impact on the HCI. The final part of the chapter discusses the limitations faced during this study covering data constraints and the methods of adapting to these.

6.2. Appropriateness of the HCI for South Africa

6.2.1. Night-time thermal comfort

In the past, some tourism indices such as the TCI (Mieczkowski, 1985) have included mean daily temperature. Recent indices such as the CCI (Ma *et al*., 2020) have also made use of daily mean air temperature, thus not eliminating the effect of night-time temperatures on tourists. However, a couple of indices have chosen to include the maximum temperature only, including the HCI and the SKI (Demiroglu *et al*., 2021). For the SKI, the thermal comfort range is defined within a range of -7 to 2℃ for 09:00-18:00 every day to account for the effects of relative humidity sub-diurnally throughout the time when skiing will take place (Demiroglu *et al*., 2021). The CIT, a beach tourism index (de Freitas *et al*., 2008), makes use of actual observations of tourists rather than average data. Interviewed tourists were required to provide their preferences for weather conditions based on a beach visit for the purpose of a picnic or a day out at the beach (de Freitas *et al*., 2008). With this in mind, it is clear that night-time thermal comfort is not a consideration for the CIT. Thermoregulation is linked to the mechanism regulating sleep, and therefore night-time thermal comfort is an important consideration as disturbed sleep can have an impact on daytime activities of tourists (Okamoto-Mizuno & Mizuno, 2012). Tourists who wish to engage in night-time activities such as game drives, will also be impacted upon by night-time thermal comfort and therefore it is an important consideration for this type of tourism (Mushawemhuka, 2021).

A key assumption of the HCI is that the inclusion of night-time thermal comfort is unnecessary because air conditioning is available in all accommodation establishments, and tourist activities are at their highest during the day (Tang, 2013; Scott *et al*., 2016). While this may be a correct assumption for destinations such as those within developed countries, only 50% of accommodation establishments in South Africa have air conditioning available (Table 5.1). In the neighboring country of Zimbabwe, Mushawemhuka *et al*. (2020) also highlight that very few establishments are air conditioned, and even if they are, rolling blackouts in the country prevent the use of these systems. A similar problem of rolling blackouts is faced in South Africa, known as ‘loadshedding’ (Muller, 2023). The growing demand for electricity in South Africa is not being met by the principal electricity supplier, Eskom (Makgopa & Mpetsheni, 2022).

There are three quality classifications under which accommodation establishments can be grouped when taking into consideration the varied levels of inequality in South Africa. The first quality classification includes the luxury accommodation establishments that can be expected to include amenities such as air conditioning, daily servicing of rooms, internet access, laundry service and room service (TGSCA, 2019). It can safely be assumed that these facilities are financially able to provide a backup source of power such as generators, inverters or stored solar power, and therefore air conditioning use will not be interrupted (Oseni & Pollitt, 2013). Tembe and Hlengwa (2022) note that a large number of accommodation establishments interviewed as part of their study on strategies used by bed and breakfast establishments and guesthouses to manage load shedding, have adopted strategies such as solar panel, gas and generator installation. It is important to note that tourism activities may include activities that fall outside of the daytime period and outside of establishments with air conditioning, including night-time game drives as part of nature-based tourism, which is a common type of tourism in South Africa (Boshoff *et al.*, 2007). In the case of luxury establishments, aside from nature-based outdoor activities, it can be assumed that guests will be able to visit establishments such as restaurants or shopping malls where uninterrupted air conditioning may be provided. Based on this quality classification, the HCI is an appropriate index to use in determining climatic suitability of destinations within South Africa.

The second quality classification includes more intermediate class establishments. In this case, depending on the location, some establishments may have air conditioning available, and some may not. It can also not be guaranteed that these establishments will have backup power available to keep these systems running during loadshedding due to the installation cost of these solutions. The HCI may not be the most reliable index to use should a more intermediate class accommodation establishment be selected. This is based on the fact that night-time temperatures may not be able to be controlled through air conditioning in all cases. The HCI is not a reliable index for budget accommodation establishments due to the high possibility that air conditioning will not be available. In the case that air conditioning is available, this in fact may have a more disruptive nature to guests if loadshedding takes place, as a result of a change in temperature interrupting sleeping patterns of guests.

Tourists may not have selected potential accommodation options at the time when they are reviewing the results of the HCI for destinations they are interested in travelling to. Therefore, it is easier to develop a threshold for destinations where the HCI is appropriate based on the air conditioning availability percentage of a destination. A 70% air conditioning availability threshold for destinations across South Africa is proposed, due to the likelihood of a tourist booking accommodation with air conditioning being above 50%. Based on Table 5-1, of the 18 destinations analysed, eight of them have above 70% air conditioning availability in accommodation establishments, namely Durban, Pilanesberg, Kimberley, Paarl, Bloemfontein, Ladysmith, St Lucia and Mbombela. Therefore, the results of the HCI are appropriate for these destinations.

6.3. Analysis of the HCI_{urban} results

6.3.1. Climatic suitability for tourism across South Africa

Despite the variety of climate zones across South Africa, including semi-arid, temperate, and sub-tropical, the HCI_{urban} scores are favourable across the region. Southern and eastern destinations near the escarpment have lower temperatures, while the warmest temperatures are found on the eastern coast, the Lowveld and the interior of the Northern Cape. Overall, the average temperature across the country is 17°C (Engelbrecht & Landman, 2010). The temperatures experienced across the country contribute to elevated HCI_{urban} results. Rainfall patterns include winter rain in the south-western region, year-round rain in the southern region and summer rain in the central and northern interior regions, with an annual rainfall of 464mm (Tyson & Preston-Whyte, 2000; Chase & Meadows. 2007; Roffe *et al.*, 2021). HCI_{urban} results are lower for the central and northern interior and eastern coast during the summer months, which can be explained by the increase in rainfall in these regions during this period. In contrast, the HCI_{urban} results are elevated during the summer months over the south-western region due to the decrease in rainfall during this period. The limited amount of annual rainfall is a contributing factor to the elevated HCI_{urban} results across the country, as the HCI favours minimal precipitation (Scott *et al.*, 2016). Across the seasons, South African destinations are more favourable for tourism in the southern hemisphere's spring and summer in comparison to Madrid and destinations in Iran. In the southern hemisphere autumn and winter months, Iran experiences higher scores, while Madrid has similar scores to South Africa in the winter months.

6.3.2. Seasonality of HCI_{urban} results

A winter peak tourism climate distribution is experienced for most destinations across South Africa as a result of cooler, but not too cold, temperatures and little to no rainfall over these specific destinations throughout the season. An analysis of the HCI_{urban} winter peak results highlights that destinations within the summer rainfall regions are more acceptable for tourism in the winter months. Generally, these destinations experience temperatures during the winter months that are more comfortable for tourists, especially destinations such as Durban, Polokwane, Kruger Mpumalanga, Upington and Kimberley. Higher average scores are calculated for the interior of South Africa, which may be due to little to no rainfall during the winter months, while coastal destinations such as East London and Durban are prone to experiencing more rainfall during winter than the interior (Favre *et al.*, 2012). Looking beyond the destinations with a winter peak seasonal distribution, the south coast, including destinations such as Cape Town, George and Gqeberha, generally display a lower $\text{HCI}_{\text{urban}}$ score during winter. Although these scores are very similar to the scores calculated across the country (ranging from ‘very good’ to ‘excellent’). The lower ratings may be due to increased rainfall over the south coast destinations during the winter season (Tyson & Preston-Whyte, 2000; Chase & Meadows. 2007; Roffe *et al.*, 2021). The spatial distribution of $\text{HCI}_{\text{urban}}$ scores is mostly in agreement with TCI scores calculated across Namibia whereby the higher the latitudinal gradient, the lower the TCI output (Noome, 2020). Should one travel to South Africa during the winter season, it can be assumed, based on the $\text{HCI}_{\text{urban}}$ scores, that all destinations are very suitable for tourism. No other studies with similar climates or latitudes to South Africa have demonstrated a winter peak based on $\text{HCI}_{\text{urban}}$ scores. During the northern hemisphere summer (and therefore the winter season in South Africa), HCI scores in Madrid range between 79-85 (‘very good’ to ’excellent’; Tang, 2013). This indicates that South Africa would be very similar to Madrid in terms of climatic suitability for the months of June, July and August. As with Madrid, similar climatic conditions and latitudinal range are observed in Iran (Hejazizadeh *et al.*, 2019). A large range of $\text{HCI}_{\text{urban}}$ scores exist throughout the winter season (summer in the northern hemisphere) within the east, center, and southeast regions of Iran, as calculated by Hejazizadeh *et al.* (2019). Higher scores are calculated over June, July and August for the central and eastern regions, ranging between 85-97 (‘excellent’ to ‘ideal’), while the south-eastern region ranges from 74-87 (‘very good’ to ‘excellent’). These results are similar to the destinations in South Africa experiencing a winter peak, however the overall scores, specifically in the central and eastern regions of Iran seem to be higher than the South African destinations.

Cape Town, Bethlehem, Johannesburg and Mahikeng have bi-modal shoulder peaks based on the $\text{HCI}_{\text{urban}}$ results ranging from ‘very good’ (70-79) in Mahikeng to ‘excellent’ (80-89) for the remaining destinations during the spring season. This may be due to increasing temperatures and minimal rainfall experienced during the build up to the summer season. Throughout the spring season, the eastern region and south and east coasts generally display lower $\text{HCI}_{\text{urban}}$ scores. For destinations such as Cape Town, Gqeberha, George and East London, this may be due to lower temperatures and higher rainfall in comparison to other regions of South Africa. Higher rainfall and humidity may also be a limiting factor, especially for Durban on the east coast, which is influenced by the warm Agulhas Current (Lennard, 2019). An increase in temperatures experienced in Kruger Mpumalanga could be the reason that the lowest $\text{HCI}_{\text{urban}}$ (72; ‘very good’) score was calculated for the spring months. The central and northern destinations, which do not have a bi-modal peak seasonal distribution still experience higher ‘excellent’ $\text{HCI}_{\text{urban}}$ scores during spring. Based on the $\text{HCI}_{\text{urban}}$ scores, Johannesburg and Bethlehem are the best destinations to visit in the spring season, followed by Cape Town and Bethlehem. A bi-modal seasonal distribution was also determined for Iran (Hejazizadeh *et al*., 2019) and Madrid (Tang, 2013). An average $\text{HCI}_{\text{urban}}$ score of approximately 85 (‘excellent’) was determined for Madrid during the spring season (Tang, 2013). An ‘excellent’ HCI rating is assigned to Polokwane, Johannesburg, Bethlehem, Bloemfontein, Kimberley, Upington, East London, Gqeberha, George and Cape Town. This demonstrates that these South African destinations, Madrid and Iran are equally suitable for tourism in spring. The south-eastern region of Iran has HCI scores of 81-92 (‘excellent’ to ‘ideal’) in April (Hejazizadeh *et al*., 2019). This indicates that the HCI scores are similar to those across South Africa in spring, albeit slightly higher for the south-eastern region of Iran in April with some ‘ideal’ ratings. The central and eastern region of Iran has $\text{HCI}_{\text{urban}}$ scores of 65-80 (‘good’ to ‘excellent) in April (Hejazizadeh *et al*., 2019). This indicates that the $\text{HCI}_{\text{urban}}$

scores are similar to those across South Africa in the spring season. It is important to note that spring is experienced at different times of the year in these countries and therefore if a potential tourist compares these destinations for the month of September, for example, the tourist would be comparing autumn results in Iran and Madrid to spring results in South Africa.

As with the HCI_{urban} calculations in Madrid and Iran (Tang, 2013; Hejazizadeh *et al*., 2019), no summer peak seasonal distributions were observed for any of the destinations across South Africa. The HCI_{urban} scores for the summer season averaged from 58 ('acceptable') in Durban and Kruger Mpumalanga to 'good' (60-69) in East London, Bloemfontein, Kimberley, Upington and Polokwane, to 'very good' (70-79) in George, Gqeberha, Bethlehem and Johannesburg. The destinations on the south coast experience a 'very good' climate, aside from East London. This may be due to the little to no rainfall and the moderate climate experienced during summer in Cape Town, George and Gqeberha (Tyson & Preston-Whyte, 2000; Chase & Meadows. 2007; Roffe *et al*., 2021). Moving over to the eastern region of the country, the lowest HCI scores ('acceptable') are experienced in Durban and Kruger Mpumalanga. This may be due to the higher temperatures and increased amount of rainfall experienced in this region (Favre *et al*., 2012). The central and far north destinations have 'good' (60-69) HCI_{urban} scores which may be influenced by higher temperatures experienced in summer. Lastly, the northern region including Johannesburg, Mahikeng and Bethlehem are rated as having 'very good' (70-79) climatic conditions. This may be the result of warmer temperatures experienced during the summer season. Should one travel during the southern hemisphere summer, it is recommended that the south coast or northern regions of South Africa be visited. No other studies with similar climates or latitudes to South Africa have demonstrated a summer peak seasonal distribution based on HCI_{urban} scores. During the northern hemisphere winter (and therefore the summer season in South Africa), HCI scores in Madrid range between 79-85 (‘very good’ to ‘excellent’; Tang, 2013), indicating that South Africa would be climatically less attractive to tourists in the months of June, July and August. Higher scores are calculated over June, July and August for the central and eastern regions of Iran, ranging between 85-97 (‘excellent’ to ‘ideal’), while the south-eastern region ranges from 74-87 (‘very good’ to ‘excellent’; Hejazizadeh *et al*., 2019). These results also indicate that Iran is better suited for tourism in its winter months. During the mid-winter months in Iran (summer in the southern hemisphere), the HCI_{urban} scores are lower than those experienced in South Africa at the same time, ranging from 48 (‘marginal’) in Rasht to 63 (‘acceptable’) in Ishfahan (Hejazizadeh *et al*., 2019). This indicates that South Africa would be chosen over Iran should tourists compare the climatic suitability for these specific months.

During the autumn season, the HCI_{urban} scores are higher over the interior than on the coasts with the average scores being ‘excellent’ (80-89) over the interior and ‘very good’ (70-79) across the coastal destinations. This may be due to increased rainfall in comparison to the interior of South Africa. The western interior region also displays a slightly lower score of 79 for Upington (‘very good’) than the northern regions which may be a result of generally higher temperatures in this region. The northern regions including Mahikeng, Bethlehem and Johannesburg and Polokwane range from 80-85 (‘excellent’) which may be the result of decreased rainfall following the summer season coupled with warm temperatures still occurring. Based on these HCI_{urban} scores, Johannesburg and Bethlehem, followed by Polokwane, Kimberley and Cape Town are the best destinations to visit in the autumn months. In comparison to international studies, an average HCI_{urban} score of approximately 85 (‘excellent’) was determined for Madrid during the autumn seasons (Tang, 2013). An ‘excellent’ HCI_{urban} rating is assigned to Polokwane, Johannesburg, Bethlehem, Kimberley, Mahikeng and Cape Town. This demonstrates that these South African destinations, Madrid and Iran are equally suitable for tourism in the autumn months. The south-eastern region of Iran has $\mathrm{HCI}_{\mathrm{urban}}$ scores 79-87 (‘very good’ to ‘excellent’) in September (Hejazizadeh *et al.*, 2019). This indicates that the $\mathrm{HCI}_{\mathrm{urban}}$ scores are similar to those across South Africa in autumn, albeit slightly higher for the south-eastern region of Iran in April with some ‘ideal’ ratings. The central and eastern region of Iran has $\mathrm{HCI}_{\mathrm{urban}}$ scores of 88-94 (‘excellent’ to ‘ideal) in September (Hejazizadeh *et al.*, 2019). This indicates that Iran is a more suitable destination during autumn with higher average $\mathrm{HCI}_{\mathrm{urban}}$ scores than the South African destinations.

6.4. Analysis of the $\mathrm{HCI}_{\mathrm{beach}}$ results

6.4.1. Climatic suitability for tourism across South Africa

The spatial distribution of the mean annual $\mathrm{HCI}_{\mathrm{beach}}$ scores indicates that moving from the eastern coast to the western coast brings an increase in the climatic suitability for tourism, however all remain within the ‘very good’ rating (Table 5.5). A tropical climate is experienced along the eastern coast as a result of the warm Agulhus Current in the Indian Ocean, inducing increased rainfall and warmer temperatures (Karmalkar *et al.*, 2012; Lennard 2019). The cold Benguela Current flows off the west coast of South Africa and plays a role in the shift in climate to more temperate, dry arid and semi-arid climate towards this coast (Karmalkar *et al.*, 2012; Lennard, 2019). This decrease in rainfall from east to west can explain the decrease in $\mathrm{HCI}_{\mathrm{beach}}$ scores. Across the seasons, South African coastal destinations are more favourable for tourism in the southern hemisphere autumn and summer months. Climatic competition is experienced in the southern hemisphere’s winter with Japan and the Canary Islands (Carrillo *et al.*, 2022; Zajch *et al.*, 2022). In the southern hemisphere autumn months, Japan experiences lower scores in their spring season, while the Canary Islands experience slightly better conditions than South Africa in the same period (Carrillo *et al.*, 2022; Zajch *et al.*, 2022).

6.4.2. Seasonality of HCI_{beach} results

Most of the destinations across South Africa's coastline display a winter peak tourism climate distribution (Figure 5-8). This could be due to the cooler temperatures and little to no rainfall in these specific destinations throughout the season. The eastern coast displays a higher HCI_{beach} score, with 'excellent' (80-89) and 'very good' (70-79) conditions. This may be a result of the warmer temperatures experienced along the eastern coast throughout winter, coupled with decreased rainfall compared to the rest of the year. The HCI_{beach} scores are generally lower for the winter season over the southern and western coastal destinations ranging from 'good' (60-69) to 'very good' (70-79). These destinations are located in a winter rainfall region, which explains why the scores are lower than the destinations along the south and east coast (Tyson & Preston-Whyte, 2000; Chase & Meadows, 2007; Roffe *et al.*, 2021). Should one travel to South Africa during the winter season, the coastal destinations that are very suitable for tourism are Durban, East London and Gqeberha. Ishinami Beach and Yonehara Beach in Japan, which both display a similar climate to Durban in South Africa, record the highest HCI_{beach} scores from September to December (autumn and winter in the northern hemisphere; Zajch *et al.*, 2022). A study was done in the Canary Islands, which has a similar climate to destinations along the western coast of South Africa such as Cape Town (Carrillo *et al.*, 2022). On average, 'excellent' (80-89) days were recorded for the spring, summer and autumn days, while more than half of the days in the winter season were considered 'excellent' (Carillo *et al.*, 2022). The results of these studies compared to the South Africa studies shows that areas with similar climates display HCI_{beach} scores that are very similar and therefore competition between these destinations may exist. Although, it is important to note that the winter seasons for these destinations are experienced in different months of the year. This indicates that South Africa may be more attractive during these destination's summer seasons and vice versa.

There are no bi-modal shoulder peak seasonal distributions observed for the HCI_{beach} destinations. This indicates that spring is not the most climatically favourable season for tourism, however the HCI scores recorded are within the ‘very good’ (70-79) range. The HCI_{beach} scores recorded are highest towards the east coast and are lower across the southern and western coast. Based on HCI_{beach} scores, East London and Durban are the best destinations to visit in the spring season, followed by Cape Town, Gqeberha and George. An ‘excellent’ (80-89) average for the Canary Islands has been observed for the spring season (Carillo *et al.*, 2022). The highest HCI_{beach} scores are recorded from September to December in Ishinami Beach and Yonehara Beach in Japan (autumn and winter months in the northern hemisphere; Zajch *et al.*, 2022). The Japanese beach destinations experience higher HCI_{beach} scores in the time of year that spring occurs in South Africa, which may result in Japan being chosen over South Africa for tourism purposes (Zajch *et al.*, 2022).

Cape Town was the only destination in South Africa that has a summer peak with an average summer HCI_{beach} score of 83 (‘excellent’; Table 5.7). This may be the result of the dry conditions experienced in the summer season. It can be observed that the average HCI scores decrease from the west to the east coast during summer. This is a result of increasing temperatures and the occurrence of summer rainfall across these destinations. Should one travel in the summer season, it is recommended that Cape Town, George and Gqeberha be visited. An ‘excellent’ (80-89) average for the Canary Islands has been observed for the summer season (Carillo *et al.*, 2022). The highest HCI_{beach} scores are recorded from September to December in Ishinami Beach and Yonehara Beach in Japan (autumn and winter months in the northern hemisphere; Zajch *et al.*, 2022). The summer averages are approximately 55 (‘acceptable’) for the beach destinations in Japan (Zajch *et al.*, 2022). Cape Town and the Canary Islands display similar seasonal distributions, as can be anticipated due to their climatic similarity (Carrillo *et* *al.*, 2022). The Japanese beach destinations experience lower HCI_{beach} scores in the time of year that summer occurs in South Africa, which may result in South Africa being more acceptable in terms of climatic suitability for tourists (Zajch *et al.*, 2022).

It has been determined that autumn is not the most climatically favourable seasons for tourism in South Africa, however the HCI_{beach} scores recorded all fell in the 'very good' range. No specific spatial distribution is observed, with both Durban, East London and Cape Town recording an HCI_{beach} score of 78. These destinations are followed by George with a score of 77 and Gqeberha with a score of 76. Based on these HCI_{beach} scores, the east coast and west coast are the best to visit. The remaining coastal destinations, namely George and Gqeberha, still fall within the 'very good' category and therefore will be acceptable for tourism. An 'excellent' (80-89) average for the Canary Islands has been observed for the spring and autumn seasons (Carillo *et al.*, 2022). The highest HCI_{beach} scores are recorded from September to December in Ishinami Beach and Yonehara Beach in Japan (autumn and winter months in the northern hemisphere. A difference is noted between the South African destinations and the Canary Islands, with the Canary Islands being slightly more acceptable than South Africa during their spring months (South Africa's autumn months; Carillo *et al.*, 2022). The Japanese beach destinations experience lower HCI_{beach} scores in the time of year that autumn occurs in South Africa, which may result in South Africa being chosen over Japan for tourism purposes (Zajch *et al.*, 2022).

6.5. Comparison to the TCI results for South Africa

Fitchett *et al*. (2017) calculated the TCI for 18 destinations across South Africa, of which six have been included in this study, namely Bethlehem, Bloemfontein, Cape Town, East London, Johannesburg and Kimberley. By comparing the TCI results to those of the HCI_{urban} and

HCI_{beach}, lower annual average results are produced by the HCI_{urban} and HCI_{beach} for each destination (Table 6.1). Differences for the HCI_{urban} range from 4 points in Gqeberha (TCI=80; HCI_{urban}=76) to 17 points in Durban (TCI=84; HCI_{urban}=67; Table 6.1). Differences for the HCI_{beach} range from 5 points in Cape Town and Gqeberha (TCI=84; HCI_{beach}=77 and TCI=80; HCI_{beach}=75 respectively) to 12 points in Durban (TCI=84; HCI_{beach}=72; Table 6.1).

Table 6.1: Difference in average annual TCI, HCI_{urban} and HCI_{beach} results

Destination	**TCI**	**HCI_{urban}**	**Difference**	**HCI_{beach}**	**Difference**
Bethlehem	81	76	-5	-	-
Bloemfontein	84	71	-13	-	-
Cape Town	84	78	-6	77	-7
East London	79	74	-5	74	-5
Johannesburg	85	78	-7	-	-
Kimberley	87	74	-13	-	-
Polokwane	87	76	-11	-	-
Gqeberha	80	76	-4	75	-5
Durban	84	67	-17	72	-12

A noticeable difference seasonally can be seen between the TCI and HCI_{urban} (Figure 6.1). For all destinations, the results of the TCI in the summer months are higher than that of both the HCI_{urban} and HCI_{beach}. Most destinations scored ‘very good’ and ‘excellent’ (80-89) under the TCI and ‘good’ (60-69) and ‘very good’ (70-79) under the HCI_{urban} calculations (Figure 6.1). The HCI_{beach} scores slightly higher than the HCI_{urban}, with one destination (Cape Town) scoring ‘excellent’ (83) for the summer months, however the TCI result for Cape Town was ‘ideal’ (92; Figure 6.1). All remaining destinations under the HCI_{beach} scored ‘good’ (Durban) or ‘very good’ (East London and Gqeberha) while these destinations scored mostly ‘excellent’ and ‘ideal’ under the TCI. This may be due to the TCI taking into account daily thermal comfort, which combines mean daily temperature and daily relative humidity (Mieczkowski, 1985; Figure 6.1). This would result in higher temperatures potentially being assigned a lower rating. However, the HCI_{beach} assumes an elevated tolerance for high temperatures with the greatest score being awarded to temperatures between 28ºC and 30.9ºC in comparison to the TCIs 20-26ºC. The lower scores for the HCI$_{\text{beach}}$ can also be explained by the weighting of the thermal comfort aspect being 2 rather than the 4 given in the TCI calculation, and a rating of 4 rather than 2 being given to the aesthetic aspect.

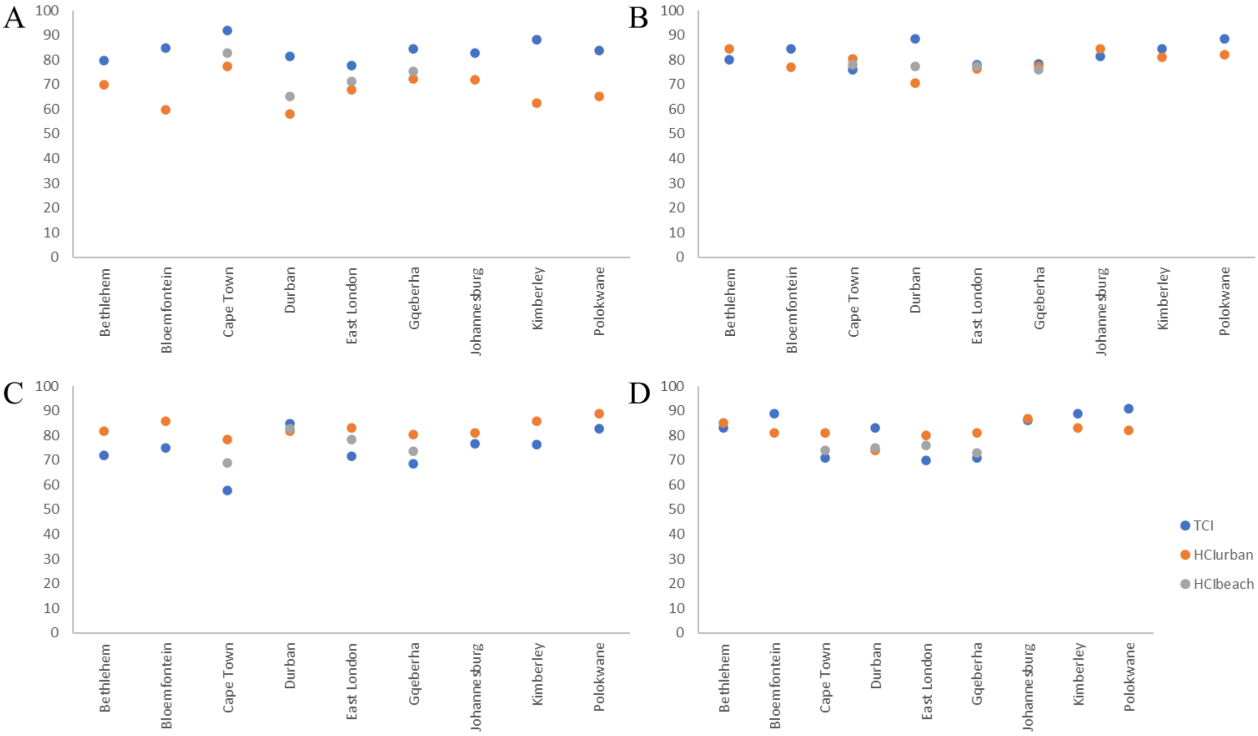

Figure 6.1: Comparison of the average summer (A), autumn (B), winter (C) and spring (D) results of the TCI, HCI$_{\text{urban}}$ and HCI$_{\text{beach}}$ for destinations (adapted from Fitchett *et al*., 2017)

In contrast to the summer months, the TCI ratings fall below the HCI$_{\text{urban}}$ and HCI$_{\text{beach}}$, with the exception of Durban where the TCI is rated above both (Figure 6.1). All of the HCI$_{\text{urban}}$ destinations were rated as ‘excellent’ (80-89), with the exception of Cape Town (78; ‘very good’). A range of ‘good’ in Cape Town (69) to ‘excellent’ in Durban (83) can be seen when calculating the HCI$_{\text{beach}}$ ratings. The TCI results range from ‘acceptable’ in Cape Town (58), to ‘good’ in Gqeberha (69), and ‘excellent’ in Durban (85) and Polokwane (83). As with the summer months, the utilization of only the maximum daily temperature by the HCI calculations will inflate the ratings of the temperature, while the inclusion of the average daily temperature by the TCI will result in a lower temperature and therefore a lower thermal comfort rating.

6.6. Comparison of results to TripAdvisor reviews

Fitchett and Hoogendoorn (2019) analysed TripAdvisor reviews to determine the proportion of reviews that mention climatic factors and the frequency distribution of climatic conditions for each accommodation establishment and each destination. The results of this analysis and the HCI_{urban} and HCI_{beach} scores for common destinations are summarised below.

Table 6.2: Climatic mentions in TripAdvisor reviews (adapted from Fitchett & Hoogendoorn, 2019)

Destination	**Percentage of climate mentions (%)**	**Most frequently mentioned climatic factor**	**HCI_{urban} score**	**HCI_{beach} score**
Bethlehem	15.2	Cold	77	-
Bloemfontein	5.5	Cold	71	-
Cape Town	5.5	Hot	79	78
Durban	8.2	Sun	67	72
East London	5.4	Hot	74	75
Gqeberha	4.7	Cold	76	75
Johannesburg	6.7	Hot	78	-
Kimberley	8.1	Hot	74	-
Polokwane	6.4	Hot	76	-

In agreement with Fitchett and Hoogendoorn (2018), the low climatic sensitivity of tourists demonstrated by TripAdvisor reviews supports the HCI output of ‘very good’ (with one occurrence of ‘good’). There is an inverse relationship between climatic suitability of a location and the number of mentions of climate, wherein the HCI score is higher for destinations that have fewer climate mentions (Fitchett & Hoogendoorn, 2018). However, not all destinations display this relationship, particularly Bethlehem and Johannesburg. Bethlehem has the third highest HCI_{urban} score (77) which is two points behind the highest HCI_{urban} score assigned to Cape Town (79) and one point behind the HCI_{beach} score (78). Bethlehem has, however, ranked first on the percentage of climate mentions. It should however be noted that a climate mention could be both positive and negative, which could explain the number of climate mentions and elevated HCI score for Bethlehem. Johannesburg, which scored the second highest HCI_{urban} score (78), has ranked fourth on the percentage of climate mentions. In contrast, and in line with the inverse relationship determined by Fitchett and Hoogendoorn (2018), Durban has the lowest HCI_{urban} and HCI_{beach} scores (67 and 72 respectively) but has ranked second on the percentage of climate mentions. Most destinations included in both this study and that of Fitchett and Hoogendoorn (2018) have a great proportion of outdoor activities and should therefore be more sensitive to daily weather fluctuations (Yu *et al*., 2009). However, there are low percentages of climate mentions for all destinations with the exception of Bethlehem.

6.7. Tourism under a changing climate

Accompanying natural attractions in South Africa, climate has been determined to be an attraction for tourism (Fitchett *et al*., 2016). Specific sectors that have been determined to be at risk due to climate change are nature tourism, cultural and heritage tourism, beach tourism, golf tourism and cruise tourism (Pandy & Rogerson, 2018). Temperatures in South Africa are projected to rise at up to double the global temperature increase rate (Engelbrecht *et al*., 2015). Temperatures over the southern coast of South Africa are expected to increase by 1-2.5ºC while temperatures over the interior regions will rise with potential exceedances of 3ºC over the northern regions in the 2021-2050 period under low mitigation (Engelbrecht, 2019). In the 2070-2099 period, an increase of a further 2-3ºC may occur over the southern coast and 4ºC over the interior (with potential exceedances of 7ºC over the northern interior) under low mitigation scenarios (Engelbrecht, 2019). Changes in extreme events such as hot extremes and heavy precipitation will become larger with increased temperatures which has a direct influence on periods of drought in southern Africa (IPCC, 2021). There is evidence that the intensity and frequency of hot extremes and heat wave days will increase, with the opposite being true for cold extremes over Africa (Engelbrecht, 2019; IPCC, 2021). Under low mitigation scenarios, for the period 2021-2050, an increase of 10-20 heat wave days is projected across South Africa, with more than an increase of 20 days potentially occurring over the North West and Northern Cape provinces (Engelbrecht, 2019). An increase of 80 or more days a year are projected for the period 2070-2099 over the interior of South Africa (Engelbrecht, 2019). An increase in heat wave days increases the risk of veld and forest fires occurring across the country and the impact on human health through heat stress (Engelbrecht, 2019). While the HCI results may not reflect these hazards, tourist experience may be negatively impacted, therefore impacting upon their desire to return to South Africa.

The southern African region is likely to become drier with an increase in temperatures and predictions of increased drought severity (IPCC, 2021; Figure 6.2). The central interior and east coast of South Africa are expected to have an increase in rainfall while the western interior, northeastern region and southwestern Cape are expected to become generally drier for the period 2021-2050 under low mitigation scenarios (Engelbrecht, 2019). For the period 2070 to 2099, a decrease in rainfall is expected over the central interior, east coast and western region of South Africa under low mitigation scenarios (Engelbrecht, 2019).

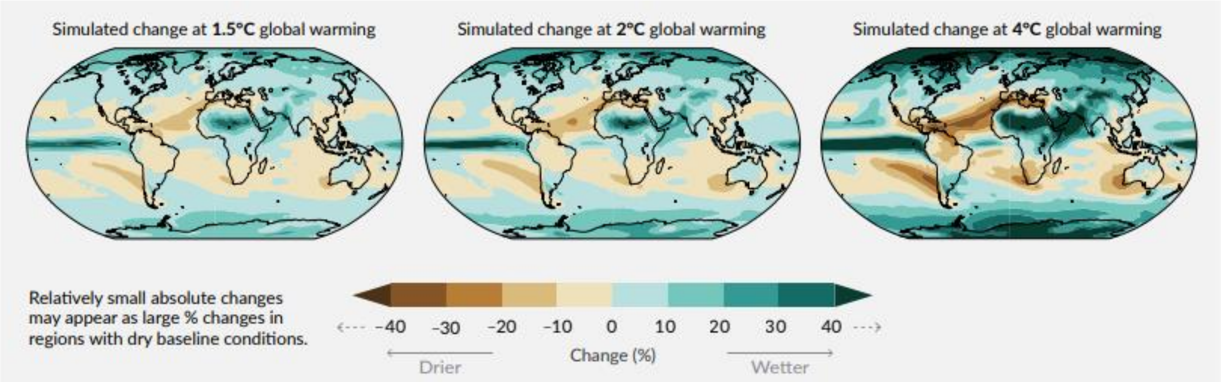

Figure 6.2: Annual mean precipitation change (%) relative to 1850-1900 (IPCC, 2021)

The lower the average precipitation, the higher the HCI ratings for destinations indicating that tourist comfortability is best if there is no precipitation (Table 6.3). Under the predicted increase in rainfall for the 2021-2050 period, a decrease in tourist comfortability can be expected for the central interior and east coast of South Africa (Table 6.3). The predicted decrease in rainfall for the western interior, northeastern region and southwestern Cape will have a positive effect on the HCI rating indicating that tourist comfortability will increase (Table 6.3). The change in rainfall predicted for the central interior and western region of South Africa for the period 2070-2099 to a decrease in precipitation indicates that tourist comfortability may start to increase for these regions. However, it is important to note that tourism is severely influenced by drought, as water supply for consumption and water-based outdoor activities may be affected (Prinsloo & Fitchett, 2023). Therefore, while the HCI may be higher as a result of decreased rainfall, tourists may in fact be negatively affected by this decrease in rainfall when it comes to comfortability in accommodation establishments and ability to partake in certain outdoor activities.

Table 6.3: Changes in the HCI climate variable ratings based on projected changes

Destination	Thermal Comfort		Wind		Precipitation		Cloud Cover	
Bethlehem	7	5	7	6*	9	8*	6	7
Bloemfontein	7	5	7	6*	9	8*	7	8
Cape Town ($\text{HCI}_{\text{urban}}$)	7	5	10	10	9	10	7	8
Cape Town ($\text{HCI}_{\text{beach}}$)	6	2	10	10	9	10	7	8
Durban ($\text{HCI}_{\text{urban}}$)	5	2	9	10 or 9	9	8*	6	7
Durban ($\text{HCI}_{\text{beach}}$)	6	2	9	10 or 9	9	8*	6	7
East London ($\text{HCI}_{\text{urban}}$)	7	5	9	10 or 9	9	10	6	7
East London ($\text{HCI}_{\text{beach}}$)	7	2	9	10 or 9	9	10	6	7
George ($\text{HCI}_{\text{urban}}$)	7	5	9	10 or 9	9	10	6	7
George ($\text{HCI}_{\text{beach}}$)	6	2	9	10 or 9	9	10	6	7
Gqeberha ($\text{HCI}_{\text{urban}}$)	7	5	8	9 or 8	9	10	6	7
Gqeberha ($\text{HCI}_{\text{beach}}$)	6	2	8	9 or 8	9	10	6	7
Johannesburg	7	5	9	10 or 9	8	10	7	8
Kimberley	5	2	9	8*	9	8*	7	8
Kruger Mpumalanga	5	0	5	8**	9	10	6	8
Mahikeng	6	4	6	8**	9	10	7	7
Polokwane	6	0	9	9	9	10	7	8
Upington	5	2	5	3*	10	10	8	9

*A continued decrease in the rating will be calculated should the climate variable increase
**A continued increase in the rating will be calculated should the climate variable decrease
Grey tiles = projections not given for these regions

Under the low mitigation scenarios, where temperatures may rise between 1-7°C and the number of heat wave days may increase by 10-80 days across South Africa, the maximum daily temperatures used to calculate the thermal comfort aspect of the HCI calculations may be negatively impacted. Based on the projected changes across South Africa, changes in thermal comfort for the 13 destinations in this study are indeed negatively impacted. Changes in thermal comfort ratings range between 2 and 6 units (Table 6.3). The greatest variations in thermal comfort ratings are seen in Polokwane, Kruger Mpumalanga and East London ($\text{HCI}_{\text{beach}}$) with changes of 6 to 0, 5 to 0 and 7 to 2 respectively. Bethlehem, Bloemfontein, Cape Town ($\text{HCI}_{\text{urban}}$), East London ($\text{HCI}_{\text{urban}}$), George ($\text{HCI}_{\text{urban}}$), Gqeberha ($\text{HCI}_{\text{urban}}$), Johannesburg and Mahikeng experience the smallest change to their thermal comfort ratings, of 2 units (Table 6.3). Under a changing climate, none of the destinations recorded positive shifts in the thermal comfort aspect. Therefore, it is clear that a negative impact on tourism comfortability will take place under the projected climate futures for South Africa.

On a global scale, extreme daily precipitation events are expected to increase by 7% for every 1ºC increase (IPCC, 2021). In South Africa, extreme rainfall events such as intense thunderstorms which often include lightning, hail, damaging winds, and flash floods, are expected to increase over the central interior and east coast for the period 2021-2050. However, a decrease in frequency for the period 2070-2099 under low mitigation scenarios is predicted (Engelbrecht, 2019). As the HCI is calculated using the average rainfall and windspeed measured over the month, extreme events may not have an impact on the overall HCI scores. However, as with drought, tourists will be negatively impacted upon by extreme rainfall events and may experience a decreased desire to visit South African destinations.

The IPCC (2021) have projected a reduction in near-surface relative humidity over South Africa as a result of increased warming over land areas (Figure 6.3). A reduction in humidity has a direct impact on the temperature felt by tourists, as a lower relative humidity allows for high temperatures to feel cooler (Jing *et al*., 2012). A decrease in relative humidity will have a positive effect on the HCI temperature ratings, meaning that tourist comfortability increases with a decrease in relative humidity over South Africa. As a result of the limited availability of sources of water vapour over land areas, terrestrial clouds are generally created through relative humidity (Liu *et al*., 2023). A decrease in relative humidity has a direct impact on decreased continental cloud cover (Liu *et al*., 2023). In terms of the HCI ratings, a decrease in cloud cover will have a positive impact on the cloud cover ratings. All destinations experience at least a one unit increase in the cloud cover variable (Table 6.3). This indicates that the projected decrease in cloud cover will have a positive impact on climatic suitability for tourists across South Africa.

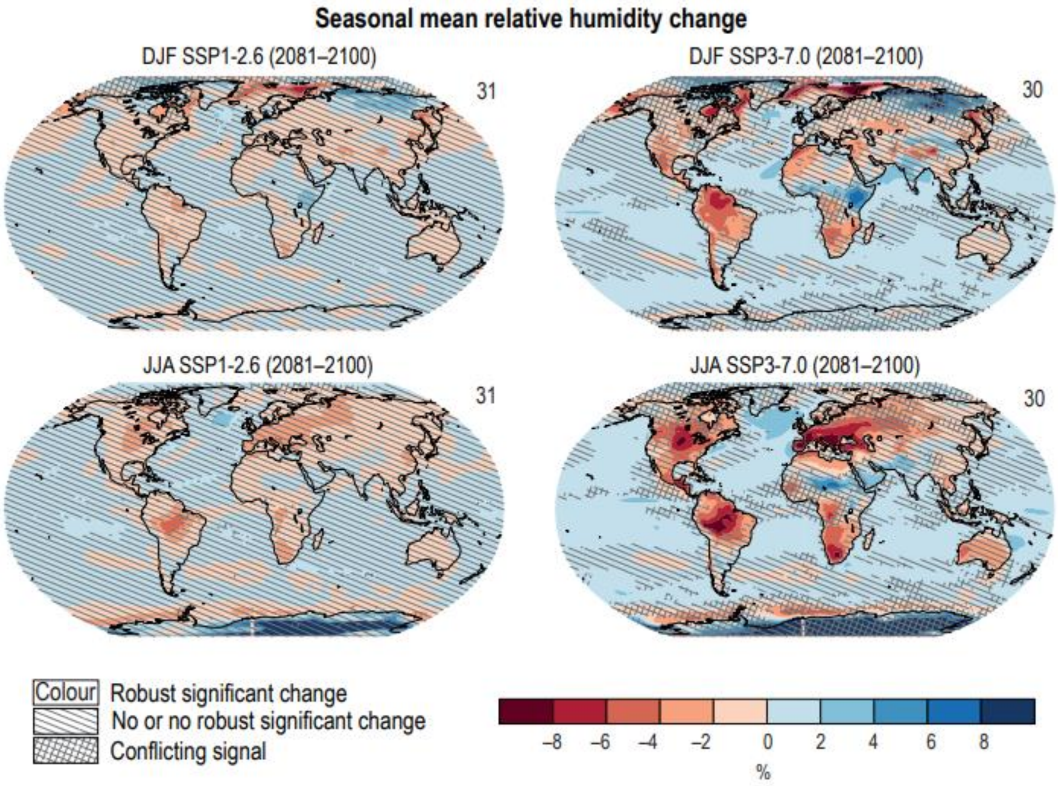

Figure 6.3: Long-term changes in seasonal mean relative humidity (IPCC, 2021)

In terms of wind speed, a future increase in wind speed and wind energy potential is predicted for southern Africa (IPCC, 2021). Engelbrecht (2019) indicated that reduced wind speeds are predicted for the southern interior of South Africa over 2021-2050 with a displacement towards the westerly winds. An increase in wind speed for the northern interior regions is projected as a result of the strengthening of continental heating due to climate change (Engelbrecht, 2019). Based on the HCI ratings of wind speed, the lower the wind speed, the better the tourism comfortability with scores of 9 and 10 being allocated to wind speeds of 10-19km/h and 0km/h and 1-9km/h respectively under the HCI_{urban} and 10-19.9km/h and 0.6-9.9km/h respectively under the HCI_{beach}. Based on wind speed projections under a changing climate, the destinations that are most negatively impacted by an increase in wind speed includes Bethlehem, Bloemfontein, Kimberley and Upington. Rating changes of 7 to 6 for both Bethlehem and Bloemfontein, 9 to 8 for Kimberley and 5 to 3 for Upington are projected (Table 6.3). Kruger Mpumalanga and Mahikeng experience the largest increase in wind speed ratings, from 5 to 8 and 6 to 8 respectively (Table 6.3). The remaining destinations that are predicted to have decreases in wind speeds, either improve by one unit (from 9 to 10 or 8 to 9) or remain in the same rating category (Table 6.3). This is dependent on the initial average wind speed, as the predicted drop in wind speeds of up to 4km/h (CSIR, 2019) can only result in an increase to the wind rating of a destination to, for example, 10, if an average of at most 13km/h is recorded for that destination. Globally, tornados, intense tropical cyclones and peak wind speeds are projected to increase with an increase in temperature. However, there is in fact a projected decrease in the frequency of tropical cyclones that make landfall over Madagascar and east southern Africa (IPCC, 2021). This usually has an impact on the weather experienced in the eastern region of South Africa (IPCC, 2021).

It is clear that extreme events, whether it be related to temperature or precipitation, are increasing as a result of climate change. The HCI makes use of average climate data and therefore is not able to take these extreme events into account due to the short period they usually occur in. Based on the scoring of the HCI, it is obvious that tourism comfortability would be greatly influenced by the extreme climatic variables that are encountered during extreme events such as flooding, heat waves or tropical cyclones. Giddy *et al*. (2017) determined that daily weather does in fact impact on tourist comfortability as the weather has a great impact on the decision to partake in outdoor activities. Therefore, should tourist comfortability be compromised, and outdoor activities be deemed unattractive as a result of an extreme event, tourists' perceptions of the climate in South Africa may be tarnished and therefore may affect tourism across the country.

6.8. Limitations

Limitations of this study relate to availability of the required climate data in developing countries such as South Africa. A limited number of weather stations are registered with SAWS and record variables such as cloud cover. A larger number of destinations (19) were originally chosen, however due to a number of weather stations not having all the required climate variables, it was narrowed down to 13 destinations. Measurements were also not always available for the full study period (1991-2021) for each destination. Fitchett *et al*. (2016) highlight that calculating accurate indices to demonstrate the suitability of a destinations climate for tourism is becoming critical. This is due to the projected changes in climatic variables and therefore, developing countries, which may be impacted the most by these changes would benefit from comprehensive meteorological recording (Fitchett *et al*., 2016). Tervo-Kankare *et al*. (2017) explain that adaptation to climate change in developing countries is hampered by high poverty levels, limited governmental resources and technologies. The tourism sector could also benefit from accurate tourism comfortability indices to determine potential threats and adaptation measures with regards to a changing climate (Fitchett *et al*., 2016). To overcome the spatial restrictions as a result of the lack of measurement of certain climatic variables, this study chose to select destinations that are distributed across South Africa. These destinations are in areas which experience different climates, but still hold some form of attraction for tourists. The destinations chosen had the correct climatic variables required to calculate the HCI. In terms of the availability of continuous data over 30 years, as required by the World Meteorological Organization (2013) for the analysis of the impacts of climate change, one method was used to adapt to this limitation. This was to include the longest continuous period for each destination and the longest common period (2008-2021) between all destinations to identify significant trends in the HCI results. This limitation is impossible to overcome fully without the assistance of SAWS in measuring and making continuous data available. Daily data of all climatic variables contained blank entries. As these variables cannot be predicted/estimated, these entries were removed from the dataset. Lastly the air conditioning data used in this study is secondary, however it is clear that air conditioning across South Africa is not ubiquitous. This therefore limits the accuracy of this index for locations where air conditioning is not readily available in tourism accommodation establishments.

6.9. Conclusion

The interpretations of the results and discussion were presented in this chapter. Overall, it was determined that the HCI can be used to determine tourism comfortability in South Africa, as long as the context of the accommodation establishments are determined in terms of air conditioning availability. In terms of suitability of destinations across South Africa, destinations score between 'acceptable' and 'excellent'. The majority of the scores fall in the 'very good' or 'excellent' range. The variability in climate experienced across South Africa means that HCI results at different destinations can vary considerably during different seasons. A winter peak distribution was clear for the majority of destinations (HCI_{urban} and HCI_{beach}) indicating that tourism comfortability will be highest during the winter months. Under a changing climate, the HCI results may either become more positive or negative depending on the climate variable.

CHAPTER 7. CONCLUSION

7.1. Introduction

Tourism is one of the most rapidly growing and largest sectors of the global economy, and includes segments such as sun and beach tourism, sports tourism, adventure tourism, nature-based tourism, cultural tourism, urban tourism, health and wellness tourism, cruises, theme parks, visiting friends and relatives, and meetings and conferences (Scott & Lemieux, 2010; Scott & Gössling, 2015; Thams *et al*., 2020; UNWTO, 2021). The growing tourism industry in South Africa has a great impact on the country's economy, with a 3.7% of the GDP and 4.7% of employment being attributed to this sector (Scott & Lemieux, 2010; Fitchett *et al*., 2016b; OECD, 2022). Africa is deemed to be most vulnerable to the threats posed by climate change (Scott *et al*., 2019). Along with natural attractions, climate is an attraction for tourism with natural, cultural and heritage, beach, golf and cruise tourism under threat as a result of climate change (Fitchett *et al*., 2016; Pandy & Rogerson, 2018). Climate resources in South Africa are an attraction for tourism, with conditions perceived as 'good' enhancing willingness of tourists to travel and satisfaction of their travel experience (Fitchett *et al*., 2016b; Saarinen *et al*., 2022). Not only do increasing temperatures, increasing rainfall and decreasing cloud cover have a negative impact on tourist comfortability, but the occurrence of extreme weather events such as hot extremes and extreme rainfall can deter tourists from visiting destinations (Gössling & Hall, 2006). These projected changes, along with increases in the occurrence and strength of weather extremes have a direct impact on outdoor activities of tourists.

Within this context, the main aim of this study was to contribute to knowledge on the nature and extent of climate change within South Africa in the last 30 years. An exploration of how this change has influenced the suitability of selected destinations for tourists according to the HCI model was completed. Through the analysis of the air conditioning availability in popular tourist destination accommodation establishments within South Africa, the appropriateness of the HCI for the South African context was determined. Through the analysis of the HCI results, changes in the annual monthly, annual climate suitability and seasonal tourism climate typologies could be determined for each destination. The trends and their strengths in the monthly and annual HCI scores using the common period and longest continuous period were determined for each destination using correlation and regression analysis. This chapter will explore the extent to which the aims and objectives have been achieved and highlight the primary results of the study. Following this, a discussion on the significance of the results and a look into future research trajectories is held.

7.2. Achievement of Study Aims and Objectives

Achievement of the fundamental study aim was accomplished through addressing of the objectives highlighted in Chapter 1. Objectives were achieved through the use of data on air conditioning in tourism accommodation establishments. Maximum daily temperature, mean daily humidity, daily cloud cover measured at three times during the day, average daily precipitation and average daily wind speed (Scott *et al*., 2016; Rutty *et al*., 2020), over a 30-year period (from 1991-2021 where data was available) for 13 destinations across South Africa was required for the HCI calculations. It must be noted that data limitations, as discussed in Chapter 6 (*6.8* Limitations), did not compromise the achievement of the objectives. The extent to which the objectives have been achieved are presented below in the order that the objectives are presented in Chapter 1 (*1.3 Aims and* Objectives).

7.2.1. Identify availability of air conditioning in tourism accommodation establishments to determine the appropriateness of the HCI for the South African context

This objective required data on accommodation establishments within popular tourism destinations across South African from the TGCSA website and air conditioning availability within these establishments from the Booking.com website. The process of achieving this objective is detailed in Chapter 4 (*4.2 Determining air conditioning availability across South* Africa). The purpose of this objective was to determine if the HCI is appropriate for the South African context based on the assumption that all accommodation establishments have air conditioning. The discussion regarding the results of this analysis can be found under Chapter 6 (*Appropriateness of the HCI for South* Africa). In summary, the likelihood of tourists booking accommodation within South Africa with air conditioning is above 50%. The results of air conditioning availability for accommodation establishments in popular tourist destinations across South Africa are provided in Chapter 5 (*5.2 Air conditioning availability across South* Africa). A 70% air conditioning availability threshold has been proposed for destinations across South Africa where the calculation of the HCI will be appropriate.

7.2.2. Calculate the HCI for 13 destinations across South Africa over a 30 year period, where possible

a. ***Determine the climactic suitability of each destination***
b. ***Determine the annual spatial distribution of the HCI scores***
c. ***Determine the seasonal distribution of the HCI scores***

Five climate variables from each of the 13 weather stations were required over the study period (1991-2021 where possible). The results of these calculations are presented in Chapter 5 (*5.3* HCIurban *and 5.4* HCIbeach). The method followed to achieve this objective is provided in

Chapter 4 (*4.3 Climate Data* Acquisition *and 4.4 Spatial distribution of the* HCI). This objective was achieved through calculating the HCI using the required climate variables on both a mean monthly and mean annual scale and determining the seasonal distribution of the HCI scores. The purpose of these calculations was to determine the suitability of the 13 selected destinations for tourism in terms of tourist climactic comfortability. The results of these calculations are presented in Chapter 6 (*6.3 Analysis of the* $_{\mathit{HCIurban}}$ results *and 6.4 Analysis of the HCIbeach* results).

The mean annual $\text{HCI}_{\text{urban}}$ scores for the longest continuous period of each destination reveal that the majority of destinations demonstrate $\text{HCI}_{\text{urban}}$ scores between 70 and 79 and are considered to have 'very good' climatic conditions for tourism. An exception is Durban, which is scored as 'good'. It was determined that the majority of the highest mean annual $\text{HCI}_{\text{urban}}$ scores were calculated for Cape Town, while the lowest mean annual $\text{HCI}_{\text{urban}}$ scores were calculated for Durban. This is in line with the lowest mean annual result for the longest continuous period. The mean annual $\text{HCI}_{\text{beach}}$ scores for the longest continuous period of each destination reveal that all destinations demonstrate scores ranging between 70 and 79. Therefore these destinations are considered to have 'very good' climatic conditions for tourism. As with the $\text{HCI}_{\text{urban}}$ results, the majority of the highest mean annual $\text{HCI}_{\text{beach}}$ scores were calculated for Cape Town, and the majority of the lowest mean annual $\text{HCI}_{\text{beach}}$ scores were calculated for Durban. Chapter 5 (*5.3.1 Mean annual HCI scores and 5.4.1 Mean annual HCI scores*) presents more detailed results on mean annual $\text{HCI}_{\text{urban}}$ and $\text{HCI}_{\text{beach}}$ scores for each year.

The highest mean monthly $\text{HCI}_{\text{urban}}$ scores were recorded in June for seven of the 13 destinations ('excellent' climatic conditions for tourism). The lowest mean monthly $\text{HCI}_{\text{urban}}$

scores were recorded in February for 10 of the 13 destinations (‘acceptable’ to very good’ climatic conditions for tourism). The highest mean monthly $\text{HCI}_{\text{beach}}$ scores were recorded in December for three of the five coastal destinations, ranging from ‘very good’ to ‘excellent’ climatic conditions for tourism. The lowest mean monthly $\text{HCI}_{\text{beach}}$ scores were recorded in August for three of the five coastal destinations (‘very good’ climatic conditions). Chapter 5 (*5.3.2 Mean monthly HCI scores and 5.4.2 Mean monthly HCI scores*) presents more detailed results on mean monthly $\text{HCI}_{\text{urban}}$ and $\text{HCI}_{\text{beach}}$ scores. A link to the regional climatic conditions experienced across South Africa is established in Chapter 6 (*6.3.1 Climatic suitability for tourism across South Africa and 6.4.1 Climatic suitability for tourism across South Africa*). Comparisons to international calculations of the HCI within countries with a similar climate were also made in Chapter 6 (*6.3.1 Climatic suitability for tourism across South Africa and 6.4.1 Climatic suitability for tourism across South Africa*). This was guided by McBoyle’s (2001) seasonal tourism climate typologies. The process followed to determine the relevant typology for each destination is provided in Chapter 4 (*4.5 Spatial distribution of the* HCI) and the typologies assigned to each destination is provided in Chapter 5 (*5.3.3 Seasonal tourism climate typologies and 5.4.3 Seasonal tourism climate typologies).* In summary, the winter season peak distribution is observed for seven of the 13 $\text{HCI}_{\text{urban}}$ destinations and three of the five $\text{HCI}_{\text{beach}}$ destinations. Therefore, this is the most common typology for destinations across South Africa. This was determined to be primarily due to the decreased rainfall over the majority of inland and coastal destinations, and a decrease in temperature that may be more comfortable for tourists visiting coastal destinations. No year-round optimal or year-round poor typologies were observed.

The $\text{HCI}_{\text{urban}}$ and $\text{HCI}_{\text{beach}}$ results were compared to TCI results for six common destinations across South Africa (Fitchett *et al*. (2017). A discussion on this comparison is provided in

Chapter 6 (*6.5 Comparison to the TCI results for South* Africa). In summary, lower annual average results are produced by the HCI calculations for all destinations. A comparison of the HCI_{urban} and HCI_{beach} results to TripAdvisor reviews was also conducted, with the outcome of this presented in Chapter 6 (*6.7 Comparison of results to TripAdvisor* reviews). In agreement with Fitchett and Hoogendoorn (2018), the low climatic sensitivity of tourists demonstrated by TripAdvisor reviews supports the mean annual HCI outputs of 'very good' (with one occurrence of 'good').

7.2.3. Determine the direction and magnitude of the changes in the HCI scores over the study period

a. ***Determine which locations are becoming more or less suitable for tourists climatically***
b. ***Explore spatial patterns of the changes***

Linear univariate regression and Pearson's correlation analysis, as described in Chapter 4 (*4.6 Statistical analyses of trends in the HCI* values) was used to identify the direction and strength of changes in the annual mean and monthly mean HCI scores. Once the direction of the trends was determined, linear regression was used to determine the rate of change of the HCI scores over the longest continuous period and the common period. A significant negative trend for the annual HCI_{urban} results was identified for Gqeberha, while significant positive trends were identified for Mahikeng, Cape Town and Bethlehem. A significant negative trend for the HCI_{beach} results was identified for Durban. Chapter 5 (*5.3.1 Mean annual HCI scores, 5.3.2 Mean monthly HCI scores, 5.4.1 Mean annual HCI scores and 5.4.2 Mean monthly HCI scores*) provides a detailed account of the statistical analysis results. This includes the significant trends identified for the mean monthly HCI_{urban} and HCI_{beach} results.

Chapter 6 (*6.7 Tourism under a changing* climate) delves into the impact of a changing climate in South Africa on the climatic comfortability of tourists and therefore on the HCI_{urban} and HCI_{beach} calculations. As extreme events are predicted to increase in terms of occurrences and intensity, it is important to note that the HCI does not necessarily reflect these hazards. Tourist satisfaction may be negatively impacted should an extreme event be experienced. The HCI calculations will be negatively impacted upon by projected increases in temperature and rainfall for certain parts of the country. However, the HCI calculations will be positively impacted by the decrease in rainfall in other parts of the country. A decrease in relative humidity and therefore a decrease in cloud cover is projected, resulting in a positive impact on the HCI. Varying wind speed changes are predicted for different parts of the country and therefore positive and negative impacts on the HCI calculations may occur. Chapter 6 (*6.7 Tourism under a changing* climate) provides the necessary background on changes across South Africa as a result of climate change and the potential impact on tourism comfortability.

7.3. Significance of the Results

The fundamental aim of this study was to contribute to the existing southern African and international literature on the nexus between climate and tourism. This was done by determining the appropriateness of the HCI for the South African context and by calculating the HCI_{urban} and HCI_{beach} for 13 tourist destinations across South Africa. In doing so, this research has contributed to a gap in the climate change and tourism nexus within South Africa, and Africa as a whole. This study can be used as a foundation for further research in South Africa and within the broader region. While there have been global studies, mostly centred on western destinations and destinations in the northern hemisphere (discussed in Chapter 2, *2.1*

History of tourism and climate change research), the HCI has not been calculated for destinations within Africa, and specifically South Africa.

As the HCI calculations have been conducted at a destination scale, the results can be used to guide tourism management with regards to adaptation and mitigation measures for a changing climate. Due to the projected changes in climate for South Africa, and the reliance of the country on the tourism sector, it is integral that an understanding of the impacts of climate change on tourist climatic comfortability is established. Tourism stakeholders, such as accommodation establishments, can make use of the results of this study to determine if certain mitigation or adaptation measures, such as air conditioning, should be implemented. These measures can be used to combat the change in tourism climatic comfortability demonstrated by the HCI results for each particular destination.

7.4. Future Research Trajectories

Future research should continue to focus on the nexus between climate change and tourism. A delve into the effects of a changing climate on tourist climate comfortability through the use of indices such as the HCI_{urban} and HCI_{beach} should be focused on. Due to the limited amount of research conducted in the southern hemisphere and in Africa itself, more research using indices should be applied in Africa and specifically for the remaining southern African countries where the TCI has been calculated. Fitchett *et al*. (2017) explains that research should focus on regional variations in HCI scores and improving climate change forecasting for tourism. Research should initially focus on the appropriateness of the HCI due to the assumption that air conditioning is available in all accommodation establishments. For outcomes where air conditioning availability is minimal, research into potential reconfigurations of the HCI with regard to night-time thermal comfort should be investigated. Through the use of global climate change projection models, such as those discussed in Chapter 6 (*6.7 Tourism under a changing* climate), climatic comfortability for tourists can be determined based on projections and used by tourism stakeholders to prepare and adapt their service offerings.

While the HCI has made use of the perceptions of tourists themselves, this did not include tourists within African countries (Scott *et al*., 2016). Based on this, research into the objective experience of tourists in terms of climate should be considered alongside future HCI calculations (Fitchett & Hoogendoorn, 2019). Fitchett and Hoogendoorn (2019) explain that self-reported satisfaction of climate conditions by tourists will push accommodation establishments into adapting their offerings to meet the desires of the tourists travelling to a particular destination. While the HCI calculations can be compared to international destinations in which the calculation has been completed, it is recommended that the HCI scores be correlated with tourist flows into and out of South Africa (Fitchett *et al*., 2017).

7.5. Synopsis

Tourism is a growing industry within South Africa that has a great impact on the economy, with employment of 4.7% attributed to this sector (Scott & Lemieux, 2010; Fitchett *et al*., 2016b; OECD, 2022). South Africa not only has natural attractions, but also has a favourable climate for tourism (Fitchett *et al*., 2016; Pandy & Rogerson, 2018). However, a changing climate poses a threat to this industry (Fitchett *et al*., 2016; Pandy & Rogerson, 2018). This study was undertaken to establish the suitability and applicability of the HCI_{urban} and HCI_{beach} for the South African context and to determine the climatic suitability for tourists across the country. A search into the availability of air conditioning at accommodation establishments within popular tourist destinations was conducted. This was done to determine the appropriateness of the HCI based on the assumption that air conditioning is available in all establishments. The HCI was calculated for a period of 30 years (1991-2021, where all climate variables were available) for 13 weather stations in South Africa, which are spread across all nine provinces. The majority of the destinations display a ‘very good’ tourist climatic comfortability. A mix of significant positive and negative trends were identified and should be continuously monitored to determine any escalation in impacts of a changing climate. An analysis of the mean annual, mean monthly and seasonal tourism typology distribution was conducted using the HCI results for each destination. This allows for specific seasons to be pinpointed for outdoor tourist activities. Lastly, the possible impacts of a changing climate on the HCI scores were discussed. This allows for possibly affected tourism stakeholders to determine if adaptation measures are required.

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