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Climate suitability for tourism in South Africa

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ABSTRACT
Tourism Climate Indices (TCIs) have been used extensively in the global North to quantify the climatic suitability of tourist destinations. TCIs have very seldom been applied in the global South. This gap in the literature is significant, due to the considerable growth that tourism sectors in the global South have experienced over recent decades. Moreover, many of these countries seldom have the infrastructure to modify indoor climates and effectively mitigate against poor weather. We present TCI results for 18 tourist destinations across South Africa. With mean annual TCI scores for the period 1995–2015 spanning 76.5 for Port Nolloth to 93 for the Pilansberg, the comparatively favourable climatic conditions in South Africa relative to much of Europe and North America is confirmed. There is distinct seasonality in TCI scores for the majority of study locations, yet the dichotomy between the South African summer and rainfall zones ensure a net balance in climatic suitability countrywide year-round. Time trends in TCI scores over recent decades indicate non-significant change for the majority of locations, and all significant trends indicate slight improvements in the climatic suitability for tourism. These results present a promising outlook of sustained climatic suitability of the region for tourism.

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Tourism Climate Index; South Africa; climate suitability; seasonality; climate change

1. Introduction

Climate is a key determinant of the success and sustainability of the tourism sector of a particular region (Becken, 2005; Gössling, Scott, Hall, Ceron, & Dubois, 2012). The comparative climate of two or more locations is a significant factor in determining tourists' selection of a destination (Gössling et al., 2012). The variable climate throughout the year often influences the seasonality of tourism, while the day-to-day weather is often a critical factor in tourists' overall satisfaction of a vacation (Becken, 2005; Gössling et al., 2012; Kyriakidis & Felton, 2008; Morabito, Crisci, Barcaioli, & Maracchi, 2004; Richins & Scarinci, 2009). Climate change, in turn, therefore has the potential to alter the relative appeal of tourism localities and regions (Rosselló & Waqas, 2015). While these changes in popularity may be positive, natural hazards and extreme events that are associated with climate change pose further threats to tourism sectors, resulting in both long- and short-term costs (Fitchett, Hoogendoorn, & Swemmer, 2016a; Rogerson, 2016). The ability to quantify the climate reliance of a tourism sector, the climate-change threats to the region and the adaptive capacity are critical to facilitate effective mitigation of these harms (Hambira & Saarinen, 2015). To ensure the sustainability of the tourism sector of a given location, the reliance on climate and adaptive capacity to climate change become crucial.

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To improve the likely efficacy of mitigation and adaptation measures, accurate information regarding the contemporary climate suitability of regions to tourism is essential (Hoogendoorn & Fitchett, 2016). To then understand the relative climatic benefits and detriments which a particular location experiences, and to quantify that climatic suitability relative to alternate destination options, an objective and standardised approach is required. Over recent decades, many indices have been developed to quantify the impact of climate on tourism (Becker, 1998; Davis, 1968; De Freitas, Scott, & McBoyle, 2008; Fergusson, 1964; Harlfinger, 1991; Murray, 1972;). These metrics have been developed to explore the suitability of various tourist activities, such as beach and water activities and game viewing with regards to climate conditions (Kovács & Unger, 2014). Despite the inherent complexity in establishing the influence of climate on tourism, it has been argued that tourists respond to the combined effects of different elements within their surrounding environment, including temperature, wind, rain, sunshine hours and humidity (de Freitas, 1990; Gomez-Martin, 2005; Moreno & Amelung, 2009). As a result, an all-encompassing index is required, including the physical, thermal and aesthetic aspects of climate suitability to tourism (de Freitas et al., 2008; Moreno & Amelung, 2009). One of the most widely used indices to date is the Tourism Climate Index (TCI) (de Freitas et al., 2008; Kovács & Unger, 2014; Moreno & Amelung, 2009). The index was originally developed by Mieczowski (1985), and has continued to be used in a largely unaltered format in studies across much of the Global North (cf. Amelung & Nicholls, 2014; Kovács & Unger, 2014; Kubokawa, Inoue, & Satoh, 2014; Mieczkowski, 1985; Perch-Nielsen, Amelung, & Knutti, 2010; Roshan, Yousefi, & Fitchett, 2016; Scott, McBoyle, & Schwartzentruber, 2004). The widespread use of this index, and its relatively broad application, makes it particularly suitable for initial studies into climate suitability to tourism in the climatically heterogeneous global South.

The role of climate change in determining tourism flows is heightened for regions that provide a significant proportion of outdoor attractions (Agnew & Viner, 2001; Sievänen et al., 2005). These attractions include, but are not limited to, nature-based tourism, adventure tourism and beach tourism (Sievänen et al., 2005). Within the global South, which remains proportionally under-investigated in terms of climate change and tourism research (Hoogendoorn & Fitchett, 2016), South Africa presents a valuable study region for initial analyses into climate-change suitability for tourism. South Africa offers a large and varied array of outdoor tourist attractions, with particularly significant visitor flows to coastal regions and beaches, the Kruger National Park and smaller national parks, waterfalls, rivers and mountainous hiking trails (Burger, Dohnal, Kathrada, & Law, 2001; Rogerson & Visser, 2006). The climate in South Africa is also highly varied, with summer and winter rainfall zones, subtropical through to mid-latitude regions, and both humid and arid regions (Nicholson, 2000). Moreover, South Africa is projected to incur disproportionately large damages under climate change, due both to the heightened severity of projected impacts, and the lowered adaptive capacity resulting from the more urgent developmental needs (Reid & Vogel, 2006). The sustainability of the South African tourism sector is thus contingent on the nature and rate of climate change, and on the adaptive capacity of both the tourism sector and the country as a whole (Rogerson, 2016).

There has been dramatic growth in the South African tourism sector following the fall of apartheid, from ∼1 million tourist arrivals in 1990 to 14.3 million in 2013 (StatsSA, 2016; Visser & Hoogendoorn, 2011). Tourism contributes 3% to the gross domestic product (GDP) of South Africa, with tourists having spent R218,9 billion (US$21.1 billion) in 2013 (StatsSA, 2016). With more than a quarter of the South African population unemployed, tourism plays an important role employing 655,609 individuals (Briedenhann & Wickens, 2004; Rogerson, 2002). The tourism sector furthermore underpins a number of local economic development strategies in an attempt to lift South Africans out of poverty after the scourge of apartheid (Rogerson, 2002). Due to the predominance of outdoor attractions and the relatively low adaptive capacity of the region to climate stressors, the South African tourism sector is particularly vulnerable to the effects of climate change and will potentially negatively affect the most vulnerable in the tourism industry (Fitchett, Grant, & Hoogendoorn, 2016b; Fitchett, Hoogendoorn, & Swemmer, 2016a; Rogerson, 2016). The capacity to anticipate and mitigate these climate-change threats to the tourism sector aligns strongly with the United Nations

Sustainable Development Goals, due to the importance of the South African tourism sector in reducing poverty, and in turn reducing inequality, and in proactively managing climate-change impacts on small to medium enterprises.

This study quantifies the climatic suitability to tourism for South Africa, applying the TCI to climatic data from 18 locations across the country. TCI calculations are made at monthly, seasonal and yearly intervals, for the period 2005–2014, and for the longest period of robust data for each respective location. Seasonal and interannual variabilities in TCI scores are investigated, and spatial variability is explored. The quantification of climatic suitability of South African destinations for tourism enables the forecasting of the sustainability of tourism in the region, to facilitate the direction of adaptation measures (Fitchett, Hoogendoorn, & Robinson, 2016c).

2. Study region

South Africa is located at co-ordinates 22°S–35°S and 17°E–33°E (Karmalkar, McSweeney, New, & Lizcano, 2012). The country spans the subtropics to the mid-latitudes, and bordered by the warm Agulhas current to the east and the cold Benguela current to the west, inducing an east–west rainfall decrease across the country. South Africa is characterised by winter rainfall conditions in the south-western region of the country, year-round rainfall along the southern coastline, and summer rainfall across the central to northern interior (Nicholson, 2000). The temperature varies considerably in South Africa, with high temperatures reaching in excess of 32 °C in summer and several degrees below 0 °C at higher elevations on the interior plateau (Jawtusch, 2014). Despite these variations, South Africa is considered to have particularly suitable climatic conditions for tourism, and climate forms a significant drawcard to the country (Preston-Whyte & Watson, 2005). Arguably, the favourable climate is a significant component of the competitive identity of South Africa as a tourist destination (Anholt, 2007).

To ensure representivity of results across this climatically heterogeneous country, 18 study locations were selected, distributed across the nine provinces of South Africa (Table 1, Figure 1). These locations each have a range of tourist attractions in their vicinity, with a proportion of outdoor activities on offer (Table 1). The selection of study locations was limited most critically by the availability of continuous, high-resolution climate data for each of the required climatic variables for the index.

3. Methods

Hourly rainfall, minimum temperature, maximum temperature, relative humidity, wind speed and sunshine hour data were obtained for the 18 study locations from the South African Weather Services. Data were obtained for the longest period for which uninterrupted records exist; all analyses were performed on both this record and the subset of this data spanning the common period 2005–2014 to facilitated comparability. All data were checked and corrected by the South African Weather Services.

To ensure comparibility with TCI outputs from the global North, the original formula developed by Mieczkowski (1985) with adaptations presented by Perch-Nielsen et al. (2010) for data limitations, was used. This form of the TCI has been used in recent studies (Kovács & Unger, 2014; Kubokawa et al., 2014; Roshan et al., 2016), and is calculated as follows:

$$\mathrm{TCI} = 2(4\mathrm{CD} + \mathrm{CA} + 2R + 2S + W)$$

where CD is the daytime thermal comfort; CA is the average thermal comfort; R is the total monthly rainfall; S is the monthly average sunshine hours; and W is the monthly average wind speed.

Each of the input variables for the model is calculated on the basis of standard climatic data (Table 2). These variables are then rated on a scale with W, R and S spanning a scale from 0 (unfavourable) to 5 (optimal), while CA and CD are scaled from −3 to 5 (Kovács & Unger, 2014; Mieczkowski, 1985; Perch-Nielsen et al., 2010; Roshan et al., 2016). The variables are then assigned a weighting for

Table 1. Details of the study sites selected for the study.

Location	GPS coordinates	Annual mean temperature (°C)	Annual mean rainfall (mm)	Tourist attractions
				- Business Tourism
Johannesburg	26.2044° S, 28.0456° E	16	543	- Arts and Cultural Tourism
				- Adventure tourism
				- Palaeo-Tourism
Pretoria	25.7461° S, 28.1881° E	17.3	517	- Historical Tourism
				- Nature Tourism
Pilanesberg National Park	25.2611° S, 27.1008° E	19.5	500	- Adventure Tourism
				- Business Tourism
				- Cultural Tourism
Cape Town	33.9253° S, 18.4239° E	16.9	853	- Business Tourism
				- Coastal Tourism
Paarl	33.7274° S, 18.9558° E	17.6	770	- Adventure Tourism
				- Historical Tourism
				- Arts and Cultural Tourism
Knysna	34.0356° S, 23.0489° E	17	779	- Lifestyle and Leisure Tourism
				- Nature Tourism
Polokwane	23.9000° S, 29.4500° E	17.3	598	- Adventure Tourism
				- Cultural Tourism
St Lucia	28.3833° S, 32.4167° E	21.6	1129	- Historical Tourism
Durban	29.8833° S, 31.0500° E	20.9	975	- Cultural Tourism
				- Coastal Tourism
Ladysmith	29.5597° S, 29.7806 ° E	18.3	740	- Business Tourism
Kimberley	28.7419° S, 24.7719° E	18	283	- Nature Tourism
				- Cultural Tourism
Port Nolloth	29.2500° S, 16.8667° E	14.7	72	- Adventure Tourism
				- Historical Tourism
Port Elizabeth	33.9581° S, 25.6000° E	17.4	453	- Coastal Tourism
				- Nature Tourism
				- Historical Tourism
East London	32.9833° S, 27.8667° E	18.2	593	- Lifestyle and Leisure Tourism
				- Arts and Cultural Tourism
Bloemfontein	29.1167° S, 26.2167° E	16.1	407	- Adventure Tourism
				- Historical Tourism
Bethlehem	28.2333° S, 28.3000° E	14.4	693	- Cultural Tourism
				- Lifestyle and Leisure Tourism
				- Nature Tourism
Nelspruit	25.4658° S, 30.9853° E	19.8	796	- Lifestyle and Leisure Tourism
				- Cultural Tourism
Belfast	256833° S, 30.0167° E	13.2	835	- Adventure Tourism

the model, from which they are summed to a final score with a maximum value of 100 (Kovács & Unger, 2014; Perch-Nielsen et al., 2010).

The calculated TCI scores are then classified in terms of the climatic suitability for tourism, ranging from impossible, with scores less than 10, to ideal, for scores greater than 90 (Table 3; Perch-Nielsen et al., 2010). These categories facilitate the comparison of the TCI results from different regions, and if performed consistently, from different studies (Roshan et al., 2016).

TCI scores were calculated for each month of each year for the 18 locations for the period 2005–2014 and for the longest period for which robust data exists. Long-term mean TCI scores for each month and season were calculated from these scores, together with a long-term mean annual score for each location. These scores are classified in terms of their climatic suitability for tourism (Table 3). It should be noted that these classifications should not over-ride the comparison of the absolute TCI score for two or more locations. First, although two locations may have the same classification for their TCI score, the tourist destination with the greater score within that category should be interpreted as having a climate more suitable than that of the lower score, rather than being of equivalent suitability. Second, similarity in score should be considered more critically than a common category;

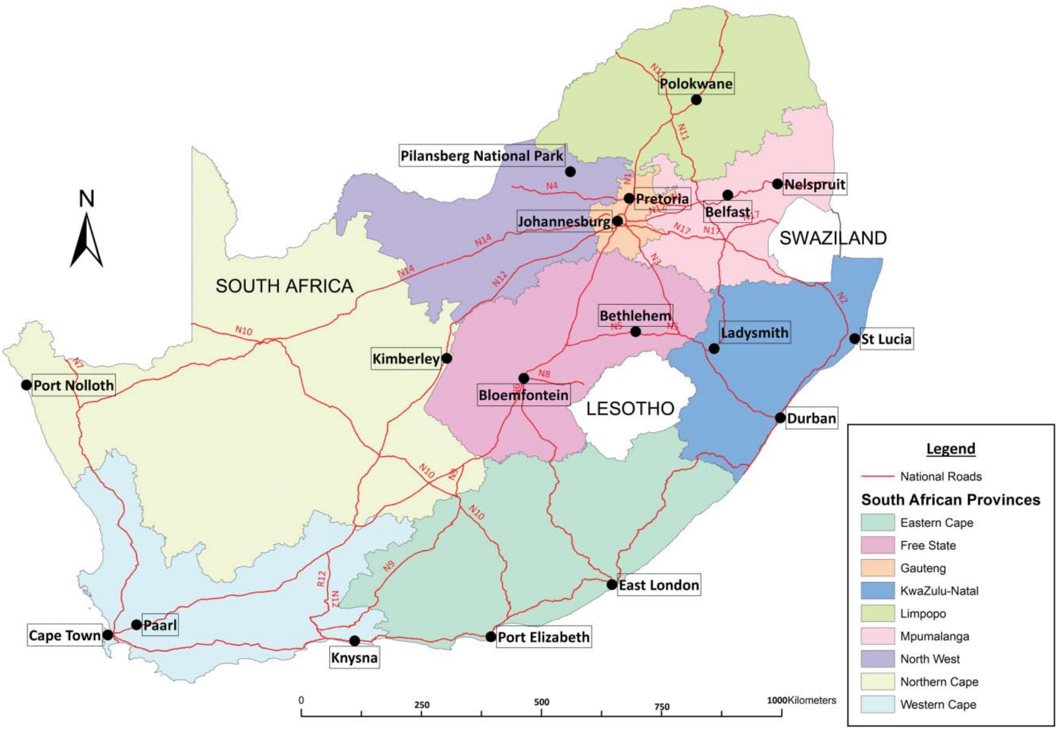

Figure 1. Map of the 18 study sites.

Table 2. The climate variables component of the TCI model.

Sub-index	Abbreviation	Climatic variables required	Weight (%)
Daytime thermal comfort	CD	Mean monthly maximum temperature (°C) Mean monthly minimum relative humidity (%)	40
Average thermal comfort	CA	Mean monthly temperature (°C) Mean monthly relative humidity (%)	10
Wind	W	Monthly average wind speed (km/h)	10
Rainfall	R	Total monthly rainfall (mm)	20
Sunshine	S	Daily sunshine (hours)	20

a score of 79 must be interpreted as more similar to a score of 80 than one of 85, despite the category cut-off positioned at 80. Finally, as the classification is based on European TCI scores (Perch-Nielsen et al., 2010), caution must be made when adopting it for a previously unstudied continent (Hoogendoorn & Fitchett, 2016).

Table 3. TCI score rating categories (Perch-Nielsen et al., 2010).

TCI score	Category
90–100	Ideal
80–89	Excellent
70–79	Very good
60–69	Good
50–59	Acceptable
40–49	Marginal
30–39	Unfavourable
20–29	Very unfavourable
10–19	Extremely unfavourable
<10	Impossible

Changes in TCI scores are explored for the period 2005–2014 and for the longest continuous study period using linear regression analysis, with the statistical significance of the trends determined by the *p*-value. The seasonal patterns of TCI scores are categorised following Scott and McBoyle's (2001) classifications.

4. Results

4.1. Mean TCI scores

For the period 2005–2015, mean annual TCI scores for the respective study sites range from 76.5 (very good) for Port Nolloth to 93 (ideal) for the Pilansberg (Table 4). All the locations demonstrate scores in the "excellent" rating category, except for East London and Port Nolloth, which were classified as having "very good" climatic conditions for tourism, with TCI scores of 76.5 and 79.2, respectively (Table 4). It is notable that Port Elizabeth, located within close proximity to East London (Figure 1) and similarly a coastal town, is categorized as having excellent climatic conditions for tourism (TCI score = 80.20). However, the difference in TCI scores between East London and Port Elizabeth is only one unit, thus yielding their climatic similarity to tourism more similar than two locations that fall within the same category, for example, Bethlehem (80.9) and Polokwane (86.8). The mean TCI scores for the longest continuous climate data-set for each location range from 76.5 (very good) for Port Nolloth to 88.20 (excellent) for Kimberley (Table 4). Comparing the annual TCI mean for the period 2005–2014 to the mean for the longest continuous data-set for each of the locations, the rating categories remain consistent (Table 4). Therefore, the values for the longest continuous data-set are mentioned only when these are statistically different to those of the common period 2005–2015, to improve comparability of the results from each of the stations.

Scott and McBoyle (2001) argue that the tourism climate resources for any destination can be categorized into one of six annual TCI distributions. These annual TCI distributions are dry season peak conditions, bimodal-shoulder peaks, winter season peaks, summer season peaks, year-round poor conditions and year-round optimal conditions (Scott & McBoyle, 2001). None of the selected locations across South Africa in this study fall into the categories of dry season peak conditions, year-round optimal conditions or year-round poor conditions. The bimodal-shoulder peak distribution is observed for 56% of the locations in this study (Figure 2). These locations have winter temperatures that are too cold to be considered suitable for tourism, but the temperatures and other climatic variables are more suitable during spring or autumn. It is interesting to note that all the locations that fall under this distributional category, are locations that are situated inland (Figure 1) and therefore experience far greater extreme temperature differences between winter and summer due to the effects of continentality.

The summer-season peak distribution is observed for 33% of the locations in this study (Figure 3). For example, TCI scores for Cape Town during the months of December to March demonstrate ideal climate conditions, ranging from 93.12 for March to 96.5 for January, whereas the winter months (particularly June and July) are categorized as having only "acceptable" climatic conditions for tourism, with TCI scores ranging from 56.16 for July to 59.20 for August (Table 4). This can be attributed to the climatic regime of the city, comprising winter rainfall and to a significant decrease in temperature during winter months. The decrease in climatic suitability in Cape Town during the winter months is more severe than for other locations in the country due to the multiple detrimental factors (increased rainfall and decreased temperatures) acting at the same time, whereas in other locations there is generally only one factor acting to reduce the climatic suitability. Located inland, a less extreme variation between summer and winter TCI scores is observed for Bloemfontein, ranging from 69 ("good") for July to 90.7 ("ideal") for September (Table 4).

The winter-season peak distribution is observed for the remaining 11% of the locations (Figure 4). These locations experience warm temperatures in winter due to the regulating effect of the warm oceans. Furthermore, the rainfall during winter is minimal, contributing to the suitability of these locations for winter tourism through low precipitation and low cloud cover. By contrast, the summer temperatures for these locations are very hot, which coupled with summer rainfall, reduces the attractiveness of these places for tourism during this season. For example, the TCI scores for Polokwane averaged for the period 2005–2014 in Polokwane, indicate ideal climatic conditions for tourism for the months excluding mid-summer (November and December). The highest TCI scores for Polokwane are observed for the months of May (at the start of winter) and September (early spring), at 90.00 and 92.9, respectively (Table 4). This is due to the summer temperatures being too warm for tourism in this town, which is located in the subtropical interior.

Table 4. Mean monthly TCI scores for the period 2005–2014 and the longest continuous dataset for each location.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
Bethlehem													
2005–2014	75	83	83	82	78	68	71.0	76.9	86.4	80.7	78.50	77.40	80.9
1981–2014	79	81	81	82	78	70	70.8	75.4	83.2	78.21	79.38	79.50	80.4
Bloemfontein													
2005–2014	84	85	86	85	83	69	74.7	79.6	90.7	87.8	83.5	85.3	84.0
1992–2014	84	85	84	86	83	72	74.2	79.4	89	86.5	84.2	85.4	85.4
Cape Town													
2005–2014	97	96	94	86	66	56	57.4	59.2	70.10	85.1	88.4	95.10	83.5
1966–2014	96	96	93	84	68	57	56.2	60.1	70.5	82.2	89.7	93.94	81.6
East London													
2005–2014	79	80	83	77	79	72	73.4	72.6	77.5	68.0	73.6	78.5	79.2
1959–2014	81	80	80	79	77	73	71.6	69.8	69.7	69.3	74.8	80.8	77.5
Johannesburg													
2005–2014	79	87	82	80	81	76	76	82.8	87.1	86.9	85.7	78.3	85.2
1992-2014	80	84	83	83	80	74	74.7	81.1	86.4	85.1	83.7	80	84.5
Kimberley													
2005–2014	84	84	88	87	83	72	75.8	82	90.10	89	89.8	90.5	87.4
1959–2014	87	86	87	86	83	74	74	81.4	88.9	89.1	90.5	90	88.2
Polokwane													
2005-2014	84	90	86	86	90	85	81.2	86.2	92.9	86.8	79.0	78.8	86.8
1993–2014	83	87	86	88	89	82	79.5	85.5	91	86.8	78.9	80.3	86.6
Port Elizabeth													
2005–2014	90	86	86	81	74	67	67.4	70.8	75.5	72.3	81.5	86.1	80.2
1959–2014	89	88	86	82	75	69	69.3	68.2	71.4	73.9	81.6	87.8	80.1
Port Nolloth													
2005–2014	88	87	84	78	71	68	71.0	67.7	71.5	74.2	80.4	87.1	76.5
199-9-2014	87	87	83	77	71	69	70.6	67.9	70.9	74.0	80.4	85.6	76.5
Belfast													
2005–2014	76	86	78	74	74	69	68.8	72.6	79.6	72.6	69.7	75.9	74.9
″	″	″	″	″	″	″	″	″	″	″	″	″	″
Durban													
2005–2014	81	84	82	88	91	88	88.5	86.3	83.6	79.5	77.4	79.8	84.2
1956–2014	80	83	83	88	89	87	83.3	84.4	83.2	80.3	80.9	81.1	84.4
Knysna													
2005–2014	92	93	91	88	79	69	67.5	68.8	78.1	75.6	82.1	90.3	85.5
1997-2014	91	93	87	87	80	73	67.6	68.8	78	78.3	83.5	89.4	85.7
Ladysmith													
2005–2014	79	88	87	89	87	80	78.9	84.4	90.4	86.6	89.4	83.3	87.8
1994–2014	81	86	86	90	87	80	77.3	85.4	89.5	87.3	87.1	82.4	87.5
Nelspruit													
2005-2014	79	83	84	86	90	83	80.0	86.1	93.9	88.4	86.3	76.7	87.1
1995-2014	83	84	85	88	91	84	80.5	86.9	92.2	88.1	84.7	81.4	87.6
Paarl													
2005–2014	97	98	98	92	70	56	61.5	59.5	76.4	93.3	91.5	98.5	88.3
1997–2014	97	98	98	91	72	58	59.7	58.8	75	92.1	92.2	97.8	86.9
Pilansberg													
2005-2014	87	90	91	90	93	90	87.1	92.8	96.7	95.8	89.6	85.5	93
2002-2014	84	87	89	89	92	90	86.3	92.9	96	92.7	89.1	85.1	91.6
Pretoria													
2005–2014	80	87	88	91	87	74	74.6	84.4	93.6	89.6	85.4	82.3	87.5
2002–2014	81	86	87	92	88	74	74.9	84.7	94	90.2	86.7	83.5	88.1
St Lucia													
2005–2014	80	78	80	82	89	84	89	88	86.8	77.6	82.6	82.5	84.3
1983–2014	79	78	81	81	85	77	77.6	82.9	83.5	78.20	80	81.1	80.7

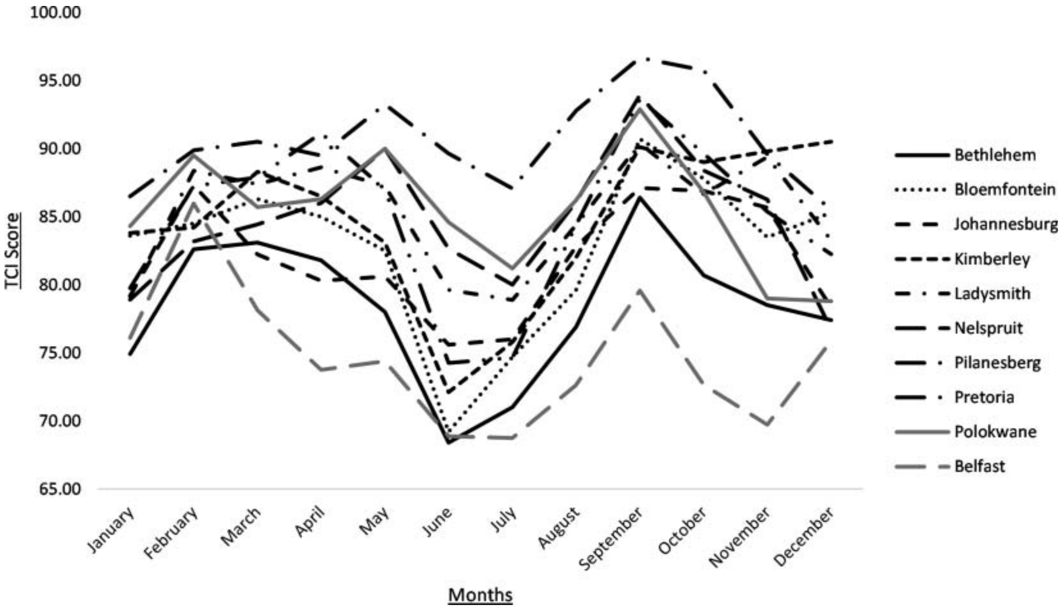

Figure 2. Locations that demonstrate a bimodal-shoulder peak distribution in mean monthly TCI scores.

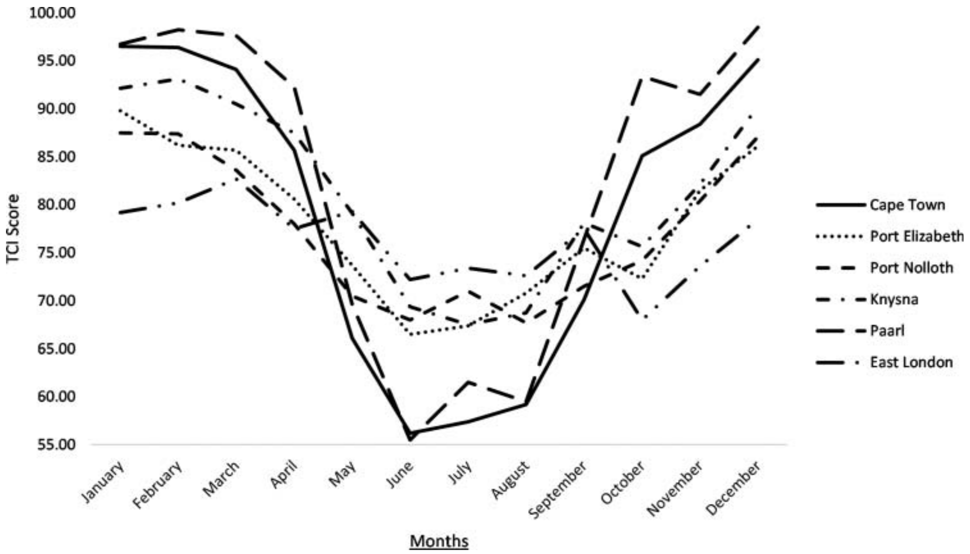

Figure 3. Locations that demonstrate a summer season peak distribution in mean monthly TCI scores.

The seasonal distribution of TCI scores across the country, and the inclusion of summer, winter and bi-modal peaks, indicates that although there are seasons for which each location is more climatically suitable for tourism, the country as a whole maintains ideal conditions for tourism year round.

4.2. TCI score time trends

Despite demonstrating very similar monthly and annual mean TCI scores (Table 4), the time trends for the common time period (2005–2015) and the longest continuous time period are notably different

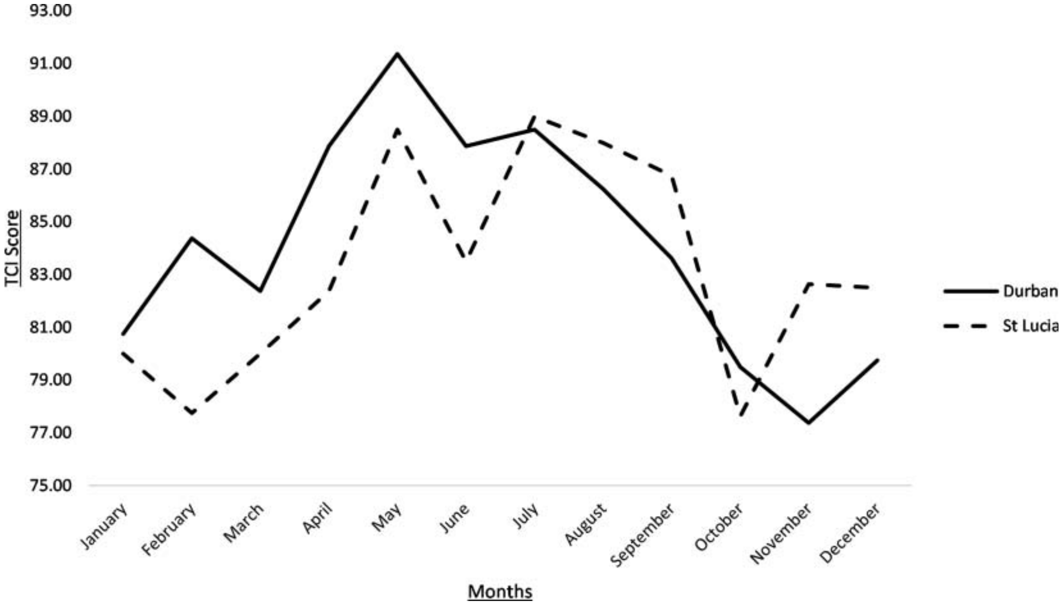

Figure 4. Locations that demonstrate a winter season peak distribution in mean monthly TCI scores.

for all of the study locations (Table 5). These differences notably include variations in both the statistical significance and the rate of change calculated for each of the time periods (Table 5). In the majority of instances of variance, time trends are significant for the long-term record but not for the short-term record. This is understandable as the short-term record has a necessarily smaller sample size, and consequently would require a very strong correlation for a significant result. However, for Knysna and Port Nolloth, a significant time trend is calculated for the short-term record (2005–2015), while the longest continuous records (1997–2015 and 1999–2015) yield non-significant time trends (Table 5). This may indicate that a more consistent trend exists for the shorter time period, while the longer time period either captures considerable variability, or trends in an opposite direction to those for the most recent decade. It is, therefore, important to explore the time trends for both the common decade and for the longest continuous period.

Statistically significant time trends are only observed for 6 out of the 18 study locations (Table 5). The statistically significant time trends for the common period 2005–2015 (Table 5) indicate improvements in TCI scores, ranging in magnitude from 0.93 units per year for Port Nolloth ($r = 0.76$, $p = 0.005$) to 0.5 units per year for St. Lucia ($r = 0.55$, $p = 0.05$). For the longest continuous data-sets available, statistically significant time trends similarly unanimously indicate improvements in TCI scores. These improvements are of a lower magnitude (Table 5), ranging from 0.29 units per year for St. Lucia ($r = 0.58$, $p = 0.0005$, 1983–2015) to 0.08 units per year for Cape Town ($r = 0.34$, $p = 0.005$). This supports the above inference that variability within longer records would likely moderate the strength and magnitude of the time trend.

All instances of decreasing time trends in TCI scores are statistically insignificant (Table 5). However, a decline in TCI scores over a recent historical period is a potential early-warning sign of continued deterioration of the climatic suitability for tourism of a particular location and warrants monitoring efforts. Decreasing trends in TCI scores are calculated for 9 of the 18 stations, with decreasing trends in the long-term record observed only for Bloemfontein and Pretoria (Table 5). For these two locations it is notable that a positive time trend is calculated for the common time period, 2005–2015. This may indicate a reversal of this trend in recent years. For the remaining seven locations, a positive trend is calculated for the longest continuous time period, while the decreasing trend is observed for the most recent decade. Although this may be influenced by climate cycles such as El

Table 5. Trends in TCI scores over the common and longest continuous time periods for each location.

Location	Rate of change (TCI score/per year)	R^2 value	*r*-Value	*p*-Value	Significance
Belfast					
2005–2015	−0.42	0.07	−0.26	0.2	Not significant
Bethlehem					
2005–2015	−0.54	0.30	−0.55	0.20	Not significant
1981–2015	0.05	0.03	0.16	0.20	Not significant
Bloemfontein					
2005–2015	0.08	0.01	0.09	0.40	Not Significant
1992–2015	−0.03	0.01	−0.07	0.4	Not significant
Cape Town					
2005–2015	−0.18	0.03	−0.18	0.30	Not Significant
1966–2015	0.08	0.11	0.34	0.005	Significant
Durban					
2005–2015	0.28	0.06	0.25	0.2	Not significant
1956–2014	0.01	0.01	0.08	0.3	Not significant
East London					
2005–2015	0.15	0.01	0.11	0.40	Not Significant
1959–2015	0.11	0.21	0.55	0.0005	Significant
Johannesburg					
2005–2015	0.35	0.35	0.41	0.10	Not Significant
1992–2015	0.2	0.12	0.34	0.05	Significant
Kimberley					
2005–2015	−0.28	0.10	−0.32	0.20	Not Significant
1959–2015	0	0	0	0.5	Not significant
Knysna					
2005–2015	0.76	0.25	0.5	0.05	Significant
1997–2015	0.04	0	0.06	0.4	Not significant
Ladysmith					
2005–2015	0.11	0.01	0.12	0.3	Not significant
1994–2015	0.08	0.03	0.18	0.2	Not significant
Nelspruit					
2005–2015	0.1	0	0.06	0.4	Not significant
1995–2015	0	0	0	0.4	Not significant
Paarl					
2005–2015	−0.11	0.01	−0.12	0.3	Not significant
1997–2015	0.24	0.13	036	0.05	Significant
Pilansberg					
2005–2015	−0.29	.09	−0.30	0.2	Not significant
1996–2015	0.2	0.1	0.32	0.1	Not significant
Polokwane					
2005–2015	−0.18	0.15	−0.39	0.10	Not Significant
1993–2014	0.06	0.02	0.15	0.20	Not significant
Port Elizabeth					
2005–2015	−0.51	0.17	−0.47	0.10	Not Significant
1959–2014	0.01	0	0.07	0.3	Not significant
Port Nolloth					
2005–2015	0.93	0.58	0.76	0.005	Significant
1999–2015	0.14	0.03	0.18	0.20	Not significant
Pretoria					
2005–2015	0.26	0.07	0.26	0.2	Not significant
2002–2014	−0.13	0.02	−0.15	0.3	Not significant
St. Lucia					
2005–2015	0.5	0.3	0.55	0.05	Significant
1983–2015	0.29	0.33	0.58	0.0005	Significant

Niño, it is possible that this reflects the beginning of a permanent deterioration in the climate suitability for tourism in these locations.

Considerably stronger time trends in TCI scores over both the common time period and the longest continuous data-set are calculated for individual months. For example, for Bethlehem, strong negative trends in TCI scores are calculated for July (−0.7 units per year, $r = -0.74$, $p = 0.005$) and December (−1.44 units per year, $r = -0.66$, $p = 0.025$). By contrast, a strong increase in TCI scores is calculated for Cape Town for the summer months of October (0.1 units per year, $r = 0.22$, $p = 0.05$), December (0.05 units per year, $r = 0.29$, $p = 0.025$) and January (0.05 units per year, $r = 0.31$, $p = 0.01$). An interesting dichotomy in trends for summer and winter months is noted for East London for the period 1959, with statistically significant increases for May (0.26 units per year, $r = 0.47$, $p = 0.0005$) and July (0.14 units per year, $r = 0.25$, $p = 0.05$), but a decreasing trend for the summer month of January (−0.08 units per year, $r = -0.2$, $p = 0.05$). Thus, while the annual trend indicates little change, an arguably more important change to the seasonal pattern of climatic suitability for tourism is occurring, which in the long term may alter regional tourist flows.

5. Discussion

5.1. Suitability of the TCI in the South African context

Mean annual TCI scores calculated in this study for 18 locations in South Africa (Figure 4), and published for a further coastal location along the South Coast of the country (Fitchett et al., 2016b) confirm the widely held perception that South Africa has particularly suitable climate for tourists (Steyn & Spencer, 2012), and is marketed as one of the top 10 reasons to visit South Africa by South African Tourism (Department of Tourism, 2011; South African Tourism, 2016), forming a critical component of the competitive identity of the country as a tourist destination (Anholt, 2007). It could be argued that the categorisation of the majority of locations as having mean annual TCI scores as “excellent” to “ideal” yields a low comparative value in these scores, and does not allow for the differentiation of tourist attractions on the basis of climate. While there is certainly less variability in TCI scores than is observed for European countries (Kovács & Unger, 2014), Japan (Kubokawa et al., 2014) or Iran (Roshan et al., 2016), in no cases do two locations have the identical TCI score. Therefore, although within the same suitability category, the absolute climate suitability should be compared on the basis of the score itself, and the difference in scores between two locations of interest. Moreover, the use of a decimal point to the score further facilitates the differentiation of the climate suitability of two locations. We would argue that this is more suitable than a re-categorisation of the classes of climatic suitability for tourism to better differentiate locations within regions of high climatic suitability, as this would hamper the ability to make comparisons between countries in different continents.

While the mean annual TCI scores are closely clustered within the categories of excellent and ideal, mean monthly TCI scores for the 18 locations demonstrate considerably greater variability. This is most notable for Cape Town, spanning climatic conditions categorised only as “acceptable” in winter, to “ideal” conditions in summer. This distinct seasonality in TCI scores is important to tourism management. First, the seasonal variation is of importance to outdoor and nature-based tourism attractions, which likely experience a decline in bookings during the climatically less suitable months. Assuming that tourists have perfect information regarding climate, for these months, locations elsewhere with more preferable climates in those months will be favoured. More important in the South African context, is the climatic heterogeneity of the region. The TCI results confirm that whilst the south-western Cape, a winter rainfall zone characterised by the frequent passage of mid-latitude cyclones, is particularly unsuitable for tourism in winter months, locations in the northern region of the country are less suitable during summer months (Table 4). The distribution of the 18 South African locations within Scott and McBoyle’s (2001) seasonal distributions of TCI scores within the bimodal-shoulder peak, the summer peak and the winter peak, indicates that tourists will not have to seek locations outside of the country during months in which the climate is unsuitable for climate in a particular location, but rather will find climatically suitable locations within South Africa year round. The TCI scores are thus of importance in anticipating and managing the seasonal preference of each of the locations. It should be noted that many international tourists prefer to visit a variety of locations during a visit to South Africa (Giddy, Fitchett, & Hoogendoorn, 2016). However, in these instances, tourists appear likely to be willing to endure poor climate in one location, if they have experienced particularly good climatic conditions at their other destinations within the country (Giddy et al., 2016). This is consistent with findings from New Zealand indicating reluctance among

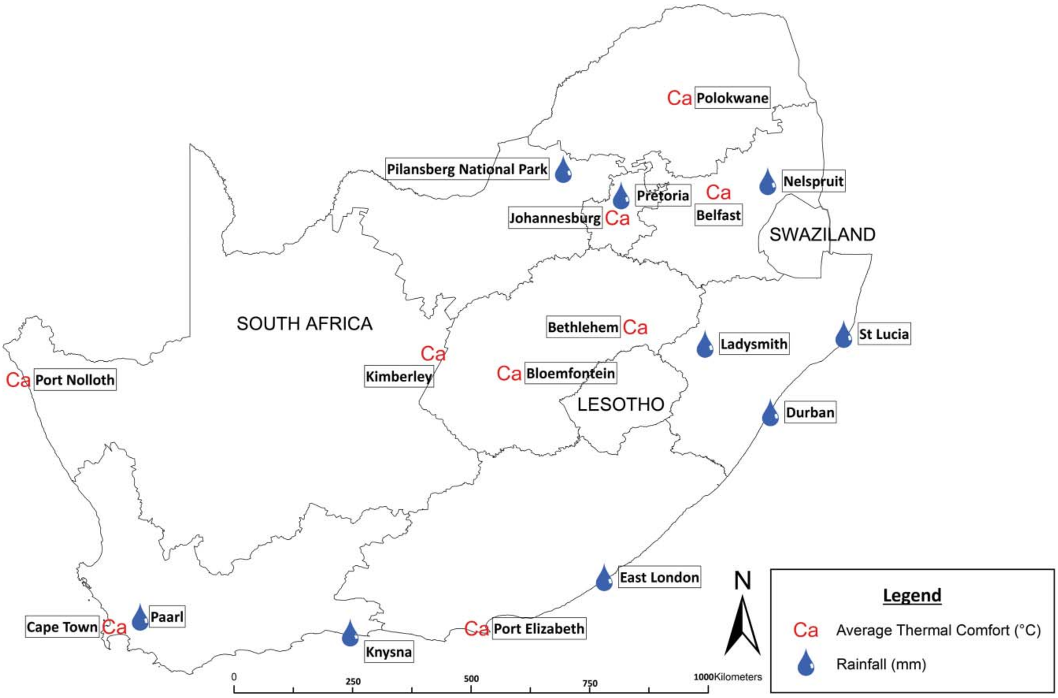

Figure 5. Map indicating the TCI component most detrimental to the mean annual TCI score for each location.

tourists to change their travel plans due to poor weather, and that such changes constitute damage control (Becken & Willson, 2013). It is important to note, however, that international tourists have been observed to demonstrate considerably greater concern for the impacts of climate change on the suitability for coastal tourism in South Africa than local tourists or accommodation establishment managers (Hoogendoorn, Grant, & Fitchett, 2016). Moreover, with greater flexibility in accessing locations, local tourists are likely to be more responsive to less severe events of undesirable climatic conditions (Fitchett et al., 2016a). Finally, purpose of travel needs to be considered (Denstadli, Jacobsen & Lohman, 2011). The climatic suitability of a location is of far greater consequence if the majority of attractions are outdoors (Fitchett et al., 2016a). At the opposite extreme, it could be posited that poor weather and climate may be of little consequence to business tourists as little time is spent outdoors, and thus climate can be artificially moderated (Maddison, 2001; Gössling & Hall, 2006). Forthcoming work from Saarinen, Rogerson and Pandy will hopefully provide insight into the validity of these arguments for the South African context.

The greatest challenge to the application of the TCI in South Africa is shortfalls in the availability of climatic data (Hoogendoorn & Fitchett, in press). Although there are approximately 200 registered weather stations across South Africa, very few record all of the variables required for calculating the TCI (Fitchett et al., 2016c). Most problematic are records of daily sunshine hours, or equivalently measures of cloud cover. However, for many of the weather stations' records of humidity and wind speed are similarly lacking or incomplete. Large data gaps present a further issue, particularly when aiming to explore time trends in mean monthly TCI scores. Finally, where long-term means, or changes in TCI scores over multiple decades are desired, changes in the measuring instrumentation become an issue. This is particularly problematic for measures of wind strength in South Africa. These problems presented the primary limitation in the selection of study sites, and at present would hinder the expansion of TCI studies for the country. Moreover, this is likely to result in a key challenge to performing similar TCI studies in many developing countries globally, due to the lack of infrastructure, and poor continuity of climate data.

5.2. *Key determinants of unfavourable TCI scores in South Africa*

Notable spatial patterns emerge when investigating the meteorologic factors that had the most negative influence on the mean annual TCI scores for the period 2005–2014. Rainfall has a strong negative influence on the TCI scores at destinations along the eastern coast and at some destinations over the northern interior. The generally warmer climate and warm Agulhas current that flows along the east coast of the country plays a major role in bringing increased levels of rainfall to regions along the east coast, while warm temperatures and moist air pushing down from the ITCZ in summer brings rainfall to the northern parts of the country (Dyson, Van Heerden, & Sumner, 2015). Similar results in Northern Cyprus indicate that that increased levels of rainfall result in a negative influence on the TCI score of a destination or region (Olya and Alipour, 2015). Although, the climate of Northern Cyprus is considered Mediterranean, and the majority of their rainfall occurs in winter, the results along with results from similar studies (c.f. Day, Chin, Syndor, & Cherkauer, 2013; De Freitas et al., 2008; Jeuring & Becken, 2013) suggest that rainfall is a key factor that greatly reduces the comfort of tourists.

For Cape Town and Port Nolloth, the average thermal comfort (CA) most significantly reduces the TCI score year-round (Figure 5). The average thermal comfort component of the TCI formula is calculated as an effective temperature and utilises mean daily temperature and mean daily relative humidity to arrive at the resultant effective temperature, and represents conditions of thermal comfort over 24 hours of the day (Perch-Nielsen et al., 2010; Rosselló-Nadal, 2014). Locations in the central interior, Bethlehem, Bloemfontein, Kimberley, Johannesburg, Belfast and Polokwane, are similarly most negatively affected by the average thermal comfort component of the TCI (Figure 5). Unlike Cape Town and Paarl, these destinations are not influenced by the cooling effects of the Benguela current, but are rather influenced by greater variations in their diurnal temperature ranges as a result of the effects of continentality. The effects of continentality make the average daily temperature in these regions much cooler than the temperatures that are considered comfortable for tourists according to the TCI.

These findings are important in informing adaptation strategies within the tourism industry. In particular, the detriments of adverse average thermal comfort can be mitigated through temperature control within accommodation establishments. Research at St. Francis Bay and Cape St. Francis on the south coast of South Africa indicate that these accommodation establishments are very amenable to making minor infrastructural changes to improve the indoor comfort of their patrons (Hoogendoorn et al., 2016). Although the outdoor thermal comfort cannot be directly controlled for, tourist attractions can make efforts to provide greater shade cover and to prevent physical exertion during peak temperature hours of the day. Moreover, these findings indicate that the greater issue is the diurnal variation in temperature, and as outdoor and nature-based tourism attractions seldom operate during the night, the adaptations of tourism establishments should be sufficient. Rainfall is considerably more difficult to control for, and in many cases prevents participation in outdoor and nature-based activities.

5.3. *Future outlook for the climatic suitability of tourism in South Africa*

The sustainability of the tourism sector of a country is largely contingent on the continued ability to attract both local and international tourists to existing tourism establishments and attractions. For countries that rely on a significant proportion of tourism products which are dependent on stable, predictable and favourable weather, climatic suitability is a key determinant in the ability to attract large visitor numbers (Agnew & Viner, 2001; Sievänen et al., 2005). Under climate change, the climatic suitability of locations is projected to change, with an ultimate reduction in climatic suitability as thresholds are exceeded (Perch-Nielsen et al., 2010; Roshan et al., 2016). This is particularly the case for countries in which the tourism sector is dominated by small to medium enterprises (Rogerson, 2002), which do not have the infrastructural resources to make on-going adaptive changes to overcome climate-change threats (Fitchett et al., 2016a).

The temporal period spanned by the data-sets in most cases is insufficient to make statistical inferences regarding climate change. However, time trends in TCI scores over periods of a decade or more may provide early warning for continued changes in the climatic suitability of a location for tourists, and would therefore prompt further investigation. It is thus very promising that the only statistically significant time trends in TCI scores, for both the common period 2005–2015 and for the longest continuous data-sets available, demonstrated net improvements in TCI scores. This would indicate that climate variability and change over recent decades has improved the objective suitability of these locations for tourists.

Despite the positive outlook of the statistically significant trends, the longevity of these trends is unknown. Caution must be made first regarding the upper limits of temperature increases. Although at present the increases in temperature are serving to improve the TCI scores for these locations, continued temperature increases will ultimately result in temperature exceeding the upper limits for thermal comfort. From this point onwards, temperature increases will act to progressively decrease the TCI score for a location over time. Thus, for locations that demonstrate contemporary improvements in TCI scores over time, the TCI variables relating to temperature must be monitored carefully.

Second, as the TCI scores for many of the locations are most negatively affected by rainfall, future rainfall projections must form a critical component of tourism management and monitoring. Future rainfall projections under a range of emission scenarios indicate that rainfall all across South Africa is set to decrease by 10%–15% (Jawtusch, 2014). Although this may pose some negative threats to South Africa (Araujo, Babatunde, & Crespo, 2014; Nhemachena, Hassan, & Chakwizira, 2014), it also suggests that destinations whose climate suitability is negatively influenced by rainfall across South Africa may see an improvement in their TCI scores as a result of the projected decrease in rainfall in the future. This decrease in rainfall will allow these destinations to market themselves as more climatically attractive, which may draw more tourists and ultimately boost local economic development in those South African regions. However, as for temperature, caution must be applied to inferences of the significance of these findings. First, rainfall projections are not uniform across the country, and for some regions rainfall is likely to increase. Second, although not captured in this model, a prolonged decrease in rainfall will ultimately result in drought conditions, which are likely to act as a deterrent to tourism. Finally, these projections do not reflect high-amplitude interannual precipitation fluctuations resulting from climatic cycles such as ENSO. It is, therefore, imperative that the climatic conditions of these locations continue to be monitored, with a particular focus on threshold conditions.

Finally, although not statistically significant, negative trends have been detected for a number of locations. These are of particular concern where the long-term record indicates little change, but the short-term record reveals a decline in TCI scores, as this is indicative of a change-point in the time trend in recent years. The climate and climatic suitability for tourism of these locations should be monitored closely in forthcoming years to determine whether these negative trends persist.

6. Conclusion and future research trajectories

This study presents the first calculation and comparison of TCI scores for multiple locations in South Africa. The ability to use the TCI model, and in turn the selection of study sites, was hampered by the absence of temporally continuous data for some of the key elements of the model. This is likely to present similar difficulties in applying the TCI to other countries in developing countries. The categorisation of mean annual TCI scores for all of the study locations within the “excellent” and “ideal” brackets confirms the high level of climatic suitability to tourism of South Africa. Although this reduces the capacity to easily differentiate between the climatic suitability of locations within the country, the benefit of comparison with global studies validates the use of the global rating categories. Subtle differences in mean annual climatic suitability are detected between each of the study locations, yet far greater variability is noted at monthly and seasonal scales. Importantly, while there are notable seasonal fluctuations in the climatic suitability for tourism at each of the locations, the heterogeneous climate of South Africa results in both summer and winter peaks for different locations, facilitating year-round tourism nationally.

The current outlook for the suitability of South African climate for tourism is positive, yet the existence of positive trends in TCI scores should not be taken to indicate the potential for improvement in perpetuity. Critically, the potential for increasing temperatures to reach the maximum threshold for human comfort, and the uncertainty in precipitation at both interannual and interdecadal scales, necessitates continued monitoring of the climatic suitability for tourism of South African towns, particularly where these local tourism sectors rely heavily on outdoor and nature-based tourism. The contemporary detriments to the climatic suitability for tourism of South African destinations indicate that small-scale infrastructural adaptations within accommodation establishments may substantially improve tourist experiences.

This study indicates the value of the TCI as a tool for evaluating the climatic suitability of destinations across South Africa, and facilitates comparison of locations within South Africa and destinations globally. It would be of value for future research to explore the extent to which these climatic differences, particularly at a monthly and seasonal scale, correlate with tourism flows both to and within the country. It is possible that the effects of climate on tourism will be more notable when such changes approach critical thresholds for human comfort, or where they pose serious challenges to outdoor and nature-based tourism. Research to explore these effects at locations that are already approaching these limits, either in South Africa or elsewhere, would have the potential to provide an early warning system and facilitate improved adaptation within the tourism sector.

This study demonstrates the capacity of the TCI to both categorise the climatic suitability for tourism in South Africa and to quantify changes in climatic suitability over decadal timescales. An important component of future research previously outlined is in determining the sensitivity of the South African tourism sector to these relative variations in climatic suitability, and to the changes over time. This critically should involve empirical studies of tourist bookings. The results of this study present considerable impetus for the calculation of TCI scores for adjacent southern African countries. These countries similarly have tourism sectors dominated by outdoor attractions and a low adaptive capacity to climate change. Moreover, an understanding of more regional variability in TCI scores would facilitate improved forecasting of climate-change impacts to tourism sectors in developing countries in southern Africa. Although poor availability of climatic data will pose similar, if not greater, limitations to the calculation of TCI scores for countries adjacent to South Africa, such challenges can be circumvented (Fitchett et al., 2016a).

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