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Quantifying the climatic suitability for tourism in Namibia using the Tourism Climate Index (TCI)

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Abstract

Tourism Climate Indices (TCIs) are the most widely used method to quantify climate suitability for tourism, yet remain more extensively applied in the Global North. Here we apply the TCI to Namibia, a country heavily economically reliant on outdoor tourism. Rising temperatures and changes in relative humidity and precipitation pose threats to nature-based and adventure tourism in Namibia. The mean annual TCI scores for the period 2008–2018 vary from classifications of 'good' for Etosha Safari at 62 to 'excellent' for Windhoek at 80. Monthly scores reveal a bimodal-shoulder and winter peak, indicating that the most suitable climatic conditions for tourism occur during the austral spring, autumn and winter months. This is consistent with the literature regarding peak tourist seasons, and fortuitously aligns with school holidays. The spatial and seasonal quantification of climate resources in Namibia derived from the TCI results can inform sustainable planning for tourism and other economic sectors sensitive to climate.

Keywords Tourism climate index · Namibia · Tourism · Climate change · Nature-based tourism

1 Introduction

The mean climate of a destination contributes to the type of tourist attractions that can be offered, the peak season for tourism, and tourists' selection between destinations (Gössling et al., 2018; Noome & Fitchett, 2019). The weather experienced during a vacation determines which of the available activities a tourist can partake in, and their enjoyment and satisfaction of a trip. Extreme weather events can have both immediate and long-term impacts on tourist destinations, damaging infrastructure, reducing the aesthetic quality of a region, and obstructing access to accommodation establishments or attractions. Climate change is therefore a major threat to the tourism sector, as it influences the day-to-day weather, the probability and severity of extreme events, and the long-term climate of a region (UNWTO, UNEP and WMO 2008; Reddy, 2012; Hoogendoorn & Fitchett, 2018a).

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Countries in the Global South are particularly vulnerable to climate change (Moreno & Becken, 2009). Many of these countries have emerging tourism sectors which are heavily dependent on outdoor conditions, and limited adaptive capacity (Hoogendoorn & Fitchett, 2018b). Sub-Saharan Africa is among the most vulnerable regions to climate change, with expected temperature increases of between 2 and 4 °C by 2100, and most of the southern African region projected to experience temperature increases of between 4 and 6 °C (Hulme et al., 2001; Engelbrecht et al. 2015; Schellnhuber et al., 2016). Therefore, careful economic analysis of the effects of climate change on environmental systems must be performed (Reid et al., 2007).

Outdoor tourism, which includes winter tourism, sporting tourism, coastal tourism, wine tourism, adventure tourism and nature-based tourism, is under particular threat of climate change (Csete et al., 2013; Fitchett et al., 2016a; Jedd et al., 2018; Nicholls, 2006; Scott et al., 2008). In addition to the direct threats to tourism posed by changing weather and climate, the climate change will also have an indirect effect on the spatial distribution of agro-ecological zones, habitats, the distribution of diseases and pests, and migration patterns of fish populations (Tervo-Kankare et al., 2018; Smith and Fitchett 2020). Regional and seasonal shifts in the global tourism sector are therefore projected to result in both ’winners’ and ’losers’ (Amelung et al., 2007; Perch-Nielsen et al., 2010: 377). Namibia, like much of southern Africa, has a wide range of nature-based attractions and outdoor tourism activities, including hiking trails, beach and coastal tourism which includes fishing, game drives, water sports, leisure beach activities and adventure tourism (Ashley 2000; Saarinen 2010). These tourism sectors provide a strong suite of economic opportunities for local communities and small-, micro- and medium-sized enterprises (Tervo-Kankare et al., 2018). Foreign investment generated from tourism leads to increased employment and local income and to improvements to existing infrastructure (Noome & Fitchett, 2019; Reid et al., 2007; Scheyvens & Biddulph, 2018; Scott et al., 2012). Due to the warmer and drier climate, rich cultural history, abundant biodiversity and impressive landscapes, tourism has allowed for steady growth and is resulting in increased revenue and job creation in Namibia (MET 2016).

To facilitate ongoing growth in the tourism sector, and to allow for the most effective adaptation to climate change, it is important to quantify the climatic resources for tourism and the spatial heterogeneity thereof. The tourism climate index (TCI; Mieczkowski, 1985) was developed for such purpose and has been applied at course spatial resolution globally, and at higher resolution particularly within the Global North (Amelung & Nicholls, 2014; Amelung & Viner, 2006; Amelung et al., 2007; Kovács & Unger, 2014; Scott et al., 2004). Although the TCI was developed with specific consideration for ‘game viewing in African national parks’ (Mieczkowski, 1985: 225), it has only recently been applied at high resolution for southern Africa, with studies for South Africa (Fitchett et al., 2016a, 2016b, 2017), Lesotho (Noome & Fitchett, 2019) and Zimbabwe (Mushawemhuka et al., 2021). These studies confirm the suitability of the index for the region, through comparison with tourists’ accounts of climatic suitability recorded through TripAdvisor reviews and captured from questionnaires (Fitchett et al., 2016a, 2016b; Fitchett and Hoogendoorn 2018; Stockigt et al. 2018). A range of other tourism climate indices have been developed, improving on aspects of the TCI where a greater range of meteorological and touristic data are available (e.g., De Frietas et al. 2008), and adapting these for specific sub-sectors, such as beach tourism (e.g., Moreno & Amelung, 2009; Rutty et al. 2020), urban tourism (Scott et al., 2016) and camping tourism (Ma et al., 2020). Few of these indices have been applied at more than a regional scale, and none have yet been confirmed against tourist experiences in southern Africa. Although the holiday climate index (HCI) has been posited as a more appropriate update of the TCI, and encouraged for global use, one of the key modifications is the removal of evening thermal comfort on the basis that tourism destinations and accommodation establishments have, in the 30 years since the development of the TCI, had air conditioning installed (Scott et al., 2016). This does not hold true for Namibia where very few establishments are air conditioned. This limitation has resulted in inflated and unrepresentative HCI scores in similarly hot and dry regions of Iran (Hejazizadeh et al., 2019) and Zimbabwe (Mushawemhuka, 2021). The TCI is thus more appropriate for use in the southern African context (Fitchett & Hoogendoorn, 2019). This study therefore employs the TCI for the first high-resolution spatial and temporal assessment of the climatic suitability and climatic challenges for tourism in Namibia, contributing towards the growing literature for southern Africa and specifically addressing tourism in the desert setting.

2 Study site

Namibia is located on the south-western region of Africa (Fig. 1; Jokish 2009; Jänis, 2011). Namibia has a relatively small population base of approximately 2.6 million people, two-thirds of whom live in rural areas (Dowling & Grünert, 2018). Namibia is one of the driest countries and is classified as an arid zone (Angula, 2010), with more than 90% of is the terrestrial area estimated to be arid, semi-arid or hyper-arid (Tervo-Kankare et al., 2018). The aridity is primarily the result of the cold adjacent Benguela Current of the west Atlantic Ocean, inducing subsidence across the west coast of southern Africa (Mendelsohn et al., 2002). There is considerable climatic variation across Namibia with an increase in temperature and rainfall from west to east (David et al., 2013; Spear et al., 2018).

Meteorological stations corresponding with seven tourist locations spanning Namibia were selected for this study on the basis of the availability of the full suite of climatological variables required for the calculation of the TCI (Fig. 1; Table 1). These do unfortunately not include the far north-east, north-west and south-east corners of the country. There is, however, higher spatial resolution in regions of greatest climatic heterogeneity.

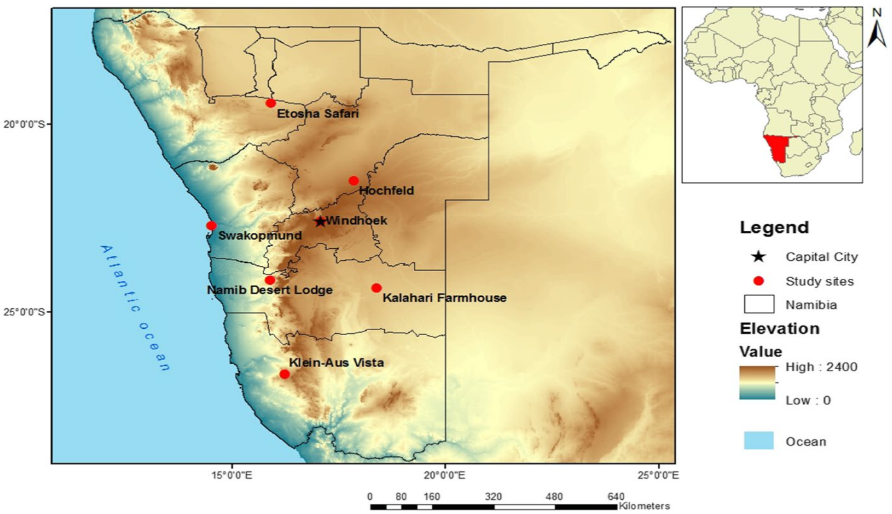

Fig. 1 Map of the study region, Namibia. The depiction indicates the administrational boarders within the country and the capital city, the study locations, topography, and the respective ocean current

Table 1 Geographic and climatic features of the study sites, each of which represent the region surrounding a meteorological station

Meteorological station	Latitude	Longitude	Elevation (m.asl)	Nearby tourist attractions	
Etosha Safari	19°24′30″ E	15°55′04″ S	1184	Mesosaurus fossil site Fish River Canyon	Engage with Hai‖Om culture Sightseeing
Hochfeld	21°25′47″ E	17°51′17″ S	1576	Hiking trails Bird watching Skydiving	4-wheel driving Guided walks and safari tours
Kalahari Farmhouse	24°20′14″ E	18°24′03″ S	1211	Wildlife tours Farm tours	Nature walks Bird watching
Klein Aus Vista	26°39′07″ E	16°14′33″ S	1403	Wild horses Heritage/history tours Eagle spotting	Mountain biking Hiking trails
Namib desert	24°06′00″ E	15°54′00″ S	664	Nature sightseeing Sand dune drives Self-drive tours	4×4 and quad biking trails
Swakopmund	22°40′44 E	14°31′52″ S	90	Desert/off-road trails Swakopmund museum Wildlife tours Heritage and cultural tours	Eco dune tours City tours Craft beer/gin tasting Sightseeing
Windhoek	22°34′36″ E	17°04′32″ S	1673	Craft centre Katutura township tour City tour National museum of Namibia	Daan Viljoen Game Reserve Cultural and heritage tours National Botanical Garden of Namibia

3 Methods

The TCI used in this study was originally developed by Mieczkowski (1985), formulated to incorporate the three aspects of climate most relevant to tourism, namely thermal comfort, physical and aesthetic components (de Freitas et al., 2008; Perch-Nielsen et al., 2010; Scott et al., 2004, 2016).

The TCI can be calculated by the following equation adapted by Perch-Nielsen (2010) for commonly available daily resolution climate data:

$$TCI = 2(4CD - CA + 2R + 2S + W)$$

This models the outdoor climate of a travel destination according to: thermal comfort (CD), average thermal comfort (CA), mean monthly sunshine hour (S), total monthly rainfall (P) and mean monthly wind speed (W). *CD* is based on the mean monthly maximum daily temperature combined with minimum relative humidity. *CA* is the combination of mean monthly average temperature and mean monthly relative humidity. *S* is calculated by dividing the mean monthly daily sunshine hours by the number of days in the given month, in other words either a 30- or 31-day month. *R* is the recorded monthly total precipitation. *W* is calculated by averaging the wind speed values within a given month. These five components of the TCI are assigned weights according to their perceived importance to tourist satisfaction. The end result score for each of the factors has the potential to either increase or decrease the mean annual TCI score for the study location (Roshan et al., 2016). The final TCI score is then classified on the basis of suitability, ranging from 'unfavourable' to 'ideal' (see Perch-Nielsen et al., 2010).

Mean TCI scores and classifications for each month were calculated for the period 2008–2018. An annual TCI score and classification was determined by averaging the TCI scores, followed by the calculation of an overall TCI score by averaging the ten annual TCI scores. This annual TCI score is classified using the six interannual climatic typologies developed by Scott and McBoyle (2001) to classify tourist destinations, namely year-round optimal, poor, summer peak, winter peak, bimodal shoulder peak and dry season peak (Bakhtiari et al. 2018). The tourism climate typologies for Namibia were plotted using the mean monthly TCI scores.

4 Results

Temperature (°C), relative humidity (%), precipitation (mm), sunshine (hr) and wind speed ($m.s^{-1}$) for the meteorological stations were averaged for the longest available data set publically available, which spanned 2008–2018 (Table 2). Marked spatial heterogeneity in the climate is notable from the monthly and annual averages, as is the distinct seasonality in Namibian climate. Mean annual TCI scores for the period 2008–2018 range from 62 'good' for the meteorological station Hochfeld to 81 'excellent' for Klein Aus Vista (Table 3). Most of the locations fall within the 'very good' climate rating, with three of the seven locations having score in the range 70–79.

Tourists seeking beach, nature-based and adventure tourism in regions near the meteorological stations of Kalahari Farmhouse, the Namib desert and Swakopmund are modelled to experience 'very good' climatic conditions. For the tourist visiting regions near the meteorological stations Klein Aus Vista and Windhoek, 'excellent' climatic conditions for

Table 2 Mean monthly climate for the weather stations over the period 2008–2018

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Etosha Safari													
Temperature	25.4	25.4	23.7	21.0	21.4	18.6	18.8	21.2	25.6	27.4	26.0	25.9	23.4
RH	38.9	38.7	39.7	34.6	29.5	23.5	16.9	19.5	26.8	32.1	37.2	39.8	31.4
Rainfall	129.5	74.9	90.9	44.6	0.0	0.1	0.0	0.0	0.3	4.8	27.4	68.7	36.8
Sunshine	125.2	156.3	145.9	158.4	207.5	189.3	186.4	173.8	153.8	137.3	152.5	140.7	160.6
Wind	8.3	8.4	7.2	7.4	7.3	7.9	6.6	11.4	11.1	12.0	14.2	8.8	9.2
Hochfeld													
Temperature	22.7	21.8	20.6	18.2	17.9	12.5	12.4	16.1	17.8	24.3	24.4	24.2	19.4
RH	35.1	35.2	32.4	25.7	19.8	7.7	7.2	9.7	13.3	22.7	26.8	34.1	22.5
Rainfall	157.7	139.4	115.8	31.7	8.0	0.0	0.7	0.2	1.0	8.1	41.0	114.3	51.5
Sunshine	116.1	179.9	152.3	173.4	160.0	183.3	258.7	159.9	115.6	139.5	173.3	161.3	164.4
Wind	5.4	5.1	4.2	3.9	4.6	4.6	5.6	5.4	5.6	6.9	7.0	6.1	5.4
Kalahari Farmhouse													
Temperature	26.9	25.8	24.1	21.5	17.2	15.6	11.9	15.2	19.5	23.2	26.4	28.0	21.3
RH	39.0	38.1	35.4	31.5	20.3	15.4	9.9	9.6	15.1	22.0	27.9	33.7	24.8
Rainfall	60.1	37.3	40.8	21.2	0.2	0.3	0.9	0.0	0.0	5.2	3.1	15.1	15.3
Sunshine	191.3	179.0	194.3	192.0	187.3	154.2	200.5	226.3	165.3	173.8	221.1	272.9	196.5
Wind	6.1	4.2	3.3	3.7	1.3	2.0	2.9	2.3	4.8	3.7	4.3	5.8	3.7
Klein Aus Vista													
Temperature	24.3	24.3	22.1	18.4	15.6	12.7	12.2	13.0	16.8	18.6	21.5	22.0	18.4
RH	31.6	32.2	25.7	20.8	17.2	9.7	7.7	8.0	11.4	15.4	19.7	23.8	18.6
Rainfall	9.5	9.8	29.7	1.8	8.3	7.0	3.5	11.7	0.1	0.0	9.5	0.0	7.6
Sunshine	160.0	222.5	127.3	211.2	212.4	163.7	156.2	185.2	178.8	184.3	185.0	197.5	182.0
Wind	12.4	10.8	14.4	13.8	14.3	14.1	16.2	14.7	15.1	16.4	16.2	15.1	14.5

Table 2 (continued)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Namib Desert													
Temperature	25.2	26.6	25.8	23.4	20.2	16.6	17.1	17.5	21.7	24.1	25.4	25.7	22.4
RH	31.9	36.4	34.7	29.9	22.5	14.4	13.2	11.9	19.1	23.0	27.5	30.5	24.6
Rainfall	14.9	12.9	30.7	54.4	15.4	0.8	1.4	1.2	2.3	10.3	0.7	3.6	12.4
Sunshine	192.0	177.7	207.3	222.8	198.4	159.3	179.6	168.2	181.6	223.6	226.2	237.2	197.8
Wind	11.2	5.9	4.7	5.4	5.3	5.4	5.5	5.0	5.9	6.0	8.5	7.5	6.4
Swakopmund													
Temperature	19.2	19.5	18.7	17.2	15.1	14.7	15.1	13.3	13.8	15.0	16.4	17.8	16.3
RH	35.1	36.1	34.6	31.6	27.2	24.6	24.4	23.7	24.8	26.5	29.9	31.2	29.1
Rainfall	1.2	4.2	3.3	5.5	4.2	2.5	1.3	1.4	2.4	0.8	0.8	0.5	2.3
Sunshine	97.1	114.0	139.5	163.6	173.5	112.7	119.4	98.0	87.7	105.8	107.6	95.2	117.8
Wind	7.2	7.3	7.1	6.4	4.8	5.6	6.2	6.2	7.1	7.3	7.5	7.0	6.6
Windhoek													
Temperature	24.0	23.1	21.5	19.6	16.8	14.0	13.5	17.2	21.8	23.8	24.0	24.6	20.3
RH	31.9	35.7	32.4	28.3	20.9	11.4	10.2	15.6	16.4	21.1	27.6	31.8	23.6
Rainfall	94.2	114.3	108.8	52.5	13.5	1.5	0.1	0.3	6.3	8.1	25.5	47.6	39.4
Sunshine	173.2	164.1	166.2	182.0	201.1	194.9	204.6	181.2	164.1	203.9	221.4	210.0	188.9
Wind	6.0	5.7	4.9	4.6	4.6	4.0	5.8	5.4	6.0	6.1	6.2	5.7	5.4

Table 3 Mean monthly TCI scores for the period 2008–2018

Meteorological station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Ann
Etosha safari	52	56	63	75	81	80	75	72	66	60	66	58	67
Hochfeld	42	52	58	74	84	84	87	81	68	57	48	39	62
Kalahari farmhouse	61	71	74	81	83	86	87	77	66	64	66	69	71
Klein aus vista	74	76	72	85	85	82	82	83	84	78	77	78	81
Namib desert	65	69	77	75	84	85	87	80	76	69	69	70	75
Swakopmund	83	90	80	77	75	72	73	74	78	79	81	75	78
Windhoek	70	73	75	84	86	88	87	86	78	78	78	75	80

Legend		
Ideal (90–100)	Good (60–69)	Marginal (40–49)
Excellent (80–89)	Acceptable (50–59)	Unfavourable (30–39)
Very good (70–79)		

tourism are modelled. Tourists visiting areas close to the meteorological stations Etosha Safari and Hochfeld are likely to experience ‘good’ climatic conditions. The mean monthly TCI scores for the respective study sites range from 39 (‘unfavourable’) in December for Hochfeld to 90 (‘ideal’) in February for Swakopmund, over the period 2008 to 2018 (Table 3).

This would suggest that tourist seeking beach tourism and adventure tourism near the Swakopmund meteorological station and town would benefit from most from the ‘ideal’ climatic conditions in February (Table 3). The majority of the locations have mean monthly TCI scores in the ‘very good’ climatic suitability rating category. The ‘excellent’ climatic suitability rating category represents 28 of the 84 months. In comparison with the very good rating, which is more sporadic and is recorded throughout the year, the bulk of the records of an excellent rating fall within the winter months of June through August. Tourists would have the ‘excellent’ climate conditions when taking part in nature-based or adventure tourism during this time. Etosha Safari and Hochfeld are the only two meteorological stations that feature ‘acceptable’ (50–59), ‘marginal’ (40–49) and ‘unfavourable’ (30–39) climatic conditions for tourism (Table 3). In spring and summer months, the other five locations demonstrate predominantly ‘good’, ‘very good’ and ‘excellent’ climatic conditions for tourism. This may be due to the geographical location of these two locations, which is situated in the more northern region of the country. The mean annual TCI scores for the meteorological stations produced a range of 62 ‘good’ for Etosha Safari and Hochfeld and 84 ‘excellent’ for Klein Aus Vista over the period 2008–2018 (Table 3). Etosha Safari, Hochfeld and the Namib desert have scores that range from ‘good’ to ‘very good’ interannually, while Kalahari farmhouse which consistently has climatic conditions that fall into the ‘very good’ category. The regions surrounding the meteorological stations at Klein Aus Vista, Swakopmund and Windhoek have climatic conditions that range from ‘very good’ to ‘excellent’ interannually (Table 3).

Exploring Scott and McBoyle’s (2001) tourism climate resource typologies, none of the selected meteorological stations in this study fall into dry season peak conditions, year-round optimal conditions or year-round poor conditions tourism climate typology categories. Two categories remain: ‘winter peak’ and ‘bimodal-shoulder peak’. The winter peak distribution accounts for 71% of the meteorological stations, including Etosha Safari, Hochfeld, Kalahari Farmhouse, Namib desert and Windhoek (Fig. 2). The distribution indicates that the climatic conditions in winter are the most conducive for general tourism in Namibia. Notably, these locations are all situated inland. It is presumed that these locations may experience greater differences between summer and winter temperatures as a result of continentality.

Meteorological stations Klein Aus Vista and Swakopmund fall into the bimodal-shoulder peak climate suitability classification. Bimodal-shoulder peaks are observed for summer and spring months at Swakopmund, and autumn and spring months at Klein Aus Vista, in contrast to the spring and winter months that is typical of the northern hemisphere (Fig. 3). The distribution of mean monthly TCI scores at the Klein Aus Vista meteorological station depicts a bimodal-shoulder peak for in the months of May and September, as May has a score of 85 and September has a score of 84 which categorises the two locations as having 'excellent' climatic conditions (Fig. 3). Swakopmund has the largest mean monthly TCI scores in February and November, indicating a bimodal-shoulder peak. February has a score of 90 which is considered 'ideal' and November has a score of 81 which is categorised as 'excellent' climatic conditions (Fig. 3). This may be because the meteorological station for Swakopmund is in the coastal town of Swakopmund, while the Klein Aus Vista station is located in a mountainous region. This may explain why the regions are both classified as having 'bimodal-shoulder peak' distributions but 'shoulder peak' months differ.

Climate change in Namibia will affect the spatial distribution of tourism flows and impact the duration and quality of climate-sensitive tourism seasons, which will have serious consequences for national and international spending (Rutty and Scott 2016). These changes to the spatial distribution of climate resources require regular monitoring and assessment over time (Perch-Nielsen et al., 2010). Understanding the spatial distribution of climate resources in a country is crucial for the management of outdoor and nature-based tourist attractions; it will provide information to the relevant stakeholders and government for implementing actions to mitigate and adapt to future projected climate conditions that will impact the suitability of destinations for tourism (Fitchett et al., 2017).

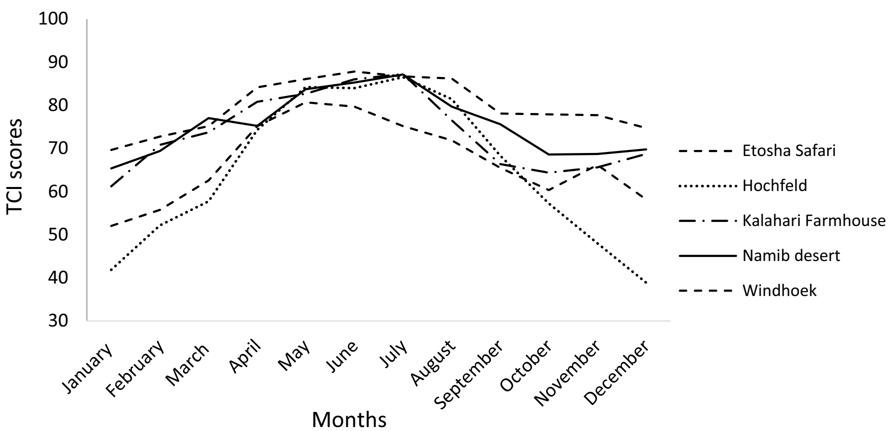

Fig. 2 The 'winter peak' distribution is present for five of the weather stations over the study period 2008–2018

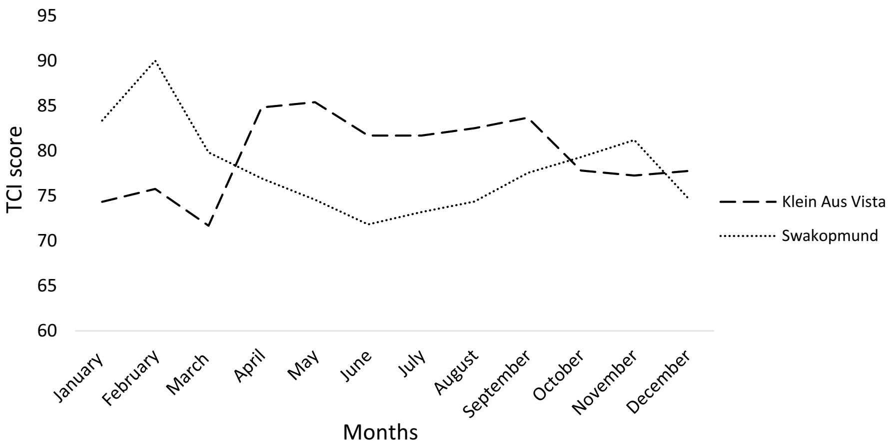

Fig. 3 The 'bimodal-shoulder peak' distribution is present only for Klein Aus Vista and Swakopmund over the study period 2008–2018

The TCI is not a predictive tool for tourist arrival; rather, the TCI calculates scores that can be used to determine the climatic suitability of destinations and climatically the best time of year to visit these destinations (Amelung & Nicholls, 2014; Amelung et al., 2007; Fang & Yin, 2015). IDW spatial interpolation of TCI scores estimates the climatic suitability of regions across Namibia over the study period. Over the period of 2008–2018, regions in the central, coastal and south-west of Namibia, including the meteorological stations at Windhoek, Swakopmund, the Namib Desert, Kalahari Farmhouse and Klein Aus Vista, are calculated to have consistently 'very good' to 'excellent' climatic conditions for tourism. (Fig. 4). The IDW spatial interpolation of the mean annual TCI scores for the period 2008–2018 reveals that central, southern and south-western regions of Namibia have climatic factors that are more suitable to tourism than those experienced in other parts of the country for the majority of the year. The northern regions of Namibia have the lowest IDW-interpolated mean annual TCI scores (Fig. 4). In spring, central and southern regions have higher TCI scores than the northern regions of Namibia. Summer has a similar spatial distribution to that of spring with lower TCI scores in the northern regions compared to the rest of the country, but the meteorological stations at Swakopmund, Windhoek and Klein Aus Vista have higher TCI scores than that of the rest of the coastal, central and southern regions. In autumn, the spatial distribution changes, whereby the southern coastal regions have the higher 'very good' TCI scores and the north and eastern parts of the country have 'average' climate conditions for tourism. The best time for travelling to Namibia in terms of climate suitability for tourism is winter, as the whole country has 'good' to 'excellent' climate conditions for tourism (Fig. 4).

The TCI is influenced by the five input climatic phenomena, namely temperature, humidity, rainfall, sunshine and wind speed. The score for each of the factors has the potential to either increase or decrease the mean annual TCI score for the study location. The TCI component that most frequently enhances the TCI scores for Namibia are wind (W) and rainfall (P), while sunshine (S) and daytime thermal comfort (CD) decrease the TCI score. Wind speed is a positive factor heightening the TCI scores for the meteorological stations of Hochfeld, Kalahari Farmhouse, the Namib desert, Swakopmund and Windhoek, with the majority of the wind speed scores exceeding the class of 4 with a

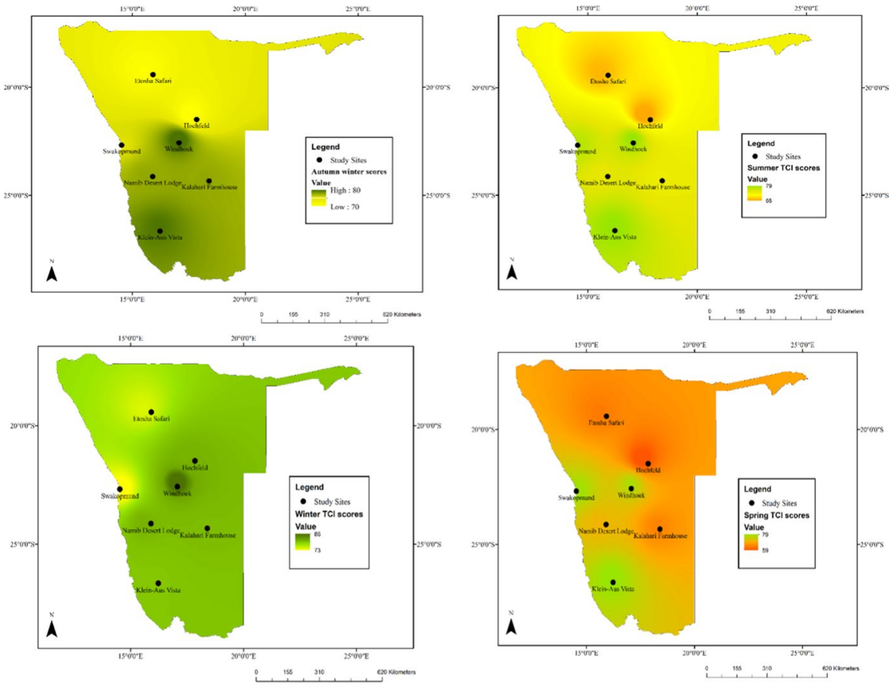

Fig. 4 Seasonal distribution of the TCI scores across Namibia, (top left) spring, (top right) summer, (bottom left) winter, and (bottom right) autumn

range from 2.88 to 12.23 km/h. Rainfall is the second highest factor to positively influence the TCI scores in Namibia with meteorological stations at Klein Aus Vista and Swakopmund returning scores ranging from 4 to 5; this means that these study sites experience mean monthly precipitation between 0.0 and 44.9 mm. Etosha Safari was the only meteorological station for which average thermal comfort (CA) is the factor that most positively influenced the TCI score. The TCI scores for the summer months were most positively influenced by wind, influenced by the absence of strong winds followed by average thermal comfort. The TCI scores increased in the winter months, equally, through the influence of precipitation and wind speed.

The TCI component that most frequently decreases the TCI score is sunshine (S), with the meteorological stations Etosha Safari, Hochfeld, Klein Aus Vista, the Namib desert, Swakopmund and Windhoek recording < 6 h sunshine per day. Daytime thermal comfort was highlighted as having the most negative impact on the TCI score for the meteorological station at Kalahari Farmhouse with scores < 3. The climatic factor that most negatively affected the TCI scores for the summer months during the study period is sunshine. Winter TCI scores were negatively affected by average thermal comfort. Daytime thermal comfort is the second highest factor that negatively influences the TCI scores in Namibia, as these study sites experience relatively low mean monthly maximum temperature (between 10 and 15 °C) and low relative humidity. Etosha Safari was the only meteorological station for which sunshine and wind are identified as factors that negatively influenced the TCI score.

5 Discussion

5.1 Regional comparison of the TCI score outputs

One of the principal benefits of using the TCI rather than a more specifically adapted index is in facilitating both regional and global comparison of output scores, and in turn of climatic suitability for tourism. The mean annual TCI scores for Namibia range from 62 for the meteorological station Hochfeld in the northeastern region of central Namibia to 81 for Klein Aus Vista, the southernmost station. These TCI scores are notably lower than for the southern African countries of South Africa, with a range of 76.5–93 (Fitchett et al., 2017), and Zimbabwe, with a range of 75.5–83 (Mushawemhuka et al., 2021). The score for Hochfeld is consistent with the mean annual TCI score of Afriski, a mountain ski resort in Lesotho (Noome & Fitchett, 2019). This is perhaps most marked, as Namibia is a hot and hyper-arid country, whereas Afriski in Lesotho is characterised by a cold alpine climate, and regular snowfall in winter (Noome & Fitchett, 2019). The scores for Namibia are somewhat counter-intuitively reduced primarily by low sunshine hours, before the thermal comfort aspect. While the country is arid to hyper-arid, frequent coastal advective cloud and fog (Hachfeld & Jürgens, 2000) reduce the total sunshine hours to considerably less than those of Zimbabwe, Lesotho and South Africa.

At a global scale, Mieczkowski's (1985) original development of the TCI included a low-resolution global map of scores. These are consistent with the outputs calculated here, ranging from excellent in southern Namibia through to very good and good for much of the central region of the country (Mieczkowski, 1985: 230). The scores for the northernmost region underestimate the scores, with a classification of acceptable (Mieczkowski, 1985: 230). Comparing the TCI scores other arid regions of the world, a selection of four stations in Pakistan has a narrower range in mean annual TCI scores from 69 to 74, but a more dominant bimodal-shoulder peak (Shahzad et al., 2021). For Iran, monthly TCI scores are reported (Roshan et al., 2016), yet from these a very large mean annual TCI score range of 58–78.2 has been calculated.

5.2 Implications for the future of tourism In Namibia

Extreme heat events, aridification and drought conditions can potentially alter the spatial distribution natural resources of national parks and game reserves in Namibia (Hoogendoorn & Fitchett, 2018b). This may have severe consequences for national parks and may undermine the future of tourism operations and activities across Namibia as 75% of the tourism sector relies economically on game viewing and trophy hunting (Dube & Nhamo, 2019; Hoogendoorn & Fitchett, 2018a, 2018b; Reid et al., 2007). Interannual variability in rainfall patterns and extreme climatic events such as severe drought potentially pose risks of water scarcity, increased spread of disease, a reduction in scenery and wildlife populations and the migration of game, and more frequent veld fires (Lendelvo et al., 2018; Orti & Negussie, 2019). Increased temperatures are threatening wildlife, as these changes will induce species migration in many regions in southern Africa (Agnew and Viner 2001; Hambira et al., 2013). Future projections in the period 2046–2065 that project with a high degree of certainty temperature increases of 1.8 °C to 3.5 °C in the summer season and 1.8 °C to 4.8 °C in winter (Dirkx et al., 2008). Many cities in the northern hemisphere, including China, Iran and parts of the Mediterranean are noticing a shift in tourism from summer to spring, as a more favourable season for tourist comfort due to temperature increases. Namibia currently has more suitable climatic conditions for tourism in summer than spring. Strong signals of warming and drying are consistent with the Coupled Model Intercomparison Project Phase 3 (CMIP3) and Phase 5 (CMIP5; Taylor et al., 2012). These consequences may lead to cancellation or reduced bookings, making unfavourable climate a main cause of declining tourist visitation (Amelung & Viner, 2006; Hoogendoorn & Fitchett, 2018a, 2018b; Lendelvo et al., 2018).

5.3 Avenues for adaptation

Adaptation is an important pillar to reduce the impact of climate change (Mimura et al., 2015). However, the competing challenges in developing countries for economic and social development, particularly on the African continent, may set back adaptation strategies—especially in the tourism sector (Hoogendoorn & Fitchett, 2018a, 2018b; Mimura et al., 2015; Pandy & Rogerson, 2020). The *Namibe Tourism Master Plan* (EDETA 2013) sets out three principles of nature-based tourism: (1) it is interested in natural and cultural areas and resources; (2) it must contribute to nature conservation; and (3) it will benefit the local residents (Morais et al., 2018). Currently, the proposed climate change action plan of Namibia only refers to tourism in relation to the threat tourists pose on the conservation of coastal zones and their pressure on natural resources (Tervo-Kankare et al., 2018). Tervo-Kankare et al. (2018) highlight the paucity of research concerning the adaptive capacity of the tourism sector in Namibia in response to climate change.

Towards effective adaptation of the Namibian tourism sector to climate change within the scope of the national plans for tourism, and acknowledging the economic strain, optimal utilisation of seasonal climate resources would likely yield the maximum return on investment. Similar strategies have been implemented at Afriski in Lesotho, offering off-season non-snow activities (Hoogendoorn et al. 2020). With the benefit of a large country and wide latitudinal range, the variations in the timing of optimal climate for tourism allow for the maximisation of tourist experience through targeted advertising of the most climatically suitable routes for each season.

To distribute the income that derives from tourism with the locals and rural areas, tourism routes between small towns are often established (Kalvelage et al. 2020), particularly as a development strategy in rural areas of southern Africa. South Africa, for example, has established tourism routes throughout the country which give variation to the tourist experience, and channel tourists to regions dominated by small, micro and medium enterprises (Rogerson & Rogerson, 2017). The Cape Wine Route was the first formal tourism route established in South Africa and is well known for wine and culinary tasting experiences (Ferreira and Hunter 2017). Tourism routes foster cooperation rather than competition among small towns, generating a synergistic effect which promotes wide benefits through new linkages between small businesses and the dispersion of cash flow over a wider area (Ferreira and Hunter 2017).

The capital city of Namibia, Windhoek, is the centre of tourism development followed by conservatories and coastal towns, namely Etosha National Park, Swakopmund and Walvis Bay (Kavita and Saarinen 2016). The northern region of Namibia hosts various tourism routes, which were launched within the last two decades by the Namibian Department of Environment and Tourism (Kokt 2017). These include the Omulunga Palm Route, Arid Eden Route and Four Rivers Route. Along these routes are major and minor tourist attractions, including Etosha National Park (the top wildlife destination in Namibia), Skeleton Coast (which derives its name from beached ships and skeletons of whale and seal) and the Namib Desert (known for hot-air ballooning, safari drives and bird watching among other activities). Some of these are particularly popular during specific climatic seasons, such as the Fish River Canyon, which is ideal for hiking in autumn to early spring to avoid the heat, and Swakopmund, a coastal town serving as a popular destination for domestic tourism to escape the heat during the summer months. Managing and marketing the routes is important to grow awareness of the local communities as well as the privately owned accommodation enterprises through information centres, activity, tour and safari operators. The results of the TCI can augment the marketing strategies for these routes to ensure optimal tourist satisfaction, and to distribute tourism income across the country within the seasons of most suitable climatic conditions for the activities on offer (Noome & Fitchett, 2019; Hoogendoorn et al. 2020).

Winter, spanning June through August, provides a favourable climate for tourist visitation across Namibia, but the attractions in the northern areas are particularly climatically suitable (blue route, Fig. 5). Tourists can arrive in Windhoek at Hosea Kutako International Airport if they are international travellers, and explore the cultural and urban tourism offered in the city. For hard adventure tourists, the Spitzkoppe inselbergs offer a range of climbing and hiking opportunities. To avoid heat stress and thunderstorms, winter would be the most suitable season to visit this region. Tourists seeking soft adventure experiences can enjoy another major attraction of the region, rock paintings. After experiencing the cultural and adventurous offerings at Spitzkoppe, tourists should travel north towards Etosha National Park for game viewing. Game viewing is most suitable July–September as the dry winter conditions make viewing easier with the wildlife conjugating around the sparse waterholes. International travellers can arrive in Windhoek as the start of their trip through Namibia in autumn (orange route, Fig. 5). Autumn is the best time of year to visit the Namib Desert with more moderate temperatures and little to no rainfall. Heading south,

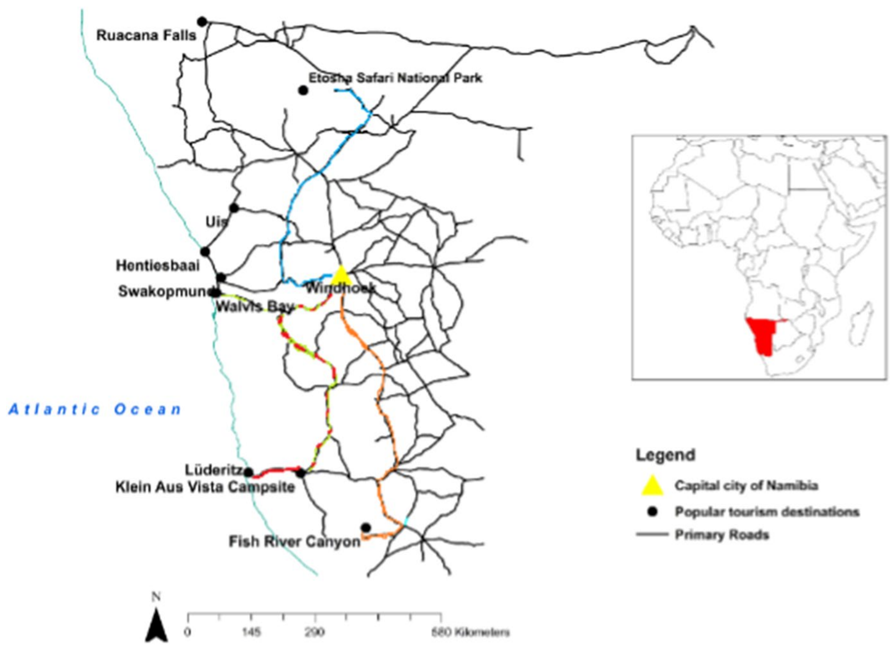

Fig. 5 Proposed seasonal travel routes to maximise climate resources

towards Klein Aus Vista for desert drives, tourists can enjoy the Four Deserts Tourism Route, the Nama Padloper Route, Canyon Diamond Route, Kalahari Route and the LudBay 4×4 Guided Self-drive Route (Kokt 2017). The Fish River Canyon is the second largest canyon in the world and the largest in Africa (Mvondo et al., 2011); the hiking trail is best to visit in the drier months, and moderate temperatures make it most suitable to visit during colder winter months.

Spring (green route, Fig. 5) is not the best time of year to visit many regions in Namibia; the towns of Swakopmund, Klein Aus Vista and city of Windhoek are the only destinations that will be climatically enjoyable for tourism. Travelling along the southern coastline, August through to November are climatically the most suitable months for tourist activities. Swakopmund would be the next destination after Windhoek for whale and dolphin watching; this should be undertaken between August and September before the whales migrate northward (Elwen et al., 2014). In the summer months (red route, Fig. 5), tourists should seek tourism attractions along the southern coastal regions for the most suitable climate. Coastal regions offer better viewing of wildlife compared to game reserves where high temperatures cause animals to migrate. In winter, the wildlife is more prone to concentrate around the waterholes, making viewings easier. The coastal regions host a variety of wildlife, the city of Walvis Bay, for example is home to the Greater Flamingos, who nest in the region after the first rains in November to March, and a number of cetaceans including whales, dolphins, turtles, fur seals and sunfish (Béchet, 2017; O'Connor et al., 2009). Whale viewings have a bimodal peak of austral winter (June–August) and late summer (February–March) in Walvis Bay. Historical and cultural attractions of Swakopmund are the next in line after Walvis Bay as an ideal tourist destination (Jänis, 2011). Other offerings in Swakopmund are seal and dolphin sighting, sand-duning and skydiving (Voulvouli, 2012). Further south, the town of Luderitz (most suitable for tourists between October and May) offers beaches, boat rides, penguin and flamingo viewing at Halifax Island, and a tour of Kolmanskop, a deserted, dust covered town.

6 Conclusion

A growing body of literature has quantified the climatic suitability of destinations for climate change through the use of tourism climate indices. These allow for the determination of the optimal season for tourism, the relative suitability of two destinations, and, with a sufficiently long data set, trends in climatic suitability. Much of this literature is situated within temperate regions of the Global North. We present the first country-level analysis for Namibia. The mean annual TCI scores for Namibia range from 62 classified as 'good' to 81 classified as 'excellent'. There is considerable interannual variation. This heterogeneity presents both challenges and opportunities for tourism in Namibia, requiring tourism marketing strategies to align with the spatio-temporal variations in highest suitability scores to maximise tourist satisfaction of the climate and available activities during their vacations. These provide relatively low-cost and low-infrastructure adaptation mechanisms, which are imperative to update as the climate continues to change.

One of the primary limitations for research using the TCI in developing countries, such as Namibia, Lesotho, Zimbabwe and South Africa, is the poor availability of uninterrupted, continuous meteorological data (Nicholson et al. 2012; Fitchett et al., 2016a, 2016b; Hoogendoorn and Fitchett 2016; Mushawemhuka et al. 2020). The selection of study regions is thus influenced more by the availability of data than the location of the primary tourism attractions. Deliberate efforts towards both ground-based and remote-sensing-derived meteorological data collection are important trajectory of future tourism climate research in Namibia. Of equal importance is future work aimed to develop a specific desert climate index targeted to outdoor tourism in arid regions such as Namibia, built from data on tourist experiences.

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