Annals of Tourism Research 77 (2019) 49–61

Contents lists available at ScienceDirect

Annals of Tourism Research

journal homepage: www.elsevier.com/locate/annals

INVITED ARTICLE

Global tourism vulnerability to climate change

Daniel Scott[a,*], C. Michael Hall[c,d,e], Stefan Gössling[b,e]

[a] Department of Geography and Environmental Management, University of Waterloo, 200 University Ave. West, Waterloo, Ontario N2L 3G1, Canada
[b] Western Norway Research Institute, Research Centre for Sustainable Tourism, Box 163, 6851 Sogndal, Norway
[c] Department of Management, Marketing & Entrepreneurship, University of Canterbury, Private Bag 4800, Christchurch 8140, New Zealand
[d] Department of Geography, University of Oulu, Oulu, Finland
[e] School of Business and Economics, Linnaeus University, 39182 Kalmar, Sweden

ARTICLE INFO

Keywords:
Tourism
Climate change
Impacts
Adaptive capacity
Decarbonization
Sustainable development goals

ABSTRACT

Climate change will have far-reaching consequence for the future of tourism. A Climate Change Vulnerability Index for Tourism (CVIT) comprised of 27 indicators provides a transparent and systematic first analysis of the differential vulnerability of the tourism sector in 181 countries. Countries with the lowest vulnerability are found in western and northern Europe, central Asia, Canada and New Zealand. High sector vulnerability is found in Africa, Middle East, South Asia and Small Island Developing States. Vulnerability is highest in many countries where tourism represents the largest proportion of GDP and regions where tourism growth is expected to be the strongest over the coming decades. Climate change will pose an increasing barrier to tourism contributions to the Sustainable Development Goals.

Introduction

Tourism is a major global economic sector that has undergone tremendous growth over the last 50 years (UN World Tourism Organization [UNWTO], 2011, 2018). The global economic contribution of the tourism sector has likewise continued to increase, with the World Travel and Tourism Council (WTTC) estimating the sectoral contribution to global economy in 2015 at US$7.2 trillion (9.8% of global GDP) and 284 million jobs (9.1% of jobs worldwide) (WTTC, 2016a). The importance of the tourism economy is even more pronounced in thousands of destination communities and the more than 90 countries where tourism represents more than 10% of national Gross Domestic Product (GDP) and a significant proportion of employment (WTTC, 2016b). With strong projected growth in international tourist arrivals in many emerging economies, the UNWTO, WTTC, and international development organizations position tourism as an important contributor to the Sustainable Development Goals (SDGs) (Hall, Scott, & Gössling, 2015; World Bank, 2017).

Climate change poses a risk to the global economy (Burke, Davis, & Diffenbaugh, 2018; Burke, Hsiang, & Miguel, 2015), particularly beyond 2 °C global warming. The challenge that climate change poses to growth in the tourism sector and its ability to contribute to the SDGs in particular, remains under researched (Becken, 2019; Hall, 2019; Janetos, Malone, Mastrangelo, Hardee, & de Bremond, 2012; Saarinen & Rogerson, 2014; Scheyvens & Hughes, 2018). In particular there continues to be very limited published research on tourism and climate change in the context of less developed countries (Hall et al., 2015; Scott, Hall, & Gössling, 2016) and the potential implications for tourism as a means of poverty reduction and sustainable development (Scheyvens & Hughes, 2018; UNWTO, 2017; World Bank, 2017).

Tourism is a highly climate-sensitive sector that is also strongly influenced by the numerous factors including the state of natural

* Corresponding author.
E-mail address: dj2scott@uwaterloo.ca (D. Scott).

https://doi.org/10.1016/j.annals.2019.05.007
Received 27 November 2018; Received in revised form 21 May 2019; Accepted 27 May 2019
Available online 05 June 2019

environment, perceptions of personal security, and capacity to meet travel costs (Scott, Hall, & Gössling, 2012a). Indeed, a comprehensive review of how 10 types of climate change impacts are affecting 89 attributes of human health, food, water, infrastructure, economy and security, found that tourism was one of only five attributes that is being impacted by all 10 types of climate impacts (Mora et al., 2018). With each of these major influences on tourism to be significantly impacted by climate change, the integrated effect is anticipated to be far-reaching in the decades ahead (Scott et al., 2012a). The UNWTO et al. (2008, p. 38) recognize climate change as, "…the greatest challenge to the sustainability of tourism in the 21st century." In 2018, the World Travel and Tourism Council (2018) joined the UNFCCC *Climate Neutral Now* initiative, committing to becoming climate neutral by 2050, and much needed collaborate on accelerating sector-wide climate action (Gössling & Scott, 2018). As such, the implications of climate change for many developing countries that plan for tourism to be a key future development strategy needs to thoroughly considered in planning and policy making, official development assistance programs, and international adaptation negotiations (Gössling, Hall, & Scott, 2009; Scott, Hall, & Gössling, 2012b). Many countries recognize the salience of tourism to advancing the climate agenda, with the tourism sector mentioned in 82 of the 182 (45%) Nationally Determined Contributions (NDCs) (or intended contributions where applicable) submitted to the UNFCCC (https://www4.unfccc.int/sites/ndcstaging/Pages/Home.aspx), with regard to prioritization for adaptation, mitigation, and climate finance (Scott & Gössling, 2018).

Despite growing sectoral awareness of the vulnerability of tourism to climate change (WTTC, 2015; Gössling & Scott, 2018), the differential climate change impacts faced by the tourism sector at the regional and destination country scale remains uncertain. A central limitation is the geographic scope of extant research. As evidenced by tourism sector content in the regional chapters of the Intergovernmental Panel on Climate Change (IPCC) Assessment Reports, potential impacts remain poorly understood in Africa, Asia, Central and South America, and Small Islands (Scott et al., 2016). These regional knowledge gaps are noteworthy, as they persist in many of the regions where tourism is anticipated to grow the fastest over the next 30 years. For example, there is a dearth of research on tourism and climate change in Asia, the world's fastest growing region for international tourist arrivals (Su & Hall, 2014), In the case of Africa, Boko et al. (2007, p. 450) emphasize that 'very few assessments of projected impacts on tourism and climate change are available' and observe, "There is a need to enhance practical research regarding the vulnerability and impacts of climate change on tourism, as tourism is one of the most important and highly promising economic activities in Africa. Large gaps appear to exist in research on the impacts of climate variability and change on tourism and related matters" (Boko et al., 2007, p. 459). These regional gaps on knowledge regarding the effects of climate change on tourism remain in the more recent 2014 IPCC assessment and the 2018 Special Report on Global Warming of 1.5 °C (IPCC, 2018).

Another salient barrier to understanding the regional implications of climate change for tourism competitiveness and sustainability has been the lack of assessments that consider the wide range of potential impacts and their interactions at the destination scale (Scott et al., 2012b, 2016). The study of climate change impacts in isolation is common within the very comprehensive multi-sectoral literature reviewed by Mora et al. (2018) (over 3200 studies), which they warn provides incomplete and potentially misleading assessment of the consequences of climate change for a location or sector of interest. Because tourism is characterized by strong global interconnectedness, the consequences of climate change and associated mitigation/adaptation responses in other countries can therefore have important implications for destination countries (Hamilton, Maddison, & Tol, 2005; UNWTO et al., 2008), including with respect to the relative attractiveness of potential destinations (Scott et al., 2012a). This includes the climate change impacts within a country's borders as well as what Hedlund, Fick, Carlsen, and Benzie (2018) refer to as 'transboundary' and 'transnational' risks that respectively reach across common borders as well as more distant countries. Consequently, diverse types of information need to be integrated to provide a fuller understanding of how multiple climate change impacts could simultaneously influence the tourism sector (Mora et al., 2018; Scott et al., 2012a, 2016).

An approach that offers promise to overcome regional information disparities and the challenge of integrating multiple forms of information is the use of country scale indicators in a multi-dimensional climate change vulnerability index. With the increasing salience of adaptation within IPCC science assessments and UNFCCC negotiations, the development of climate change vulnerability indices has been an active area of research (Barnett, Lambert, & Fry, 2008; Hinkel, 2011; Klein, 2009; Malone & Engle, 2011), and reflect Westermeyer's (2010) calls for improved climate and climate change data and capacity building for development purposes. Although the overall vulnerability of low-income countries to some of the major effects of climate change is well recognized (Nurse et al., 2014; Wheeler, 2011), tourism is not explicitly considered in most global climate change vulnerability indices, e.g. Climate Change Vulnerability Index and Risk Atlas (Maplecroft, 2016); Notre Dame-Global Adaptation Index (ND-GAIN) (Notre Dame Adaptation Institute, 2016); Transnational Climate Impacts Index (Benzie, Hedlund, & Carlsen, 2016); and Climate and Regional Economics of Development - Vulnerability Index (Stanton, Cegan, Bueno, & Ackerman, 2012).

Similarly, while Hedlund et al.'s (2018) Transnational Climate Impacts Index recognizes the importance of remittances of migrant works (financial pathway) and share of imports for GDP (trade pathways), it overlooks the major contribution that tourism makes to both. The sole exception is the Climate Vulnerability Monitor of the Development Assistance Research Associates (DARA) (2012), where a sectoral framework was utilized. Not considering tourism in multi-sectoral vulnerability indices disadvantages the "special case" (Brooks, Adger, & Kelly, 2005, p. 161) of Small Island Developing States (SIDS) where tourism is a major component of national economies (Hall, 2015). Non-representation of a factor likely to contribute substantially to climate change related economic impacts is detrimental to these countries if vulnerability index rankings are used to inform allocations of adaptation support (Füssel, 2009; Hedlund et al., 2018; Wheeler, 2011).

This paper presents a Climate Change Vulnerability Index for Tourism (CVIT) that integrates 27 indicators representative of a range of internal domestic and transnational impacts on the tourism sector of 181 countries, as well as indicators of tourism sector and destination country adaptive capacity. The objectives of the paper are threefold. First, to provide a transparent and systematic approach to compare the climate change vulnerability of the tourism sector of each country in order to partially overcome persistent

regional knowledge gaps. By revealing underlying spatial patterns of climate change vulnerability in the sector, 'hotspots' that should be prioritized for further analysis will be identified (de Sherbinin, 2014). Second, by comparing the relative vulnerability of the tourism sector to the economic importance of tourism to national economies (as a percentage of GDP), the paper aims to stimulate discussion among tourism stakeholders and international development organizations about where climate change is most likely to compromise tourism competitiveness and growth, and where adaptation assistance may be most needed if tourism is to contribute to the SDG 2030 agenda. Finally, by developing the first composite climate change vulnerability index for tourism, it is hoped the sector can be better represented in future updates of comprehensive global vulnerability indices.

The development and application of climate change vulnerability indices

Indices are well established as analytical tools in a wide range of policy and business decision-making contexts, including tourism (e.g., Travel and Tourism Competitiveness Index, Tourism Confidence Index, Destination Brand Index, Holiday Climate Index). However, their development and application are not without debate (Surminski & Williamson, 2012). Nardo et al. (2005) and Saltelli (2007) emphasize that although indices have the capacity to provide the 'big picture' by summarizing complex issues into a single comprehensive measure, poorly constructed or misinterpreted indicators and indices can invite simplistic conclusions and mislead government and business leaders. Nevertheless, a particular strength of indices is the ability to integrate diverse types of biophysical, social, economic, and governance data to operationalize a multi-dimensional representation of vulnerability (Malone & Engle, 2011) as well as function as a systematic rapid assessment tool for climate change related vulnerability (NESP Earth Systems and Climate Change Hub, 2018).

A prominent application of indices in climate change research and policy has been to operationalize the concept of vulnerability. Vulnerability is a concept for which there is no broadly agreed definition. Füssel and Klein (2006), Füssel (2010) and Hinkel (2011) provide critical overviews of the plurality of vulnerability definitions used by various scholarly communities and specifically the disparate conceptualizations in climate change research. Here we adopt the IPCC 4th Assessment (2007) definition that corresponds to an outcome (or end-point) conceptualization: "Vulnerability is the degree to which a system (geophysical, biological and socio-economic) is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity." As this definition articulates, vulnerability is a multidimensional concept that cannot be observed and measured directly, and therefore must be 'constructed' (Hinkel, 2011). Although there are different definitions of what constitutes vulnerability (Malone & Engle, 2011), we have used the IPCC approach because it is one the most commonly used conceptualizations in the climate change field and has particularly utility for policy-makers.

The concept of vulnerability is also central to international climate change policy. The Paris Climate Agreement (UN, 2016) makes multiple references to prioritizing support for 'particularly vulnerable' countries, including with regard to international collaboration on adaptation (Article 7–2), provisions of scaled-up financial resources for mitigation and adaptation (Article 9–4), and capacity building (Article 11–1). Although finance for climate change adaptation has steadily grown over the first two decades of the 21st century, there remains a substantial gap between estimated annual costs of adaptation and available funds (UNEP, 2017). Some policy makers and Parties to the UNFCCC have suggested allocations should be prioritized on the basis of relative vulnerability (Wheeler, 2011); whereby answering the question of which countries are most vulnerable becomes more consequential (Ford et al., 2015).

While policy-makers, donor countries, and development organizations seek metrics to rank vulnerability, the application of vulnerability indices for prioritization of adaptation assistance remains contentious because of the substantial normative decisions required in index construction (Barnett et al., 2008; Füssel, 2009, 2010; Hinkel, 2011; Klein, 2009). Malone and Engle (2011) summarize the range of theoretical and methodological criticisms of indicator-based methods, as well as the critique that the demonstrated impact on decision-making remains limited. They suggest that indicator-based methods provide transparent frameworks for comparative analysis that are more appropriately used to understand regional vulnerability (Malone & Engle, 2011). This recommended application is consistent with the objectives of this study.

The application of climate change vulnerability indices to the tourism sector is not new, however all three previous analyses have important limitations. Deutsche Bank Research (2008) developed the first climate change vulnerability index for the tourism sector. It considered four factors influencing climate change impacts in 66 countries. Unfortunately, the methodology, including indicator variables, data sources, data transformation, and index weightings are not at all transparent. Malone and Engle (2011: 464) emphasize that full transparency is required so that methodological assumptions can be assessed by experts, decision-makers and stakeholders potentially affected by any such ranking exercise. This lack of transparency from a financial institution that may be advising corporate tourism and other investors was one of the primary motivations to develop the CVIT.

A second index was developed by Perch-Nielsen (2010) to examine the climate change vulnerability of beach tourism in 51 countries. This index is the strongest conceptually and methodologically, as well as the most transparent. This study had two primary limitations. First, only three of the 13 indicators used were specific to the types of impacts or the adaptive capacity of the tourism sector. The limited number of tourism sector indicators was partially related to data availability. Since the study was conducted, new indicators have become available (e.g. the World Economic Forum (WEF) (2015) *Travel and Tourism Competitive Index*). A second limitation was the specific focus on beach tourism, which does not provide insight into the full scope of climate and mitigation policy impacts that will challenge the sector. This study is conceptually and methodologically consistent with Perch-Nielsen (2010), but expands the scope of the vulnerability assessment across the entire tourism sector as available data allowed.

The Development Assistance Research Associates (DARA) (2012) *Climate Vulnerability Monitor* incorporated tourism as one of six

industry sectors. While only a small component of the index, the tourism sector is very poorly operationalized, with two indicators used to represent the sector (i.e., impacts on ski and reef tourism). These two indicators are meaningful to only a small subset of countries and were nonsensically extrapolated globally from studies in single countries (ski – Austria; reef - Barbados and Belize). The lack of any consideration of climate mitigation impacts for travel costs and accessibility and the relative adaptive capacity of the tourism sector were additional visible gaps.

Methods

Indicator selection

The conceptual framework of Scott et al. (2012b) guided the initial process of indicator identification. The conceptual framework outlined four broad pathways by which climate change and climate policy could affect major components of the global tourism system, including: (1) direct climatic impacts, (2) indirect climate-induced environmental change, (3) indirect climate-induced socioeconomic change, and, (4) mitigation and adaptation policy responses outside of the sector. The initial set of indicators were determined from a comprehensive review of the literature and then subsequently refined using the guidance criteria outlined by OECD (2008) and Hinkel (2011): consistent with current knowledge; relevance to sector domain; broad spatial relevance; quantified at the country scale with broad global coverage; data is open access; and data quality. Final indicator selection, as well as data sourcing and indicator weighting, were also informed by consultations with tourism scholars and experts at three events that included formal discussions on the role of indicators in assessments of tourism vulnerability to climate change and their relevance for policy making (particularly identifying most vulnerable tourism economies): *Global Environmental Change and Economic and Labour Market Implications for Islands* in Valletta, Malta (December 2014); *World Summit on Sustainable Tourism* in Vitoria-Gasteiz, Spain (November 2015); and *Desirable Transport Futures in* Freiburg, Germany (June 2016). The fora allowed for a range of comments from experts in different areas of tourism and climate change research and policy-making, diverse geographic representation, as well as from different levels of governance. This provided new insights on the relative significance of different indicators, additional data sources on indicators, possible weighting schemes of indicators, as well as their general availability and their relative value and validation in terms of expert opinion.

Indicator aggregation and weighting

A final set of 27 indicators was used to operationalization the CVIT. Indicators were derived from 16 data sources (Table 1). Indicator selection was based on their comprehensiveness, relevance as perceived by expert opinion, data availability, as well as comparison with existing indices. We were especially cognizant of utilizing indicators that allowed us to include developing economies given their relative economic dependence on tourism. Several of the indicators used in CVIT are themselves indices that are a composite of multiple variables to represent complex phenomena such as: climate resources for tourism, socio-economic impacts of extreme weather, political stability, tourism competitiveness, country image and branding, governance, wealth distribution, and human development. The eight composite indicators were examined for commonality of individual variables. Few were found so that there were no concerns regarding duplication of measurement or undue weighting of common constituent variables. Suitable global indicators could not be found for some factors identified in the literature and consultations, including: insurance costs, degradation or loss of natural and cultural heritage sites, decline or loss of tourist attracting species (e.g., sport fish, polar bears), and beach loss and nourishment costs. These indicators were not included, but could be added to improve the index should suitable data sets become available in the future.

The 27 selected indicators are described in Table 1 and were integrated into six index dimensions representing:

(1) tourism assets [TA] (five indicators) - degradation or loss of natural and cultural heritage assets that attract tourists (climate, ecosystems, beaches, snow) as well as damage to tourism infrastructure and destination communities;
(2) tourism operating costs [TOC] (five indicators) – impacts on climate sensitive tourism operator costs (energy, water, food) that will alter competitiveness;
(3) tourism demand [TD] (six indicators) – impacts that alter domestic and international markets (economic growth), including mobility costs (mitigation policy) to reach destination countries;
(4) host country deterrents [HCD] (three indicators) - impacts that deter destination choice of international tourists (weather disasters, and health and security risks);
(5) tourism sector adaptive capacity [TSAD] (five indicators) – capacity of the tourism sector in a country to adapt to climate change;
(6) host country adaptive capacity [HCAD] (three indicators) – capacity of the destination country to adapt to climate change and maintain tourism assets, infrastructure and socio-political conditions conducive to international tourism.

Indicators can be combined into a composite index in a number of different ways, with potentially important implications for index scores. Little justification for giving more or less weight to specific sub-index components or individual indicators was found in the literature or the tourism expert consultations that we undertook. Therefore, in order to provide an improved comparison of the implications of different weightings, the study utilized two separate weighting approaches to explore the robustness of the comparative vulnerability rankings.

The first weighting set adopted the common approach of equally weighting all variables included in the index. This assumes each

Table 1
CVIT indicators and data sources.

Sub-index component	Indicator	Dimension of vulnerability operationalized and assumptions	Units and data source
Tourism Assets (TA)	Climate suitability for tourism	The extent to which climate suitability for general tourism is projected to change (positively or negatively).	Tourism climate index score (2050) (Amelung, Nicholls, & Viner, 2007)
	Ecotourism impact (terrestrial)	Greater ecosystem change will degrade ecotourism attractions.	Biome distribution score (% land area projected to change biome type by 2070–2100) (ND-GAIN, 2016)
	Ecotourism impact (marine)	Greater biodiversity change will degrade ecotourism attractions.	Change in marine biodiversity score (species turnover by 2050) (ND-GAIN, 2016)
	Coastal/beach tourism impact	Greater land area exposed to sea level rise and storm surge will increase beach and coastal tourism infrastructure damage and loss.	% land area below 4 m above sea level exposed to storm surge with 1 m SLR (ND-GAIN, 2016)
	Ski tourism impact	Reduced ski season length, increased snowmaking costs, and greater travel distances will reduce winter sports tourism.	Change in ski season and snowmaking costs – scores averaged from survey of experts (2 North America, 4 Europe, 1 Asia-Oceania)
Tourism Operating Costs (TOC)	Water competition and costs	Areas with greater existing competition for water are more likely to face cost increases and use restrictions.	Current water stress (all sectors) (World Resource Institute, 2016)
		Areas where changes in precipitation adversely impact water resources are likely to face cost increases and use restrictions.	Change in water stress (2050) (Schlosser et al., 2014)
	Energy costs	Electricity grids more dependent on fossil fuels will see greater decarbonization transition costs.	% electricity from fossil fuels (World Bank, 2016a)
		Marginal costs increase with greater GHG emission reduction ambitions.	National emission reduction ambitions (UNFCCC, 2019)
	Food costs	Less local food supply options will increase transportation costs for tourism, may degrade cultural/food tourism, and increase sensitivity to price volatility.	Food import dependency (ND-GAIN, 2016)
Tourism Demand (TD)	Climate change influence on international arrivals	Changes in climate at destinations and source markets will alter the pattern of international tourism.	% change in international arrivals (Hamilton et al., 2005)
	Economic growth in country's top 5 international markets	Reduced economic growth (GDP) adversely affects disposable income for tourism.	Change in GDP from climate change (2050) (Burke et al., 2015)
	Distance to country's top 5 international markets	Long haul destinations have higher travel costs and are at greater exposure to price increases resulting from emission reduction policies.	Average distance (km) from geocentroid of destination country to top 5 markets – calculated based on arrival data (UNWTO, 2012)
	% international leisure arrivals	Leisure tourists are more likely to change destinations because of climate change impacts than business of friends/family travellers.	% of international arrivals for leisure tourism (UNWTO, 2012)
	Climate change influence on domestic departures	Changes in climate at destinations and source markets will alter the pattern of international tourism.	% change in domestic departures (Hamilton et al., 2005)
	Economic growth in country (domestic GDP)	Reduced economic growth (GDP) adversely affects disposable income for tourism.	Change in GDP from climate change (2050) (Burke et al., 2015)
Host Country Deterrents (HCD)	Weather disasters	Extreme weather events are widely recognized as one of the greatest impacts of climate change and can damage tourism infrastructure and destination communities, deterring travellers during recovery and creating reputational damage.	Climate risk index score (GermanWatch, 2018)
	Security impacts	Civil unrest, political strife and conflict are strong deterrents for tourists. Fragile State Index measures proximity to state failure.	Fragile state index score (Fund for Peace, 2018)
	Health impacts	Disease outbreaks and presence of some disease vectors deter tourists.	Change in vector born disease (malaria by 2050) (ND-GAIN, 2016)

(*continued on next page*)

Table 1 (*continued*)

Sub-index component	Indicator	Dimension of vulnerability operationalized and assumptions	Units and data source
Tourism Sector Adaptive Capacity (TSAC)	Tourism competitiveness	Higher multifaceted competitiveness provides greater adaptive capacity.	Travel and tourism competitiveness index score (World Economic Forum (WEF), 2015)
	Country image and brand attractiveness	Stronger global tourism brand provides greater destination rebranding capacity to overcome adversely impacts on tourism assets.	Country brand ranking (tourism edition) (Bloom Consulting, 2018)
	Outbound market size	Outbound international tourists could convert to domestic tourists if travel cost structures or attractions change.	Number of international departures (UNWTO, 2016)
	Wealth distribution	More equal wealth distribution increases the number of potential domestic tourists. Social inequality also degrades a country's capacity to adapt.	GINI index (most recent year available) (World Bank, 2018)
	Quality of transport infrastructure	Higher quality transport systems provide greater accessibility throughout a country (destination substitution) and are less prone to prolonged disruption.	Trade and transport infrastructure score (ND-GAIN, 2016)
Host Country Adaptive Capacity (HCAC)	Socio-economic conditions that support adaptation	Countries with more developed education, infrastructure, and health systems have greater adaptive capacity. Multi-criteria analysis indicates the Human Development Index outperforms other indices as a national-level metric of social vulnerability to climate change (Füssel, 2010).	Human development index score (UNDP, 2016)
	Governance quality	Governance systems characterized by political stability, regulatory quality, and control of corruption, provide greater adaptive capacity.	Combined rank score of six World Governance Indicators (World Bank, 2016c)
	Sustainability governance and performance	Stronger sustainability performance is supportive of adaptive capacity among ecosystems vital to tourism.	Environmental Performance Indicator score (Yale University, 2016)

indicator is an equally important contributor to vulnerability and that different components of the index can compensate for each other. This may not be the case in the tourism sector at the individual country scale. For example, high impacts to Austria's ski tourism industry cannot be compensated by low impacts (negative or positive) to its cultural or ecotourism and similarly adaptive capacity provided by snowmaking will not be able to fully offset the impacts of reduced natural snowfall and higher temperatures. Equally weighting all indicators has the effect of increasing the weight of sub-index components with a greater number of variables and reducing the weighting of components where known data gaps prevented additional indicators from being included in the final index (e.g., insurance related operating costs, viticulture impacts on wine tourism). With a large number of indicators needed to represent the wide range of climate and carbon mitigation impacts, the contribution of tourism sector adaptive capacity (TSAC) and country wide adaptive capacity (HCAC) is limited to just below 30% in the first weighting set.

The IPCC AR5 echoed the broader literature (Scott & Becken, 2010; UNWTO et al., 2008) when it observed that the ability of the tourism sector to cope with a range of macro-scale shocks, including terrorism, natural disasters, disease outbreaks, and the global financial crisis of 2008/2009, when it stated that, “the adaptive capacity of the tourism industry is high overall, except for destinations where climate change is projected to degrade core natural assets and diversification opportunities are limited” (Reisinger et al., 2014: p. 1401). The second weighting set, recognizes this adaptive capacity by weighting the sectoral and national adaptive capacity (TSAC + HCAC) equally with the four index dimensions that operationalize the diverse climate change impacts (TA, TOC, TD, HCD). Under the second weighting set, the weighted contribution of each sub-index component was defined and then each indicator that comprised the component was equally weighted.

The two equations below present the structure and relative contribution of the sub-index components to the cumulative CVIT score under the two weighting sets:Weighting set 1 : CVIT = TA (18.5%) + TOC (18.5%) + TD (22.3%) + HCD (11.1%) + TSAC (18.5%) + HCAC (11.1%)Weighting set 2 : CVIT = TA (12.5%) + TOC (12.5%) + TD (12.5%) + HCD (12.5%) + TSAC (25%) + HCAC (25%)Where:

TA = tourism assets
TOC = tourism operating costs
TD = tourism demand
HCD = host country deterrents
TSAC = tourism sector adaptive capacity
HCAC = host country adaptive capacity

The results of weighting set 1 and 2 were compared to examine the robustness of the findings. The correlation among the individual country index scores was very high (0.97) and when the weighting of adaptive capacity was increased under weighting set 2 the countries that were the 30 most and least vulnerable remained virtually unchanged, although their order changed slightly. Considering the limited differences in the vulnerability rankings between the two weighting sets, only the results of weighting set 1 (equal weighting of all indicators) are presented.

Data transformation and missing variables

As indicated in Table 1, the individual indicators are expressed in diverse units and in order to be combined into the CVIT the original data were transformed to common ranked quintiles (scales of 1 to 5). The normalized scores were transformed so that for all variables a higher value was indicative of higher vulnerability (i.e., either higher potential of negative impacts or lower adaptive capacity). The majority of indicators displayed a linear data distribution suitable for quintile-based classification. For the four indicators where the data distribution was highly skewed (sea level rise, mitigation ambitions and timeframes to achieve, vector-born disease, outbound tourists), the Jenks Natural Breaks Optimization method was used.

In light of the regional gaps in knowledge on tourism and climate change outlined above, the inclusion of as many countries as possible was an important goal of the study, particularly for countries where tourism is a major part of the national economy and where substantial tourism losses would degrade the country's overall climate change adaptive capacity; a knock on effect that has not been well recognized in the literature. Data were collected for 192 countries, but with diverse sources, data gaps were found for some countries. For some indicators, missing country data could be in filled where the contribution to cumulative vulnerability was obvious (e.g., landlocked countries have no coastal tourism to be impacted by sea level rise and storm surge). Where a value in the most current dataset was missing for a country, a value from the next most recent year was substituted (e.g., 2016 World Bank GINI scores were not available for all countries, and in the worst-case data as far back as 2001 had to be used). In order to balance opposing goals of index comprehensiveness and inclusivity, countries were included if at least 70% of the 27 indicators were available and where none of the six index dimensions were missing half or more of the variables. Where a variable was missing for a dimension, a pro-rated dimension score was calculated from the available variables (e.g., if only 4 of the 5 indicators in the 'Tourism Assets' dimension were available, each would be weighted as 1.25). By allowing some missing variables, CVIT was able to include 181 countries instead of only the 127 countries with complete data for all variables. Importantly, 16 SIDS and several LDC countries with significant tourism economies could be included with this approach. We consider this a necessary and appropriate compromise to include many countries that are highly dependent on their tourism economy.

Results

Fig. 1 presents the combined score for all of the indicators of climate and carbon mitigation impacts (TA, TOC, TD, HCD) and adaptive capacity (TSAC, HCAC) dimensions using the first weighting set. The mean score for both dimensions is used to define vulnerability quadrants. The countries with both high potential impacts and low adaptive capacity are located in the shaded upper-right quadrant and include several SIDS and LDCs (e.g., Djibouti, Dominican Republic, Solomon Islands). Countries in the lower-left quadrant have the lowest potential climate change impacts and the highest capacity to adapt. Countries in this quadrant include several northern temperate countries where the literature projects winter tourism activities will be adversely impacted, but are likely to see opportunities in other tourism segments (Scott et al., 2012b). Several large and growing tourism economies are located in the lower-right quadrant, indicative of higher potential impacts on tourism assets and demand, but moderate (India, Mexico) to higher levels of adaptive capacity (Greece, Japan).

As indicated in the methods, the adaptive capacity score was reversed in the transformation process in order that higher scores on all variables contribute to higher vulnerability. As such, a higher score signifies vulnerability associated with lower capacity to adapt

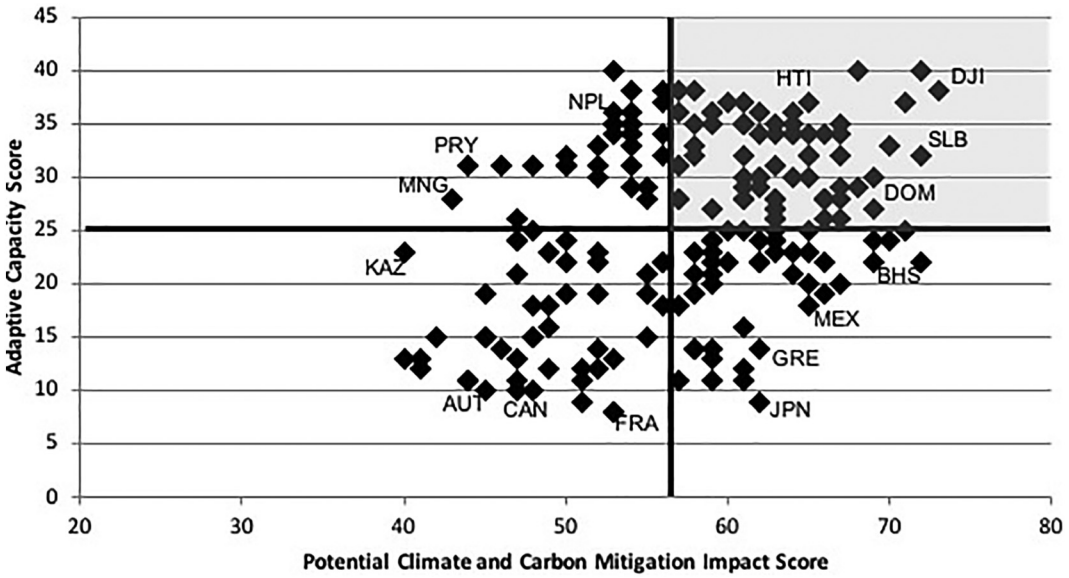

Fig. 1. Comparison of climate change impact and adaptive capacity scores.

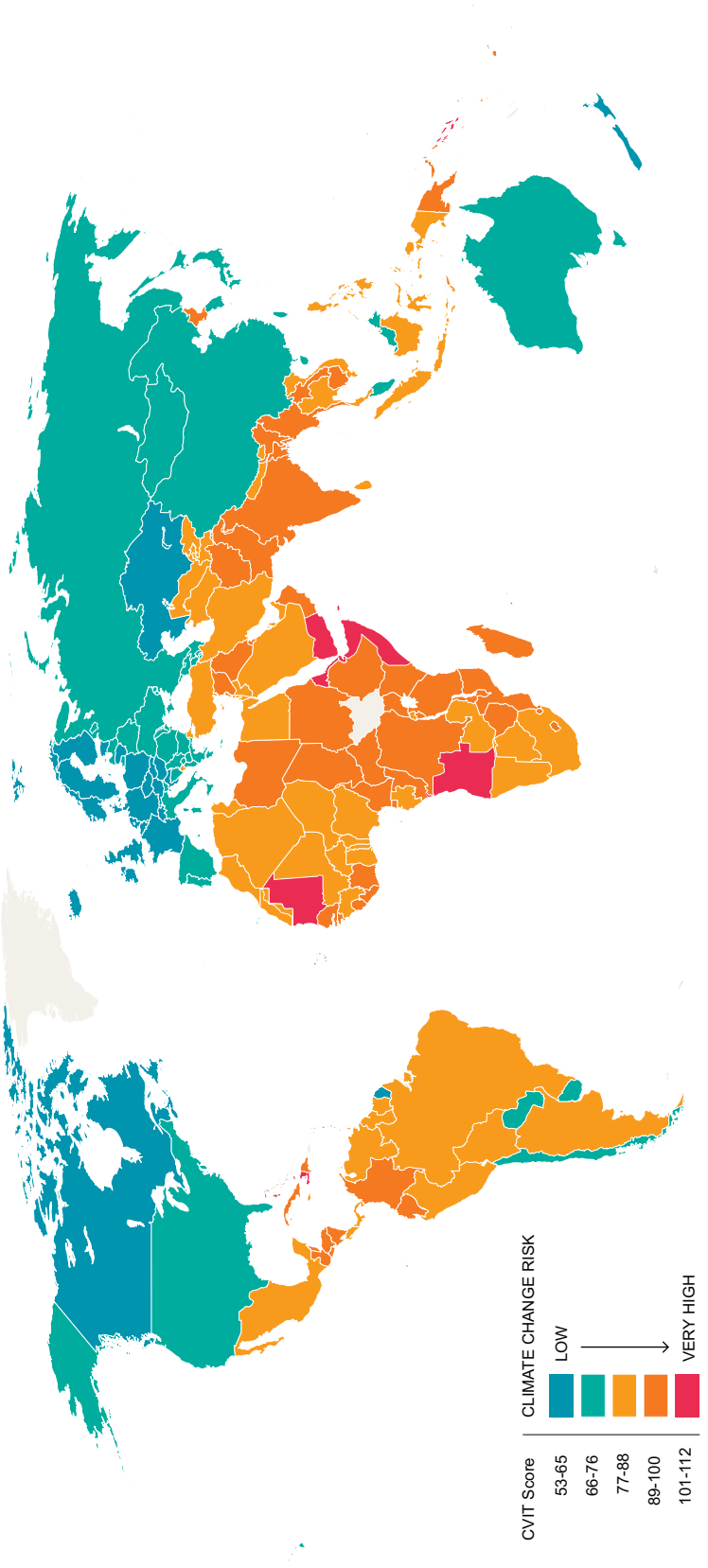

Fig. 2. Global distribution of CVIT scores.

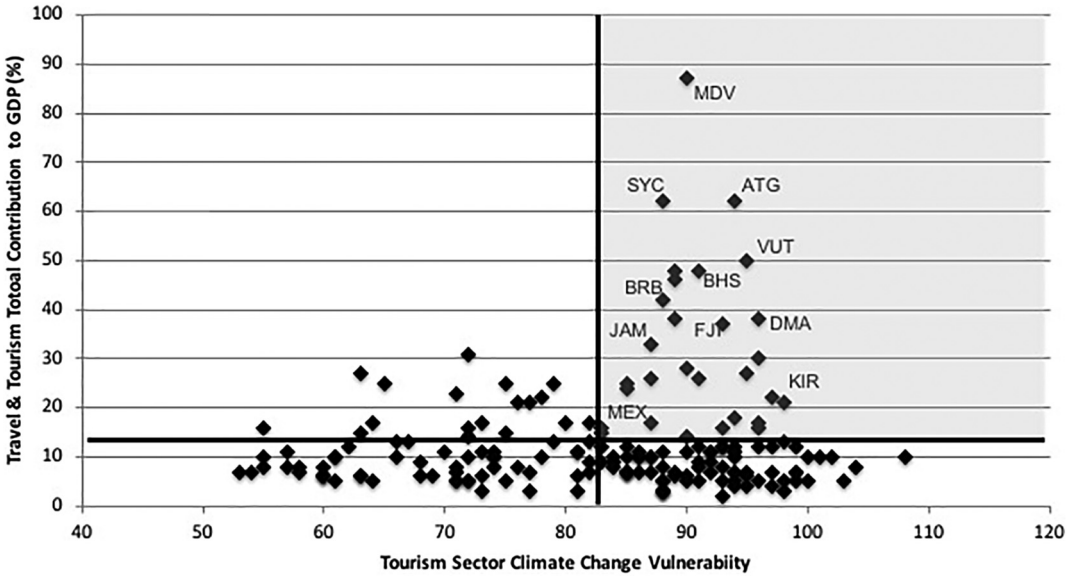

Fig. 3. Comparing tourism sector climate change vulnerability and contribution to national economy.

to the impacts of changing climate and decarbonization of the global economy. Exposure to multiple climate and carbon mitigation impacts can be similar between rich and poor countries (e.g., small island states), but variations in adaptive capacity of the tourism sector in the country and the country itself resulted in different overall vulnerability.

The global distribution of climate change vulnerability in the tourism sector is presented in Fig. 2. Countries are classified into equal interval quintiles of CVIT scores. Vulnerability hotspots are found in Africa, the Middle East, South Asia and SIDS in the Caribbean as well as Indian and Pacific Oceans. Countries with the lowest CVIT scores are found in western and northern Europe, central Asia, as well as Canada and New Zealand.

Figs. 1 and 2 reveal the global geography of climate change vulnerability in the tourism sector, but in order to understand where climate change is likely to be most impactful, Fig. 3 provides a comparison between climate change vulnerability (CVIT scores) and the relative importance of the tourism economy in each country (% GDP from tourism in 2015). The quadrants are again defined by the means of each axis. The shaded upper-right represents countries that are rated as highly vulnerable and where tourism represents a significant proportion of the national economy (more than 15% GDP). These countries are almost exclusively SIDS, including the Maldives, Seychelles, Mauritius, Antigua and Barbuda, Bahamas, Saint Lucia, Grenada, Barbados, Jamaica, Vanuatu, Fiji, and Kiribati. Non-SIDS in this quadrant include Costa Rica, Belize, Honduras, Laos, Thailand, Cambodia, Vietnam, Namibia, and Gambia. The largest tourism economy in this high vulnerability quadrant is Mexico, which was ranked the sixth largest destination country by arrivals in 2017 (UNWTO, 2018).

Looking to the future it is important to understand how climate change vulnerability aligns with expected tourism growth. Table 2 compares the projected annual growth in international tourist arrivals from 2020 to 2030 with CVIT scores in each of the UNWTO tourism regions. Broadly, climate change vulnerability is highest in regions where the largest growth in tourism is projected under the UNWTO (2011) Business as Usual scenario through 2030, which do not include potential impacts of climate change on tourism growth. The sub-regions of Sub-Saharan Africa and South Asia, where the highest rates of growth are projected at over 5% annually, are two of the most vulnerable sub-regions. To borrow an analogy from air travel, climate change will generate a headwind for tourism growth in these regions, one that is not well understood or being considered in tourism projections. Indeed, as already noted, the Africa and Asia chapters of the IPCC AR5 are almost devoid of region-specific empirical assessments of tourism sector climate change impacts or sectoral adaptation strategies (Scott et al., 2016).

Discussion

An important question to ask with respect to index outcomes is whether the CVIT reveals geographic patterns of vulnerability that are substantially different from those presented in previous tourism sector indices or expert assessments. A comparison of the most and least vulnerable countries from CVIT, two previous tourism sector indices, and one expert ranking is provided in Table 3. Positively, the regional outcomes of the CVIT are broadly consistent with the expert rankings found in UNWTO et al. (2008). In contrast, there are some very visible differences with the two previous indices by Development Assistance Research Associates (DARA) (2012) and Deutsche Bank Research (2008).

All of the countries rated as most vulnerable by the Development Assistance Research Associates (DARA) (2012) *Climate Vulnerability Monitor* tourism sub-index are tropical SIDS (Table 3), because they are proximate to coral reefs that are anticipated to be highly impacted. Many of these countries are also rated as highly vulnerable by CVIT, but that is the result of compounding impacts

Table 2
A comparison of climate change vulnerability and projected tourism growth.

Tourism region	International Arrivals Market Share (% in 2014)[a]	Projected Annual Growth (%) 2020–2030[b]	CVIT score[c]
Africa	**4.9**	**4.6**	**92.6**
North Africa	1.7	4.0	88.3
Sub-Saharan Africa	3.2	5.4	93.0
Americas	**18.0**	**2.2**	**86.6**
North America	10.6	1.4	69.6
Caribbean	2.0	1.7	92.3
Central America	0.8	4.5	89.4
South America	2.5	3.9	83.3
Asia and the Pacific	**23.2**	**4.2**	**87.1**
North-East Asia	12.0	4.2	72.0
South-East Asia	8.5	4.3	85.1
Oceania	1.2	2.0	90.9
South Asia	1.5	5.3	90.6
Europe	**51.4**	**1.8**	**67.1**
Northern Europe	6.3	1.4	57.1
Western Europe	15.4	1.4	60.0
Central-Eastern Europe	10.7	2.5	69.3
Southern-Mediterranean Europe	19.0	1.9	72.6
Middle East	**4.5**	**4.0**	**90.5**

[a] (UNWTO, 2015).
[b] (UNWTO, 2011).
[c] Average of countries with CVIT scores in each UNWTO tourism region.

Table 3
A comparison of tourism sector climate change vulnerability ratings.

CVIT[a]	DARA-tourism (Development Assistance Research Associates (DARA), 2012)[b]	Deutsche Bank Research (2008)[c]	Expert Rankings (UNWTO et al., 2008)[d]
Most vulnerable countries			
Eritrea, Djibouti, Somalia, Yemen, Solomon Islands, Angola, Haiti, Comoros, Mauritania, Kiribati, Gambia, Bangladesh, Nicaragua, Sudan, Iraq, Libya, Madagascar, Papua New Guinea, Guinea-Bissau, Micronesia, Dominican Republic, Afghanistan, Pakistan, Saint Kitts and Nevis	Bahamas, Dominica, Fiji, Kiribati, Malaysia, Maldives, Marshall Islands, Micronesia, Palau, Seychelles, Solomon Islands, Timor-Leste, Tuvalu, Vanuatu, Antigua and Barbuda, Grenada, Jamaica, Samoa, Sri Lanka, Barbados, Saint Lucia, Saint Vincent, Trinidad and Tobago	Australia, Tunisia, Morocco, Malta, Cyprus, Greece, Turkey, Portugal, Spain, Egypt, Mexico	Caribbean, Indian and Pacific SIDS; Mediterranean region countries; Australia and New Zealand Note: data gaps in Africa, the Middle East, Southeast Asia, and Central-South America precluded expert ratings of these regions.
Least vulnerable countries			
Liechtenstein, Denmark, Finland, Austria, Sweden, Norway, Hungary, Switzerland, Canada, United Kingdom, Netherlands, Ireland, Czech Republic, Slovak Republic, Luxembourg, Germany, France, Poland, Iceland, Kazakhstan, Belgium, New Zealand, Estonia, Croatia, Slovenia	Afghanistan, Bulgaria, China, Togo, Costa Rica, Mexico, Philippines, Russia, Thailand, Canada, Dominican Republic, Greece, Kenya, Mauritius, Portugal, South Africa, Tunisia, USA, Malta	Denmark, Benelux countries, Germany, Poland, United Kingdom, Sweden, Norway, Russia, Finland, Canada, New Zealand, Switzerland	Only 'hotspots' were identified.

[a] 25 most/least vulnerable countries and ties.
[b] 23 countries rated with acute vulnerability and a sample of the 122 countries rated as low vulnerability.
[c] Countries with 'negatively affected' and 'positively affected' ratings.
[d] Only 'hotspots' of vulnerability were identified.

associated with marine biodiversity loss, sea level rise, water security and cost, imported food costs, long haul distance to markets, very small domestic markets, low competitiveness and high substitutability (see also Hall, 2015). The majority of countries (66% of 184) were rated as low vulnerability by Development Assistance Research Associates (DARA) (2012). In sharp contrast, CVIT rated several of these same countries in the high vulnerability categories (Dominican Republic, Mauritius) and several others in the middle quintile (Costa Rica, Togo, Philippines, Thailand, Greece, South Africa, and Tunisia). That France, Austria, and Norway were considered by DARA to be more vulnerable than most countries were entirely based on projected impacts to ski tourism, and does not reflect the diversity of tourism in each of these countries. In short, while tourism was one of six industry sectors represented in the Development Assistance Research Associates (DARA) (2012) *Climate Vulnerability Monitor*, the very limited representation of the

sector is a major concern and as a result tourism should be re-operationalized or eliminated from that index entirely.

The Deutsche Bank Research (2008) index concluded that the tourism sector in 36% of the countries it assessed would see a net benefit from tourism. The most positively affected countries are broadly similar with those rated least vulnerable by CVIT. Where the results differ substantially are with respect to the most vulnerable countries. None of the countries rated as most vulnerable by Deutsche Bank Research (2008) were in the two most vulnerable quintiles of CVIT. Because the Deutsche Bank Research study only included 66 countries, most small developing countries and no SIDS were included. The lack of transparency regarding indicators and data sources used or the aggregation and weighting of the Deutsche Bank index prevent further explanations of observed differences.

The conclusions of this analysis are not without limitations. A number of future refinements to CVIT are possible. As the body of climate change and tourism research continues to grow (see Fang, Yin, & Wu, 2017), the ability to compare tourism regions around the world on specific climate change impacts will become increasingly possible. Similarly, as extant indicators become available for a greater number of countries, either through improved monitoring or new open access data, there will be opportunities to expand the inclusivity of the CVIT. An important area for further research will be the development of indicators that could be utilized to assess climate change vulnerability at the sub-national scale. This would represent a significant contribution to inform policy, investment and management decisions in the sector. Another important area of future work is to explore how the range of climate change impacts interconnects at the community destination scale over different timescales.

A further potential area of refinement of the CVIT is the use of greater consultation with potential end users and/or via the use of end users as part of a formal reference group for indicator selection and potentially monitoring of climate change impacts and progress on mitigation and adaptation. Although experts in the area of climate change and tourism were consulted in the development of the initial version of the CVIT it is possible that policy and industry actors may offer different insights into indicator selection and relevance than researchers. The use of reference groups or specific workshops on indicator selection for rapid assessment measures for vulnerability assessments may also assist in making decisions regarding the inclusion or rejection of indicators, the relative weighting of indicators, and the identification of significant areas for which indicators are missing a more robust process (NESP Earth Systems and Climate Change Hub, 2018). Nevertheless, it needs to be stressed that assessment tools such as the CVIT are by their nature an iterative process given the dynamic nature of tourism and climate change as well as the potential availability of new comprehensive data sets that can help develop indicators where information was previously absent. Such developments, for example, would be extremely valuable in better connecting tourism and climate change indicators to the SDGs (UNWTO & UNDP, 2017). There exists a very interesting opportunity for collaboration among tourism academics and the Global Sustainable Tourism Dashboard (2019) to add indicators utilized in the CVIT and CVIT calculations to the Dashboard or refine the CVIT to utilize indicators from the Dashboard and other annually updated indicators already in the index, so that year-over-year tracking of climate change vulnerability could be brought to the global tourism community. Such an initiative would have parallels with the Lancet Countdown on Global Health and Climate Change, through the provision of sector relevant indicators on climate change impacts as well as progress on mitigation and adaptation.

Conclusion

This paper presents a new index to examine the climate change vulnerability of the global tourism sector. The index improves on previous tourism sector focused indices through increased comprehensiveness of indicators for climate and carbon mitigation impacts that will influence tourism, as well as operationalization of tourism sector adaptive capacity. These factors make the index particularly relevant for providing insight into the implications for tourism as a mechanism to advance the SDGs (UNWTO & UNDP, 2017), especially given the vulnerability of populations with high levels of poverty (Scheyvens & Hughes, 2018). Indeed, some of the developing countries that could benefit most from the economic and employment contribution of tourism are also the most vulnerable to climate change (Burke et al., 2015, 2018; IPCC, 2018), creating a vicious cycle of tourism growth, emissions growth and increased vulnerability. The dissonance between international tourism emissions dominated by air travel from major outbound markets (Lenzen et al., 2018; Scott, Gössling, Hall, & Peeters, 2015) and the climate change vulnerability measured by CVIT has been a driver of repeated calls for an International Air Passenger Adaptation Levy to support climate change adaptation in highly vulnerable countries (Baker, 2011; Scott et al., 2015).

Contrasting results with previous sectoral indices that did not possess the comprehensiveness or inclusiveness of CVIT, demonstrates the value of the index to improve understanding of tourism sector macro-scale vulnerability to climate change. It is hoped that any future global vulnerability index that includes indicators for specific economic sectors, like the DARA *Climate Vulnerability Monitor*, will utilize these results to represent the tourism sector.

By identifying where climate change impacts on tourism will compound and where high climate change vulnerability coincides with the highest contribution of tourism to national economies, the analysis sheds light on which countries most need to incorporate tourism into National Adaptation Plans and/or Nationally Determined Contributions. That tourism is most vulnerable to climate change in precisely the regions of the world where tourism is anticipated to grow the fastest through the 2030s has not been considered in tourism projections and in advocacy of tourism as a means of achieving the UN SDGs. The World Bank (2017), for example, in a specific tourism context notes the contribution that tourism can make to raise climate change awareness, not the extent to which climate change can impact tourism's potential contributions to development, although it does also highlight the importance of actions such as the development of renewable energy, and sustainable farming and fishers in a more general context.

The analysis also provides new insight into the geography of tourism sector climate change vulnerability and contributes toward addressing the persistent regional knowledge gaps identified by UNWTO et al. (2008) and the IPCC (Boko et al., 2007; Wong et al., 2014) (see also discussion by Scott et al., 2016). As the UN agency responsible for the promotion of sustainable and universally

accessible tourism, the UNWTO must do more to accelerate research in these regions to assess potential impacts of climate change and develop adaptation strategies that will enable tourism to prepare for a post +2 °C world and efficaciously contribute to the Sustainable Development Goals - 2030 Agenda.

As Becken (2019) and Gössling and Scott (2018) have discussed, there are systemic challenges that continue to pose barriers to tourism industry and government organization leadership on a coordinated sector climate change response. We echo their calls for an urgent increase in collaboration among tourism academics and with a broad range of other disciplines and industry and government to develop and implement climate change solutions and track progress in support of the Paris Agreement targets and pressing timelines.

References

Amelung, B., Nicholls, S., & Viner, D. (2007). Implications of global climate change for tourism flows and seasonality. *Journal of Travel Research, 45*, 285–296.

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

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

Becken, S. (2019). Decarbonising tourism: Mission impossible? *Tourism Recreation Research*. https://doi.org/10.1080/02508281.2019.1598042.

Benzie, M., Hedlund, J., & Carlsen, H. (2016). Introducing the transnational climate impacts index: Indicators of country-level exposure methodology report. Stockholm: Stockholm Environment Institute. Available from https://www.sei-international.org/publications?pid=2972.

Bloom Consulting (2018). Country brand ranking – Tourism edition 2017-18. Available from https://www.bloom-consulting.com/en/pdf/rankings/Bloom_Consulting_Country_Brand_Ranking_Tourism.pdf.

Boko, M., Niang, I., Nyong, A., Vogel, C., Githeko, A., Medany, M., ... Yanda, P. (2007). Africa. In M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, & C. E. Hanson (Eds.). *Climate change 2007: Impacts, adaptation and vulnerability* (pp. 433–467). Cambridge: Cambridge University Press.

Brooks, N., Adger, W. N., & Kelly, P. M. (2005). The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. *Global Environmental Change, 15*, 151–163.

Burke, M., Davis, W. M., & Diffenbaugh, N. (2018). Large potential reduction in economic damages under UN mitigation targets. *Nature, 557*, 549–553.

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

Deutsche Bank Research (2008). *Climate change and tourism: Where will the journey take us?* Berlin: Author.

Development Assistance Research Associates (DARA) (2012). *Climate vulnerability monitor* (2nd ed.). Madrid, Spain: Author. Retrieved from http://daraint.org/climate-vulnerability-monitor/climate-vulnerability-monitor-2012/.

Fang, Y., Yin, J., & Wu, B. (2017). Climate change and tourism: A scientometric analysis using CiteSpace. *Journal of Sustainable Tourism, 26*(1), 108–126.

Ford, J. D., Berrang-Ford, L., Biesbroek, R., Araos, M., Austin, S. E., & Lesnikowski, A. (2015). Adaptation tracking for a post-2015 climate agreement. *Nature Climate Change, 5*, 967–969.

Fund for Peace (2018). Fragile states index-2018. Retrieved from https://fundforpeace.org/2018/04/24/fragile-states-index-2018-annual-report/.

Füssel, H. M. (2009). Review and quantitative analysis of indices of climate change exposure, adaptive capacity, sensitivity, and impacts. *World development report development and climate change background note*Washington D.C.: World Bank. Available from http://lacer.lacea.org/handle/10986/9193.

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

Füssel, H. M., & Klein, R. J. T. (2006). Climate change vulnerability assessments: An evolution of conceptual thinking. *Climatic Change, 75*, 301–329.

GermanWatch (2018). Global climate risk index 2018. Available from https://www.germanwatch.org/en/node/14987.

Global Sustainable Tourism Dashboard (2019). Available from https://tourismdashboard.org/.

Gössling, S., Hall, C. M., & Scott, D. (2009). The challenges of tourism as a development strategy in an era of global climate change. In E. Palosou (Ed.). *Rethinking development in a carbon-constrained world* (pp. 100–109). Helsinki: Ministry of Foreign Affairs.

Gössling, S., & Scott, D. (2018). The decarbonisation impasse: Global tourism leader's views on climate change mitigation. *Journal of Sustainable Tourism*. https://doi.org/10.1080/09669582.2018.1529770.

Hall, C. M. (2015). Global change, islands and sustainable development: Islands of sustainability or analogues of the challenge of sustainable development? In M. Redclift, & D. Springett (Eds.). *Routledge international handbook of sustainable development* (pp. 55–73). Abingdon: Routledge.

Hall, C. M. (2019). Constructing sustainable tourism development: The 2030 agenda and the managerial ecology of sustainable tourism. *Journal of Sustainable Tourism*. https://doi.org/10.1080/09669582.2018.1560456.

Hall, C. M., Scott, D., & Gössling, S. (2015). Tourism, climate change and development. In R. Sharpley, & D. Telfer (Eds.). *Tourism and development* (pp. 332–357). Bristol: Channel View.

Hamilton, J., Maddison, D., & Tol, R. S. J. (2005). Climate change and international tourism: A simulation study. *Global Environmental Change, 15*, 253–266.

Hedlund, J., Fick, S., Carlsen, H., & Benzie, M. (2018). Quantifying transnational climate impact exposure: New perspectives on the global distribution of climate risk. *Global Environmental Change, 52*, 75–85.

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

Intergovernmental Panel on Climate Change (IPCC) (2007). Climate change 2007: Working group II: Impacts, adaptation and vulnerability. Summary for policy makers. Available from https://www.ipcc.ch/publications_and_data/ar4/wg2/en/spmsspm-e.html.

IPCC (2018). In V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, ... T. Waterfield (Eds.). *Global warming of 1.5°C*. Geneva: IPCC.

Janetos, A. C., Malone, E., Mastrangelo, E., Hardee, K., & de Bremond, A. (2012). Linking climate change and development goals: Framing, integrating, and measuring. *Climate and Development, 4*(2), 141–156.

Klein, R. (2009). Identifying countries that are particularly vulnerable to the adverse effects of climate change: An academic or a political challenge? *Carbon & Climate Law Review, 3*(3), 284–291.

Lenzen, M., Sun, Y., Faturay, F., Ting, Y., Geschke, A., & Malik, A. (2018). The carbon footprint of global tourism. *Nature Climate Change*. https://doi.org/10.1038/s41558-018-0141-x.

Malone, E. L., & Engle, N. L. (2011). Evaluating regional vulnerability to climate change: Purposes and methods. *Wiley Interdisciplinary Reviews: Climate Change, 2*(3), 462–474.

Maplecroft (2016). Climate change vulnerability index and risk atlas. Retrieved https://maplecroft.com/about/news/ccvi.html.

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

Nardo, M., Saisana, M., Saltelli, A., Tarantola, S., Hoffman, A., & Giovannini, E. (2005). Handbook on constructing composite indicators: Methodology and user guide. *OECD statistics working paper STD/DOC(2005)* (pp. 3). Paris: OECD.

NESP Earth Systems and Climate Change Hub (2018). Climate change and the Shark Bay World Heritage Area: Foundations for a climate change adaptation strategy and action plan. *Earth systems and climate change hub report no. 7*. Aspendale, Australia: NESP Earth Systems and Climate Change Hub.

Notre Dame Adaptation Institute (ND-GAIN) (2016). Notre dame-global adaptation index. Retrieved from http://index.gain.org/about/download.

Nurse, L. A., Mclean, R. F., Agard, J., Briguglio, L. P., Duvat-Magnan, V., Pelesikoti, N., ... Webb, A. (2014). Small islands. In V. R. Barros, C. B. Field, D. J. Dokken, M.

D. Mastrandrea, K. J. Mach, T. E. Bilir, ... L. White (Eds.). *Climate change 2014: Impacts, adaptation, and vulnerability. Part B: Regional aspects* (pp. 1613–1654). Cambridge: Cambridge University Press.
OECD (2008). *Handbook on constructing composite indicators: Methodology and user guide.* Paris: OECD.
Perch-Nielsen, S. (2010). The vulnerability of beach tourism to climate change – An index approach. *Climatic Change, 100*(3), 579–606.
Reisinger, A., Kitching, R., Chiew, F., Hughes, L., Newton, P., Schuster, S., ... Whetton, P. (2014). Australasia. In C. B. Field, V. Barros, D. Dokken, K. Mach, M. Mastrandrea, T. Bilir, ... L. White (Eds.). *Climate change 2014: Impacts, adaptation, and vulnerability. Part B: Regional aspects. Contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change* (pp. 1371–1438). Cambridge: Cambridge University Press.
Saarinen, J., & Rogerson, C. M. (2014). Tourism and the millennium development goals: Perspectives beyond 2015. *Tourism Geographies, 16*(1), 23–30.
Saltelli, A. (2007). Composite indicators between analysis and advocacy. *Social Indicators Research, 81*(1), 65–77.
Scheyvens, R., & Hughes, E. (2018). Can tourism help to "end poverty in all its forms everywhere"? The challenge of tourism addressing SDG1. *Journal of Sustainable Tourism*. https://doi.org/10.1080/09669582.2018.1551404.
Schlosser, C. A., Strzepek, K., Gao, A., Gueneau, A., Fant, C., Paltsev, S., ... Reilly, J. (2014). The future of global water stress: An integrated assessment. *Report. MIT joint program on the science and policy of global change report number 254*Cambridge, MA: MIT Joint Program on the Science and Policy of Global Change, Massachusetts Institute of Technology. Available from http://globalchange.mit.edu/files/document/MITJPSPGC_Rpt254.pdf.
Scott, D., & Becken, S. (2010). Adapting to climate change and climate policy: Progress, problems and potentials. *Journal of Sustainable Tourism, 18*(3), 283–295.
Scott, D., & Gössling, S. (2018). *Tourism and climate change mitigation: Embracing the Paris agreement – Pathways to decarbonization.* Brussels: European Travel Commission.
Scott, D., Gössling, S., Hall, C. M., & Peeters, P. (2015). Can tourism be part of the decarbonized global economy?: The costs and risks of alternate carbon reduction policy pathways. *Journal of Sustainable Tourism, 24*(1), 52–72.
Scott, D., Hall, C. M., & Gössling, S. (2012a). *Tourism and climate change. Impacts, mitigation and adaptation.* Abingdon: Routledge.
Scott, D., Hall, C. M., & Gössling, S. (2012b). International tourism and climate change. *Wiley Interdisciplinary Reviews – Climate Change, 3*(3), 213–232.
Scott, D., Hall, C. M., & Gössling, S. (2016). A review of the IPCC 5th assessment and implications for tourism sector climate resilience and decarbonization. *Journal of Sustainable Tourism, 24*(1), 8–30.
de Sherbinin, A. (2014). Climate change hotspots mapping: What have we learned? *Climatic Change, 123*(1), 23–37.
Stanton, E., Cegan, J., Bueno, R., & Ackerman, F. (2012). *Estimating region's relative vulnerability to climate damages in the CRED model.* Stockholm: Stockholm Environment Institute. Available from https://www.sei-international.org/publications?pid=1838.
Su, Y.-P., & Hall, C. M. (2014). Climate change and tourism in Asia: a review. *United Nations world tourism organisation (UNWTO), Responding to climate change: Tourism initiatives in Asia and the Pacific* (pp. 27–40). Madrid: UNWTO.
Surminski, S., & Williamson, A. (2012). *Policy indexes–what do they tell us and what are their applications?: The case of climate policy and business planning in emerging markets. Working paper 88.* London: Centre for Climate Change Economics and Policy and Grantham Research Institute on Climate Change and the Environment.
UNDP (2016). Human development data (1980–2015). Retrieved from http://hdr.undp.org/en/data#.
UNFCCC (2019). NDC registry (interim). https://www4.unfccc.int/sites/ndcstaging/Pages/Home.aspx.
UNWTO (2015). *UNWTO Tourism Highlights 2015 Edition.* Retrieved https://www.e-unwto.org/doi/pdf/10.18111/9789284416899.
United Nations (2016). *United Nations treaty collection chapter XXVII environment, 7.d Paris Agreement, Paris, 12 December 2015 (C.N.92.201).* New York: Author. Available from https://treaties.un.org/doc/Publication/CN/2016/CN.92.2016-Eng.pdf.
United Nations Environment Programme (UNEP) (2017). *Adaptation gap report 2017.* Nairobi, Kenya: UNEP. https://wedocs.unep.org/bitstream/handle/20.500.11822/22172/adaptation_gap_2017.pdf?isAllowed=y&sequence=1.
United Nations World Tourism Organization, & United Nations Environment Program and World Meteorological Organisation (2008). *Climate change and tourism: Responding to global challenges.* Madrid: UNWTO.
UNWTO (2011). Tourism towards 2030: Global overview. *UNWTO general assembly, 19th session, Gyeongju, Republic of Korea, 10 October 2011.* Madrid, Spain: Author.
UNWTO (2012). *Compendium of tourism statistics 1995–2010.* Madrid: Author. CDRom.
UNWTO (2016). Tourism and the sustainable development goals. Retrieved from http://www.tourism4development2017.org/knowledge/tourism-and-the-sustainable-development-goals/.
UNWTO (2017). *Making tourism a tool to fight poverty: Ten years of the ST-EP initiative.* Madrid: Author.
UNWTO (2018). UNWTO tourism highlights 2018 edition. Retrieved from https://www.e-unwto.org/doi/pdf/10.18111/9789284419876.
UNWTO, & UNDP (2017). *Tourism and the sustainable development goals – Journey to 2030.* Madrid: UNWTO.
Westermeyer, W. (2010). Observing the climate for development. *Climate and Development, 2*, 276–290.
Wheeler, D. (2011). Quantifying vulnerability to climate change: Implications for adaptation assistance. *Centre for Global Development. Working paper 240*Washington D.C.: Centre for Global Development. Available from http://www.cgdev.org/publication/quantifying-vulnerability-climate-change-implications-adaptation-assistance-working.
Wong, P.P., Losada, I., Gattuso, J.P., Hinkel, J., Khattabi, A., McInnes, K., Saito, Y., and Sallenger, A. (2014). Coastal systems and low-lying areas. In CB Field, V Barros, D Dokken, K Mach, M Mastrandrea, T Bilir, … and L White (Eds.), Climate change 2014: Impacts, adaptation, and vulnerability. Part B: Regional aspects. (pp. 361–409). Cambridge: Cambridge University Press.
World Bank (2016a). World development indicators: Electricity production, sources, and access. Retrieved from http://wdi.worldbank.org/table/3.7.
World Bank (2016c). Worldwide governance indicators. Retrieved from http://data.worldbank.org/data-catalog/worldwide-governance-indicators.
World Bank (2017). *20 reasons sustainable tourism counts for development.* Washington D.C.: World Bank.
World Bank (2018). GINI index – Data. Development research group. Available from https://data.worldbank.org/indicator/SI.POV.GINI?view=map.
World Economic Forum (WEF) (2015). *Travel and tourism competitiveness report 2015.* Gland: Author Available from.
World Travel and Tourism Council (2018). WTTC and UN climate change in new partnership to tackle climate change. https://www.wttc.org/about/media-centre/press-releases/press-releases/2018/wttc-and-un-climate-change-in-new-partnership-to-tackle-climate-change/.
World Travel and Tourism Council (WTTC) (2016a). *Travel & tourism economic impact 2016 annual update summary.* London: Author. Available from http://www.wttc.org/-/media/files/reports/economic-impact-research/2016-documents/economic-impact-summary-2016_a4-web.ashx.
World Travel and Tourism Council (WTTC) (2016b). Global tourism data gateway. Retrieved from http://www.wttc.org/datagateway.
Yale University (2016). Environmental performance index. Retrieved from http://epi.yale.edu/data.

Daniel Scott is a University Research Chair in Global Change and Tourism at the University of Waterloo, Canada and a Vice-Chancellor Visiting Fellow at the University of Surrey, UK.

Stefan Gössling is a professor at the School of Business and Economics, Linnaeus University, Sweden and the sustainable tourism research co-ordinator at the Western Norway Research Institute.

C. Michael Hall is a professor at the University of Canterbury, New Zealand and docent, University of Oulu, Finland. He also holds positions at Linneaus University, Sweden and the University of Eastern Finland.