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Iterative Impacts of Climate and Tourism: Policy, Practice, and Pathways for Sustainable Development

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Abstract

Tourism is both a contributor to and a casualty of climate change. This paper explores the bidirectional relationship between climate systems and tourism industries, offering an interdisciplinary review of their dynamic interactions. It analyses how climate change alters tourism destinations - such as mountain, coastal, and heritage sites - while tourism, in turn, significantly contributes to

environmental degradation through carbon emissions, infrastructure development, and consumption patterns. Drawing on global examples, the paper examines the vulnerabilities of small island economies, alpine regions, and coastal heritage sites, providing empirical support for climate-related risks in the tourism sector.

The paper also discusses sustainable policy and adaptation strategies including green aviation fuels, eco-tourism practices, smart technologies, and sustainable infrastructure. Framing tourism within the Sustainable Development Goals (SDGs), the paper emphasizes the need for multi-stakeholder governance, climate risk disclosure, and regional adaptation measures. It concludes by proposing policy directions and future research priorities aimed at aligning tourism growth with global climate commitments under the Paris Agreement.

This study contributes to sustainability science by integrating climate resilience and tourism management into a coherent development narrative, offering actionable insights for researchers, policymakers, and practitioners seeking to enhance sustainability in tourism-dependent economies.

Keywords: sustainable tourism, climate change, adaptation, mitigation, development policy, SDGs.

JEL Classification: Q01; Q50; Q56.

Introduction

Tourism is one of the world's largest and fastest-growing economic sectors, accounting for approximately 10.4% of global GDP and supporting over 334 million jobs worldwide (WTTC, 2021). However, this economic dynamism comes with a substantial environmental cost. Tourism is increasingly recognized not only as a sector vulnerable to the consequences of climate change but also as a significant contributor to it. The mutual dependency between tourism and climate has created a complex and cyclical interaction that poses urgent challenges for sustainability and long-term development, particularly in climate-sensitive regions such as small island developing states, alpine regions, and coastal heritage sites.

Climate change alters environmental conditions critical to the attractiveness and viability of tourism destinations - such as temperature stability, biodiversity, seasonal cycles, and disaster frequency - disrupting established travel patterns and jeopardizing the resilience of tourism-dependent economies. At the same time, the tourism industry contributes significantly to global greenhouse gas emissions, especially through high-carbon activities such as air travel, infrastructure expansion, and food and energy consumption. These impacts, both direct and indirect, challenge the sector's alignment with global sustainability frameworks, including the United Nations Sustainable Development Goals (SDGs) and the climate targets outlined in the Paris Agreement.

This paper explores the bidirectional impacts of tourism and climate change from a sustainability science perspective. It aims to analyse sector-specific vulnerabilities, assess the carbon footprint of tourism-related activities, and identify policy and technological pathways for mitigation and adaptation. By integrating empirical evidence and policy insights, the study contributes to a broader understanding of how the tourism industry can transition toward climate-resilient, inclusive, and sustainable development.

1.1. Literature Review

Tourism and climate change share a complex, bidirectional relationship that is increasingly under scrutiny. On one hand, climate change significantly threatens tourism through rising sea levels, extreme weather events, and the degradation of natural attractions like coral reefs and snow-capped mountains - imperilling destinations and reducing tourist

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flows. On the other hand, tourism itself contributes to climate change, accounting for an estimated 8% of global greenhouse gas emissions due to air travel, infrastructure, and resource-intensive hospitality practices. Within this context, the United Nations' Sustainable Development Goals (SDGs) offer a strategic roadmap to address these dual challenges. SDG 13 (Climate Action) calls for urgent reductions in emissions and enhanced climate resilience, directly relevant to tourism's carbon footprint and vulnerability. SDG 12 (Responsible Consumption and Production) encourages eco-friendly tourism models, while SDG 8 (Decent Work and Economic Growth) and SDG 11 (Sustainable Cities and Communities) emphasize the need for sustainable, inclusive tourism that protects both livelihoods and local cultures. Aligning tourism development with the SDGs fosters a future where travel remains a force for good, economically viable, environmentally responsible, and socially inclusive. This section of the study explores the iterative impacts with a focus on complexities arising because of these impacts and delve deeper into the phenomenon.

Climate Impacts on Tourism

Climate change has been a concern for a long time. Viner & Agnew (1999) reported in 1999 that the ecosystem of many popular holiday destinations is very sensitive to climate change. In their report, they noticeably mentioned that the 1990s were the warmest decade of the 20th century. They speculated of warming of .2 to .3 degrees centigrade per decade and a rise of 4 to 10 centimetres in sea levels per decade. Thus, the small island economies that depend on tourism will be impacted more severely in the coming decades.

Furthermore, in their report, they argue that climate change will increase the risk of various types of diseases around the world that will prove to be a roadblock for tourism. Based on the data they collected they predicted that the eastern Mediterranean region, a tourist hotspot, will have more than average days with temperatures above 40 degrees centigrade. For Australia, the cloud cover will decrease, and the popular tourist spots will become less popular because of higher harmful ray exposure. Also, there is a threat of the re-emergence of malaria in Spain which is a popular tourist destination for the UK and Scandinavian countries (Viner & Agnew, 1999).

The predictions made by Viner and Agnew are remarkably close to the facts today. In recent times we have seen these changes happening around the world. Global temperatures have increased significantly causing the glaciers to melt, and sea levels have been rising creating a threatening situation for small island destinations. These rising temperatures and irregular weather occurrences such as heatwaves, storms, and frequent wildfires have been impacting the appeal and accessibility of tourism destinations. The effect of climate change was predicted on mountain destinations as well. Viner & Agnew (1999) speculated lesser snowfall and shorter skiing seasons will impact winter tourism around the world and popular winter destinations such as the Alps and the Rockies will suffer a decrease in visitation.

Climate change has also affected small island economies around the world. Small island countries in the Caribbean that are highly dependent on tourism revenue flows, have suffered the biggest losses. In these countries tourism accounts for 20 to 30% of their GDP. The recent strong hurricane seasons because of climate change, have costed them $741 million in the year 2017. Furthermore, the small tourism operators have been pushed to the edge because of the increase in insurance premiums.

A recent news report (Martiny, 2022) corroborated the predictions postulated by Weiner and Agnew in 1999. It was reported that sea levels have been rising and have covered up parts of the popular ‘Es Trenc’ beach in Mallorca. Scientists have found that the ‘Es Trenc’ beach has decreased by 40 meters from what it was originally in 1956. The effects of climate change have become very pronounced in the past few years. around the world. There have been forest fires in the Mediterranean, North America, Asia, and South America, which have caused widespread destruction of ecosystems and landscapes. Similarly, historic floods in Europe and North America have displaced people and destroyed habitats. Regions such as California in the western US have been facing a historic drought that is forcing people to move out. These extreme events caused by climate change have exposed the extremely sensitive nature of the tourism industry. It was reported that the number of natural disasters which can be attributed to climate change has increased by four times since 1970. Consequently, tourism destinations built upon natural and cultural elements have become endangered (Nugent, 2021).

Mountain Tourism

Mountain tourism primarily depends on the weather conditions in the region. Weather conditions dictate the tourism outcome at mountain destination sites (Kubokawa et al., 2014). Activities such as sightseeing glaciers and snow skiing are dependent on weather-related factors. It is predicted that changes happening in the climate in the form of global warming will impact mountain tourism activities and thus the number of tourists visiting mountain tourism destinations. (Scott et al., 2012).

Global warming has accelerated natural disasters happening in mountain regions around the world. Heavy rains resulting because of climate change have resulted in landslides affecting destinations and their accessibility (Fernandes, 2016). Historic flooding was reported in the state of California in February 2017 that affected Sierra Nevadas. This heavy rain resulted in landslides in the mountains of Sierra Nevada impacting the natural scenic spots and local infrastructures such as roads, hiking trails, and service areas for tourists (Schmidt et al., 2017).

Similar events of landslides were reported in the Indian Himalayas in August 2021. More recently in July 2020 cloud bursting happened in the northern Indian Himalayas (Chatterjee, 2017). A massive flash flood hit Qinghai province in western China in August 2022. Pakistan is currently going through a disaster caused by massive monsoon floods of unprecedented magnitude. These events have caused heavy damage to infrastructure natural resources and human lives (Borenstein, n.d.). Some of the popular ski resorts in different regions of the world are also severely impacted by global warming. Heatwaves are becoming more common in regions like Hungary, where summer tourism conditions are expected to deteriorate due to higher temperatures (Kovács, 2024). Many ski resort operators in the Alpine regions have started using snow cannons to create artificial snow so that skiing tourism doesn't get affected because of decreased snowfall amounts (Martiny, 2022).

These recent news items are clear indications of damage caused by climate change in the mountainous as well as low-lying regions around the world. Global warming has been accelerating these less frequent than natural disasters

Coastal Tourism

Coastal tourism includes activities that are related to beaches and seashores. Rising temperatures around the world has created a noticeable impact on the availability of these natural resources for the purpose of tourism. The rise in temperatures because of climate change around the world has resulted in sea level rise (Church & White, 2011). Global warming has impacted the coastal ecosystems and beaches around the world for recreation. (Raquel et al., 2017). Many of the prominent beaches around the world are projected to be eroded because of the expected sea level rise (El-Masry et al., 2022). Furthermore, abnormal precipitation patterns in coastal areas have impacted the tourism revenues (Ye, 2023).

Coastal ecosystems where marine wildlife is the main attraction for visitors will also get affected indirectly because of climate change or global warming. There's a very high probability of losing marine habitats as an indirect effect of climate change. It is predicted that low lying coastal areas might lose 20 to 70% of shorebird habitats in case of two-degree centigrade warming in global temperatures. (Galbraith et al., 2002). Similarly, total nesting beaches will also get affected negatively because of sea level rise and intense storms. (Poloczanska et al., 2009).

Marine ecosystems are protected by coral reefs. These coral reefs are part of the marine ecosystems that attract tourists and deter beach erosion. Global warming is increasing the temperatures and this in turn is causing coral bleaching. Because of these damages to the coral reefs, many marine species are expected to extinguish (Marshall et al., 2011). Damage to these marine ecosystems will be devastating for small island economies such as the Caribbean Island countries. Coral reef-associated tourism contributes 40% of the GDP in Tobago and 21% of the GDP of Saint Lucia (Cesar et al., 2004; Burke et al., 2008). Furthermore, these small islands will get deprived of natural resources because of the sea level rise.

Heritage Tourism

Heritage tourism is another facet of the tourism industry that is not at the forefront when studying the impact of climate change on tourism. According to the National Trust for historic preservation, the heritage tourism phenomenon is generally perceived as traveling to experience the places, artifacts, and activities that authentically represent the stories and people of the past. Heritage tourism involves cultural heritage assets that are historic, natural, and cultural that are non-renewable (Haugen & Matteson, 2011). Heritage tourism, which combines the appreciation of cultural and natural heritage with travel, is increasingly vulnerable to the impacts of climate change. Rising temperatures, changing precipitation patterns, sea-level rise, and extreme weather events are altering the integrity of heritage sites, disrupting tourism activities, and challenging the sustainability of these destinations. Climate change is impacting those assets because of humidity and biological degradation by affecting interior fabric and art collections. (Floy, 2015). Consequently, the numerous tourist destinations and economic ecosystems that are built around cultural and heritage tourism are also under threat because of Climate change.

Coastal heritage sites, such as ancient ruins, archaeological sites, and historic buildings, are at risk due to rising sea levels and increased flooding. For example, the Gullah Communities of South Carolina and the coastal castles of Western Andalusia are experiencing erosion and saltwater intrusion, threatening their structural integrity (Reeder-Myers, 2015;

"Climate change impacts on cultural heritage building foundations in Western Andalusia", 2022).

Higher temperatures and drought conditions are altering the physical environment of heritage sites. In Switzerland's Lavaux region, vineyards that are part of a UNESCO World Heritage Site are experiencing heat and drought stress, potentially requiring the introduction of new grape varieties to maintain the landscape's visual integrity (Beniston, 2008). In colder regions, climate change is leading to more frequent and intense freeze-thaw cycles, which can cause stone decay in historic buildings. For instance, porous limestone used in cultural heritage structures is prone to fracture networks due to ice crystallization, accelerating degradation (Kock et al., 2015). Changes in soil moisture due to drought and temperature fluctuations are causing subsidence and shrinkage effects in heritage buildings. The Church of the Sagrario in Seville is one such example, where surface clays are affecting the foundation ("Climate change impacts on cultural heritage building foundations in Western Andalusia", 2022).

1.2. Tourism's Environmental Footprint

The global impact of tourism on the environment and climate is growing each day. Between 2009 and 2013 tourism global carbon footprint increased from 3.9 to 4.5 GtCO2e, four times higher than previously estimated and international arrivals and tourism receipts have been growing three to five percent annually and are forecasted to grow four percent annually resulting in the current global tourism accounts for 8% of the global greenhouse gas emission. (Lenzen et al., 2018).

Historical estimates of global carbon emissions from the global tourism industry have resulted in values of 1.3 to 1.17 GtCO2 for 2005 WTO (Gössling & Peeters, 2015) and 1.12 GtCO2 for 2010 (Gössling & Peeters, 2015) accounting for an estimated 2,5-3% of global carbon emissions. However, missing from these calculations are the underlying supply chains supporting the tourism industry, thus the results are not fully representing the actual carbon footprint.

Breaking down the tourism industry's carbon footprint into sectors shows the following: Transportation 49%, Goods 12%, Food and Beverage 10%, Agriculture 8%, Services 8%. Lodging 6%, Construction & Mining 6% and Other 1%. The majority of the carbon emission footprint is produced by and in high-income countries (Lenzen et al., 2018).

Transportation

The transportation sector is the main contributor to global warming in tourism with 49% of the emissions produced during travel. Airplanes, followed by cars and motorcycles are the highest polluters of travel. The focus on reducing carbon emissions is of high priority to further impact climate change as the demand for transportation increases. Three main areas to focus upon are demand, technological improvement, and alternative fuels (Hu et al., 2022).

The Airline industry has pledged to become net zero carbon emitter by 2050 by focusing on (1) Green fuel: replacing jet fuel with "sustainable aviation fuel (SAF) originating from renewable sources such as used cooking oil and plants. Resulting in an 80% reduction of carbon emissions. (2) Offsets: travellers would be charged an offset fee. Offset credits would then be invested in clean energy projects, planting trees or supporting other efforts. (3) Direct eye capture is the technology that brings carbon dioxide from the atmosphere and stores it

underground. (4) Electric and hydrogen is focusing on scale battery capacity to enable to power aircrafts and if renewable power can create hydrogen fuel in the quantities needed to enable flying an aircraft (World Economic Forum). More interestingly, the European sleeping trains are making a comeback, and few European nations have already introduced short flight bans (Bearne, 2023)

Food and Beverage Elements

Food-related tourism, particularly wine tourism, has emerged as a significant sector within the global tourism industry. It offers economic benefits to regions and provides unique cultural and gastronomic experiences for tourists. However, this growing sector also has environmental implications, particularly concerning climate change. wine tourism, contributes to environmental degradation through carbon emissions, resource consumption, and waste generation. The transportation of tourists to and from destinations, along with the energy required for accommodations and tourist activities, significantly contributes to greenhouse gas emissions. A study on wine tourism in Australia revealed that tourism activities account for over one-third of the wine industry's carbon footprint, highlighting the need for sustainable practices (Sun & Drakeman, 2021).

The production and transportation of food and beverages for tourists also contribute to the environmental impact. Wine production, in particular, involves processes such as irrigation, fermentation, and packaging, all of which require significant energy and resources. The use of synthetic fertilizers and pesticides in vineyards further exacerbates environmental issues, contributing to soil degradation and biodiversity loss (Rosen & Bradley, 2023).

In general, a quarter of the global carbon emissions are caused by the global food industry, which includes production, post-farm processes and distribution (Lenzen et al., 2018). There are four key areas to consider when trying to allocate carbon emissions to the food industry. These are as follows:

Firstly, ‘Livestock & Fisheries’ (31%), produce carbon emissions in numerous ways; cattle produce methane, manure management, pasture management; additionally, there is fuel consumption from fishing vessels. Second, ‘Crop Production’ (27%), of which 21% comes from crop production for human consumption and 6% from crop production for animal feed. These are the combined carbon emissions from fertilizers and manure which release nitrous oxide; additionally, rice production produces methane, and agricultural machinery produce carbon dioxide. Third, ‘Land Use’ (24%), which is the conversion of forests, and grasslands into cropland (8% of emissions) and pasture (16% of emissions). Finally, ‘Supply Chain’ (18%) is regarded as the entire food process from the farm to table (farm production, transportation, packaging, distribution and retail). (Poore and Nemecek, 2018).

These four areas discussed are essential to lowering the carbon emissions produced by the food and beverage industry. Unfortunately, one third of the food production emissions are wastage from either supply chain losses or consumers. To reduce the wastage, the food industry should focus on durable packaging, proper refrigeration, and food processing. For example. processed fruit and vegetables produce 14% less waste than fresh fruit and vegetables and processed seafood emits 8% lower emissions than fresh.

For the food and beverage industry, reducing carbon emissions will be one of the main challengers over the next few decades. There needs to be a variety of solutions to create food and beverage alternatives both affordable and to scale, such as changing diets, reduce food waste, address agricultural efficiency and the use of technology.

Tourist Facilities and Infrastructure Construction

Tourism is a significant contributor to many economies worldwide, but the construction of tourist facilities can have profound environmental and climatic impacts. The facilities sector consists of two main areas: the construction process, and the facilities consumption. During a buildings' construction process there are another two areas of focus: transportation of building materials as well as the manufacturing of building materials, which are CO2 producing activities. Furthermore, facilities produce CO_2 when their energy sources are not renewable. Thus, there are numerous organizations and associations around the world which focus on energy efficiency as well as zero emission buildings such as the US LEED certifications. Furthermore, countries have also started to focus on incentives for sustainable travel, for example Florida Green Lodging.

Tourist facilities often require significant resources, including water and energy, which can strain local ecosystems. The high energy consumption and water usage in tourist accommodations can lead to resource depletion and pollution. In Ukraine, the concentration of tourist infrastructure has been linked to water pollution due to inadequate wastewater treatment systems (Pankiv & Gunko, 2017). Additionally, the production of solid waste from tourist activities contributes to environmental degradation and increases greenhouse gas emissions (Gündüz & Atak, 2023).

The construction and operation of tourist facilities contribute to carbon emissions, which exacerbate climate change. The use of fossil fuels in transportation, energy generation, and waste management in tourist areas increases the carbon footprint of these regions (Deb et al., 2023; Ruhoma & Sallam, 2024). Furthermore, the construction process itself, including the use of materials and transportation of goods, contributes to emissions (Karami et al., 2016; Pachaury, 2024).

The development of tourist infrastructure often leads to land use changes, such as the conversion of natural habitats into tourist facilities. This can result in the loss of carbon sequestration capacity and increased greenhouse gas emissions (Singgalen, 2022; Miloradov & Eidlina, 2018). The construction of tourism infrastructure in Dodola Island led to a significant decline in vegetation cover, as measured by the Normalized Difference Vegetation Index (NDVI) and Soil Adjusted Vegetation Index (SAVI) (Singgalen, 2022).

Moreover, the construction of tourist facilities often leads to habitat destruction, particularly in coastal and fragile ecosystems. Development of hotels, resorts, and resorts in coastal areas can result in the destruction of mangrove forests and coral reefs, which are critical carbon sinks (Singgalen, 2022; Ruiz, 2015). Similarly, the expansion of tourism infrastructure in sensitive areas like the Cayo Coca in Cuba has been shown to disrupt local ecosystems, leading to biodiversity loss and increased vulnerability to climate change (Ruiz, 2015).

Additionally, the construction of tourist facilities can also have socio-economic impacts that indirectly contribute to climate change. The influx of tourists can lead to over-tourism, which strains local resources and increases the environmental footprint of tourist destinations

(Omar et al., 2023; Gündüz & Atak, 2023). Additionally, the displacement of local communities and the disruption of traditional livelihoods can lead to increased vulnerability to climate change (Hosseini et al., 2024; Miloradov & Eidlina, 2018).

Each type of tourism infrastructure plays a distinct role in the functioning of a destination. The Table 1 below presents key infrastructure categories, their primary functions, and the sustainability principles that should guide their development.

Table1: Key types of tourism infrastructure and their sustainability considerations

Infrastructure Type	Primary Function	Sustainability Considerations
▪ Transportation Hubs	▪ Connect tourists to destinations (airports, rail)	▪ Low-emission design, intermodal systems, renewable energy use
▪ Access Roads & Trails	▪ Enable internal movement within destinations	▪ Erosion control, eco-sensitive materials, integration with nature
▪ Accommodation Facilities	▪ Provide lodging and hospitality	▪ Eco-certification, energy efficiency, waste and water management
▪ Recreational Facilities	▪ Enhance leisure and cultural experiences	▪ Community engagement, controlled land use, cultural heritage respect
▪ Utility Infrastructure	▪ Support operations (energy, water, waste, telecom)	▪ Green energy, circular waste systems, digital equity
▪ Signage & Information Systems	▪ Guide, inform, and ensure safety	▪ Multilingual and accessible design, digital integration

To align with the UN Sustainable Development Goals (SDGs) - especially SDG 9 (Industry, Innovation and Infrastructure) and SDG 11 (Sustainable Cities and Communities) - future tourism infrastructure must be:

- Low-carbon and climate-resilient;
- Socially inclusive, involving local communities in planning and benefits;
- Technologically adaptive, integrating smart systems and digital services;
- Culturally sensitive**,** preserving the identity of local heritage.

The main issue in providing energy to facilities is the source of the energy. Currently, the global energy mix is made up of the following energy sources: (1) Oil 31.6%, (2) Coal 27.6%, (3) Gas 25%, (4) Hydropower 7%, (5) Nuclear 4.4%, (6) Wind 2.6%, (7) Solar 1.4% (Ritchie, Our World in Data, 2021). To reduce carbon emissions each country must place the focus on providing its population with renewable energy sources.

Few key areas of focus in reducing carbon emissions in facilities such as accommodations are: (1) Air conditioning, (2) Generic electric devices, (3) Kitchen services, (4) Lighting. Each of these areas are continuously improving efficiency and lowering the usage of energy as well as reducing carbon emissions.

Furthermore, indirect CO_2 emissions are also created by the tourism industry by utilizing space intended for trees which absorb CO_2 are now covered by physical structures such as buildings, parking lots, roads etc. To alleviate the unnecessary usage of land, architects are developing zero emissions buildings and construction materials are changing, in turn limiting the damage on the environment.

1.3. Policy and Governance Implications

Nations around the world have agreed on lowering their carbon emissions to help stabilize global temperatures and possibly reduce them in the future. Moving away from carbon-based fuels by advancing the research in the area of environmentally friendly energy options such as solar power, the use of electric vehicles, development of hydrogen-based fuel cell technologies are a few examples of worldwide efforts.

Extensive research has been undertaken to address the issue of rising sea levels that is threatening beaches, and marine ecosystems around the world. Efforts have been made for adapting these coastal regions and landscapes so that the tourism flows are not disrupted. Also, new ways of improved forest management are being sought to mitigate the risk of forest fires. Since small operators are at the forefront of losing because of these natural disasters, directing government support to help small businesses will help them continue services when a natural disaster happens. There are several steps that have been proposed and actively pursued to address the issue of climate change and its effect on tourism. One such measure is the proposal of mandatory climate risk disclosure by businesses around the world. This will enforce companies and their financing partners to be transparent about how their business is exposed and impacted by climate change.

Tourism sector must adapt strategies that are critical for building resilience. For example, tourism businesses near Iran's Lake Urmia are adapting to climate change by raising risk awareness and improving response efficacy (Torabi et al., 2024). In Slovenia, adaptation strategies focus on addressing the vulnerabilities of winter tourism while capitalizing on the potential benefits of longer summer seasons (Turnšek et al., 2024).

Sustainable tourism practices, such as green tourism and eco-tourism, are being promoted as a way to mitigate the impacts of climate change. These practices aim to reduce the environmental impact of tourism while supporting local communities (Cemara & Ismail, 2024). Smart tourism initiatives, such as early warning systems and fire detection sensors, similar to those in Rwanda (Lukenangula, 2023), should be implemented to manage climate-related risks and protect tourists and workers. On the consumer side, digital technologies and platforms can be used to assist in creating travel plans that focus on destinations least impacted by climate change in a given time frame.

Lastly, effective adaptation and mitigation require collaboration among stakeholders, including policymakers, businesses, and tourists. Integrating climate research into policy frameworks can help develop tailored strategies for different tourism zones ("Climate Change Impacts on the Tourism Industry in Georgia", 2023). Also, raising risk awareness and improving response efficacy are critical for building resilience in the tourism sector (Torabi et al., 2024).

Climate change presents significant threats to heritage tourism, endangering cultural and natural sites while destabilizing tourism-dependent economies. Rising sea levels, temperature fluctuations, and extreme weather events directly impact these destinations, while disruptions to tourism infrastructure and economic stability add further complexity. Simultaneously, climate change is reshaping global tourism, with some regions experiencing extended seasons while others, such as Alpine destinations, face threats to their winter tourism industries (Torabi et al., 2024; Turnšek et al., 2024). Understanding how tourism

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businesses perceive risk and adapt to climate challenges is essential for strengthening resilience ("Opportunities and Drawbacks for Alpine Tourism Under Climate Change", 2023).

Despite these risks, innovative solutions can enhance adaptation, sustainability, and long-term viability. Smart tourism technologies and sustainable practices provide effective tools for mitigating climate-related risks (Lukenangula, 2023; Cemara & Ismail, 2024). Protecting cultural heritage in this evolving landscape requires a blend of traditional knowledge, modern technology, and international cooperation. By fostering collaboration among policymakers, businesses, and tourists, the industry can develop strategic responses that safeguard both natural and cultural assets. Ultimately, a proactive and cooperative approach is essential for ensuring that tourism not only survives but thrives in the face of climate change.

The global impact of tourism on climate change is profound and multifaceted, with both direct and indirect effects. While tourism contributes significantly to greenhouse gas emissions, it is also vulnerable to the impacts of climate change, which threaten the sustainability of destinations and the livelihoods they support. Addressing these challenges requires a combination of adaptation and mitigation strategies, as well as continued research and collaboration among stakeholders. By understanding the complex relationships between tourism and climate change, we can work towards a more sustainable and resilient future for the global tourism industry.

Gastronomic tourism, particularly wine tourism, offers substantial economic and cultural benefits but also poses significant environmental challenges. The impact of climate change on food production and tourism patterns necessitates the adoption of sustainable practices and collaborative efforts among stakeholders. By prioritizing sustainability, regions can reduce the environmental impact of tourism while preserving the unique cultural and gastronomic experiences that attract visitors.

The construction of tourist facilities has significant implications for the environment and climate. While the direct impacts include habitat destruction, resource consumption, and carbon emissions, the indirect impacts involve land use changes, disruption of local ecosystems, and socio-economic factors. However, the implementation of sustainable practices, community engagement, and effective policy frameworks can lower these impacts. By adopting eco-friendly technologies, promoting responsible tourism practices, and enforcing regulations, the tourism industry can reduce its environmental footprint and contribute to climate change mitigation.

In global context, human activity has elevated global temperatures by around 1.2 °C since the pre-industrial era (1850–1900), and the last decade (2010–2019) has recorded the highest temperatures, with the six warmest years occurring since 2015. The year 2023 saw a series of climatic records and extreme events, potentially making it the warmest year on record and possibly the hottest in the last 100,000 years (World Meteorological Organization, [WMO], 2024). The catastrophic effects of climate change are currently more pronounced than ever with extreme heatwaves across southern Europe, the US, China, and India, major wildfires in Greece and Canada, and mass coral bleaching in Australia and parts of the Caribbean (Scott, 2024). To combat climate change, institutional investors have made a concerted effort to tighten carbon and climate-risk disclosures, reduce emissions, and improve governance (Scott, 2021).

The Paris Climate Agreement represents a worldwide consensus, ratified by 195 countries, to decarbonize the economy. This effort aims to prevent the severe consequences of climate change by limiting global warming to "well below 2°C" and, ideally, stabilizing the climate at +1.5°C above pre-industrial levels (United Nations, 2015). The Paris Agreement established a structure that compels Parties to report on their progress and update emission reduction objectives every five years (beginning in 2023) to address the discrepancy between the Parties' voluntary emission reduction aims and their agreed-upon policy objective. Global climate change poses a significant challenge for society, progressively impacting investment, planning, operations, and demand within the tourism sector (Ma & Kirilenko, 2020).

Tourism cannot be considered sustainable unless it can be eventually decarbonized to a level consistent with the science-based policy targets of the Paris Climate Agreement. Destinations' extreme reliance on climate-related elements like temperature, sun, and snow cover is one of the main direct effects that contributes to the tourism industry's high susceptibility to climate change. As the climate changes, tourism is one of the economic sectors most impacted, resulting in both new opportunities and several vulnerabilities. For example, the immediate consequences of increased temperatures and sea level rise can indirectly impact the vital natural resources of tourist destinations. This includes reduced snow cover, shorter snow seasons, coral bleaching, increased risk of wildfires, and coastal erosion.

Conversely, the poleward shifts of comfortable temperatures during the summer holiday season are conducive to bringing more visitors to Northwest Europe and midlatitude areas in North America. The direct and indirect effects of rapid climate change and comprehensive government policies will alter the competitiveness, sustainability, and geography of tourism (Scott & Hall, 2019). Climate change is imminent, and the repercussions of procrastination and inadequate sectoral readiness should be especially alarming for the tourism industry.

To enhance the discussion on the effects of the global climate crisis on tourism and its development, additional research should concentrate on residents' perceptions of the crisis by examining their views on governmental policies implemented to address the issue and their positions regarding these measures. The global climate crisis is an existential threat to humanity and the tourism industry; thus, tourism scholars must enhance transdisciplinary partnerships to support climate action. Lastly, sustainable tourism must embrace the climate change phenomena in future research endeavours.

Conclusion

This paper has explored the iterative relationship between climate change and tourism, emphasizing their dynamic interdependence and the urgent need for integrated, sustainable responses. As demonstrated, tourism is both a contributor to and a casualty of climate change, with rising emissions, unsustainable infrastructure, and resource-intensive practices exacerbating environmental degradation, while increasingly frequent extreme weather events threaten destinations and livelihoods. Examining impacts across diverse domains - mountain, coastal, and heritage tourism, food and beverage sectors, transportation, and infrastructure development - this research illustrates the sector’s vulnerabilities and the broad spectrum of climate-induced challenges. Importantly, the study frames these challenges within the Sustainable Development Goals (SDGs), reinforcing the need for multi-stakeholder governance, sustainable policy interventions, and technological innovation to ensure climate-resilient tourism systems.

The findings underscore that sustainability in tourism must be grounded in decarbonization strategies aligned with the Paris Climate Agreement, greater investment in eco-tourism and smart technologies, and enhanced risk awareness and disclosure practices. The industry must also recognize the disproportionate vulnerabilities faced by small island states, low-income regions, and heritage sites, and prioritize inclusive, adaptive responses.

Ultimately, sustainable tourism is no longer optional - it is imperative. The global tourism industry stands at a critical juncture, where proactive planning, collaborative governance, and science-based policy alignment can shape a future in which tourism continues to thrive without compromising planetary boundaries. This paper calls for intensified research, cross-sectoral partnerships, and policy innovation to support a just, climate-conscious transformation of the tourism sector.

Credit Authorship Contribution Statement

D.M. and A.P. contributed to the overall conceptualization of the study and led the design of the research framework. D.S.M. and P.H. were primarily responsible for developing the methodology, formulating the core arguments, and drafting the original version of the manuscript. P.H., K.A. and T.H. conducted an extensive literature review.

Conflict of Interest Statement

The authors declare that they have no financial or personal conflicts of interest that could influence the results or interpretations presented in this article. No external funding sources were received for the conduct of this research.

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