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THE IMPACT OF CLIMATE RISKS ON THE SUSTAINABILITY OF WINTER TOURISM DESTINATIONS: THE CASE OF AZERBAIJAN

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Summary. Although global climate change affects all branches of tourism, winter tourism is one of the most climate-sensitive forms of destination development. Declining snow cover, the upward shift of the snow line, shorter winter seasons, more frequent extreme weather events, and growing pressure on water and energy resources weaken the economic and environmental sustainability of mountain ski destinations. The purpose of this article is to examine conceptually how climate risks influence the sustainability of winter tourism destinations and to assess adaptation opportunities in Azerbaijan through the cases of the Shahdag and Tufandag winter-summer tourism complexes. The article uses a conceptual and analytical research approach by synthesizing international academic literature, climate-risk reports, official tourism information, and Azerbaijan-specific sources. The analysis shows that the future competitiveness of winter tourism cannot depend solely on snowmaking technologies. Instead, year-round product diversification, water and energy efficiency, early-warning systems, carbon-footprint reduction, local community participation, and climate-informed planning must be applied together. Although Azerbaijan's mountain resorts benefit from elevation advantages and modern infrastructure, their long-term sustainability requires more systematic monitoring of snow reliability, climate-risk mapping, and adaptation-oriented investment governance.

Keywords: climate risks, winter tourism, sustainable tourism, Shahdag, Tufandag, snowmaking, adaptation.

1. Introduction. Climate change has become one of the central global forces reshaping strategic planning in the tourism sector in the twenty-first century. Tourism contributes to climate change through transport, accommodation, energy consumption, and other emission-generating activities, while at the same time it is directly affected by climate variability and long-term climatic shifts [1; 2]. This dual relationship makes sustainable tourism development especially complex. The sector creates economic growth, employment, and regional development opportunities, but it also depends heavily on natural resources, energy systems, landscape quality, and vulnerable ecosystems.

Winter tourism is among the clearest examples of this dependence. Skiing, snowboarding, snow tubing, and other winter activities require reliable snow cover, a sufficient number of cold days, and safe mountain conditions. Global warming, however, reduces the amount and duration of snow in many mountain regions, moves the snow line to higher elevations, and changes the timing of the beginning and end of the winter season [3; 4]. As a result, the classical business model of winter tourism, which relies on seasonal ski activity supported by natural snow, is becoming increasingly uncertain and exposed to risk. Mountain and winter tourism occupy an important place in Azerbaijan's tourism development strategy. The Shahdag and Tufandag winter-summer tourism complexes have played a significant role in the formation of modern tourism infrastructure in the country's mountain regions. Official information presents Shahdag as a mountain resort located between 1,435 and 2,552 meters above sea level and equipped with multiple ski slopes and lift systems [5]. Tufandag, in turn, combines the mountain tourism potential of Gabala with winter and summer recreational activities [6]. These facilities contribute both to domestic tourism and to Azerbaijan's competitiveness in the regional tourism market.

At the same time, the development of winter tourism cannot be secured by infrastructure alone. Snow reliability, the availability of water resources, energy costs, extreme weather events, changing tourist behavior, and environmental constraints are among the key factors that will shape the future of winter tourism destinations. Therefore, the main research question of this article is formulated as follows: through which channels do climate risks affect the sustainability of winter tourism destinations, and which adaptation strategies should Azerbaijani mountain resorts apply in response to these risks? The purpose of the article is to analyze the impact of climate risks on the sustainability of winter tourism destinations on the basis of international experience and the Azerbaijani case, and to propose a sustainability-oriented conceptual framework for the Shahdag and Tufandag complexes. In line with this aim, the article examines the climate sensitivity of winter tourism, the economic and ecological consequences of risk exposure, the current opportunities of Azerbaijan's mountain tourism sector, and future directions for adaptation.

2. Literature review. 2.1. Climate change and the climate sensitivity of winter tourism. In the international literature on winter tourism, one of the central concepts is snow reliability. Snow reliability refers to the availability of sufficient snow cover for a destination to operate winter tourism activities for an economically viable period. Steiger and co-authors systematize climate risks for ski tourism and show that rising temperatures, decreasing natural snow, and the increasing cost of artificial snow production weaken the long-term resilience of ski resorts [3].

Recent studies also show that climate risks are not limited to the amount of snow. In mountain tourism, climate change is directly linked to water resources, energy use, safety, infrastructure resilience, and tourist demand [4]. Declining snow cover shortens the season in lower-elevation resorts, pushes activities toward higher altitudes, and increases investment and maintenance costs. This process alters the geographical boundaries of the so-called snow economy and intensifies pressure on higher mountain environments. The scale of this risk is clearly demonstrated by the model-based study conducted by François and colleagues on 2,234 European ski resorts. Their findings indicate that, without snowmaking, 53 percent of European ski resorts would face a very high risk of insufficient snow supply under a 2°C global warming scenario, while the share would rise to 98 percent under a 4°C scenario. Even when snowmaking covers 50 percent of ski slopes, the risk remains 27 percent under 2°C warming and 71 percent under 4°C warming [7]. These figures confirm that snowmaking is an adaptation instrument, but not a complete solution to the problem.

2.2. Snowmaking, resource dependence, and the risk of maladaptation. Snowmaking is one of the most widely used adaptation tools in winter tourism destinations. It is applied to secure the opening of the season, maintain a minimum snow depth on key ski slopes, and ensure service continuity during peak tourist demand. However, artificial snow also increases demand for water and energy. For this reason, the literature discusses not only the adaptive role of snowmaking but also its possible maladaptive effects [8].

Maladaptation emerges when a short-term risk-reduction measure creates new ecological or economic problems in the long term. For example, as temperatures rise, snow production may require more energy and water, while climate change itself may increase water-scarcity risks in many regions. Moreover, if snowmaking is powered by carbon-intensive energy, winter tourism may reinforce the very climatic processes that threaten its future. Therefore, contemporary research recommends that snowmaking technologies should be combined with renewable energy, water-saving systems, recycling practices, and efficient destination governance [7; 8].

2.3. Sustainability and the year-round tourism approach in mountain destinations. Sustainability in winter tourism does not mean simply preserving the ski season. It means maintaining the economic, social, and ecological functions of the destination over the long term. In this regard, diversification is one of the key strategies. Mountain resorts increasingly develop hiking, cycling, cable-car sightseeing, wellness and spa services, cultural events, local food experiences, and community-based activities during spring, summer, and autumn in order to reduce their dependence on the winter season [4; 9].

Sustainability is also a governance issue. Climate-informed tourism governance involves meteorological monitoring, risk mapping, infrastructure resilience audits, emergency planning, local community participation in decision-making, and the evaluation of investment projects against future climate scenarios. This approach treats the destination not merely as a marketing product but as a socio-ecological system whose resilience depends on the coordination of environmental, economic, and social variables.

3. Methodological approach. This article is conceptual and analytical in nature. It does not rely on a new empirical survey or experiment. Instead, it systematizes academic and official sources related to winter tourism, climate risks, mountain destination sustainability, snowmaking, and adaptation governance. Methodologically, the article combines an integrative literature review, comparative case interpretation, and conceptual framework development.

The analysis was carried out in three stages. First, international studies on the climate sensitivity of winter tourism were reviewed. Second, open information on climate risks, mountain tourism infrastructure, and the Shahdag and Tufandag complexes in Azerbaijan was summarized. Third, based on the synthesized material, a conceptual model was developed to explain sustainability and adaptation mechanisms for winter tourism destinations. The main limitation of the study is the restricted public availability of detailed annual data on snow depth, water consumption, energy costs, and tourist flows for the resorts under discussion. Therefore, the analysis is conducted primarily at a conceptual and strategic level. Nevertheless, the available sources provide a sufficient basis for identifying the main risk channels and adaptation needs of winter tourism destinations.

4. Conceptual framework and discussion. 4.1. Channels through which climate risks affect winter tourism. Climate risks affect winter tourism destinations through several interrelated channels. The first channel is the reduction of natural snow cover. Rising temperatures increase the probability that winter precipitation will fall as rain rather than snow and reduce the duration of snow persistence on the ground. This may lead to later season openings and earlier closures. The second channel is the increase in extreme weather events. Sudden warming, strong winds, fog, avalanche risk, and rainstorms raise safety costs and interrupt the continuity of resort services. The third channel is resource pressure. Snowmaking, lift systems, hotel infrastructure, and transport generate demand for energy and water. When climate change limits water availability, meeting this demand becomes more difficult and more expensive. The fourth channel is tourist behavior. If tourists lose confidence in snow reliability, they may delay reservations, choose alternative destinations, or replace winter tourism with other forms of recreation. The fifth channel is reputation and investment risk. If snow unreliability continues over time, the brand image and investment attractiveness of the destination may decline.

Table 1.

Channels of climate-risk impact on winter tourism destinations

Risk channel	Main manifestation	Consequence for the destination	Management response
Declining snow cover	Rising snow line and shorter season	Fewer ski days and lower revenue	Snow-reliability monitoring, snowmaking, and elevation-sensitive planning
Extreme weather events	Strong wind, fog, sudden warming, flooding, and avalanche risk	Higher safety costs and service interruptions	Early-warning systems, emergency plans, and insurance mechanisms
Water and energy pressure	High resource demand for snowmaking and infrastructure	Higher operating costs and ecological burden	Efficient technologies, renewable energy, and water management
Changing tourist behavior	Weak confidence in snow guarantee and late booking	Demand volatility and revenue uncertainty	Year-round activities, flexible packages, and risk communication
Reputation and investment risk	A destination gaining a snow-poor image	Lower brand value and weaker investment appeal	Sustainability branding, transparent information, and green certification

Source: Compiled by the author based on [3], [4], [7], [8] and [9].

4.2. Current situation of winter tourism destinations in Azerbaijan. Azerbaijan's mountain-ski tourism is concentrated mainly on the northern and north-western slopes of the Greater Caucasus. The Shahdag and Tufandag complexes are the main examples of winter tourism infrastructure in the country. According to Shahdag's official information, the resort includes a wide system of ski and snowboard slopes, 20 lifts, 45 kilometers of ski area, and an elevation range of 1,435-2,552 meters [5]. These indicators strengthen its position as the largest mountain resort in Azerbaijan.

The Tufandag complex is located in the Gabala district and is presented in official information together with ski school services, lifts, slopes, equipment rental, hotels, and restaurant facilities [6]. Its advantage lies in the already established tourism brand of Gabala, the diversity of recreational opportunities, and proximity to year-round leisure infrastructure. Thus, both complexes are not merely ski areas; they are key elements of a broader mountain tourism system. Azerbaijan's climatic diversity creates both opportunities and risks for winter tourism. The country includes different climatic zones, and snow cover forms in mountain areas during winter. However, general warming trends may weaken the reliability of this snow cover [10]. Climate-risk reports on Azerbaijan emphasize the country's exposure to hydrometeorological hazards, water scarcity, floods, and extreme weather events [11]. Although these risks are not specific only to winter tourism, they are highly relevant for the water, energy, and safety planning of mountain resorts.

Table 2.

Sustainability-oriented comparison of Shahdag and Tufandag complexes

Indicator	Shahdag	Tufandag	Sustainability meaning
Geographical position	Gusar district, Greater Caucasus	Gabala district, Greater Caucasus	Both complexes use the climatic advantages of mountain areas
Elevation factor	1,435-2,552 m range [5]	Mountain zone of Gabala with lift and slope infrastructure [6]	Elevation improves snow reliability but does not guarantee it fully
Core tourism product	Skiing, snowboarding, winter and summer activities	Ski school, lifts, mountain activities, hotel and spa services	Product diversity reduces seasonal risk
Year-round activity potential	Summer activities, zip-line, coaster, trekking, and family attractions [5]	Hiking, quad-bike tours, mountain coaster, and rope-line activities [6]	The main instrument for reducing dependence on winter
Climate risk	Changing snow season and water-energy costs	Snow sensitivity and weather variability, especially in lower-elevation areas	Risk management requires continuous monitoring

Source: *Compiled by the author based on official information from Shahdag and Tufandag and climate-risk sources [5; 6 and 11].*

4.3. Adaptation strategies: technology, diversification and governance. The sustainability of winter tourism in Azerbaijan should be built around three main adaptation directions: technological adaptation, product diversification, and climate-informed governance. Technological adaptation includes snowmaking, snow retention, slope design based on microclimatic conditions, energy-efficient lift systems, and digital weather monitoring. Artificial snow can reduce seasonal risk in the short term, but its expansion cannot be considered sustainable unless water and energy requirements are properly assessed [7; 8].

Product diversification means that winter tourism should not be understood only as skiing. Mountain hiking, cycling routes, wellness and spa services, nature observation, local gastronomy, rural tourism, family entertainment, and cultural events can extend the economic season of the destination. The official pages of Shahdag and Tufandag already present summer and adventure activities alongside winter services, which shows that this direction has begun to take shape [5; 6].

Climate-informed governance requires decisions to be based not only on past weather experience but also on future climate scenarios. When new slopes, hotels, and technical infrastructure are planned, elevation, exposure, water-source durability, wind regime, avalanche risk, and transport accessibility should be assessed together. This approach is particularly important for the planning of new tourism zones, because ski infrastructure built in an unsuitable location may create both economic losses and ecological pressure in the future.

4.4. An integrative governance model for sustainability

Table 3.

Integrative model for climate resilience in winter tourism destinations

Model level	Core elements	Strategic function	Application direction for Azerbaijan
Climate data	Snow depth, temperature, wind, water resources, and extreme-weather indicators	Early identification of risk	Creating a permanent snow-reliability database for Shahdag and Tufandag
Technological adaptation	Snowmaking, energy-efficient equipment, and slope management	Operational reduction of seasonal risk	Managing snowmaking systems through water and energy audits
Product diversification	Summer activities, wellness, rural tourism, festivals, and events	Reducing dependence on snow	Branding mountain resorts as year-round tourism centers
Environmental governance	Carbon footprint, waste, water protection, and landscape impact	Combining adaptation and mitigation	Green certification and renewable-energy projects
Community and market connection	Local communities, tourist awareness, and flexible sales packages	Increasing social acceptance and economic benefit	Involving Gusar and Gabala communities in alternative tourism products

Source: *Compiled by the author based on [4], [7], [8], [11] and [12].*

The model demonstrates that the sustainability of winter tourism cannot be based on a single technology. Snowmaking helps to manage the season, but because of resource limits, temperature thresholds, and ecological effects, it can only be one component of a broader sustainability model. The key principle is to connect climate data with strategic decision-making, expand the product portfolio through year-round activities, and reduce pressure on mountain ecosystems. For Azerbaijan, this model can be used both in the management of existing resorts and in the planning of future mountain tourism projects. For example, if annual monitoring of snow depth and temperature is made publicly available for Shahdag and Tufandag, a more transparent decision-making environment will be created for investors, tourists, and public authorities. At the same time, broader involvement of local communities in the tourism value chain may increase income opportunities outside the winter season.

5. Conclusion. Climate risks create a fundamental strategic challenge for the sustainability of winter tourism destinations. Global warming reduces snow cover, raises the snow line, and shortens the ski season. International studies show that even in European resorts with advanced snowmaking infrastructure, high snow-supply risk remains serious under 2°C and 4°C warming scenarios [7]. This finding indicates that winter tourism cannot be protected through technical solutions alone and requires a broader sustainability strategy.

In the Azerbaijani case, the Shahdag and Tufandag complexes are the main destinations shaping the country's winter tourism potential. Their high-mountain location, modern lift and slope infrastructure, and year-round activity concept are important advantages. However, climate change does not make these advantages automatically sustainable. Changing snow reliability, rising demand for water and energy resources, extreme weather events, and more flexible tourist behavior require systematic risk management for these destinations. The main conclusion of the article is that the sustainability of winter tourism requires an integrative approach. In this approach, snowmaking, energy and water efficiency, digital monitoring, emergency planning, year-round product

diversification, carbon-footprint reduction, and local community participation should be implemented in an interconnected manner. In the short term, the central goal is to manage seasonal risk, in the long term, the goal should be to transform mountain destinations into ecologically responsible and competitive tourism systems that are not dependent only on winter conditions.

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