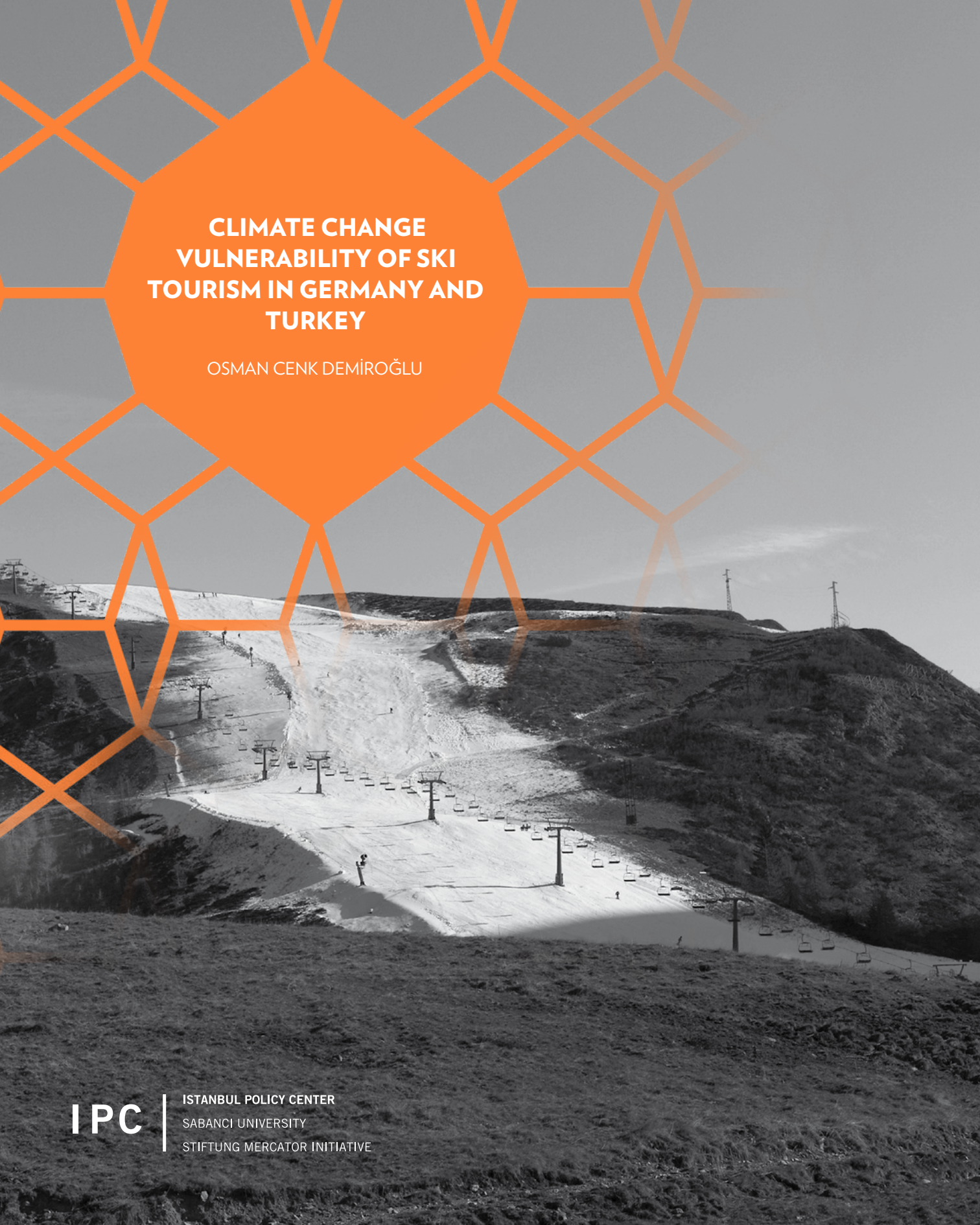
CLIMATE CHANGE VULNERABILITY OF SKI TOURISM IN GERMANY AND TURKEY

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IPC | ISTANBUL POLICY CENTER
SABANCI UNIVERSITY
STIFTUNG MERCATOR INITIATIVE

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The interpretations and conclusions in this report belong solely to the author and do not reflect IPC's official position.

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INTRODUCTION

Contemporary climate change, i.e. global warming, is one of the most challenging threats to our world. The effects of the phenomenon are and will continue to be felt by many components of natural and human systems, mostly in a negative way. The tourism industry, as one of the largest sectors of the global economy, is also under threat due to the already realized and anticipated negative impacts of climate change. Ski tourism in particular remains one of the most vulnerable subsectors of the industry given its high exposure and sensitivity and relatively low adaptive capacity.

This report first reviews the literature on climate change vulnerability of ski tourism and then focuses on two cases at the national level. As the departure point, Germany, one of the most well-established ski countries that has been leading the fight against climate change for more than a decade, is examined through specific research studies and practical issues. Following this, benchmark examples are synthesized in order to understand the climate change vulnerability of ski tourism in Turkey, where the industry has been growing rapidly in recent years. Finally, implications, conclusions, and suggestions are provided based on a comparative comprehension of the gaps to be fulfilled scientifically and practically.

LITERATURE REVIEW

Contemporary Climate Change

Climate change is a phenomenon coeval with the history of Earth. For millions of years, the Earth's climate has been changing due to astronomical, astrophysical, and geological causes such as orbital cycles, solar variation, plate tectonics, and volcanism. However, the contemporary climate change is one of a kind due to its dominant anthropogenic cause. Human activities, such as extensive fossil fuel usage and deforestation, have generated an unprecedented increase in greenhouse gas emissions since the Industrial Revolution, leading to a surface temperature rise of 0.85°C since 1880.[1]

The Intergovernmental Panel on Climate Change (IPCC),[2] the leading scientific authority on climate change research, expects irreversible impacts from the ongoing climate change should the anthropogenic greenhouse gas emissions not be mitigated as soon as possible. Moreover, their projections reveal that a warming would be inevitable for the 21st century, despite any best practice on mitigation, due to the lagged effects of previous emissions. Therefore, global society's acknowledgement of and adaptation to the ongoing and forthcoming impacts of climate change is a vital issue in building resilience.

Climate Change Vulnerability

The IPCC[3] has defined "vulnerability" as "the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change." According to the IPCC definition, vulnerability is a function of exposure, sensitivity, and adaptive capacity of the system. Within this context, exposure refers to the magnitude and rate of climate change on the system, sensitivity indicates the degree to which the system is directly or indirectly affected, and adaptive capacity is the adjustment ability of the system to cope with or benefit from the (potential) consequences of climate change.

The debate among academics on the common understanding of a definition for climate change vulnerability and its interrelation to concepts such as exposure, sensitivity, adaptive capacity, and resilience is ongoing. While some argue vulnerability is a potential superset of its determinants (Fig. 1), others may claim it as an intersection of those determinants (Fig. 2). In this report, vulnerability is treated simply as an umbrella concept encompassing the exposure, sensitivity, and adaptive capacity of ski tourism—the system—to climate change impacts. The "exposure-sensitivity" determinant is dealt in one part by assessments of the current and the future impacts on ski tourism, while the "adaptive capacity" is discussed in terms of the ability to utilize the sector-specific adaptation options. The more the exposure-sensitivity and the less the adaptive capacity are, the more the vulnerability and the less the resilience become.

1 D. L. Hartmann et al., "Observations: Atmosphere and Surface," in *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change,* ed. T. F. Stocker et al. (Cambridge and New York: Cambridge University Press, 2013), 161.

2 IPCC, *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge: Cambridge University Press, 2007).

3 Ibid., 869-883.

Figure 1: Vulnerability as a Superset of its Determinants[4]

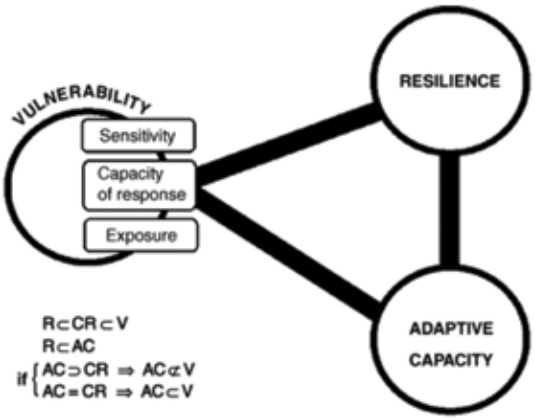
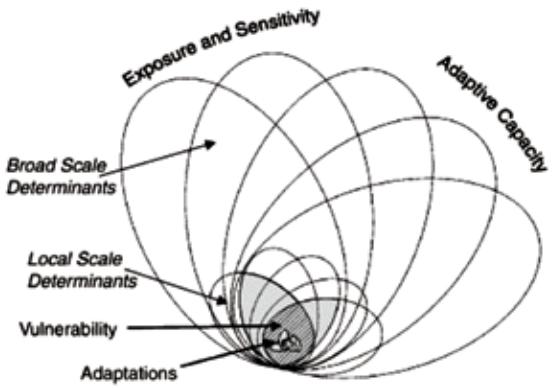


Figure 2: Vulnerability as an Intersection of its Determinants[5]



Tourism Industry and Climate Change

The tourism industry is one of the largest sectors of the global economy. In 2014, the number of international tourist arrivals reached 1.13 billion, accounting for 1.25 trillion USD worth of expenditures.[6] In addition, the volume of domestic tourism is estimated to be five times the volume of international tourism in terms of arrivals.[7] Altogether, the industry makes up 10% of the Gross World Product (GWP) by contributing 7.6 trillion USD worth of direct, indirect, and induced revenues, as well as 277 million jobs, accounting for 9% of global employment.[8] The total contribution of tourism to GWP will amount to 11.4 trillion USD (10.5%) by 2025, and the contribution to employment will be 357 million jobs (10.7%).[9] Further, the number of international tourist arrivals is expected to increase to 1.8 billion by 2030.[10]

Despite its generous contributions to global economic development and highly positive growth expectations, the tourism industry is both a concern and a victim of climate change. On the one hand, the industry contributes 5% of GHG emissions, 75% of which is generated by the transportation industry.[11]

4 G. C. Gallopin, "Linkages between Vulnerability, Resilience, and Adaptive Capacity," *Global Environmental Change* 16 (2006): 301.

5 B. Smit and J. Wandel, "Adaptation, Adaptive Capacity and Vulnerability," *Global Environmental Change* 16 (2006): 286.

6 "UNWTO Tourism Highlights 2015 Edition," World Tourism Organization, accessed January 16, 2016, http://www.e-unwto.org/doi/pdf/10.18111/9789284416899.

7 "Some Points on Domestic Tourism," Frédéric Pierret, accessed January 16, 2016, http://dtxtq4w60xqpw.cloudfront.net/sites/all/files/elements_on_domestic_tourism.pdf.

8 "Travel & Tourism: Economic Impact 2015 World," World Travel & Tourism Council, accessed January 16, 2016, http://www.wttc.org/-/media/files/reports/economic%20impact%20research/regional%202015/world2015.pdf.

9 Ibid.

10 "UNWTO Tourism Highlights 2015 Edition."

11 UNWTO and UNEP, *Climate Change and Tourism: Responding to Global Challenges* (Madrid: World Tourism Organization, 2008).

On the other hand, tourism is listed among the most vulnerable economic sectors to climate change, especially due to its high dependence on climate as a resource and the fact that climate is a major limiting factor to travel.[12] Undoubtedly, ski tourism is among the most critical subsectors of the industry, since the most basic element of this tourism form is snow—a natural system highly exposed and sensitive to climate change.[13]

Ski Tourism and Climate Change

With 120 million total domestic and international visitors accounting for 400 million visits each year, the ski tourism industry has been one of the most important sectors for socioeconomic development in certain regions, e.g. the Alps. Moreover, ski tourism has maintained its status as a socioeconomic driver for recently emerging domains such as China, Russia, and Turkey.[14] However, today both conventional and rising destinations are confronted with the major challenge of climate change. The impacts have already been severely felt in some parts of the world, but the experts warn that there will be much worse to face as ski tourism is claimed to be "the most directly and the most immediately affected" tourism type.[15] Together with the increasing experience of the industry and the negative impacts of climate change during the 2000s, in which the warmest 14 years of the past 135 years have occurred,[16] there has been an exponential growth in the number of studies focused on climate change and ski tourism, reflecting geographical[17] and methodological diversity (Fig. 3).

Some researchers have focused on the recent impacts of climate change on ski tourism during the anomaly seasons through analogue[18] and econometric approaches for an understanding of how the future could be, in which the anomalies eventually become the normals. Burakowski and Magnusson[19] examined how the seasons with relatively lower snowfall differed from the rest in terms of skier visits, revenues, employment, and added value in the United States during the 1999-2010 period, and calculated a loss of 15 million skier visits, 1 billion USD ski resort revenues, 12,965 jobs, and 810 million USD added value. Dawson et al.[20] looked into actual impacts experienced in the Northeast United States during the 1998-1999 and the 2001-2002 seasons, which averaged the mid-range and the high-emissions warming scenarios, respectively. The results showed that

12 D. Scott, C. M. Hall, and S. Gössling, *Tourism and Climate Change: Impacts, Adaptation and Mitigation* (London: Routledge, 2012).

13 D. G. Vaughan et al., "Observations: Cryosphere," in *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change,* ed. T. F. Stocker et al. (Cambridge and New York: Cambridge University Press, 2013).

14 L. Vanat, *2015 International Report on Snow & Mountain Tourism: Overview of the Key Industry Figures for Ski Resorts* (Genéve: Laurent Vanat, 2015).

15 D. Scott, C. M. Hall, and S. Gössling, *Tourism and Climate Change,* 201-202.

16 "Warming Trend Continues in 2014," World Meteorological Organization, accessed January 18, 2016, https://www.wmo.int/media/content/warming-trend-continues-2014.

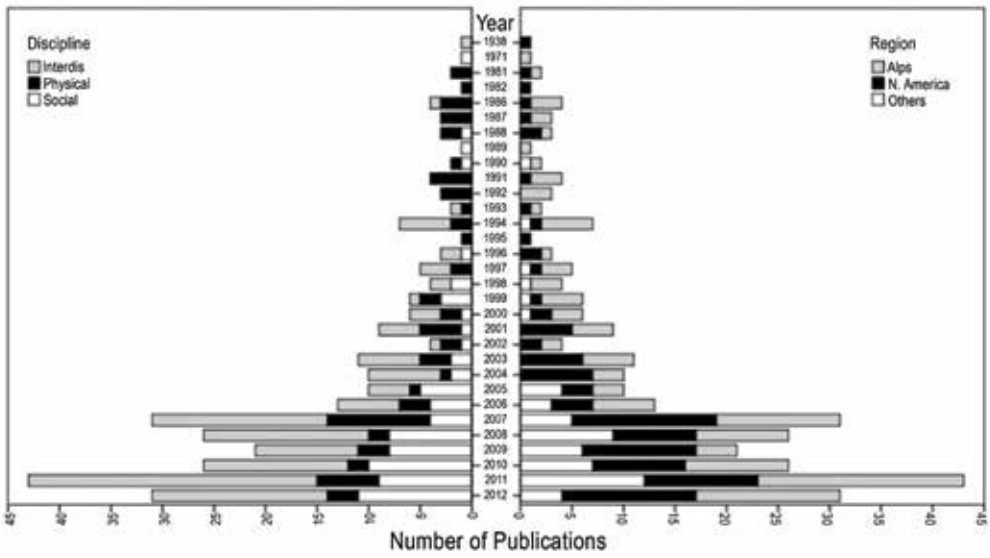
17 O.C. Demiroglu, "Skiklima: A Geo-Bibliography of Ski Tourism and Climate Change Research," accessed January 18, 2016, http://www.skiklima.com.

18 Contrary to models that simulate the future, analogues are observed facts to be treated as proxies for future expectations.

19 E. Burakowski and M. Magnusson, *Climate Impacts on the Winter Tourism Economy in the United States* (New York: Natural Resources Defense Council, 2012).

20 J. Dawson, D. Scott, and G. McBoyle, "Climate Change Analogue Analysis of Ski Tourism in Northeastern USA," *Climate Research* 39 (2009): 1-9.

Figure 3: Trends and Clusters on the Quantities of Publications on Climate Change and Ski Tourism[22]



such anomalies led to losses of 38.6% to 39.2% in natural snowfall and 3.9% to 11.4% in season length as well as an additional energy consumption of 31.4% to 36.7% by snowmaking. In the Alps, Steiger[21] followed a similar method and revealed that the relatively warm 2006-2007 season ended with reductions in snowfall by 37%, season length by 7%, and skier visits by 11%. In Slovakia, Demiroglu et al. [23] found out that a 1% decrease in snow depth and a 1°C increase in mean temperature would reduce skipass sales by 1.2% and 6%, respectively.

In addition to these studies, others also quantified the changes in visitation with respect to climatic variables such as temperature, snowfall, snow depth, visibility, and windiness based on observations from ski areas in Japan,[24] the United States,[25,26] Austria,[27] Romania,[28,29] and

21 R. Steiger, "The Impact of Snow Scarcity on Ski Tourism: An Analysis of the Record Warm Season 2006/2007 in Tyrol (Austria)," *Tourism Review* 66 (2011): 4-13.

22 O. C. Demiroglu, H. Dannevig, and C. Aall, "The Multidisciplinary Literature of Ski Tourism and Climate Change," in *Tourism Research: An Interdisciplinary Perspective,* ed. Metin Kozak and Nazmi Kozak (Cambridge: Cambridge Scholars Publishing, 2013), 225.

23 O. C. Demiroglu, J. Kucerova, and O. Ozcelebi, "Snow-Reliability and Climate Elasticity: Case of a Slovak Ski Resort," *Tourism Review* 70 (2015): 1-12.

24 T. Fukushima et al., "Influences of Air Temperature Change on Leisure Industries: Case Study on Ski Activities," *Mitigation and Adaptation Strategies for Climate Change* 7 (2003): 173-189.

25 L. C. Hamilton, B. C. Brown, and B. Keim, "Ski Areas, Weather and Climate: Time Series Models for Integrated Research," *International Journal of Climatology* 27 (2007): 2113-2124.

26 C. Shih, S. Nicholls, and D. F. Holecek, "Impact of Weather on Downhill Ski Lift Ticket Sales," *Journal of Travel Research* 47 (2009): 359-372.

27 M. Falk, "Impact of Long-term Weather on Domestic and Foreign Winter Tourism Demand," *International Journal of Tourism Research* 15 (2011): 1-17.

28 C. Surugiu, A. I. Dincă, and D. Micu, "Tourism Destinations Vulnerable to Climate Changes: An Econometric Approach on Predeal Resort," *Buletinul Universităţii Petrol – Gaze din Ploieşti* 62 (2010): 111-120.

29 C. Surugiu et al., "Effects of Climate Change on Romanian Mountain Tourism: Are They Positive or Mostly Negative?" *European Journal of Tourism, Hospitality and Recreation* 2 (2011): 42-71.

Australia.[30] In addition to studies focusing on the observed impacts, many others attempted to model and project the potential impacts of climate change on ski tourism. Table 1 summarizes results from such research that applied the so-called "100 day rule,"[31] defined as a climatic threshold of a minimum of 30 cm deep and 100-day snow cover duration for financial viability of a ski resort,[32] in order to assess the "natural snow reliability" of major ski tourism domains.

Following such comprehension of present and potential impacts, one-third of climate change and ski tourism research has focused on adaptation issues. Initially, Swiss researchers compiled supplier adaptation strategies becoming common in the ski industry in coping with the impacts of climate change.[33,34] Canadian researchers, on the other hand, have later managed to suggest an updated adaptation categorization (Fig. 4) and a decision tree (Fig. 5) considering supply-side measures as well as consumer behavior. As such, spatial, temporal, and functional substitution responses of tourists and recreationists have been underlined, while considerable attention has been given to the technical, operational, and political adaptation options at the micro and macro levels.

Despite the variety of adaptation options, snowmaking has become the primary remedy sought for easing the immediate impacts of climate change on snow cover and recovering snow reliability technically.[35] In the Alps, artificially made snow coverage of ski slopes has reached 36% in Switzerland, 62% in Austria, and almost 100% in Italy.[36] Indeed, today even the International Olympic Committee is so convinced of a pessimistic future for natural snow cover that they have recently selected Beijing as the host to the Winter Olympic Games in 2018, bearing in mind that the facilities will mostly have to be backed up by artificial snowmaking[37] as even former host venues are now faced with deteriorating natural snow conditions.[38]

Snowmaking, however, comes along with its costs and consequences. Increasing energy burdens and costs and competition for common water resources, which are expected to become scarcer with climate change, are the top two concerns.[39,40,41]

30 C. M. Pickering, "Changes in Demand for Tourism with Climate Change: A Case Study of Visitation Patterns to Six Ski Resorts in Australia," *Journal of Sustainable Tourism* 19 (2011): 767-781.

31 U. Witmer, *Erfassung, Bearbeitung und Kartierung von Schneedaten in der Schweiz* (Bern: Geographisches Institut der Universität Bern), 193.

32 In the literature, a ski resort and a ski area are distinguished by their capacities, usually by a threshold of 4 lifts and 5 km of slopes. This report uses both terms interchangeably.

33 U. König and B. Abegg, "Impacts of Climate Change on Winter Tourism in the Swiss Alps," *Journal of Sustainable Tourism* 5 (1997): 46-58.

34 H. Elsasser and R. Bürki, "Climate Change as a Threat to Tourism in the Alps," *Climate Research* 20 (2002): 253-257.

35 R. Steiger and M. Mayer, "Snowmaking and Climate Change," *Mountain Research and Development* 28 (2008): 292-298.

36 C. Rixen et al., "Winter Tourism and Climate Change in the Alps: An Assessment of Resource Consumption, Snow Reliability, and Future Snowmaking Potential," *Mountain Research and Development* 31 (2011): 229-236.

37 Tom Peck, "Beijing Wins Right to Host 2022 Winter Olympics - Despite Lack of Snow", *The Independent*, accessed, January 18, 2016, http://www.independent.co.uk/sport/olympics/beijing-wins-right-to-host-2022-winter-olympics-despite-lack-of-snow-10429940.html

38 D. Scott et al., "The Future of Olympic Winter Games in an era of Climate Change," *Current Issues in Tourism* 18 (2015): 913-930.

39 A. Damm, J. Köberl and C. Töglhofer, "Economic Impacts of Climate Change on Winter Tourism: Challenges for Ski Area Operators" (paper presented at the general assembly for European Geosciences Union, Vienna, Austria, April 22-27, 2012).

40 C. M. Pickering and R. Buckley, "Climate Response by Ski Resorts: The Shortcomings of Snowmaking," *Ambio* 39 (2010): 430-438.

41 C. Rixen et al., "Winter Tourism and Climate Change in the Alps: An Assessment of Resource Consumption, Snow Reliability, and Future Snowmaking Potential," *Mountain Research and Development* 31 (2011): 229-236.

Moreover, any energy supplied by fossil fuels means a contribution to GHG emissions, thus, global warming. Last but not least, snowmaking is based on a technology that itself is also limited by climatic factors that require relatively cold and dry weather conditions, meaning it is another system sensitive to climate change.[42] Therefore, some resorts have attempted to use additives for better performance, which have potential side effects on soil and vegetation.[43] On the contrary, snow reliability recovery by snowmaking is a stubborn fact. In Austria, snowmaking has helped increase the ratio of snow reliable ski resorts from 52%, 28%, and 8% to 80%, 57%, and 19% under 1°C, 2°C, and 4°C, respectively.[44] Likewise in New Zealand,[45] snowmaking is predicted to restore the 100-day limit for all 10 resorts even until the 2090s (see Table 1). Tourists, on the other hand, seem to have varied satisfaction levels concerning the implementation of this measure for now.[46,47,48]

42 O. C. Demiroglu et al., "Technical Climate Change Adaptation Options of the Major Ski Resorts in Bulgaria," in *Sustainable Mountain Regions: Challenges and Perspectives in Southeastern Europe,* ed. B. Koulov and G. Zhelezov (Basel: Springer International Publishing Switzerland, 2016).

43 C. Rixen, V. Stoeckli, and W. Ammann, "Does Artificial Snow Production Affect Soil and Vegetation of Ski Pistes? A Review," *Perspectives in Plant Ecology Evolution and Systematics* 5 (2003): 219-230.

44 B. Abegg et al., "Climate Change Impacts and Adaptation in Winter Tourism," in *Climate Change in the European Alps: Adapting Winter Tourism and Natural Hazards Management,* ed. S. Agrawala (Paris: OECD, 2007), 25-60.

45 J. Hendrikx and E. Ö. Hreinsson, "The Potential Impact of Climate Change on Seasonal Snow in New Zealand: Part II—Industry Vulnerability and Future Snowmaking Potential," *Theoretical and Applied Climatology* 110 (2012): 619-630.

46 M. Pütz et al., "Winter Tourism, Climate Change, and Snowmaking in the Swiss Alps: Tourists' Attitudes and Regional Economic Impacts," *Mountain Research and Development* 31 (2011): 357-362.

47 C. M. Pickering, J. G. Castley, and M. Burtt, "Skiing Less Often in a Warmer World: Attitudes of Tourists to Climate Change in an Australian Ski Resort," *Geographical Research* 48 (2010): 137-147.

48 D. Hopkins, "The Sustainability of Climate Change Adaptation Strategies in New Zealand's Ski Industry: A Range of Stakeholder Perceptions," *Journal of Sustainable Tourism* 22 (2014): 107-126.

49 Bruno Abegg et al., "Climate Change Impacts and Adaptation in Winter Tourism," 33-34.

50 R. Steiger and B. Abegg, "The Sensitivity of Austrian Ski Areas to Climate Change," *Tourism Planning & Development* 10 (2013): 480-493.

51 A. Matzarakis et al., "Assessment of Tourism and Recreation Destinations under Climate Change Conditions in Austria," *Meteorologische Zeitschrift* 21 (2012): 157-165.

52 Skiing potential: Mean annual frequency of days with snow cover over 10 cm (for cross-country skiing) and 30 cm (for Alpine skiing)

53 U. König and B. Abegg, "Impacts of Climate Change on Winter Tourism in the Swiss Alps," *Journal of Sustainable Tourism,* 5 (1997): 46-58.

54 H. Elsasser and P. Messerli, "The Vulnerability of the Snow Industry in the Swiss Alps," *Journal of Mountain Research and Development* 21 (2001): 335-339.

55 Bruno Abegg et al., "Climate Change Impacts and Adaptation in Winter Tourism," 34.

56 Line of natural snow reliability: The lowest altitude where a minimum 30 cm deep snow cover can last for 100 days in a season

57 Bruno Abegg et al., "Climate Change Impacts and Adaptation in Winter Tourism," 36.

58 G. Diolaiuti et al., "The Recent Evolution of an Alpine Glacier Used for Summer Skiing (Vadretta Piana, Stelvio Pass, Italy)," *Cold Regions Science and Technology* 44 (2006): 206-216.

59 Bruno Abegg et al., "Climate Change Impacts and Adaptation in Winter Tourism," 36.

60 J. Moen and P. Fredman, "Effects of Climate Change on Alpine Skiing in Sweden," *Journal of Sustainable Tourism* 15 (2007): 418-437.

Table 1: Future Climate Change Impacts on the Natural Snow Reliability of Ski Tourism Destinations

Region	Country	Scope	Model Projections
Alps	Austria	228 ski resorts[49]	Number of naturally snow-reliable ski resorts down to 153, 115 and 47 by a warming of 1°C, 2°C and 4°C, respectively
		228 ski resorts[50]	Number of naturally snow-reliable ski resorts down to 121, 64 and 18 by a warming of 1°C, 2°C and 4°C, respectively
		37 health resorts[51]	Skiing potential[52] to decrease moderately in 2021-2050 and distinctly in 2071-2100
	Switzerland	352 ski resorts[53]	339, 155, and 101 ski resorts will survive should the line of natural snow reliability[56] rise up to 1200, 1500, and 1800 masl
		230 ski resorts[54]	Number of naturally snow-reliable ski resorts down to 195, 144 and 102 by a warming of 1°C, 2°C and 4°C, respectively
		164 ski resorts[55]	Number of naturally snow-reliable ski resorts down to 142, 129 and 78 by a warming of 1°C, 2°C and 4°C, respectively
	Italy	87 ski resorts[57]	Number of naturally snow-reliable ski resorts down to 71, 59 and 21 by a warming of 1°C, 2°C and 4°C, respectively
		1 summer ski resort[58]	Skiing to finish by 2030s due to glacier retreat
	France	148 ski resorts[59]	Number of naturally snow-reliable ski resorts down to 123, 96 and 55 by a warming of 1°C, 2°C and 4°C, respectively
North/ East/ West Europe	Sweden	1 ski resort[60]	Ski season down from 162 to 96 by the 2070s
	Bulgaria	1 ski resort[61]	Natural snow reliability maintained for 2031-2050
	Andorra	3 ski resorts[62]	Natural ski season at 1900 masl to decrease by 30 to 95% with a temperature rise of 2 to 4°C
Asia Pacific	Australia	9 ski resorts[63]	Natural snow reliability[66] lost for all resorts by 2070 under the pessimistic scenario
		6 ski resorts[64]	Natural snow-based ski season to decrease by 10 to 60% by 2020 and by 15 to 99% by 2050
		2 ski resorts[65]	Ski season down from 94-155 days to 85-106 days by 2040s and 48-75 days by 2090s
	New Zealand	10 ski resorts[67]	Ski season down from a maximum of 223 days to 176-187 days by 2040s and 74-155 days by 2090s
		2 ski resorts[68]	Ski season down from 125-254 days to 111-232 days by 2040s and 52-139 days by 2090s
	South Korea	1 ski resort[69]	Natural snow reliability at risk by 2030s
North America	Canada	1 ski resort in Ontario[70]	Stress on natural snow reliability by 2050s and a possible drop-out by 2080s
		4 ski resorts[71]	Natural snow reliability maintained for 2020s and 2050s under both the low and high impact scenarios
		3 ski resorts in Québec[72]	Natural snow reliability maintained in 2020s but possibly jeopardized for 1 resort in 2050s

Table 1: Future Climate Change Impacts on the Natural Snow Reliability of Ski Tourism Destinations

Region	Country	Scope	Model Projections
	United States	2 ski resorts[73]	Natural snow reliability lost by 2020s under the high impact scenario
		1 ski resort in Colorado[74]	Snow density increase by 20% by 2030s but "powder" quality still maintained at 90 kg/m^3
		15 ski resorts in Vermont[75]	Natural ski season down from 125-173 days to 107-166 days by 2050s and 68-153 days by 2080s
		41 ski resorts in Northeast[76]	Number of naturally snow-reliable ski resorts down to 31, 24-27 and 14-18 by 2020s, 2050s, and 2080s, respectively
		103 ski resorts in Northeast[77]	Number of naturally snow-reliable ski resorts down to 41-42, 34-41 and 30-35 by 2020s, 2050s, and 2080s, respectively
		34 ski resorts in California[78]	Natural ski season down by 22-103 days by 2080s

61 M. Mochurova, T. Kaloyanov, and P. Mishev, "Impacts of Climate Change on Winter Tourism in Borovets," *Economic Studies* 2 (2010): 98-126.

62 M. Pons-Pons et al., "Modeling Climate Change Effects on Winter Ski Tourism in Andorra," *Climate Research* 54 (2012): 197-207.

63 U. König, *Tourism in a Warmer World: Implications of Climate Change due to Enhanced Greenhouse Effect for the Ski Industry in the Australian Alps* (Zürich: University of Zürich, 1998).

64 K. J. Hennessy et al., "Climate Change Effects on Snow Conditions in Mainland Australia and Adaptation at Ski Resorts through Snowmaking," *Climate Research* 35 (2008): 255-270.

65 J. Hendrikx et al., "A Comparative Assessment of the Potential Impact of Climate Change on the Ski Industry in New Zealand and Australia," *Climatic Change* 19 (2013): 965-978.

66 The rule has been modified by resetting the threshold to 60 days.

67 J. Hendrikx and E. Ö. Hreinsson, "The Potential Impact of Climate Change on Seasonal Snow in New Zealand: Part II—Industry Vulnerability and Future Snowmaking Potential," *Theoretical and Applied Climatology* 110 (2012): 619-630.

68 J. Hendrikx et al. "A Comparative Assessment of the Potential Impact of Climate Change on the Ski Industry in New Zealand and Australia," 965-978.

69 I. Heo and S. Lee, "The Impact of Climate Changes on Ski Industries in South Korea: In the Case of the Yongpyong Ski Resort," *Journal of the Korean Geographical Society* 43 (2008): 715-727.

70 D. Scott, G. McBoyle, and B. Mills, "Climate Change and the Skiing Industry in Southern Ontario (Canada): Exploring the Importance of Snowmaking as a Technical Adaptation," *Climate Research* 23 (2003): 171-181.

71 D. Scott et al., "Climate Change and the Sustainability of Ski-Based Tourism in Eastern North America: A Reassessment," *Journal of Sustainable Tourism* 14 (2006): 376-398.

72 D. Scott, G. McBoyle, and A. Minogue, "Climate Change and Quebec's Ski Industry," *Global Environmental Change* 17 (2007): 181-190.

73 D. Scott et al., "Climate Change and the Sustainability of Ski-Based Tourism in Eastern North America: A Reassessment," 181-190.

74 B. Lazar and M. Williams, "Climate Change in Western Ski Areas: Potential Changes in the Timing of Wet Avalanches and Snow Quality for the Aspen Ski Area in the Years 2030 and 2100," *Cold Regions Science and Technology* 51 (2008): 219-228.

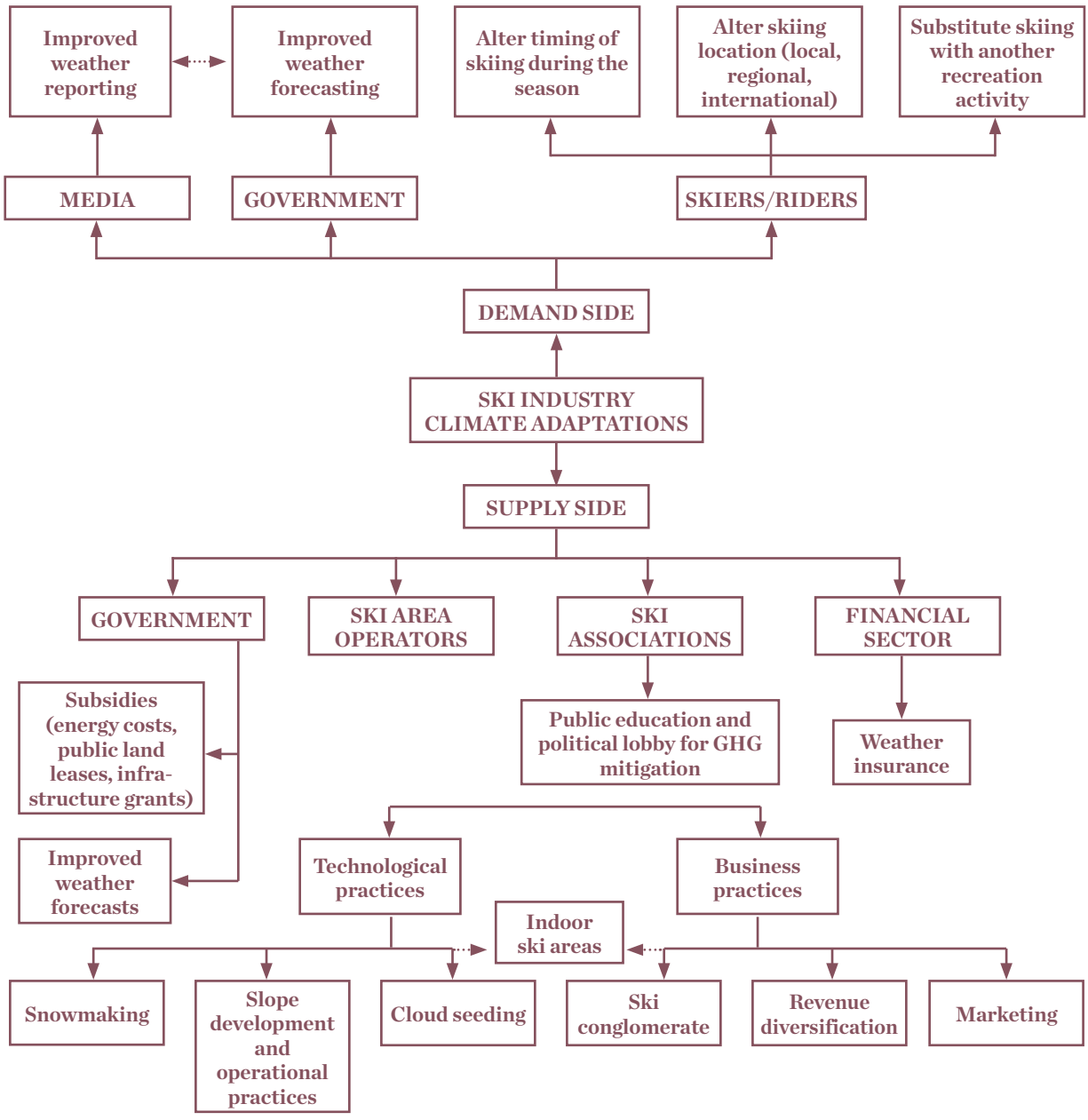
75 J. Dawson and D. Scott, "Climate Change Vulnerability in the Vermont Ski Tourism Sector," *Annals of Leisure Research* 10 (2007): 550-571.

76 D. Scott, J. Dawson, and B. Jones, "Climate Change Vulnerability of the US Northeast Winter Recreation-Tourism Sector," *Mitigation and Adaptation Strategies for Global Change* 13 (2008): 577-596.

77 J. Dawson and D. Scott, "Systems Analysis of Climate Change Vulnerability for the US Northeast Ski Sector," *Tourism and Hospitality Planning & Development* 7 (2010): 219-235.

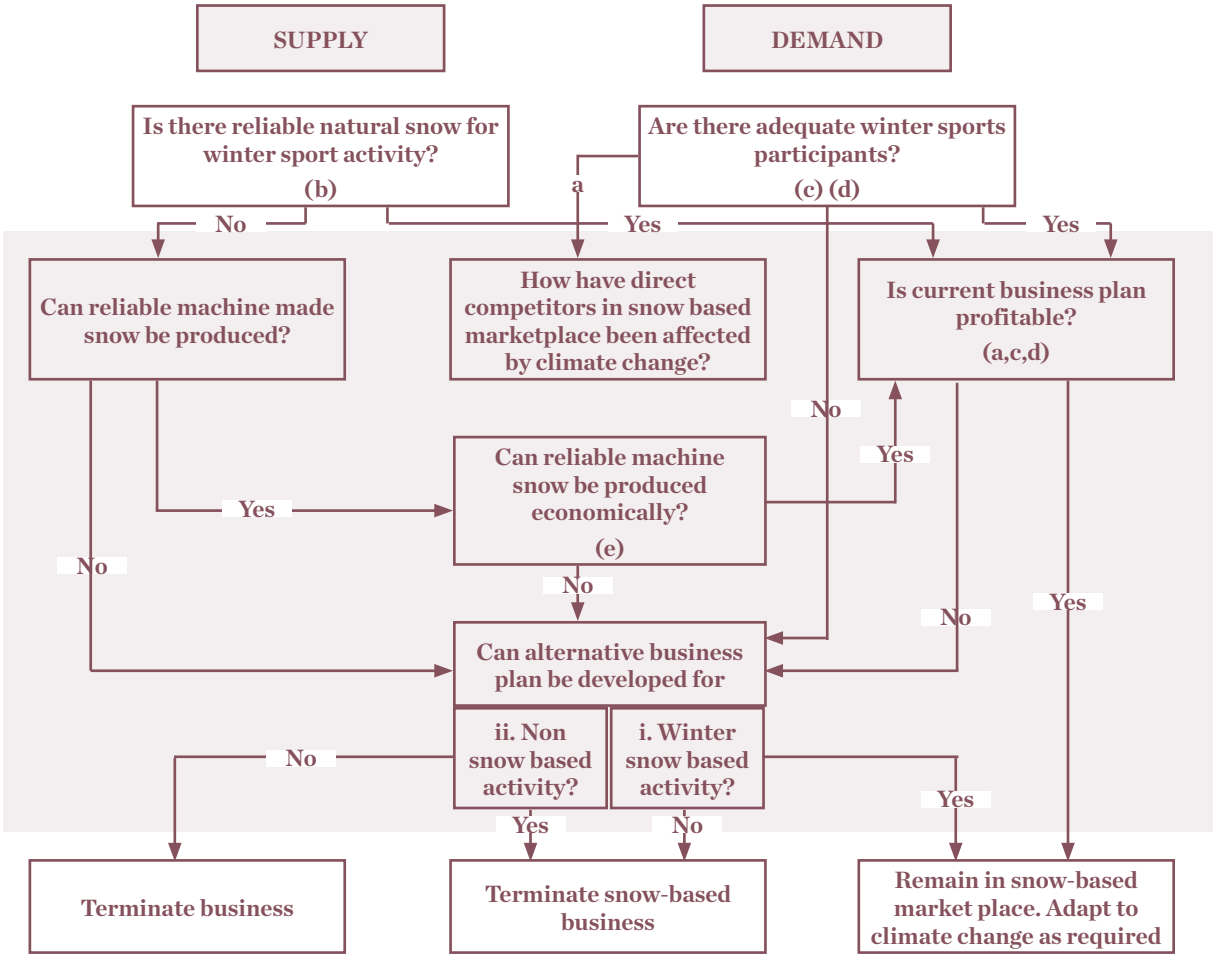
78 K. Hayhoe et al., "Emissions Pathways, Climate Change, and Impacts on California – Supporting Text," *Proceedings of the National Academy of Sciences,* 101 (2004): 12422-12427.

Figure 4: Climate Change Adaptation of the Ski Industry[79]



79 D. Scott and D. McBoyle, "Climate Change Adaptation in the Ski Industry," *Mitigation and Adaptation Strategies for Global Change* 12 (2007): 1415.

Figure 5: A Decision Tree for Climate Change Adaptation of the Ski Industry[80]



a) Marketplace competition is likely to decline according to existing literature. If demand remains stable or dilutes proportionality less than supply, there would be a net transfer of demand throughout the remaining marketplace.
b) Are necessary "natural" climate conditions present
c) numbers could stabilize or increase if there were increases in travel costs or emission rights
d) numbers could decrease because of changing demographics (aging and multi culturalism); social trends; climate variability; and cost
e) direct operator costs - capital investments for snowmaking systems and their upgrades; increased operating costs (energy, water, labour) of snowmaking if more snow needed at higher temperatures. Also consider indirect economic changes- changes in skier demand, marketplace and market share)
f) examine alternative marketing plans to increase participation rates

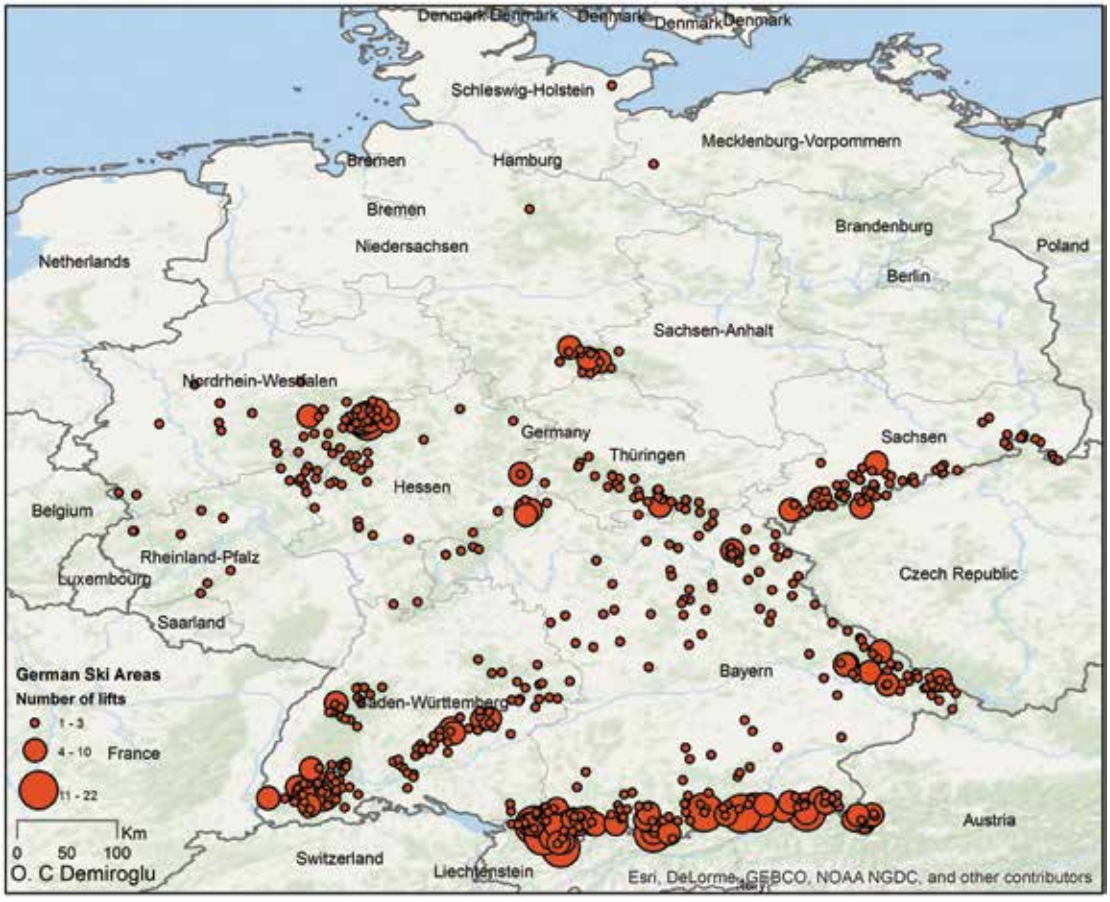
80 J. Dawson and D. Scott, "Managing for Climate Change in the Alpine Ski Sector," *Tourism Management* 35 (2013): 252.

CLIMATE CHANGE VULNERABILITY OF SKI TOURISM IN GERMANY

Ski Tourism in Germany

Germany is one of the most important countries for the global ski tourism market. Ski sports have evolved there for over a century, and ski tourism became significantly industrialized during the post-WWII period, following a similar trend in neighboring Alpine countries Austria, Switzerland, France, and Italy. Today, Germany is the top international ski tourist generator country, especially for the Alpine countries and the Czech Republic, followed by the UK and the Netherlands. In fact, overnight customer base for Austria, which attracts the most international ski tourists in the world, is made up mostly (39%) of Germans with

Figure 6: Ski Areas and Resorts in Germany[81]



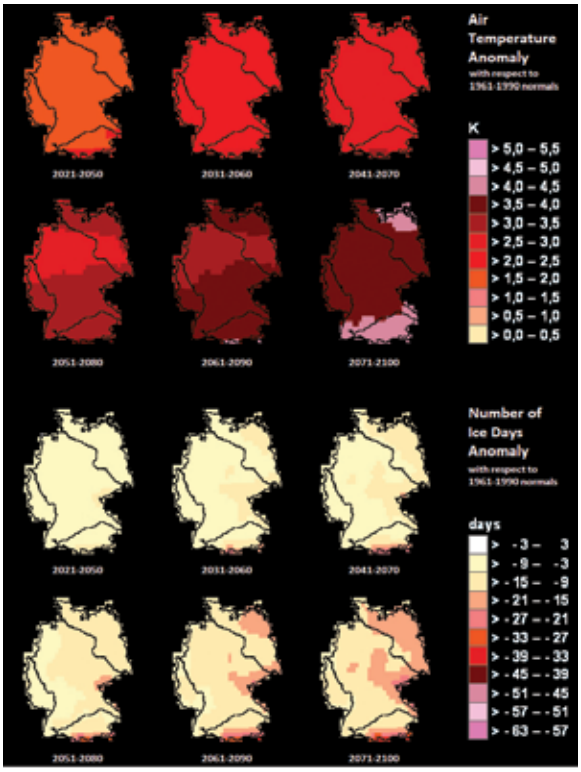
81 Data obtained from http://www.skiresort.info/ski-resorts/europe/germany.

regard to the domestic component (23%). Further, Germany is one of the three countries in the world, together with the United States and Japan, which hosts around 15 million individual skiers annually, constituting 12.5% of the global figure. In addition, it is one of the top three countries in terms of number of ski areas – 599. However, most of the few large ski resorts are concentrated in the Bavarian Alps and the Black Forest in Baden-Württemberg along the southern border with Austria, Switzerland, and France—whereas other clusters are observed in Eifel Mountains in the west, Harz Mountains in the mid-north, Thüringen Forest in the east, Ore Mountains (Erzgebirge) on the Czech border, and the Bavarian Forest in the southeast. Moreover, Germany is home to four of the world's largest indoor ski areas, located in the western and northern plains of the country.[82] Such facilities, together with the hundreds of natural micro ski areas dispersed throughout the country, are vital venues in retaining and maintaining the German skier base that is badly needed for the survival of the domestic and even the Alpine market. The major ski resorts aligned in the South are significant flagships of the German ski heritage and tourism product. However, climate change has recently become a major concern for the sustainability of many of these German ski areas and resorts.

Impacts of Climate Change on Ski Areas and Resorts in Germany

Simulations on changes in climatic elements such as air temperature and ice days, where air temperature is below 0°C, depict a clearly worsening exposure to climate change in Germany, especially over the major ski resort clusters in the Bavarian mountainous south, throughout the 21st century (Fig. 7). Although a hot spot analysis on the elevations of ski areas and resorts favor South Bavaria in terms of a lower exposure expectation compared to the rest of Germany (Fig. 8), an earlier report by the OECD[83] determines the ski resorts of the Bavarian Alps to be the most sensitive to climate change in comparison to resorts in other Alpine countries—such that only five (13%) or one (3%) of the present 39 ski resorts in Bavaria will remain naturally snow reliable with temperature increases of 2°C and 4°C, respectively, whereas the number of reliable resorts will range from 201 (32%) to 399 (63%) out of a total of 627 resorts in the other four countries under the two warming scenarios (see Table 1).

Figure 7: Future Simulations for Changes in Air Temperature and Ice Days in Germany[84]

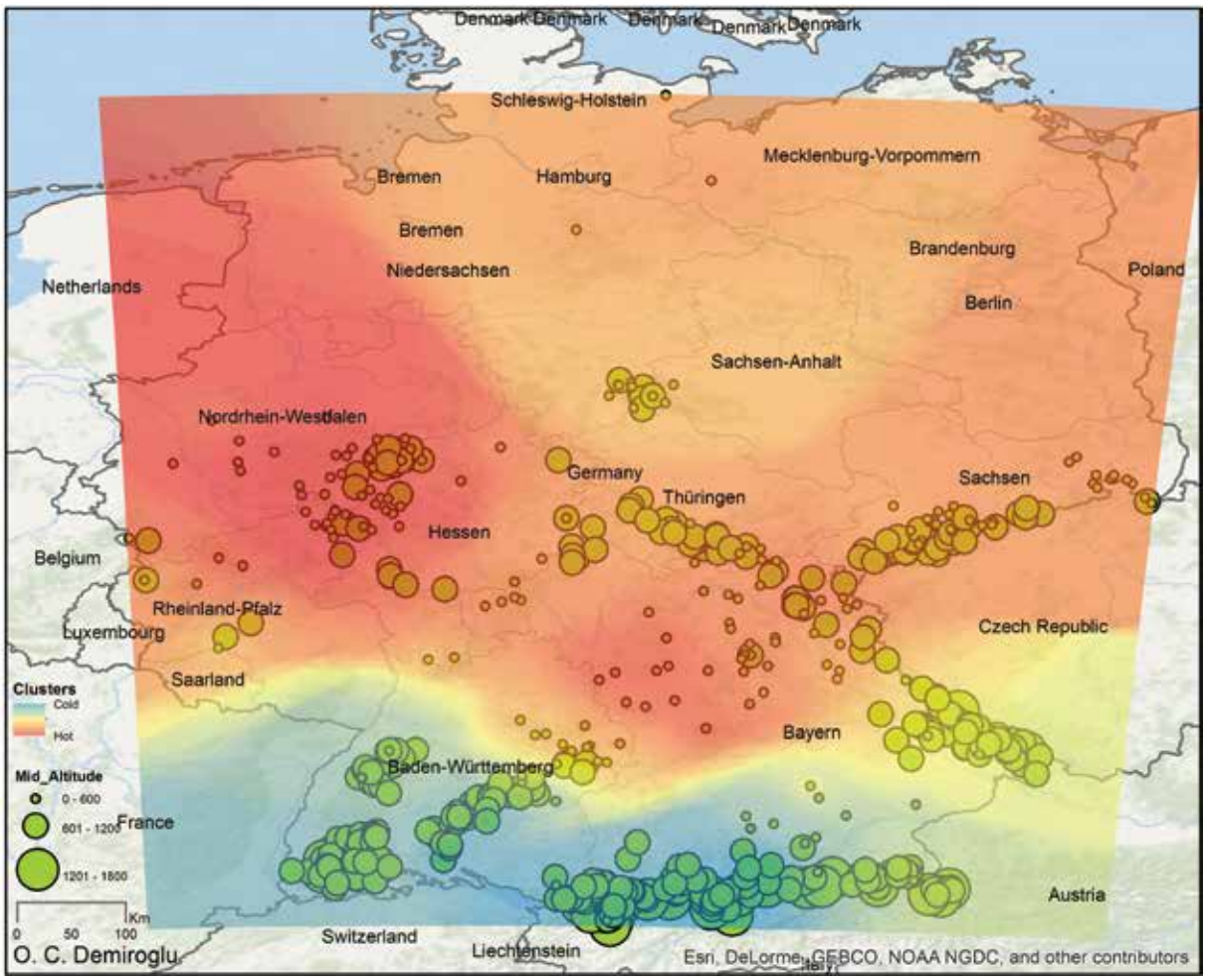


82 Laurent Vanat, *2015 International Report on Snow & Mountain Tourism,* 18-20.

83 Bruno Abegg et al., "Climate Change Impacts and Adaptation in Winter Tourism," 34.

84 Based on Deutscher Klimaatlas at http://www.dwd.de/DE/klimaumwelt/klimaatlas/klimaatlas_node.html.

Figure 8: Hot and Cold Clusters of German Ski Areas and Resorts' Altitudinal Exposure[85]



The Bavarian Alps are the lowest in altitude of the Alpine ranges and the lowest in latitude compared to the locations of other German ski areas. Within Bavaria, the western part, Allgäu (Photo 1), is relatively more sensitive than the eastern parts due to its lower altitude as well as the increasing maritime effects of the Mediterranean.[86] A recent study displays such conditions in natural snow reliability (Fig. 9) by taking into account the two-week Christmas-New Year's holiday period, known as the "Christmas rule,"[87] where a major portion of

85 Data obtained from http://www.skiresort.info/ski-resorts/europe/germany.

86 Bruno Abegg et al., "Climate Change Impacts and Adaptation in Winter Tourism," 30-31.

87 Daniel Scott et al., "Climate Change and the Sustainability of Ski-Based Tourism in Eastern North America: A Reassessment," 376-398.

Photo 1: Snow conditions at a ski area in Allgäu, Bavaria, Germany – early February 2008[88]



the seasonal resort revenues aggregate. Moreover, another recent study[89] reveals a shift of the "optimal ski days," when the climatic conditions are ideal for skiing, from the Christmas period until Easter. The region as a whole is home to the largest ski resorts of Germany and is economically dependent on ski tourism at certain localities, making it one of the most vulnerable ski destinations in Europe.[90] Today one of the region's most reliable resorts and home to the Winter Olympic Games in 1936 is now among the most vulnerable Olympic venues to climate change[91]: the least exposed ski area by the national summit at 2,962 masl has already had to discontinue its summer skiing operations for good.[92]

Significant climate change impacts on German ski destinations are not only limited to the Bavarian Alps. Just northeast of the Alps, the ski areas in the Fichtel Mountains are expected to experience deteriorating natural snow conditions by the 2020s, and only one resort is projected to survive by 2060.[93] In the Southwest, the Black Forest (Schwarzwald), one of the major winter tourism attractions in Germany, is also prone to the immediate impacts of the change. An early study found that the regional snow cover will last more than 65% less at 500-1000 masl elevations and 25 to 44% less above 1200 masl in the 2021-2050 period with respect to the 1994-2003 baseline.[94] On average, a reduction of the ski season by 40% is projected for the region in the 2021-2050 period with respect to the 1971-2000 normals,[95] and a 22% loss is projected for the largest ski resort, with respect to 1961-1990.[96]

88 Image available at http://www.allgaeu-humor.de/01humor_bergbahn_hopfen.htm.

89 A. Berghammer and J. Schmude, "The Christmas–Easter Shift: Simulating Alpine Ski Resorts' Future Development under Climate Change Conditions Using the Parameter 'Optimal Ski Day'," *Tourism Economics* 20 (2014): 323-336.

90 E. Tranos and S. Davoudi, "The Regional Impact of Climate Change on Winter Tourism in Europe," *Tourism Planning and Development* 11 (2014): 163-178.

91 Daniel Scott et al., "The Future of Olympic Winter Games in an era of Climate Change," 913-930.

92 M. Mayer, "Summer Ski Areas in the Alps: First Victims of Climate Change?" (paper presented at the pre-conference symposium for the International Geographical Union, Trier, Germany, August 22-25, 2012).

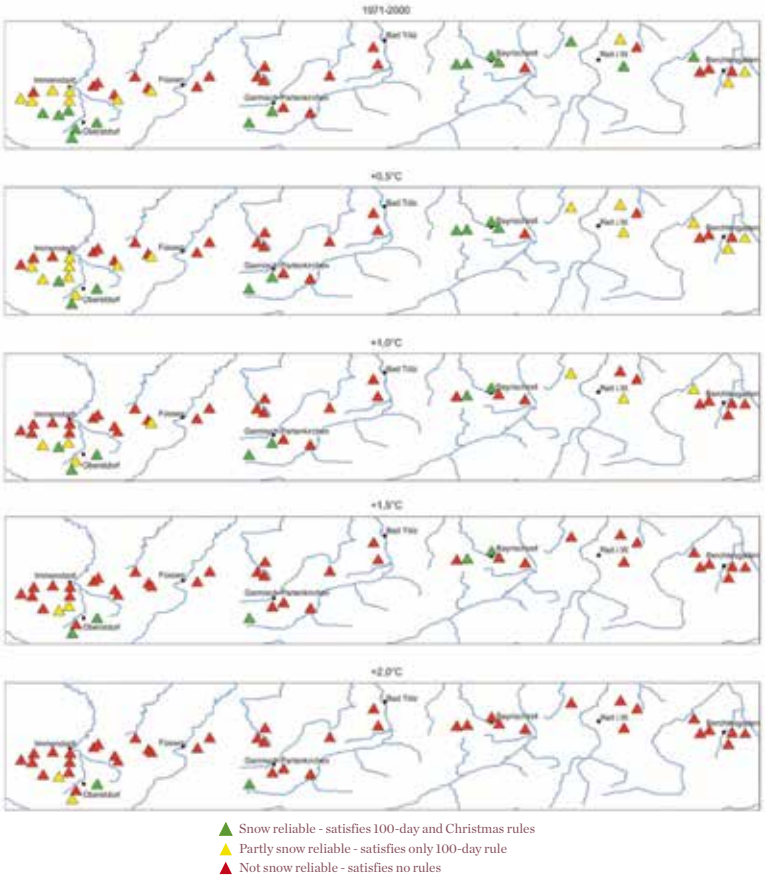
93 A. Matzarakis, "Tourismus im Mittelgebirge bei Klimawandel," (paper presented at the Annaberger Klimatage, Freiberg, Germany, May 10-11, 2006).

94 C. Schneider and J. Schönbein, *Klimatologische Analyse der Schneesicherheit und Beschneibarkeit von Wintersportgebieten in deutschen Mittelgebirgen* (Köln: Deutsche Sporthochschule Institut für Natursport und Ökologie, 2006).

95 C. Endler and A. Matzarakis, "Climatic Potential for Tourism in the Black Forest, Germany — Winter Season," *International Journal of Biometeorology* 55 (2011): 339-351.

96 C. Endler, K. Oehler, and A. Matzarakis, "Vertical Gradient of Climate Change and Climate Tourism Conditions in the Black Forest," *International Journal of Biometeorology* 54 (2010): 45-61.

Figure 9: Change in the Natural Snow Reliability of Ski Resorts in the Bavarian Alps[97]



Ski Tourism Adaptation to Climate Change in Germany

As noted earlier, snowmaking has become the most common measure for the adaptation of ski tourism businesses to climate change. Our findings[98] show that currently 121 of the 595 outdoor ski areas and resorts, representing 977 km of the 1427 km total slopes, in Germany are equipped with snowmaking.

The availability of snowmaking has strong positive correlations with the size and the daily lift price, as well as the base elevation, of ski areas and resorts (Table 2). Thus, primarily touristic ski resorts in the Bavarian Alps represent a majority of the snowmaking facilities (Fig. 10). According to recent calculations,[99,100] 500 ha of slopes are covered

97 R. Steiger, *Auswirkungen des Klimawandels auf Skigebiete im bayerischen Alpenraum* (Innsbruck: Deutscher Alpenverein, 2013), 18-19.

98 Data obtained from http://www.skiresort.info/ski-resorts/europe/germany.

99 R. Steiger, *Auswirkungen des Klimawandels auf Skigebiete im bayerischen Alpenraum.*

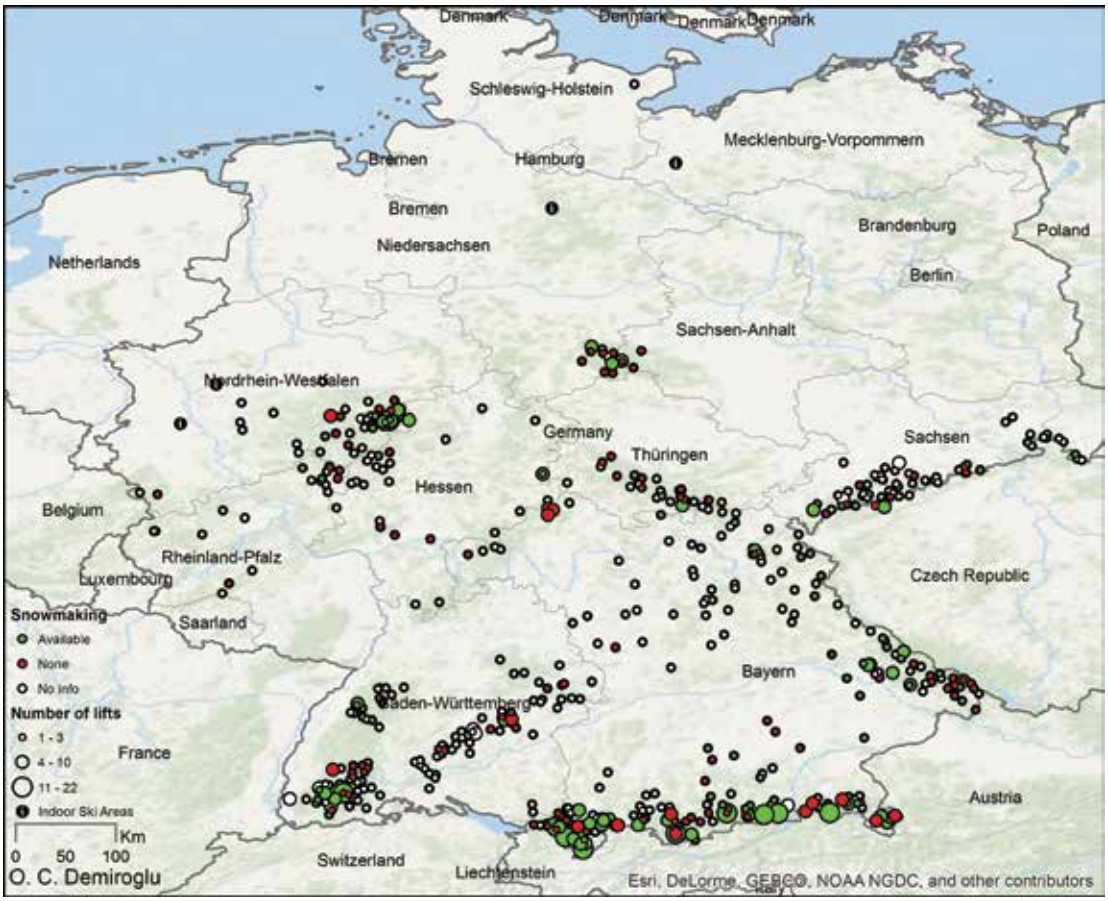
100 M. Mayer and R. Steiger, "Skitourismus in den Bayerischen Alpen – Entwicklung und Zukunftsperspektiven" in *Tourismus und Regionalentwicklung in Bayern,* ed. H. Job and M. Mayer (Hannover: ARL, 2013), 164-212.

Table 2: Relationship of Snowmaking Availability and Ski Area/Resort Characteristics in Germany

Variables		Number of Lifts	Slope Length	Ticket Price	Bottom Altitude	Mid Altitude	Top Altitude
Snowmaking	Pearson Correlation	.672*	.569*	.540*	.469*	.356*	.221*
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000
	N	592	595	400	595	595	595

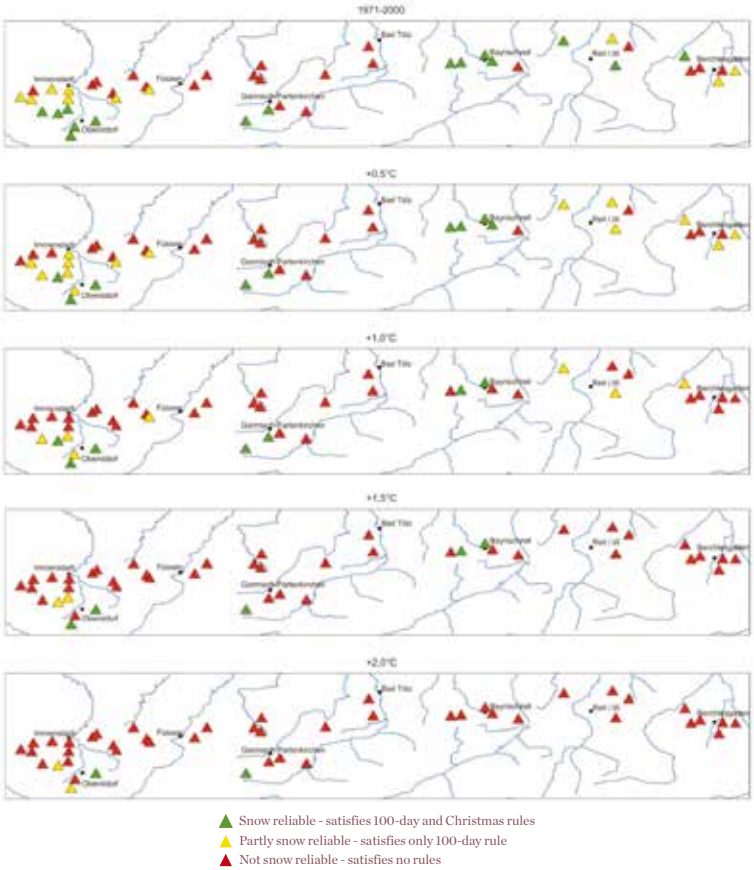
* Correlation is significant at the 0.01 level (2-tailed).

Figure 10: Snowmaking Availability at German Ski Areas and Resorts[101]



101 Data obtained from http://www.skiresort.info/ski-resorts/europe/germany.

Figure 11: Change in the Technical Snow Reliability of Ski Resorts in the Bavarian Alps[102]



with artificially made snow in this area, which has certainly become essential to the survival of ski resorts by materially improving their snow reliability (see Fig. 9 vs. Fig. 11).

State-of-the-art multi-agent based models have simulated more complex and site-specific findings on the adaptive capacities of ski resorts in the Bavarian Alps. Climate change impact assessments, which take account also of comparative socio-political scenarios under the "open competition" and the "public welfare" themes, have revealed that the two Bavarian cases will face severe to moderate impacts by the 2050s compared to their relatively more resilient Austrian competitor.[103] No feasible ski tourism future is foreseen for the most severely affected Bavarian resort due to the insufficient number of skiable days even under the open competition scenario where snowmaking extension and

102 R. Steiger, *Auswirkungen des Klimawandels auf Skigebiete im bayerischen Alpenraum,* 20-21.

103 A. Soboll and A. Dingeldey, "The Future Impact of Climate Change on Alpine Winter Tourism: A High-Resolution Simulation System in the German and Austrian Alps," *Journal of Sustainable Tourism* 20 (2012): 101-120.

ski area expansion are strongly encouraged. Thus, diversification is highly emphasized for reduced vulnerability. For the other Bavarian resort, snowmaking investments are recommended by researchers as such investments seem to retain its financial viability. As a result, investments into new tourism products and modern ski and snowmaking facilities for these two nearby ski resorts are considered to be the only possible way to sustain good economic conditions within the surrounding localities according to the open competition scenario.

Such suggestions for economic sustainability, however, are prone to creating development path dependency and jeopardizing public welfare, especially given the technical limits, financial costs, and environmental consequences of current snowmaking technologies such as the persistent cold air requirements and increased pressure on water resources due to input needs, very high fixed and operational expenses, and noise pollution that could disturb the natural habitat as well as the visitors. Most of the German ski resort areas lie at low altitudes, and thus relatively warmer temperatures, and are run by micro establishments that have very limited financial resources, hence not eligible candidates for adopting snowmaking as adaptation. This is also reflected in Table 2—the snowmaking diffusion is less observed for low-lying, low-priced, and small-sized ski areas but more common at the larger resorts in Bavaria. In this respect, multi-agent based models[104] further simulate a 700 masl threshold of technical snowmaking limits in and around Bavaria for the 2050s under the open competition scenario. Below this altitude, snow-dependent tourism development does not seem to be viable, resulting in a loss of attractiveness and overnight stays in the respective municipalities, while a majority of ski resorts that lie above this limit enjoy increased revenues. Such an increase comes with the costs of doubling water consumption to more than 5,000,000 m^3/year by the 2050s, mostly for the sake of additional snowmaking. In fact, under a public welfare scenario, Bavaria, especially at the Alpine municipal level, is simulated to be prone to heavy economic losses as stricter regulations on snowmaking would prevent resorts from adapting to climate change and lead to spatial substitution by tourists, whilst water consumption levels would remain almost stable.

Such adaptation developments and projections nowadays also form the basis of popular public debate in Bavaria, where the water regulations are considered to be loosening and snowmaking extension and ski area expansion approvals have been eased.[105] For instance, recently a major ski resort was granted extension and expansion approval and, in addition, financial contribution by the Bavarian government. Such an act was strongly objected to by concerned NGOs on the grounds that it would jeopardize common water resources and underutilize public finances for what is perceived as maladaptation.[106] A scientific expert report[107] on the issue confirmed the unsustainability of this practice given that a 1°C increase from the 1981-2010 period, which is likely to be experienced in the very near future, would lead to a loss of snow reliability at the resort–despite snowmaking–and an increase of 27% in both water and energy consumption at the Bavarian ski resorts in general, the latter also contributing to global warming through increased CO_2 emissions depending on the type of energy

104 A. Soboll and J. Schmude, "Simulating Tourism Water Consumption under Climate Change Conditions Using Agent-Based Modelling: The Example of Ski Areas," *Annals of the Association of American Geographers* 101 (2011): 1049-1066.

105 B. Abegg et al., "Climate Change Impacts and Adaptation in Winter Tourism," 49.

106 "Ski Tourism: An İnsatiable Hunger," CIPRA, accessed January 25, 2016, http://www.cipra.org/en/news/ski-tourism-an-insatiable-hunger.

107 R. Steiger, *Auswirkungen des Klimawandels auf Skigebiete im bayerischen Alpenraum.*

source and production. Such infeasibility and unsustainability of snowmaking as technical adaptation is also true for the neighboring ski tourism region, the Black Forest, where snowmaking capacity is estimated to be reduced by 25% by the 2050s,[108] leaving even the highest and the largest ski resort of the region without technical snow reliability within the century.[109] Having already utilized the highest terrains, moving the resorts is not a technical adaptation option[110]; yet, the improving climate comfort of the mountains in the warmer season is a good departure point for diversification alternatives.[111]

Studies on the exploration of stakeholder adaptive capacities are limited in Germany. The only known study[112] with public and private suppliers has been carried out in Saxony with the ski operators of the Ore Mountains. The feedback reflected a skeptical approach to the commonly anticipated impacts of climate change and a reluctance to act on it. Most of the visitors (69%) to the region, on the other hand, have a strong tendency to realize their ski trips at other regions with more snow reliability, such as the nearby Czech resorts. Likewise, a similar spatial substitution tendency has also been observed with the neighboring Fichtel Mountains visitors.[113] Overall, the relative unpreparedness of the suppliers—combined with the high exposure and business sizes of ski areas, limits, costs, and consequences of technical adaptation methods—and the high elasticity of the visitors for spatial substitution, is a strong signal for the German ski industry to consider diversification and cooperation at a more national or even cross-border scale to reduce vulnerability and build resilience.

108 C. Endler and A. Matzarakis, "Climatic Potential for Tourism in the Black Forest, Germany – Winter Season."

109 P. Schmidt, R. Steiger, and A. Matzarakis, "Artificial Snowmaking Possibilities and Climate Change Based on Regional Climate Modeling in the Southern Black Forest," *Meteorologische Zeitschrift* 21 (2012): 167-172.

110 C. Endler, K. Oehler and A. Matzarakis, "Vertical Gradient of Climate Change and Climate Tourism Conditions in the Black Forest."

111 C. Endler and A. Matzarakis, "Climate and Tourism in the Black Forest during the Warm Season," *International Journal of Biometeorology* 55 (2011): 173-186.

112 A. Hoy, S. Hansel, and J. Matschullat, "How Can Winter Tourism Adapt to Climate Change in Saxony's Mountains?" *Regional Environmental Change* 11 (2012): 459-469.

113 W. Seifert, "Klimaänderung und (Winter-)Tourismus im Fichtelgebirge – Auswirkungen, Wahrnehmung und Ansatzpunkte zukünftiger touristischer Entwicklung" (Diplomarbeit, Universität Bayreuth, 2004).

CLIMATE CHANGE VULNERABILITY OF SKI TOURISM IN TURKEY

Ski Tourism in Turkey

Despite its high-ranking position in terms of international tourism arrivals and receipts and a strong domestic market base,[114] the Turkish tourism industry is mainly comprised of coastal and cultural products within a few certain regions,[115] not skiing—although the country is home to a vast mountainous terrain regularly covered with snow during winter and early spring months. A rough assessment[116] of the said physical potential has been estimated to cover a land of 155,000 km^2 – an area comparable to the total physically skiable potential terrain of all the Alpine countries extending from France to Slovenia. Since the 2000s, the number of ski areas and resorts have risen dramatically, with many more in planning or construction (Fig. 12). Expert reviews report a top spot growth ranking for Turkey in terms of new lift deliveries for the 2003-2012 period.[117] Furthermore, the Turkish Ski Federation has recently announced a macro policy to establish 100 ski resorts, with 5,000 hotels and 275,000 beds worth 49 billion EUR, and raise the currently small number of snow sports enthusiasts to 4 million throughout the country over 12-year time span.[118] Such ambitious goals will definitely signify the place of Turkey on the global ski map and help recover regional disparities, yet it will need to take into account major challenges[119] such as lack of snow sports culture in general, demographic and economic insufficiency, insecurity around most of the physically viable ski terrain, lack of destination management knowhow specific to ski resorts, and last but not the least, climate change.

Impacts of Climate Change on Ski Areas and Resorts in Turkey

Turkey's aforementioned physical ski tourism potential is a natural consequence of its high altitude terrain, especially in the East, compensating for its relatively low latitude. Such high elevations combined with the immediate continentality as well as the orographic lift due to the coastal mountain ranges result in dominant cold and snowy climate zones that would otherwise be only specific to the Alpine, the Arctic, and the Siberian regions.

Future projections, however, pronounce a significant shrinkage of such climatic zones throughout the century, whether be it in a globalizing, fossil-intensive (A1FI) or a locally focused, sustainably developing (B2) world (Fig. 13). Indeed, Turkish cryospheric components are already at stake as some of the warmest years have been observed frequently in recent decades (Fig. 14). As a result, snow cover features, as well as glacial areas, have severely deteriorated. A recent study[120] has found that the total area of the 13 glaciers in Turkey has decreased from 25 km^2 to 11.2 km^2 since the 1970s. One particular glacier, which lies on top of one of the largest ski resorts in the country, has been found to be retreating at a rate of 4.2 m/year since

114 UNWTO, *Compendium of Tourism Statistics, Data 2009 – 2013* (Madrid: UNWTO, 2015).

115 K. Göymen, "Tourism and Governance in Turkey," *Annals of Tourism Research* 27 (2000): 1025-1048.

116 O. C. Demiroglu, *Kış Turizmi* (Ankara: Detay, 2014).

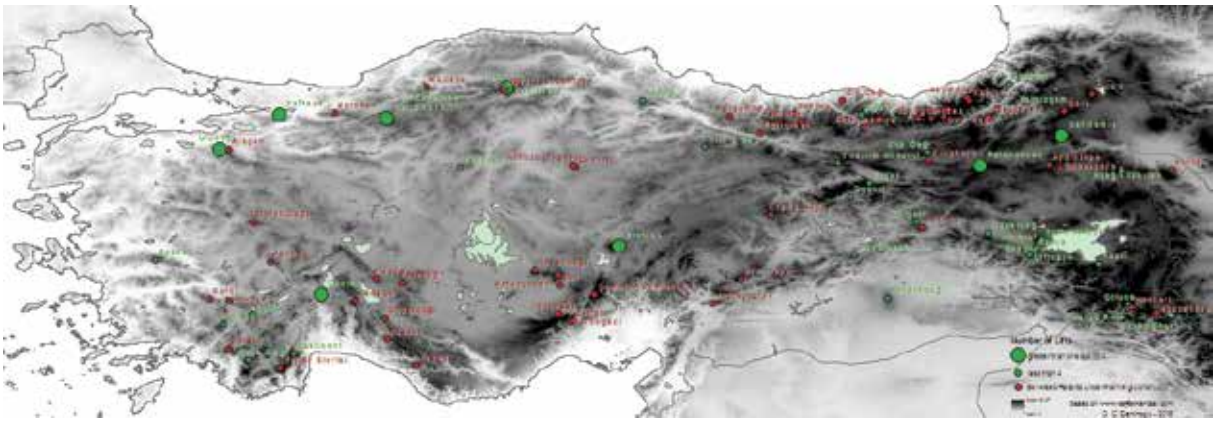
117 L. Vanat, "The Global Ski Market: Changing Trends and the Impact on the Euro-Asian Region" (paper presented at the 1st Euro-Asian Ski Resorts Conference, Almaty, Kazakhstan, October 8, 2013).

118 S. Hudson and L. Hudson, *Winter Sports Tourism: Working in Winter Wonderlands* (Oxford: Goodfellow, 2015), 179-180.

119 O. C. Demiroglu, *Kayak Turizmi Forumu'ndan Kayak Turizmi Politikasına Notlar* (Istanbul: Istanbul Policy Center, 2015).

120 D. D. Yavaşlı, C. J. Tucker, and K. A. Melocik, "Change in the Glacier Extent in Turkey during the Landsat Era," *Remote Sensing of Environment* 163 (2015): 32-41.

Figure 12: Ski Areas and Resorts in Turkey



the 1900s[121] (Fig. 15) and almost went extinct after shrinking from an area of 0.06 km^2 in the 1970s to an area of 0.002 km^2 in the 2010s, reduced to mere patches,[122] building a proxy that represents the recent climate change at the ski resort site and, moreover, signaling a negative development for the summer ski terrain. Likewise, non-glacial ski resorts have also witnessed such cryospheric deterioration trends, as evidenced by meteorological observations over the snow cover depth of one of the most popular ski resorts in the country (Fig. 16).

Besides the few early introductory reviews,[123] most studies on the impacts of climate change on snow-based tourism in Turkey have been carried out under the previous and the present Istanbul Policy Center–Sabancı University–Stiftung Mercator Initiative Fellowship projects and the works of the Boğaziçi University Center for Climate Change and Policy Studies. A holistic approach by Şen[124] has initially underlined the negative effects of rising temperatures on snow sports tourism, while Ceber et al.[125] have carried out the first regional climate modeling studies on the winter tourism domain of Turkey. The latter study has identified the most exposed regions of the late 21st century by taking into consideration two of the IPCC's fairly new scenarios–RCP4.5 and RCP8.5–which represent the greenhouse gas concentration pathways that could lead to an increase, i.e. +4.5 W m^{-2} and +8.5 W m^2, in radiative forcing by the year 2100 with respect to the pre-industrial levels (Fig. 17).

121 M. A. Sarıkaya, M. Zreda, and A. Çiner, "Glaciations and Paleoclimate of Mount Erciyes, Central Turkey, since the Last Glacial Maximum, Inferred from ^{36}Cl Cosmogenic Dating and Glacier Modeling," *Quaternary Science Reviews* 28 (2009): 2326-2341.

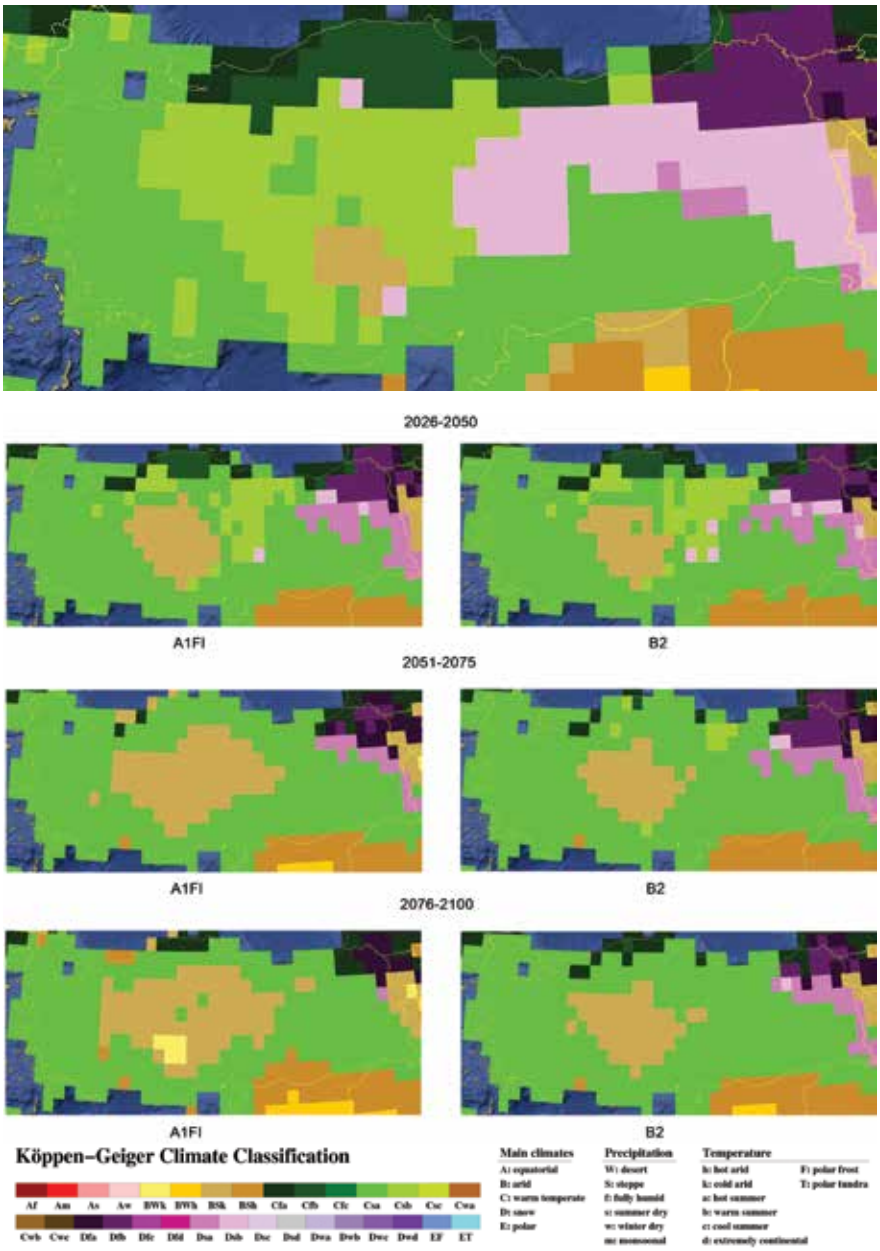
122 D. Yavaşlı, C. Tucker, and K. Melocik, "Change in the Glacier Extent in Turkey during the Landsat Era."

123 Ö. Zeydan and B. Sevim, "İklim Değişikliğinin Kış Turizmine Etkileri," (paper presented at the TMMOB İklim Değişikliği Sempozyumu, Ankara, Turkey, March 13-14, 2008).

124 Ö. L. Şen, *A Holistic View of Climate Change and Its Impacts in Turkey* (Istanbul: Istanbul Policy Center, 2013), 25.

125 Z. P. Ceber, T. Ozturk, and M. L. Kurnaz, "Impacts of Climate Change on Winter Tourism in Turkey," (paper presented at the International Conference: Sustainability Issues and Challenges in Tourism, Istanbul, Turkey, October 3-5, 2013).

Figure 13: Predicted Changes in Köppen-Geiger Climate Zones in Turkey[126]



126 Based on World Maps of Köppen-Geiger Climate Classification at http://koeppen-geiger.vu-wien.ac.at/shifts.htm.

Figure 14: Annual Mean Temperature Anomalies in Turkey[127]

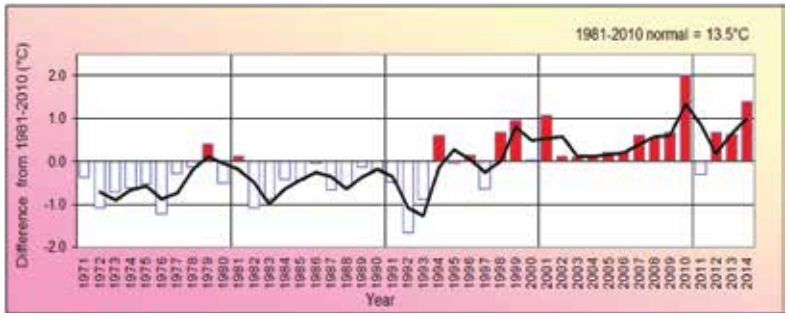
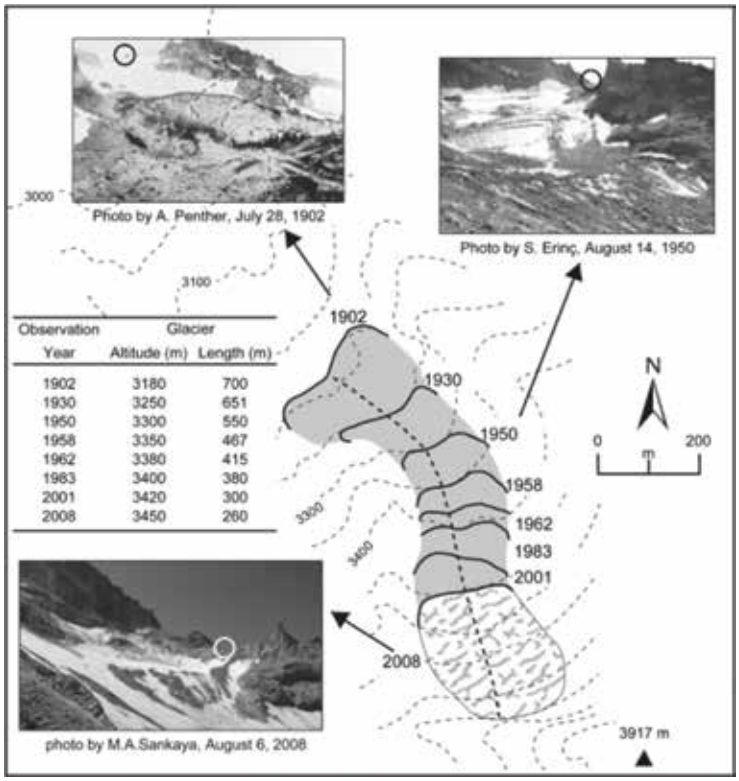


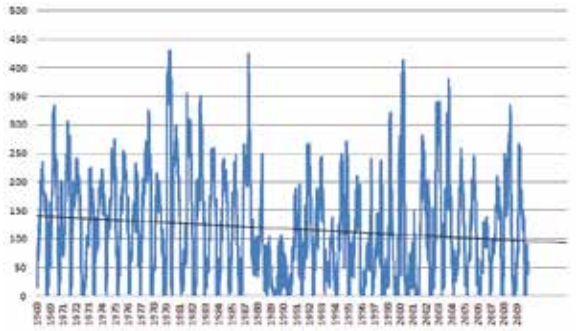
Figure 15: Retreat of a Major Turkish Ski Resort's Overhead Glacier[128]



127 Turkish State Meteorological Service, *State of the Climate in Turkey in 2014* (Ankara: Ministry of Forestry and Water Affairs, 2015), 2.

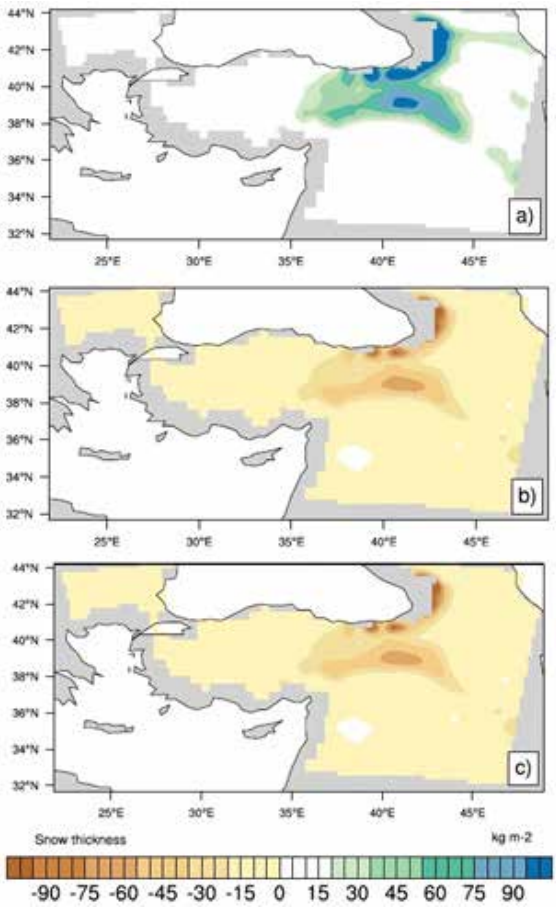
128 Mehmet Sarıkaya, A. Zreda, and A. Çiner, "Glaciations and Paleoclimate of Mount Erciyes," 2337.

Figure 16: Snow Depth (cm) Observations and Trend at a Major Ski Resort (1877 masl) in Turkey[129]



Building on the study by Ceber et al.,[130] we have taken further steps in assessing the impact of climate change on ski resorts by improving its methodology through a refinement on the spatio-temporal resolution and the impact indicators.[131] The scope of the study was limited to Northeast Turkey, where a cluster of high snow amounts (Fig. 17a), mountainous terrain (Photo 2), and consequently, some of the country's largest and newest, as well as most of the proposed, ski resorts exist (Fig. 12). The region is also of special importance as some of our recent studies[132] and our Russian

Figure 17: Projected Changes in the Absolute Amount of Winter (DJF) Snow Water Equivalent (kg m-2) from 1970-2000 (a) to 2070-2100 under the RCP4.5 (b) and the RCP8.5 (c) Scenarios for Turkey[133]



129 T. Özturk et al., "Projections for Changes in Natural and Technical Snow Reliability of a Major Turkish Ski Resort by Using RegCM 4.3.5" (poster presented at the general assembly of the European Geosciences Union, Vienna, Austria, April 27 – May 2, 2014).

130 Ibid.

131 O. C. Demiroglu et al., "A Refined Methodology for Modelling Climate Change Impacts on Snow Sports Tourism" (poster presented at the general assembly for European Geosciences Union, Vienna, Austria, April 12-17, 2015).

132 O. C. Demiroglu and L. Lundmark, "Küresel Isınmanın Türkiye'deki Başlıca Kayak Merkezlerine Etkisi: Geleceğe Yönelik bir Analog olarak 2010 Sezonu Anomalisi ve Uyum Süreci," in *14. Ulusal Turizm Kongresi: Turizmde Yenilik,* ed. K. Karamustafa (Ankara: Detay, 2013), 178-195.

133 Ceber, Ozturk, and Kurnaz, "Impacts of Climate Change on Winter Tourism in Turkey."

Photo 2: The Mountainous Terrain of Northeast Turkey, January 2015



counterparts[134] have deemed it to be more resilient within the country and relative to the Alps—whilst others have also reported a significant decrease in the amount and duration of snow cover especially at the coastal peripheries.[135]

Employing a hydrostatic regional climate model, RegCM4.4, at the İklimBU Lab of the Boğaziçi University Center for Climate Change and Policy Studies, we were able to carry out a dynamic, double-nested scaling of the HadGEM2 general circulation model down to a resolution of 10 km for the relatively optimistic RCP4.5 scenario. The process provided us with daily outputs on snow water equivalent (SWE) values for the 1971-2000 and the 2021-2050 periods. SWEs were converted into snow depths through reference snow density values.[136] Taking account of the average seasonal days with certain snow depth thresholds, i.e. 30 cm, 50 cm, and 70 cm for sufficient, good, and excellent conditions, respectively, we were able to assess natural snow reliability (NSR) for three operational ski resorts in Northeast Turkey, according to the aforementioned 100 Days Rule.[137] The results were summarized[138] as follows:

134 N. Pestereva, N. Y. Popova, and L. M. Shagarov, "Modern Climate Change and Mountain Skiing Tourism: The Alps and The Caucasus," *European Researcher* 30 (2012): 1602-1617.

135 T. Yüksek and F. Yüksek, "Küresel İklim Değişiminin Rize Turizmine Olası Etkileri," in *Doğu Karadeniz Bölgesi Sürdürülebilir Turizm Kongresi Bildiri Kitabı,* ed. U. Akdu ve İ. Çalık (Gümüşhane: Gümüşhane Üniversitesi Turizm Fakültesi, 2015), 388-396.

136 U. S. Sorman and O. Beser, "Determination of Snow Water Equivalent over the Eastern Part of Turkey Using Passive Microwave Data," *Hydrological Processes* 27 (2013): 1945-1958.

137 Urs Witmer, *Erfassung, Bearbeitung und Kartierung von Schneedaten in der Schweiz,* 193.

138 O. C. Demiroglu et al., "Impact of Climate Change on Natural Snow Reliability, Snowmaking Capacities, and Wind Conditions of Ski Resorts in Northeast Turkey: A Dynamical Downscaling Approach," *Atmosphere* 7 (2016): 52.

Table 2: Changes in Natural Snow Reliability (NSR) for Selected Ski Resort Sites in Northeast Turkey

	NSR@30cm		NSR@50cm		NSR@70cm	
Ski Resort	**1971-2000**	**2021-2050**	**1971-2000**	**2021-2050**	**1971-2000**	**2021-2050**
SR1	107	87*	90*	64*	75*	49*
SR2	126	105	104	84*	85*	66*
SR3	132	114	113	91*	93*	70*

* Denotes that the average seasonal days fall short of the 100 Days Rule.

The results indicate a general decline in natural snow reliability for all three sites until the end of the first half of the century. Yet, in absolute terms, no ski resort faces a threat of losing the minimal natural snow reliability conditions (NSR@30cm > 100 days), except for the newly opened SR1. However, we should note that SR1 has one of the highest ski area vertical drops in the world, making its sensitivity highly relative at the chosen altitude references for assessment. In this study, the reference coordinates were located at the lower half of the ski area.

Looking at natural snow reliability under good conditions, all resorts will face problems in the upcoming decades. In addition to a shortage in snow quantity, it could be claimed that the much anticipated "powder" snow quality is also at stake as the Mediterranean climate (Csa) is expected to take over most of the humid continental climate (Dfb and Dsb) zones (see Fig. 13). This would possibly modify snow density characteristics that determine snow quality, as is the case in Colorado.[139]

Before we look into adaptation options for these cases, we should note that the application of the 100 Days Rule is universal. For this reason, we have looked into the actual financial outcomes of various ski resort establishments available at SR2 for a specific season. We found that the breakeven days could range from 68 to 122.[140] Therefore, we should acknowledge that the natural snow reliability comparisons here were made on standardized, rather than customized, assessments.

Ski Tourism Adaptation to Climate Change in Turkey

In Germany and around the world, snowmaking is the first and foremost adaptation method to climate change in the ski tourism industry. Turkish ski resorts, however, have fallen behind their North American and European counterparts, who have engaged in the widespread use of this technology since the 1970s and 1990s, respectively.

In Turkey, snowmaking facilities have been installed only recently in just three major resorts throughout the country. In fact, the first ever snowmaking system had been purchased in 1998 for a ski resort in Northeast Turkey, but its initial utilization was not necessary until late 2008 due to a delay of skiable natural snowpack for more than a month. Today,

139 Brian Lazar and Mark Williams, "Climate Change in Western Ski Areas," 219-228.

140 O. C. Demiroglu and N. An, "Questioning Witmer's 100 Days Rule for Snow Reliability Analyses," in *Proceedings of the 4th International Conference on Climate, Tourism and Recreation – CCTR2015*, ed. O. C. Demiroglu et al. (Istanbul: Istanbul Policy Center, 2015), 103-104.

this particular resort is only partially equipped with snowmaking due to fragmented operational ownership; however, it is still one of the first destinations to start the season early. Likewise, a renovated ski resort in Central Anatolia also enjoys extended seasons by snowmaking for the entire ski areas, as its organization has been restructured under a destination management company who was able to implement central decision making in developing an integral snowmaking system.

In response to the snowmaking developments in Northeast and Central Anatolia, popular resorts in the Northwest, which have long been holding competitive advantages of market proximity, have also reconsidered their plans, especially following the anomalously warm winters in 2010[141] and 2014 (see Fig. 14). In doing so, part owner of one resort invested in "snow-guaranteed" marketing, which initially failed as the ski areas have not been ready by the promised opening dates. This has initiated discussions on the definition and the perception of "snow guarantee," to which we have contributed some popular[142] and academic[143] pieces that urge the use of compensation such as refunds and vouchers.

One Northwestern ski resort has also suffered from defragmented ownership, such that the snowmaking facilities, initially invested in 2002, have never been in full operation due to lack of contribution and cooperation from multiple operators. However, efforts to renovate, extend, and fully operate the system are now back on the agenda for the 2015-2016 season.

In order to understand the future capacity of snowmaking (SM) in the Northeastern ski resorts (see Table 2), we have made further use of the regional climate modeling outputs.[144] The three hourly values on near surface temperature and relative humidity for the 1971-2000 control period and the 2021-2050 RCP4.5 scenario period at the ski resort reference points have been converted into wet bulb temperatures (WBT). The WBTs have been treated as indicators of snowmaking availability such that total seasonal hours below -4°C reflect total capacity (T-SM) and those below -7°C show quality production capacity (Q-SM). The latter is then also filtered for the November-December totals in order to assess the critical base-layer formation capacity (B-SM), which is minimally desired as 120 hours (5 days). As with natural snow reliability, an overall decline is projected also for the snowmaking capacities of the three resorts (Table 3). In terms of total snowmaking and quality snowmaking, the declining trend is the strongest at SR1. Regarding base layer formation, all resorts lose their capacities by 25 to 30%, whilst SR1 falls below the desired 120 production hours limit. Therefore, some natural snow cover formation is essential for this resort to support the base layer formation before the critical New Year's week. However, we should recall that this ski resort has a very high ski area vertical drop; thus, it is likely that the snowmaking capacity could improve further with generally colder air in higher terrains. Nonetheless, the overall results are relatively positive, blessed by the drier and colder climate of the region, and it outperforms the snowmaking capacity of a more maritime Northwestern resort that plans to invest in snowmaking in the upcoming season. Our RegCM projections[145] for

141 O.C. Demiroglu and Linda Lundmark, "Küresel Isınmanın Türkiye'deki Başlıca Kayak Merkezlerine Etkisi," 178-195.

142 "Kar Garantili Kış Turizmi," O. C. Demiroglu, accessed January 26, 2016, http://www.tuyed.org.tr/haber/kar-garantili-kis-turizmi.

143 O. C. Demiroglu, "Misunderstanding and Obfuscation of Snow Reliability and Snow Guarantee," in *Proceedings of the 4th International Conference on Climate, Tourism and Recreation – CCTR2015*, ed. O. C. Demiroglu et al. (Istanbul: Istanbul Policy Center, 2015), 105-107.

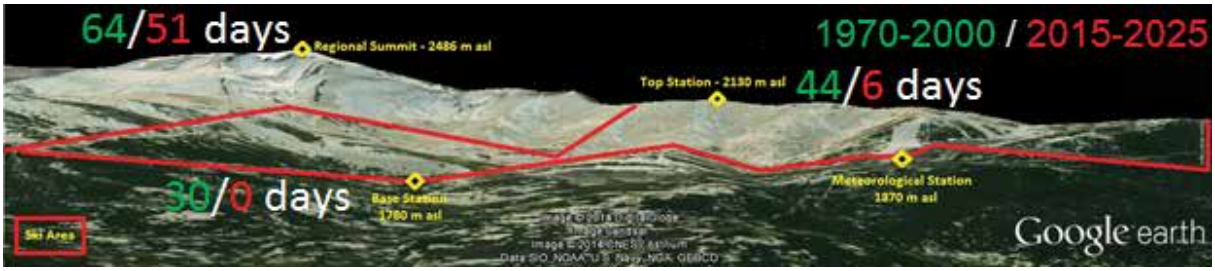
144 O. C. Demiroglu et al., "Impact of Climate Change on Natural Snow Reliability, Snowmaking Capacities, and Wind Conditions of Ski Resorts in Northeast Turkey: A Dynamical Downscaling Approach," *Atmosphere* 7 (2016): 52.

145 T. Özturk et al., "Projections for Changes in Natural and Technical Snow Reliability of a Major Turkish Ski Resort by Using RegCM 4.3.5."

Table 3: Changes in Snowmaking (SM) Hours for Major Ski Resorts in Northeast Turkey

	T-SM		Q-SM		B-SM	
Ski Resort	**1971-2000**	**2021-2050**	**1971-2000**	**2021-2050**	**1971-2000**	**2021-2050**
SR1	1265	902	636	414	133	94
SR2	2237	1830	1338	993	344	259
SR3	2472	2057	1508	1134	426	298

Figure 18: Changes in Quality Snowmaking Capacity (Q-SM) of a Ski Resort in Northwest Turkey



the next decade for the resort imply a severe deterioration of quality snowmaking conditions at both the base and the top of the ski areas, with respect to the 1970-2000 period, while the higher terrains adjacent to the resort are promising for the future in terms of snowmaking capacity, despite a reduction of 20% (Fig. 18).

Utilizing higher terrains could be a viable, but possibly unsustainable, climate change adaptation strategy for Turkish ski resorts as exemplified above in terms of not only technical but also natural snow reliability. Looking at freezing levels, i.e. 0°C isotherms, determined by Demiroglu and Lundmark[146] for 12 Turkish ski resorts (Fig. 19) during the anomalously warm 2010 winter season (see Fig. 14), we can say that at least five of these resorts—SRa, SRb, SRf, SRi, SRk—should consider moving operations higher to their potential summit terrains. Recent developments confirm these suggestions as SRa, SRi, and SRk have engaged in extension or expansion projects, while official plans for redeveloping SRb have proposed the utilization of higher terrains. SRf, on the other hand, is also depicted in Fig. 18, where there is a certain need to immediately achieving better snowmaking capacity. Therefore, a cable car that climbs up to the regional summit is considered by resort operators. Moreover, the main summit of the stratovolcano offers even higher terrain with better skiing conditions. However, it should be noted that going higher for climate change adaptation could over-egg the pudding as such areas tend to be more ecologically sensitive and more physiologically challenging for the visitors due to possible acclimatization problems especially above 3500 masl.

146 O.C. Demiroglu and Linda Lundmark, "Küresel Isınmanın Türkiye'deki Başlıca Kayak Merkezlerine Etkisi," 178-195.

Figure 19: Changes in Freezing Levels over the Selected Ski Resort Terrains in Turkey



In order to further understand the vulnerability of ski tourism in Turkey, we have investigated the adaptive capacities of its stakeholders, namely the operators and political actors on the supply side and the consumers on the demand side, who are the ultimate end means of adaptation adoption or behavior. For this reason, a focus group study was realized during the Turkish Ski Tourism Forum[147] and a survey[148] was administered to ski tourists. The latter data collection method was carried out through online[149] and on-site contacts until a favorable sample size was reached.

Focus group discussions reflected a highly contrasting acknowledgement of and adaptation to climate change by industry representatives. The skeptic attitude, which is a major basis of the science-industry perception gap in climate change adaptation,[150] was dominant especially with one participant who deeply questioned state-of-the-art technology's capability in modeling climate change and the overall ability of human beings to affect the climate. Moreover, the observed changes were rather perceived as a result of city growth linked "urban heat islands" and the immediate impacts of newly opened hydroelectric power plants on mountain microclimates, both contributing negatively to natural snowfall. Snowmaking, on the other hand, was seen as a need for competition but not necessarily climate change adaptation. In this sense, other operators were also interested in the future snowmaking capacity in their ski areas, especially around the start of the season. Alternative ski areas on dry materials and grass were also brought up as adaptation alternatives should the conventional snowmaking methods not suffice.

147 O. C. Demiroglu, *Kayak Turizmi Forumu'ndan Kayak Turizmi Politikasına Notlar.*

148 O. C. Demiroglu, "Türkiye'deki Kış Sporları Turistlerinin İklim Değişikliği Algı ve Uyumları üzerine Ampirik bir Çalışma" (paper presented at I. Ulusal Altnernatif Turizm Kongresi, Erzincan, Turkey, 2016).

149 Online survey administered at http://www.kayakiklim.com.

150 B. Abegg and R. Steiger, "Challenges in Climate Change Adaptation: The Case of Alpine Winter Tourism," in *Proceedings of the 4th International Conference on Climate, Tourism and Recreation – CCTR2015*, ed. O. C. Demiroglu et al. (Istanbul: Istanbul Policy Center, 2015), 119-123.

Table 4: Demographic Profiles of Turkish Ski Tourists Surveyed Online and On-site (n: 394)

Origin	n	%	Gender	n	%	Marital Status	n	%	Education	n	%
Istanbul	317	82	Male	310	79	Unmarried	271	70	Graduate	261	67
Ankara	19	5	Female	79	20	Married	115	30	Undergraduate	96	25

Table 5: Snow Sports Habits of Turkish Ski Tourists Surveyed Online and On-site (n: 394)

Most Practiced Sport	M	Destination General	%	Destination Domestic	M	Destination Abroad	M
Snowboarding	3.11	Turkey	67	Ski Resort in Northwest Turkey	3.29	Alps	2.31
Skiing	2.73	Abroad	3	Ski Resort in Northwest Turkey	3.23	Balkans	2.03
		Both	30	Ski Resort in Central Turkey	2.03	Caucasus	1.16

Decision Factors	M	Snow Info Source	M	Main Purpose of Visit	M	Visitation Period	%
Snow Conditions	4.61	Private Portals	4.09	Recreation	4.45	November	0.3
Leisure Time Availability	3.69	Internet Forums	3.72	Socialization	3.28	December	2.5
Financial Availability	3.54	Webcam	3.21	Health	3.15	January	37.1
Company from Friends/Family	2.97	State Service	3.12	Professional Training	2.19	February	52
Aprés-ski Options	2.85	Ski Resort Media	2.84			March	7.6
Security Conditions	2.41	Ski Resort Phone Call	1.99			April	0.5

National policymakers, on the other hand, have demonstrated a more positive comprehension and willingness for adaptation action. The attitude has admittedly changed especially as a consequence of the anomalously warm and dry 2007 winter season. Such experience resulted initially in the installation of a widespread snowmaking system for a renovated resort. Today, the planners view it as an imperative to carry out site selection analyses with more stress on climatic feature. For this reason, new resort proposals now include the establishment of meteorological stations within their zones. Moreover, the planners emphasize incentives towards the development of proposals with a strong market

potential in order to build up resilience from scratch by playing on the "winners" and reducing relative vulnerability.

Last but not least, the survey results provide us with important findings on the attitudes, perceptions, and responses of Turkish ski tourists to climate change. Administered to a sample of 394 visitors, the survey results (Table 4) tell us that Turkish skiers are mostly male and unmarried, very well educated, dominantly originating from Istanbul, relatively young (median age: 31), and with medium-high income (average monthly salary: 4,808 TRY). Looking into their snow sports habits (Table 5) on a Likert scale of 1 to 5, we see that snowboarding is more popular compared to skiing, and ski resorts in Northwest Turkey are the most favored destinations, followed by the Alps. Snow conditions are the top factor in ski trip decisions, for which the most popular information source is a private web portal. Visitors prefer recreation as the main purpose of visit, and February and January are the most common months to visit.

The fact that snow conditions is the main criterion in ski trip decisions further elevates the role of climate change in the future of Turkish ski tourism. The poor score from the State Meteorological Service with respect to alternative information sources on snow conditions, such as web portals and forums, should urge policymakers to establish improved weather forecasting services tailored for tourism as one of the initial steps in climate change adaptation (see Fig. 4). In Norway, for instance, ski tourists' reliance on the official forecasts was the highest compared to alternative sources.[151]

When questioned directly on climate change, those surveyed displayed a strong awareness, literacy, and negative perception of the phenomenon, unlike the general[152] Turkish public. Agreement level with the statement "climate changes due to a general warming trend" was 4.2, and the dominant anthropogenic cause of warming was acknowledged by 61%, whilst a further 27% viewed both the human and the natural causes as contributing equally to warming. The negative impacts of climate change on Turkish ski resorts have already been observed by 70% of the sample while another 17% expects them to be visible within the next 25 years. Such results are similar to the findings with ski tourists elsewhere[153,154] as expected, since the subjects themselves are among the most readily exposed human systems.

Findings that relate consumer standpoint to supplier vulnerability indicate that the 30 cm threshold commonly taken as reference in assessment studies may be too optimistic as the minimum snow depth required by the subjects is 78 cm (65 cm if rental equipment is used). Moreover, artificially made snow is not favored much, scoring only 2.5, while the niche segment of professional training-purpose visitors shows a weak but significantly ($p<0.01$) positive correlation ($\rho=0.21$) in favor of snowmaking. Snow guarantee, on the other hand, is mostly perceived as synonymous to snowmaking availability, setting the stage for operators to take advantage of this by offering guarantee without an actual warrant on lack of snow, such as refunds or vouchers.[155,156]

151 O. C. Demiroglu, H. Dannevig, and C. Aall, "Norwegian Summer Skiing Experience in a Changing Climate: Prospects for Mitigation, Adaptation and Substitution Behaviours" (poster presented at the International Adventure Conference, Sogndal, Norway, 2014).

152 "Kamuoyu İklim Değişikliği ile Mücadelede Türkiye'nin Sorumluluk Üstlenmesine Şartlı Destek Veriyor," EDAM, accessed January 26, 2016, http://www.edam.org.tr/tr/File?id=3172.

153 M. Pütz et al., "Winter Tourism, Climate Change, and Snowmaking in the Swiss Alps," 357-362.

154 O. C. Demiroglu, Dannevig and Aall, "Norwegian Summer Skiing Experience in a Changing Climate."

155 "Kar Garantili Kış Turizmi."

156 O. C. Demiroglu, "Misunderstanding and Obfuscation of Snow Reliability and Snow Guarantee."

Contrary to suppliers, consumers have a relatively higher adaptive capacity as they are equipped with the options of substituting their usual ski resort trip with visits to more snow reliable resorts (spatial substitution), visits to the same resort in more snow reliable and/or less frequent periods (temporal substitution), and other leisure activities (functional substitution). When asked how they responded to the bad snow season of 2013-2014 (see Fig. 14), which scored 2.1 in terms of snow conditions (where 1 is "very bad," 2 is "bad," 3 is "normal," 4 is "good," and 5 is "very good"), the subjects reflected loyalty to their favorite ski resort, with 31% having no substitution for the favorite ski resort, and 27% visiting the same resorts at a different time of the season or less frequently. Nonetheless, spatial substitution was also considerably favored, with 11% of the respondents opting for a ski vacation abroad and another 8% within Turkey. Functional substitution was a third option, where 13% saved their vacations for spring and summer and another 7% took up an alternative winter activity during their vacations such as ice skating.

Questions on the future substitution behaviors of the subjects implied that said "resort loyalty" is at stake. On a Likert scale of 1 to 5, with five indicating higher tendency, the respondents stated that they would favor spatial substitution within Turkey (3.74) and abroad (3.29) or temporal substitution (3.56) should the negative impacts of climate change become more visible over their usual resort(s) and vacation times. The "same place, same time" motto would diminish, with a score of 2.38. Other activities such as tour skiing in more reliable terrains or trying dry (Photo 3) or indoor skiing seemed to be

Photo 3: World's Largest Dry Ski Slope due open in 2016 in Ankara, Turkey[157]



157 Image available at http://www.snowflex.com/files/1514/4040/8890/ 2015-08-13_10.26.04_3.jpg.

infrequent substitutes, with scores of 1.73, 1.57, and 1.45, respectively. Quitting snow sports for good also had a relatively low score – 1.9.

The substitution tendencies showed some significant correlations with each other as well as other variables. Those who were relatively satisfied with snow conditions in the 2013-2014 season seemed to be the most loyal with no substitution tendency (ρ=-0.12; $p<0.05$), whereas the more dissatisfied subjects tended more toward spatial substitution abroad (ρ=-0.28; $p<0.01$) and within Turkey (ρ=-0.26; $p<0.01$).

There was a strong positive correlation among those who opted for functional substitution in the forms of indoor and dry skiing (ρ=0.68; $p<0.01$). The training segment correlated with tendencies towards backcountry (ρ=0.21; $p<0.01$), indoor (ρ=0.11; $p<0.05$), and dry skiing (ρ=0.15; $p<0.01$) in addition to skiing abroad (ρ=0.14; $p<0.01$), while the recreational segment would stick to the same place at the same time (ρ=0.17; $p<0.01$) or through temporal substitution (ρ=0.20; $p<0.01$).

Those who favored snowboarding tended more toward indoor facilities (ρ=0.16; $p<0.01$) while the skiers showed an opposite trend (ρ=-0.14; $p<0.01$).

Quitting skiing for good was less likely for those with higher tenure (ρ=-0.25; $p<0.01$).

When compared with the overall climate vulnerability of ski tourism in Germany, the Turkish case seems to be more promising in terms of resilience should the authorities and investors decide on the best locations and the practices throughout the forthcoming winter tourism development loop. However, relative vulnerabilities of the regions within the country display different pictures in the sense that those regions, with the exception of the high-altitude Northeast, will be more exposed to negative impacts and have less capacity for technical adaptation. Combined with the spatial substitution tendencies of consumers, resorts of these regions will need to consider non-technical adaptation methods (see Fig. 4) and follow a more complex decision making process (see Fig. 5) given the rising competition from the relative resilience and the consequent "winner" status of the Northeast and neighboring Bulgaria.[158]

158 O. C. Demiroglu et al., "Technical Climate Change Adaptation Options of the Major Ski Resorts in Bulgaria."

CONCLUSIONS AND RECOMMENDATIONS

This report was a synthesis of works on climate change vulnerability of ski tourism in Germany and Turkey. It followed an eclectic approach to cover all physical and human aspects of the issue by reviewing several studies, including the author's own, that employ various methodologies such as spatial analyses, climate models, surveys, and focus groups. In return, the outcomes helped build a thorough and comparative understanding of sensitivity and adaptive capacity of ski tourism stakeholders for contemporary climate change.

In Germany, relative vulnerability with respect to the overall Alpine region is high. This is mostly due to local/regional economic dependencies on the ski tourism industry combined with higher exposure of lower altitude mountainous terrains. Concerning the latter issue, higher altitudes of the Bavarian Alps and the Black Forest do not compensate for the lack of latitude that would otherwise allow for more snow reliability. This contrasting picture is also valid within the country, beyond the Alps, where many ski areas are located in low-lying terrains as one goes north. As most of these areas are run by micro and small-sized enterprises, adaptation options become limited with minimal financial resources and operational skills in addition to physical challenges. Thus, the role of macro actors is essential in adapting these areas, whose survival is vital for the overall social and economic sustainability of ski tourism as these easily accessible areas could be considered one of the major reasons for having a widespread ski culture throughout Germany. Regarding the more industrialized ski resorts and their dependent localities along the southern border, involvement of the macro actors is once again important as finding the balance for avoiding both recessions and maladaptation would require the engagement of regulatory bodies, especially in a geography where there are likely more winners in the neighboring countries that pose a threat in regards to spatial substitution.

In Turkey, it might be too early to talk about climate change winners and losers in terms of ski tourism supply as the country is still in the initial phases of utilizing its mountains and developing ski tourism further to meet international standards. However, some established resorts and areas do present some meaningful clusters of various vulnerability degrees. Those in the inner Northeast and the high altitude central regions present a sounder resilience, owing to less exposure with high altitude and latitude and a better adaptive capacity based on the continentality that provides them with the cold, dry air needed for snowmaking. In the maritime north, the resorts again hold the latitude advantage but less of an altitudinal potential, with the exception of the eastern parts. These areas may have had the highest quantities of snowfall in the past, but this feature is prone to becoming more variable and short seasoned in the upcoming decades, challenging investment and operational profitability. Combined with relatively less technical snow reliability due to wetter conditions and the primary tendency of consumers for spatial substitution, these resorts, especially in the Northwest, will have to deal with fiercer competition against each other and the emerging competitors in the Northeast and inner regions of the country as well as neighboring destinations in the Balkans and the Caucasus. A third vulnerability/resilience group could be defined as those ski resorts and areas that are exposed to climate change due to lack of altitude and/or latitude, but also enjoy high proximity to major markets, especially the urban centers. At first glance, these resorts and areas might seem to be highly vulnerable to change, but here impact

assessments could be modified in terms of snow reliability duration thresholds, as shorter but nonetheless still denser seasons could still bring in the necessary business volumes to surpass breakeven levels. However, such a scenario may not hold true for the many other micro and small ski areas, as these are mostly scattered in the rural regions far from demand bases. Therefore, governmental intervention could generally be needed to support these establishments with incentives and subsidies. This is especially important since the national snow sports development goal is critically based on developing a sound domestic market base. Artificial ski areas that have been on the agenda in recent years, however, provide no strong climate change adaptation alternative for the ski tourism industry and could only be regarded as a remedy for the survival of snow sports but not of the mountain resorts and areas themselves. However, a mix-use area through the application of dry materials on actual ski areas could be an option to adapt to climate change.

Turkey, unlike many established ski destinations, holds the unique advantage of being a developing market in relation to climate change adaptation. Construction of many resorts is now being proposed, and most of the existing resorts are due for renovation. In this respect, political actors still have the chance to acknowledge and implement adaptation measures to prevent climate change. However, clear reference to the issue is not visible in the main policy documents such as the Tourism Strategy of Turkey-2023. Thus, firstly policy documents need to be updated with priority given to the issue of climate change. Better cooperation of policymakers with scientists and experts could then yield detailed impact assessment reports that would draw a healthier roadmap for the forthcoming winter tourism loop.

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NOTES

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