

Impacts of climate change in tourism in Europe. PESETA-Tourism study

Bas Amelung, Alvaro Moreno



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Preface

The main objective of the PESETA (Projection of Economic impacts of climate change in Sectors of the European Union based on bottom-up Analysis) project is to contribute to a better understanding of the possible physical and economic effects induced by climate change in Europe over the 21st century. PESETA studies the following impact categories: agriculture, river basin floods, coastal systems, tourism, and human health.

This research project has followed an innovative, integrated approach combining high resolution climate and sectoral impact models with comprehensive economic models, able to provide estimates of the impacts for alternative climate futures. The project estimates the impacts for large geographical regions of Europe.

The Joint Research Centre (JRC) has financed the project and has played a key role in the conception and execution of the project. Two JRC institutes, the Institute for Prospective Technological Studies (IPTS) and the Institute for Environment and Sustainability (IES), contributed to this study. The JRC-IPTS coordinated the project and the JRC-IES made the river floods impact assessment. The integration of the market impacts under a common economic framework was made at JRC-IPTS using the GEM-E3 model.

The final report of the PESETA project (please visit <http://peseta.jrc.ec.europa.eu/>) is accompanied by a series of technical publications. This report presents in detail the tourism physical impact assessment, methodology and results.

Antonio Soria

Acting Head of Unit

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JRC-IPTS

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1. Introduction

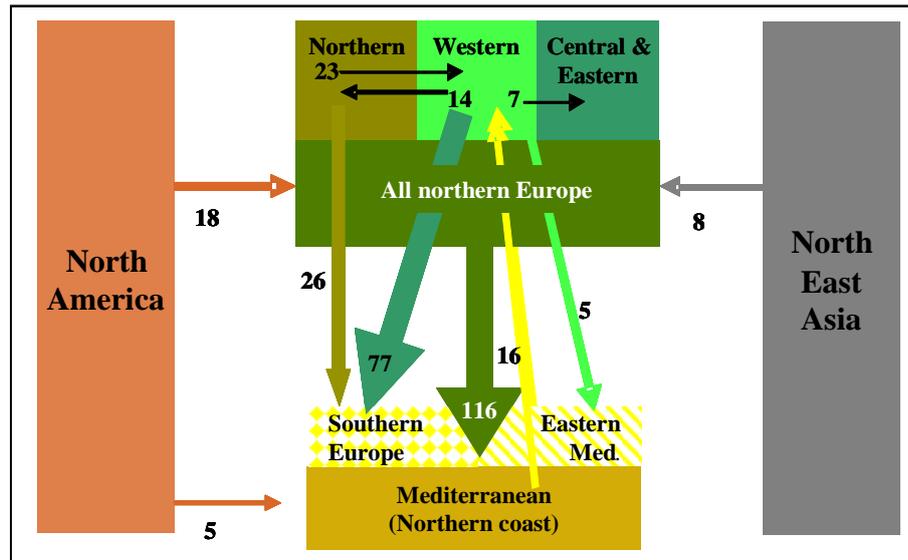
This document contains the results of the physical impact assessment for tourism within the context of the PESETA project. The final report of the PESETA project is available at the Institute for Prospective Technological Studies (JRC-IPTS) website (please visit <http://peseta.jrc.ec.europa.eu/>) (Ciscar *et al.*, 2009).

Tourism is a multi-billion euro industry that is highly dependent on climate resources. Climate change may provoke shifts in tourist flows, with large economic implications. Higham and Hall (2005) identified climate change as the number one challenge to tourism in the 21st century. In the Fourth Assessment Report of the IPCC, tourism has considerably more prominence than in the previous assessments (Amelung *et al.*, 2007), although the sector still does not receive the attention it merits based on its economic importance. Climate change will impact tourism in many different ways. Tourism encompasses a highly diversified range of holiday types. All of these segments may have very specific weather requirements. One needs wind for sailing, snow for skiing, and relatively high temperatures for sunbathing on the beach, etc. Climate change can therefore be expected to have very diverse implications for all these different segments of the tourism market. A review of all segments is beyond the scope of the PESETA assessment study, in particular since the baseline information on weather preferences is far from complete. In fact, the study of current relationships between weather, climate and tourism has gained renewed interest only recently, as the interest in the potential impact of climate change on tourism is growing. A bottom-up approach to the evaluation of the impact of climate change on tourism in Europe is therefore only possible to a limited extent.

This document presents an assessment of two major tourism segments for which previous studies exist and that are also among the most climate-dependent and climate change sensitive ones: light outdoor activities (including beach tourism) and winter sports.

The annual migration of northern Europeans to the countries of the Mediterranean coast in search of the traditional summer ‘sun, sand and sea’ vacation is the single largest flow of tourists across the globe, accounting for one-sixth of all tourist trips in 2000 (Todd, 2003), see also Figure 1.

Figure 1. International tourism in Europe: origins and destinations



Source: Todd (2003).

This large group of tourists, totalling around 100 million per annum, spends an estimated 100 billion euros per year. Any climate-induced change in these flows of tourists and money would have very large implications for the destinations involved, though not necessarily for the European Union as a whole. It is very likely that the main impact of climate change on light outdoor tourism activities will be on distribution rather than volume. The distributional effects will greatly depend on adaptation. Will tourists respond to climate change by altering their activity patterns during their holidays, go to the usual destinations in other seasons, or will they choose completely different destinations? It is not possible to predict with any degree of certainty which of these adaptation options will dominate, which is why in the PESETA project different options are explored using scenario analysis. This assessment sketches the changes in climatic suitability using the Tourism Climatic Index (TCI), and discusses the potential implications of climate change for water availability.

Mountain regions are important destinations for global tourism and snow cover and pristine mountain landscapes that are the principal attractions for tourism in these regions are the features that are most vulnerable to climate change. Nature-based tourism is a vital component of tourism in mountain regions of the world. Climate change is projected to have substantial impacts on sensitive mountain environments, with implications for the attractiveness of mountain environments for tourism and the occurrence of natural hazards. Winter sports represent an important and dynamic element in the economies of mountain and alpine communities in Europe and the consequences of climate change on this type of tourism are more evident than for other tourist activities.

The impact of climate change on the snow-based sports tourism industry is potentially severe. The multi-billion euro winter sports industry has been repeatedly identified as at risk to global climate change due to the close linkage between economic performance and climate through the availability of natural snow and suitable climatic conditions to make snow. Known vulnerabilities exist in a range of European countries; the projected impacts on destinations in these nations vary in magnitude and over different time horizons. The key climate change impacts of interest to the winter sports industry relate to ‘natural snow reliability’ and also ‘technical snow reliability’ (i.e., cold enough temperatures to make snow). The latter is important in areas where snowmaking is widespread, and 'artificial' snow covers a high proportion of skiable terrain.

The alpine-ski industry in Europe is mainly located in three countries: France, Austria and Switzerland (see Table 1). In France, mountain regions occupy 22.8% of the national territory, and the country represents 28% of all areas in Europe suitable for skiing. In Switzerland and Austria, mountain regions represent 65% and 70% of their respective territories, which is equivalent to 20% and 19% of the total European ski area. Tourism is of particular importance in Austria. Revenues of tourism add up to more than €14.2 billion, and the sector contributes an estimated 18% to the Austrian GDP. Winter-sports tourism in Austria is as important as summer tourism. In other countries like Spain or Italy winter tourism is considered as marginal compared to other types of tourism (e.g. coastal tourism).

Table 1. *Winter sports in Europe*

	Number of stations and ski resorts	Number of chairlifts	Skiers	Turnover winter season 2002/2003
France	308	3865	3 540 769	970 M€
Austria	255	3016	3 139 718	901 M€
Switzerland	230	1672	1 587 000	588 M€
Germany	322	1311		40,4 M€
Italy	200	3100		431 M€
Spain	28	338	364 809	151 M€
Andorra	4	104	140 645	46 M€

Source: SEATM (2004).

2. Methodology and Data

Below, the methodology applied and data used for the physical impact assessment are presented for light outdoor activities and for winter sports. For the first category, the focus is on thermal conditions, for the second category on the availability of snow.

2.1. Outdoor tourism

In the 1960s and 1970s systematic research was performed on the influence of climatic conditions on the physical well being of humans. This research yielded important insights, ranging from preferred temperatures, and the role of relative humidity to the role of wind. Hatch (1984, 1988) and Mieczkowski (1985) are among the very few who applied the general findings about human comfort to the specific activities related to recreation and tourism. It should be noted that the appreciation of climatic conditions is dependent on a host of non-climatic factors, such as the level of activity, clothing, and genetic set-up (Matzarakis, 2001).

Mieczkowski devised a tourism climatic index (TCI), which is based on the notion of “human comfort,” and consists of five sub-indices, each represented by one or two monthly climate variables. The five sub-indices and their constituent variables are as follows: (i) daytime comfort index (maximum daily temperature (in °C) and minimum daily relative humidity (%)); (ii) daily comfort index (mean daily temperature (°C) and mean daily relative humidity (%)); (iii) precipitation (total precipitation, in mm); (iv) sunshine (total hours of sunshine); and (v) wind (average wind speed, in m/s or km/h). The index is calculated as follows:

$$TCI = 8CID + 2CIA + 4R + 4S + 2W$$

where CID = daytime comfort index, CIA = daily comfort index, R = precipitation, S = sunshine, and W = wind speed. With an optimal rating for each variable of 5, the maximum value of the index is 100.

All sub-indices are calculated with mean monthly values. The thermal comfort indices are based on effective temperature, which is a measure of temperature that takes the effect of relative humidity into account. The wind sub-index combines information about wind speed and temperature. The other indices are based on single variables and reflect either the

empirical findings of physiological research or qualitative assessments of tourist preferences. A crucial issue is the fact that tourists' appreciation of climatic conditions depends on activity levels. Beach holidays, for example, require other climatic conditions than biking trips. Mieczkowski took light outdoor activities as the point of reference for his rating system, and his example is followed here. The rating scheme is detailed in Table 2. For a detailed description of the set of variables, see Mieczkowski (1985).

In the Mieczkowski TCI, the highest weight is given to the daytime comfort index to reflect the fact that tourists are generally most active during the day, and that temperature is a key determinant of climate fitness. Sunshine and precipitation are given the second-highest weights, followed by daily thermal comfort and wind speed. The maximum TCI score is 100, the minimum TCI score is -30, which is attained when both CID and CIA adopt their minimum score of -3. For each of the sub-indices, Mieczkowski considered several alternative indicators, and several alternative ways of translating these indicators into ratings, choosing solutions that were both theoretically defensible and practically feasible. The weights used in equation one do have some basis in scientific knowledge, but they do contain a strong element of subjective judgement.

Table 2. Mieczkowski's weighting scheme

Rating	Effective temperature (°C)	Mean monthly precipitation (Mm/month)	Mean monthly sunshine (Hours/day)	Wind speed (Km/h)			Wind chill cooling (Watts/m2/hr)
				Normal	Trade wind	Hot climate	
5.0	20 – 27	0.0 – 14.9	>10	<2.88	12.24 – 19.79		
4.5	19 – 20 27 – 28	15.0 – 29.9	9 – 10	2.88 – 5.75			
4.0	18 – 19 28 – 29	30.0 – 44.9	8 – 9	5.76 – 9.03	9.04 – 12.23 19.80 – 24.29		<500
3.5	17 – 18 29 – 30	45.0 – 59.9	7 – 8	9.04 – 12.23			
3.0	15 – 17 30 – 31	60.0 – 74.9	6 – 7	12.24 – 19.79	5.76 – 9.03 24.30 – 28.79		500 – 625
2.5	10 – 15 31 – 32	75.0 – 89.9	5 – 6	19.80 – 24.29	2.88 – 5.75		
2.0	5 – 10 32 – 33	105.0 – 104.9	4 – 5	24.30 – 28.79	<2.88 28.80 – 38.52	<2.88	625 – 750
1.5	0 – 5 33 – 34	105.0 – 119.9	3 – 4	28.80 – 38.52		2.88 – 5.75	750 – 875
1.0	-5 – 0 34 – 35	120.0 – 134.9	2 – 3			5.76 – 9.03	875 – 1000
0.5	35 – 36	135.0 – 149.9	1 – 2			9.04 – 12.23	1000 – 1125
0.25							1125 – 1250
0.0	-10 – -5	>150.0	<1	>38.52	>38.52	>12.24	>1250
-1.0	-15 – -10						
-2.0	-20 – -15						
-3.0	<-20						

Source: Based on Mieczkowski (1985).

Hatch (1988) developed a similar index, the ‘climate code’, which is based on similar variables but a different weighting scheme. Despite the differences, the shifts in suitability patterns that the two indices project are very similar. Here, only the analyses with the Mieczkowski TCI are reported on.

Based on a location’s index value, its suitability for tourism activity is then rated on a scale from -30 to 100. Mieczkowski divided this scale into ten categories, ranging from “ideal” (90 to 100), “excellent” (80 to 89) and “very good” (70 to 79) to “extremely unfavourable” (10-19) and “impossible” (-30 to 9). In this study, a TCI value of 70 or higher is considered attractive to the “typical” tourist engaged in relatively light activities such as sight-seeing and shopping. Table 3 illustrates the rating scale for tourism comfort.

Table 3. Tourism Climatic Index Rating System

Numeric value of index	Description of comfort level for tourism activity
90 – 100	Ideal
80 – 89	Excellent
70 – 79	Very good
60 – 69	Good
50 – 59	Acceptable
40 – 49	Marginal
30 – 39	Unfavourable
20 – 29	Very unfavourable
10 – 19	Extremely unfavourable
Below 9	Impossible

Source: Mieczkowski (1985).

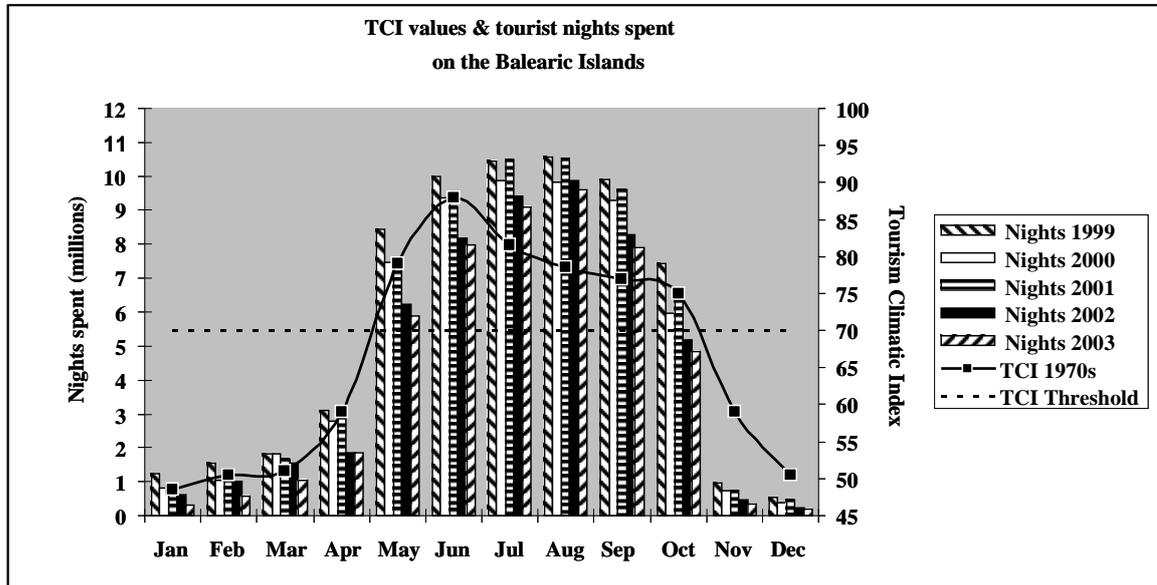
2.1.1. Validation

Validating the performance of TCIs as a predictor for tourist demand is troublesome. First and foremost, climatic conditions are by no means the only determinant of tourist patterns; rather, there is an amalgam of factors involved, including price, distance, landscapes, income, and cultural heritage. Furthermore, not only the climatic conditions per se are important, but also the conditions relative to those of competing areas (Hamilton et al., 2003). All significant tourist flows and destinations should therefore be studied in an integrated manner, rather than in isolation. This puts strong requirements on the completeness and consistency of datasets.

In practice, the resolutions of the tourism data and the climate data are very different. Climate datasets are typically grid-based and have a temporal resolution of a day, or a month. Tourism datasets are typically country-based and have a resolution of a year. More detailed datasets are

available for a number of individual destinations or even countries, but no complete and consistent dataset can be compiled with these.

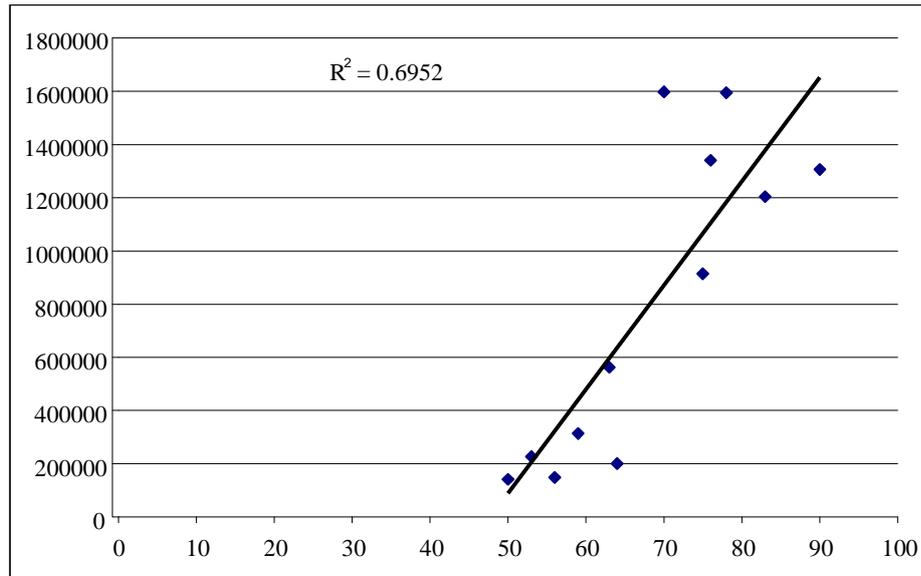
Figure 2. *Tourist nights spent in the Balearics by foreigners in relation to scores on the Tourism Climatic Index*



In part because of data limitations, TCI performance in predicting visitation levels has not yet been tested rigorously. TCI scores have, however, been compared with actual tourist demand for several individual tourist destinations. Scott et al. (2004) compared the Mieczkowski TCI with tourist demand in 17 North American cities. In the absence of arrival data on the required spatial and temporal resolutions, TCI scores were compared with hotel prices, which are assumed to increase with higher demand. The accommodation cost curves were found to resemble the TCI curves for each of the cities examined. Amelung and Viner (2006) compared Majorca's (Mieczkowski-based) TCI curve with the number of nights spent on Majorca by foreigners. A striking result was that more than 85% of the annual total of nights spent were accounted for by those six months in which TCI values were in excess of 70 points in the years 1999-2003 (see Figure 2). The similarity of the patterns were confirmed by statistical analysis (Figure 3).

In the context of the PESETA project, a statistical analysis of the relationship between tourists' arrivals and the TCI has also been carried out for the Mediterranean countries. The predictive power of the TCI is high, with an R^2 of 0.72, a value very similar to the one obtained for the example of Mallorca.

Figure 3. Correlation between TCI scores and arrivals for the Spanish island of Mallorca in 2005



Although this body of evidence is not conclusive, the positive results do support the hypothesis used in this report that TCIs can be effective indicators for the climatic attractiveness of tourist destinations.

2.1.2. Using the TCI for climate change research

Mieczkowski's and Hatch's TCIs were originally devised to assess the quality of existing climates for tourist purposes. Climate change research has nevertheless opened up new fields of application for TCI analyses. The combination of the TCI with projected scenarios of future climate conditions has so far been limited. Indeed, only a handful such studies were identified by the authors (e.g. Amelung et al., 2007; Amelung, 2006; Amelung & Viner, 2006; Scott et al., 2004). These studies demonstrate both the utility of adoption of the TCI approach in analyses of potential climate change impacts, and the substantial impacts that such change might have on tourism patterns in Europe, Canada, the United States and Mexico over the coming century.

In this report, Mieczkowski's TCI is used to explore the impacts of climate change on climate resources for tourism in Europe. The monthly data that are needed to calculate the index values were supplied by the PESETA team. The data for the short term future ('2020s') were produced by the Rossby centre RCA3 model, using ECHAM4 boundary conditions. This dataset contains monthly means for every year between 2011 and 2040. To arrive at the 30-

year climate normals that were needed for the calculations, the monthly means were averaged over the thirty-year periods of 1961-1990 and 2011-2040. Using only one model was deemed sufficient for the PESETA project for the '2020s' as for this short-term different models produce similar results. The Rossby centre data were supplied as a 95x85 rotated grid.

Differences between models are much higher for the longer term future. To reflect this higher uncertainty, data were taken from two different models, using two different scenarios. The two models are the HIRHAM model, driven by the HadAM3 GCM, and the RCA model, driven by the ECHAM4 GCM. The scenarios used are the A2 and B2 SRES scenarios. Both datasets were available from the PRUDENCE website. The Prudence data were supplied as a 80x100 CRU grid.

2.2. Winter sports

The assessment of winter sports is based on existing studies. Quite a number of these exist now, and no new modelling activities were undertaken. Estimates of the changes in the availability of snow can be deduced directly from the output of the General Circulation Models (GCMs). Bürki et al. (2003) and Elsasser and Bürki (2002) assessed the implications of these GCM results for the Alps; Harrison et al. (1999) did the same for the Scottish mountains. Others have established relationships between temperature change and upward shifts in the snow line (Schär et al., 1998). This relationship allows the assessment of the viability of ski resorts on various altitudes under different climate change scenarios.

According to Bürki et al. (2003), experience shows that a ski resort can be considered snow-reliable if, in 7 out of 10 winters, a sufficient snow covering of at least 30 to 50 cm is available for ski sport on at least 100 days between December 1 and April 15. From these conditions that characterise a profitable resort it can be derived that the main parameter that differentiates the quality and reliability of a ski station is the length of the ski season. The financial viability of ski infrastructures (such as skilifts), restoration services and the accommodation resources with regard to the expenses of the maintenance of such services are indeed dependent on the length and quality of the season. In general, the economic impact of climate change on the ski industry is based on the shift of this parameter in the future.

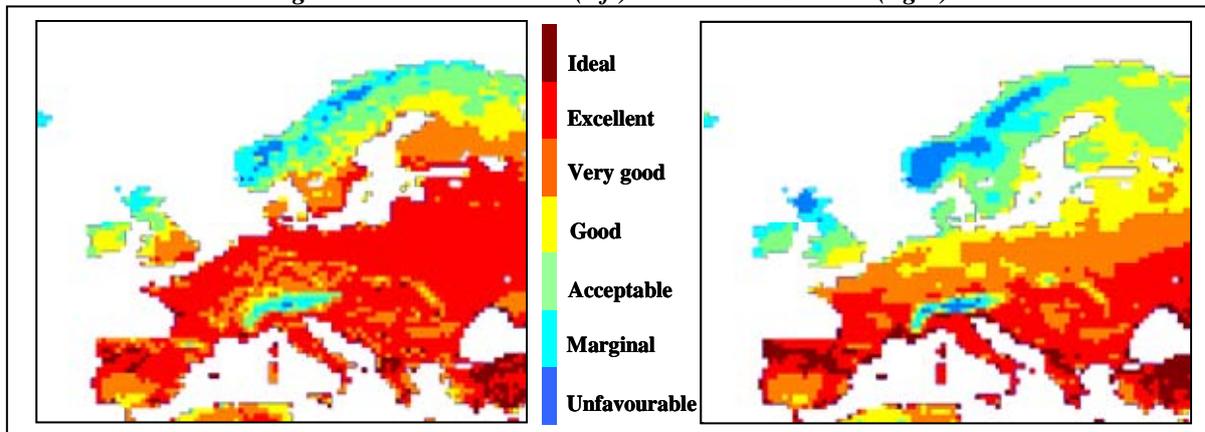
The other parameter which is relevant to the study of the impacts of climate change on snow-based activities is the snowline altitude. Seasonal and inter-annual variations together with the altitudinal and latitudinal grading of European mountain ranges make the snowline a parameter very specific to each region. For example in the case of the French Alps this line is around 1200-1500 meters, whereas in Austria 400 meters are considered the minimum altitude for profitable skiing (Walter, 2001). Starting from these or similar baseline conditions, a number of studies have been performed, showing the impact of climate change on snow-reliability and the snowline altitude.

3. Results

3.1.1. Light outdoor activities: Baseline

Currently, summer is the best season for most types of outdoor tourism for most if not all countries in Europe. Excellent conditions (in particular for beach tourism) can be found around the Mediterranean sea. This general picture is reproduced by the analysis with the Tourism Climatic Index (TCI), as is shown in Figure 4.

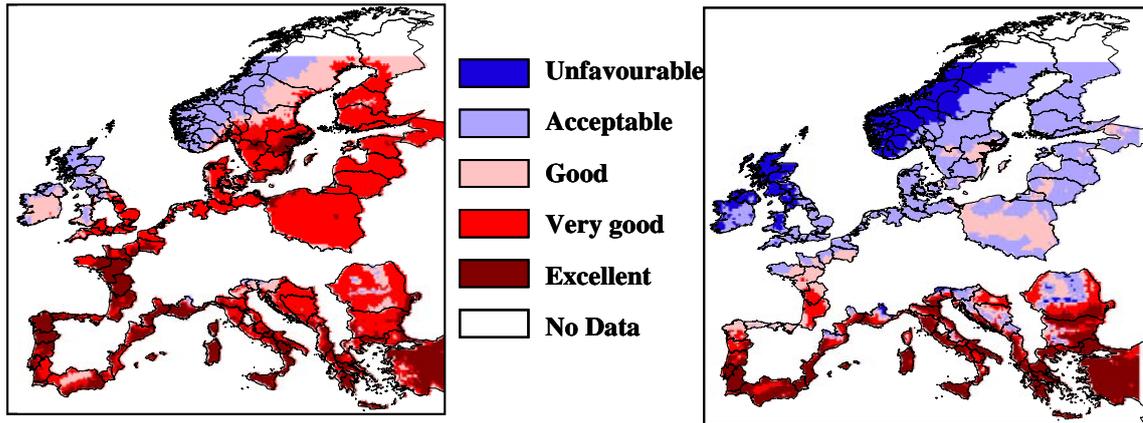
Figure 4. Baseline climatic conditions for tourism in summer in the period 1961-1990 (1970s'), according to the HIRHAM model (left) and the RCAO model (right)



Both models reproduce good to ideal conditions in most of continental Europe. The models coincide in evaluating the conditions in parts of Spain, Greece and Turkey as ideal, and the general conditions in the south of Europe as excellent. Nevertheless, the findings are clearly distinct for the northern half of Europe. The HIRHAM model produces a picture in which continental Europe is almost entirely red, representing excellent conditions. One has to bear in mind that the TCI describes the climatic attractiveness for general outdoor tourism activities, which has lower thermal requirements than, for example, beach tourism.

Moreno et al. (2007) adjusted the TCI for beach tourism, specifying a higher optimal temperature range. Figure 5 depicts the differences between the original TCI specification (left) and the beach-specific TCI version (right) for the summer season in the 1961-1990 period for the European coastal areas. Clearly, the beach-specific TCI shows a much greater difference between northern Europe and the Mediterranean than the original, general TCI specification.

Figure 5. *Climate suitability for tourism in Europe's coastal areas, according to the original TCI (left) and the beach-specific TCI (right) in the summer of the baseline period of 1961-1990*



Source: Moreno et al. (2007).

The RCAO and HIRHAM models show more similar TCI patterns in the shoulder seasons. Figure 6 depicts the conditions in March, April, May (MAM, 'spring') in the two panels at the top, and September, October, November (SON, 'autumn') in the two panels at the bottom, according to the HIRHAM (left) and RCAO (right) models. The southern half of Europe boasts good to excellent conditions in autumn and in particular spring, whereas in the northern regions of Europe, conditions are acceptable at best. In winter, conditions are unfavourable in the whole of Europe.

A proxy for a region's length of the season that is suitable for general tourism activities can be obtained by counting the average number of months per year with TCI scores above a certain threshold. The example of Mieczkowski (1985) and Amelung and Viner (2006) is followed in using a threshold value of 70. Figure 7 shows the number of very good months ($TCI > 70$) in the 1970s, according to the HIRHAM model (left) and the RCAO model (right). The HIRHAM model produces somewhat more optimistic values for the northern and western parts of Europe, whereas the RCAO model yields better results for Spain, and sections of Italy and other Mediterranean countries. Both models confirm the position of the Mediterranean as Europe's number one position for general outdoor tourism activities.

Figure 6. Baseline climatic conditions for tourism in spring (top) and autumn (bottom) in the period 1961-1990 (1970s'), according to the HIRHAM model (left) and RCAO model (right)

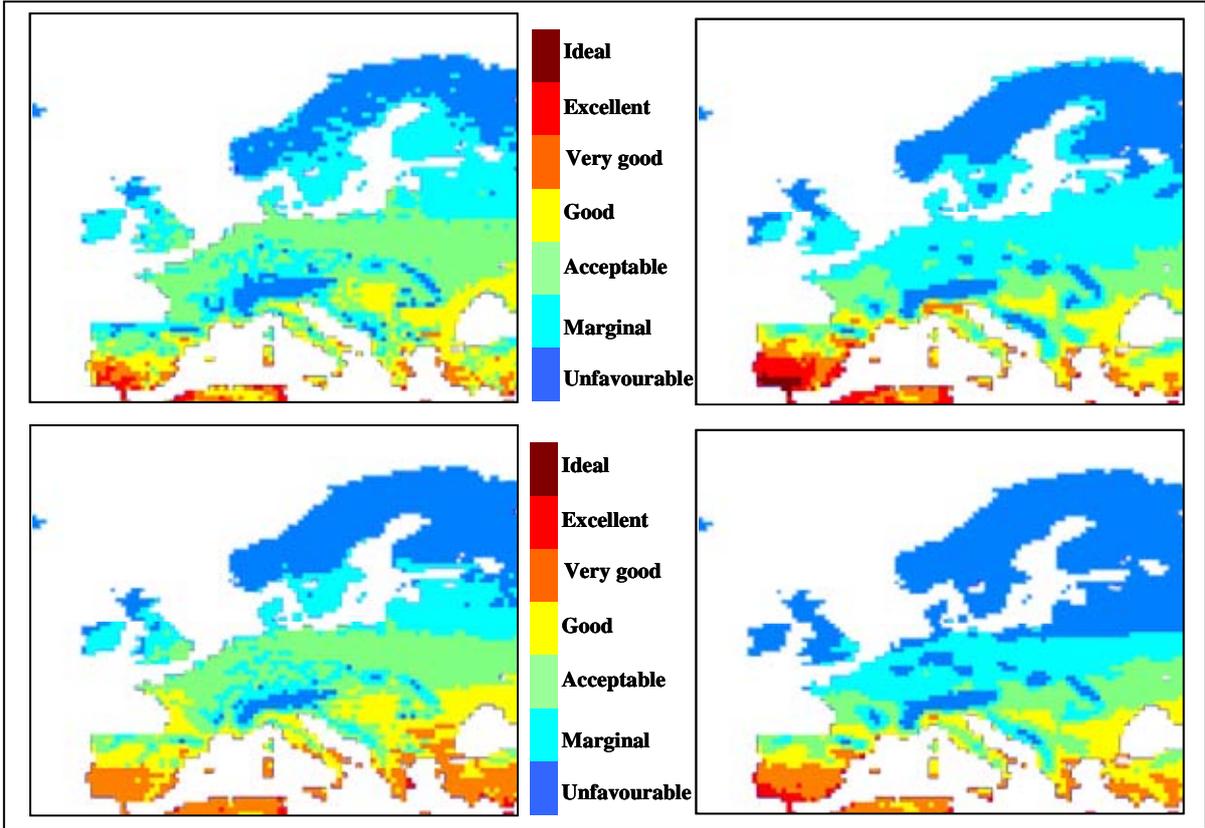
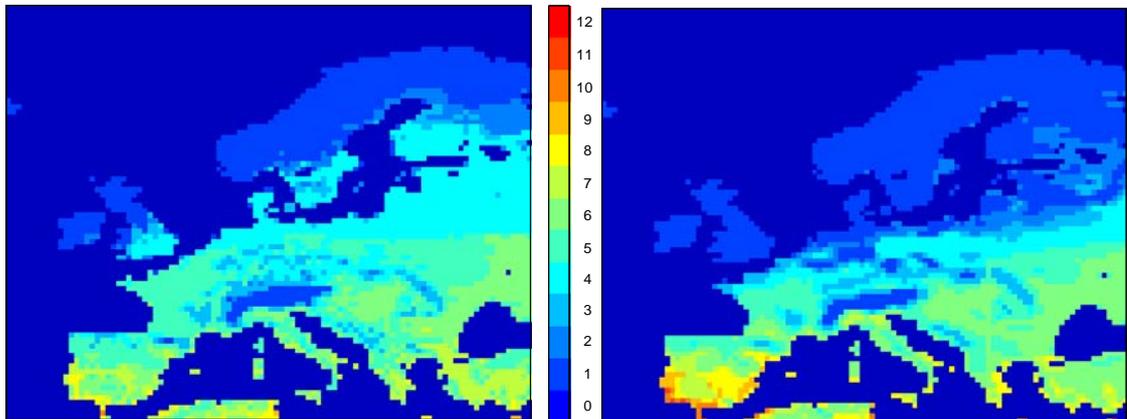


Figure 7. Average number of months per year with $TC > 70$, i.e. number of months with very good conditions or better, in the 1970s according to the HIRHAM model (left) and the RCAO model (right)



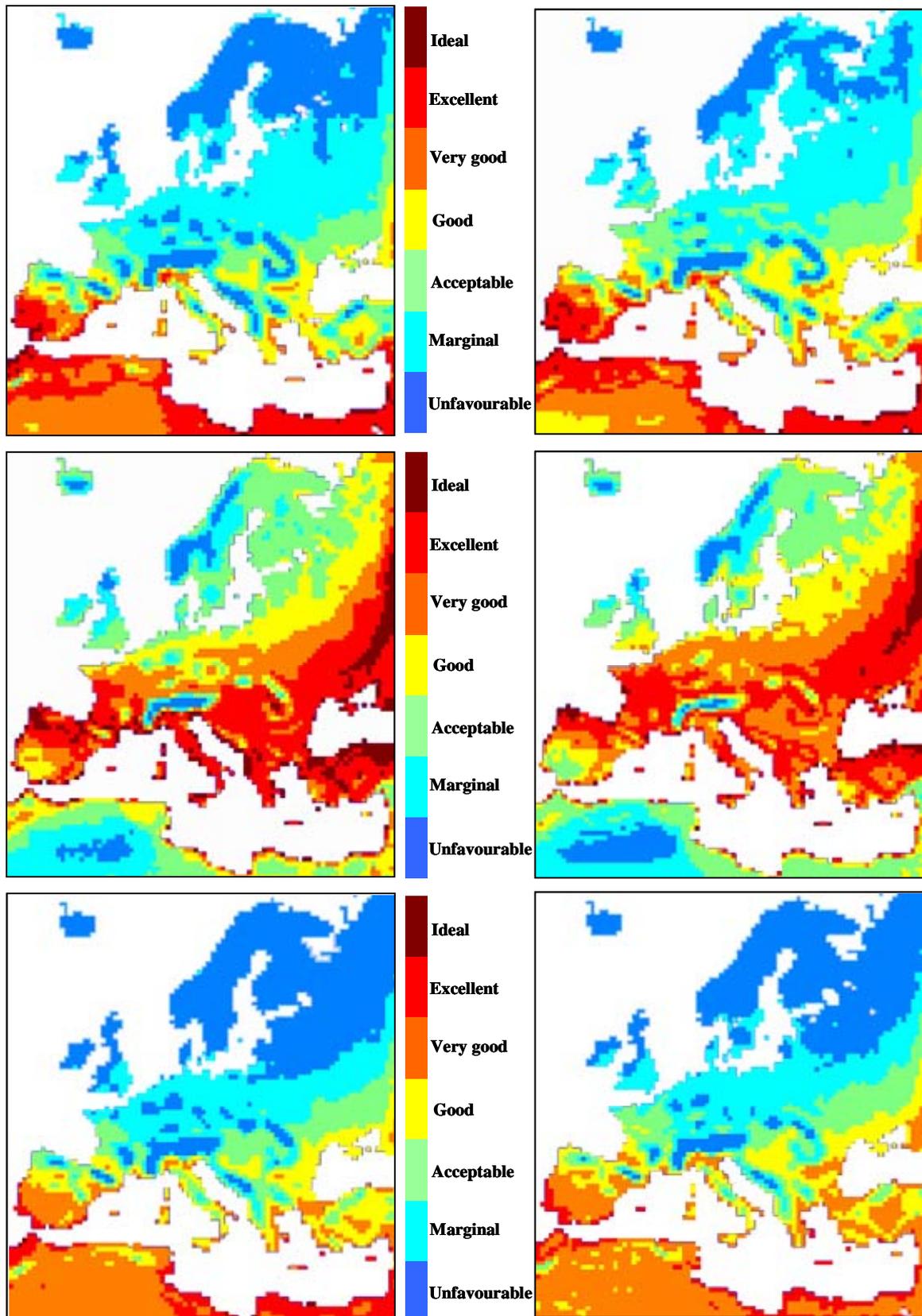
3.2. Light outdoor activities: future

To assess the impact of climate change on the distribution of climatic resources for Europe, simulated data were fed into the TCI model. The results are presented by time slice ('2020s' and '2080s') and by season.

3.2.1. Changes between the 1970s and the 2020s

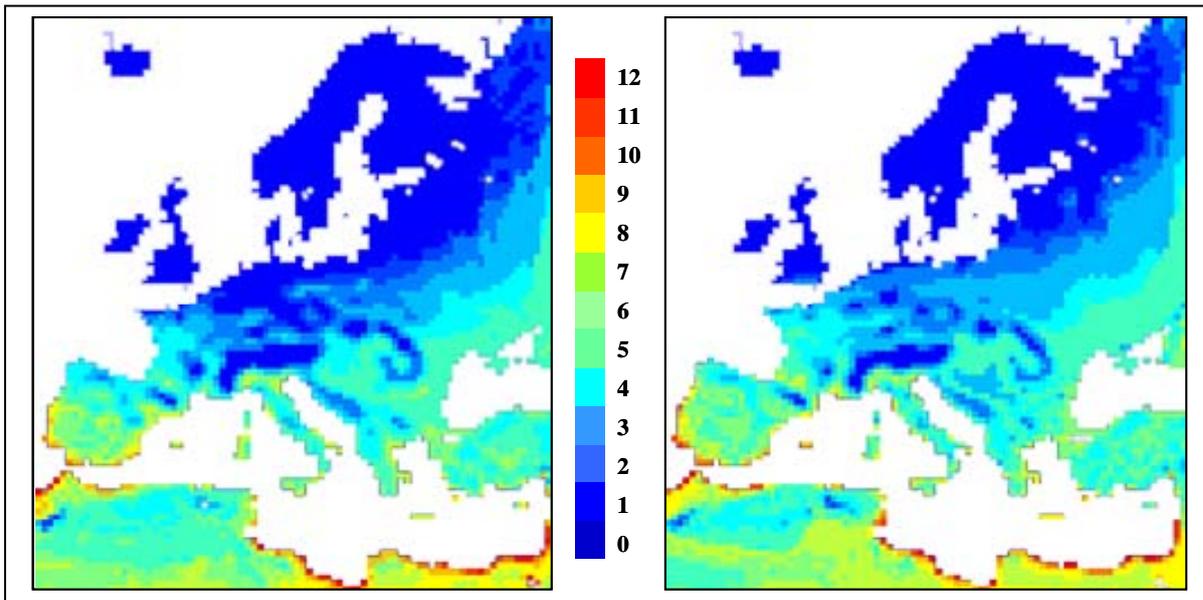
Although changes between the baseline ('1970s') and the 2020s are modest, certain trends are becoming visible. In all three seasons (winter is disregarded, because conditions remain unfavourable in almost the whole of Europe), there is a poleward trend in TCI patterns (see Figure 8). In spring and autumn, these changes are small, but they are positive in most areas of Europe. Changes are most significant in the Mediterranean region, where the area with very good to ideal conditions increases. In more northern regions, conditions improve but remain acceptable at best. In summer, changes are mixed. In the interior of Spain and Turkey, in parts of Italy and Greece, and in the Balkans, conditions deteriorate. In the northern and western parts of Europe, however, TCI scores increase.

Figure 8. TCI scores in spring (top), summer (middle) and autumn (bottom) in the 1970s (left) and the 2020s (right) according to the Rossby Centre RCA3 model



The net effect of the changes in spring, summer and autumn (winter is irrelevant) are shown in Figure 9. This Figure depicts the number of months with a TCI above 70 ('very good months') in the 1970s (left) and the 2020s (right). The changes between the two periods are clearest in northwestern Europe, where some areas increase their season length by one or two months.

Figure 9. Average number of months per year with $TC > 70$, i.e. number of months with very good conditions or better, in the 1970s (left) and the 2020s (right) according to the Rossby Centre RCA3 model



3.2.2. Changes between the 1970s and the 2080s

By the end of the 21st century, the distribution of climatic resources in Europe is projected to change significantly. All four model-scenario combinations agree on this, but the magnitude of the change and the evaluation of the initial conditions differ.

For the **spring** season (see Figures 10 and 11), all model results show a clear extension towards the north of the zone with good conditions. Compared to the RCAO model, the Hirham model projects relatively modest changes. In the HIRHAM-A2 scenario, spring conditions will have become very good to excellent in most of the Mediterranean by the end of the century. Good conditions are projected to be more frequent in France and the Balkans. The same tendency is visible in the B2 scenario, albeit at a slower pace.

The direction of change in the RCAO model runs is similar, but its magnitude is much larger. Excellent conditions, which are mainly found in Spain in the baseline period, will have spread across most of the Mediterranean coastal areas by the 2080s. In the northern part of continental Europe, conditions improve markedly as well, from being marginal to good and even very good.

In **summer** (see Figures 12 and 13), the zone of good conditions also expands towards the North, but this time at the expense of the south. In the HIRHAM models, conditions will become excellent throughout the northern part of continental Europe, as well as in Finland, southern Scandinavia, southern England and along the eastern Adriatic coast. At the same time, climatic conditions in southern Europe deteriorate enormously. In parts of Spain, Italy, Greece, and Turkey, TCI scores in summer go down by tens of points, sometimes dropping from excellent or ideal (TCI>80) conditions to marginal conditions (TCI between 40 and 50).

These summertime losses are even larger, and more extensive geographically in the RCAO model runs. In the B2 scenario, much of the Mediterranean, and in the A2 scenario even much of the southern half of Europe loses dozens of TCI points, ending up in the marginal-good range, down from the very good-ideal range the region was in during the 1970s. Interestingly, according to the RCAO model, the changes are so quick that the belt of optimal conditions will move from the Mediterranean all the way up to the northern coasts of the European continent and beyond. In the A2 scenario, excellent conditions can only be found in a very narrow coastal area, stretching from the North of France to Belgium and the Netherlands, and in some coastal areas in Poland. According to these results, the improvement in conditions in the northern half of Europe may be short-lived, although the UK and Scandinavia may have more time to benefit.

Changes in **autumn** (see Figures 14 and 15) are more or less comparable to the ones in spring. TCI scores improve throughout Europe, with excellent conditions covering a larger part of southern Europe and the Balkans. TCI scores in the northern parts of Europe remain lower than in the south, but the improvements are significant. Large areas attain good conditions (in the HIRHAM model, up from acceptable ones) or acceptable conditions (in the RCAO model, up from marginal ones).

Projected changes in **winter** (see Figures 16 and 17) are of much less interest than the changes in other seasons, as most of Europe is and will remain unattractive for general

tourism purposes (not winter sports!) in winter. There are some changes, however, in the southern-most areas in Europe. In particular in the south of Spain, conditions are projected to improve from being unfavourable to marginal or even acceptable.

Figure 10. TCI scores in spring in the 1970s (left) and the 2080s (right), according to the HIRHAM model, A2 (top) and B2 (bottom) scenarios

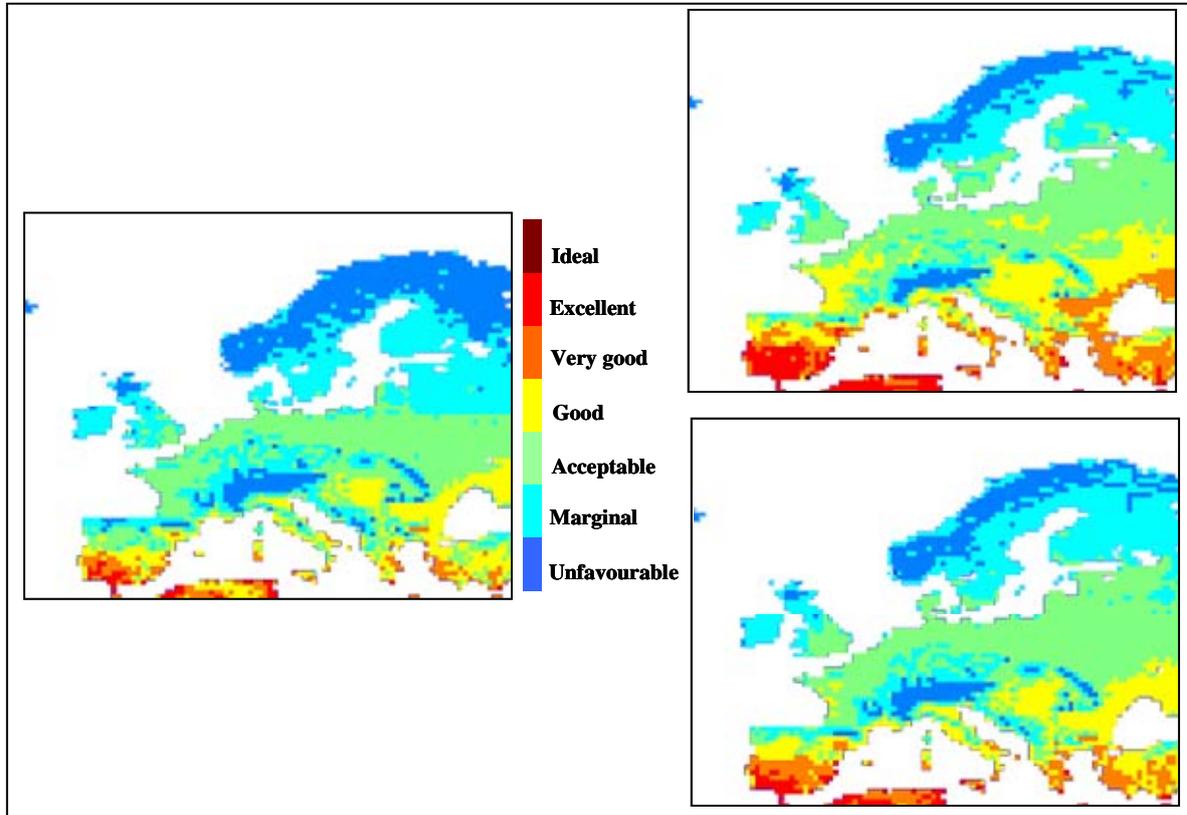


Figure 11. TCI scores in spring in the 1970s (left) and the 2080s (right), according to the RCAO model, A2 (top) and B2 (bottom) scenarios

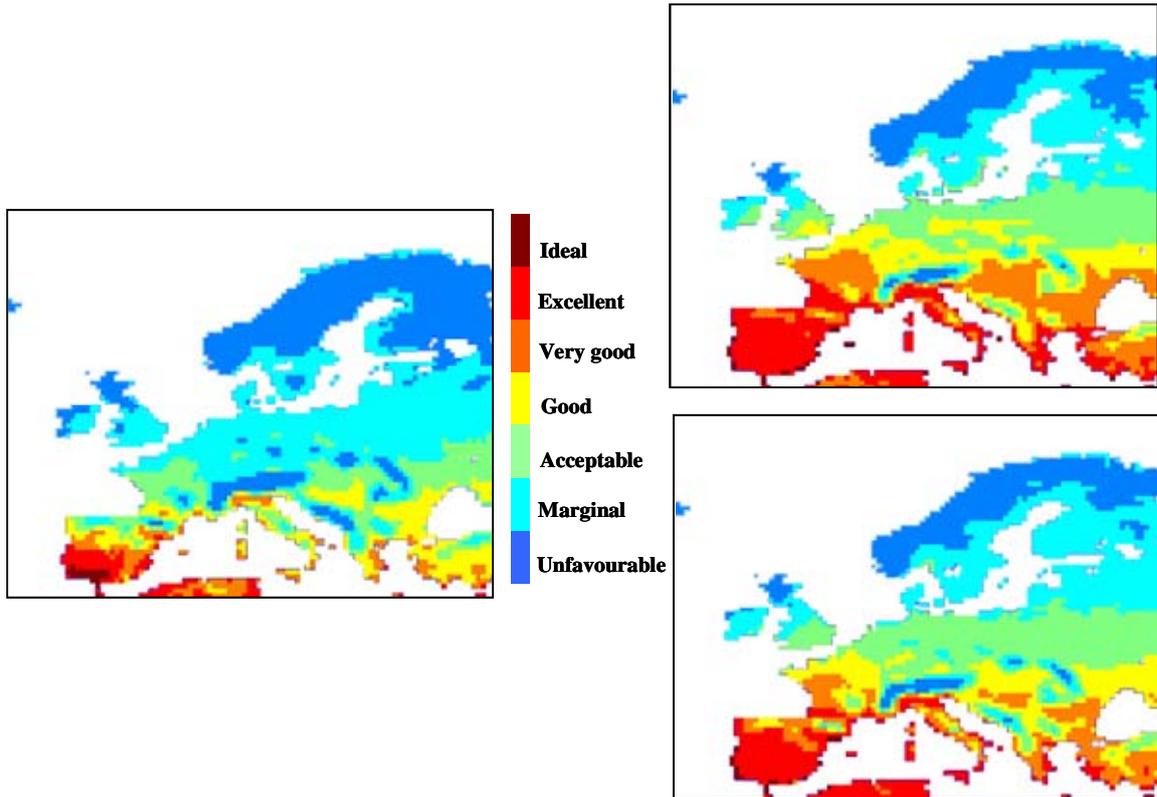


Figure 12. TCI scores in summer in the 1970s (left) and the 2080s (right), according to the HIRHAM model, A2 (top) and B2 (bottom) scenarios

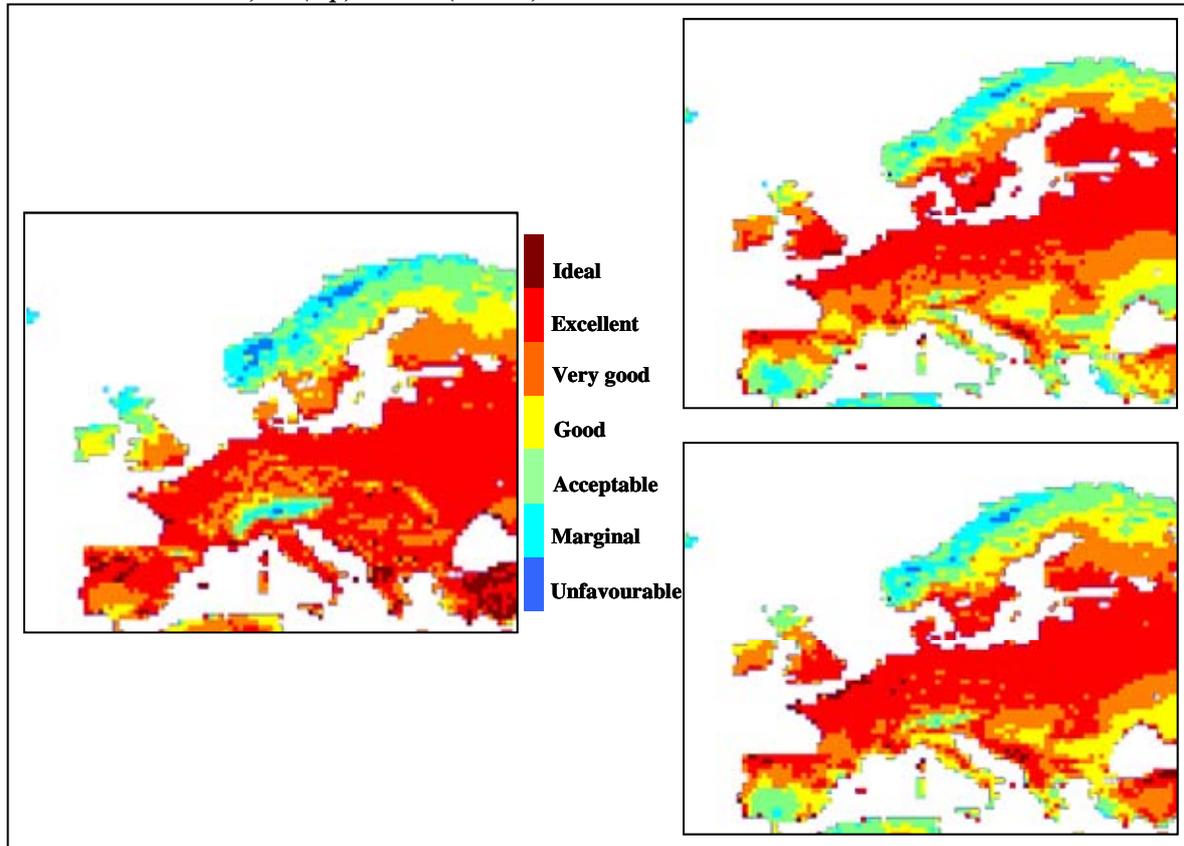


Figure 13. TCI scores in summer in the 1970s (left) and the 2080s (right), according to the RCAO model, A2 (top) and B2 (bottom) scenarios

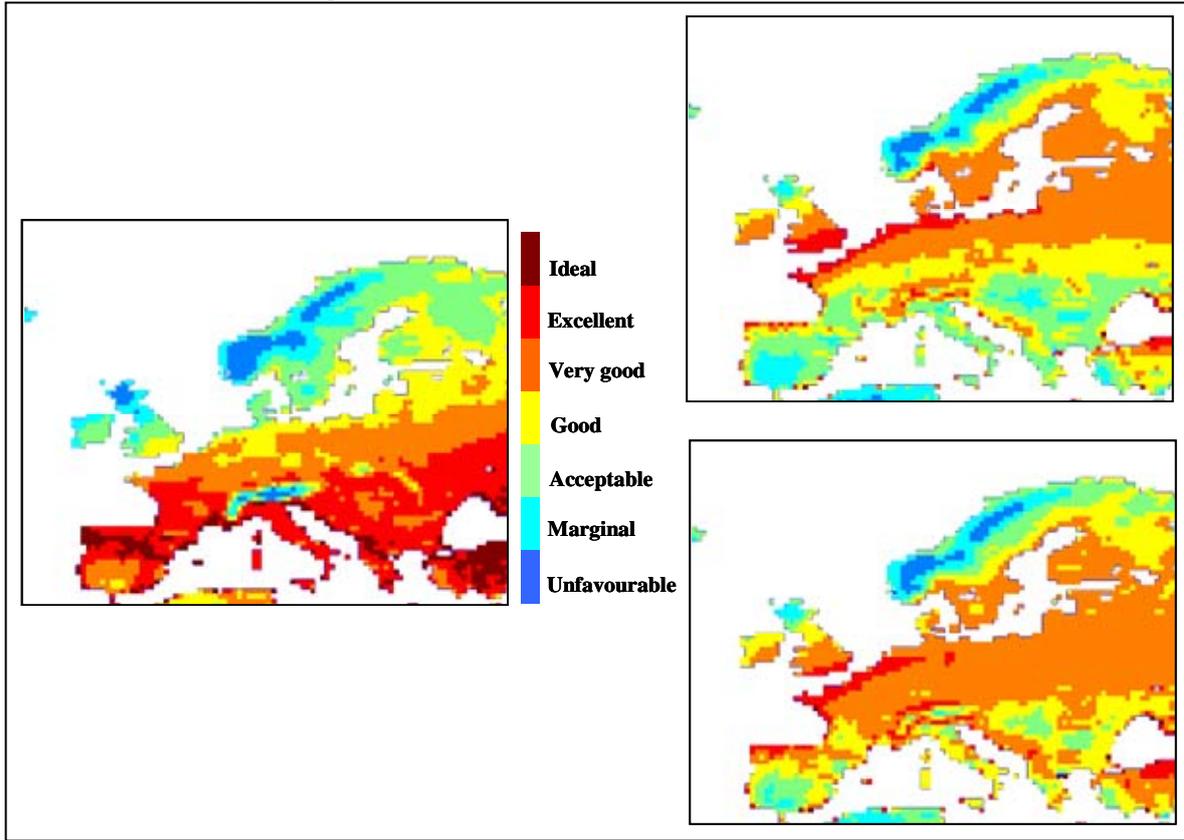


Figure 14. TCI scores in autumn in the 1970s (left) and the 2080s (right), according to the HIRHAM model, A2 (top) and B2 (bottom) scenarios

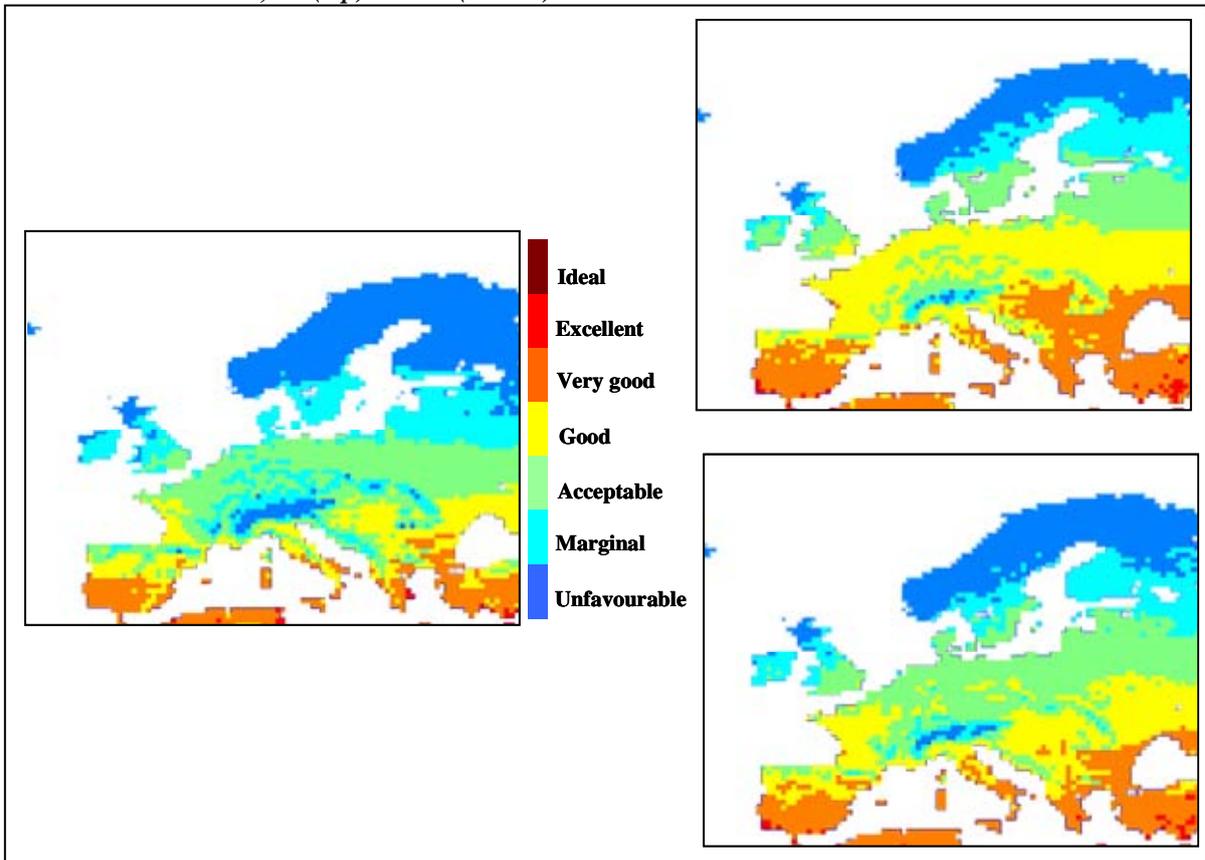


Figure 15. TCI scores in autumn in the 1970s (left) and the 2080s (right), according to the RCAO model, A2 (top) and B2 (bottom) scenarios

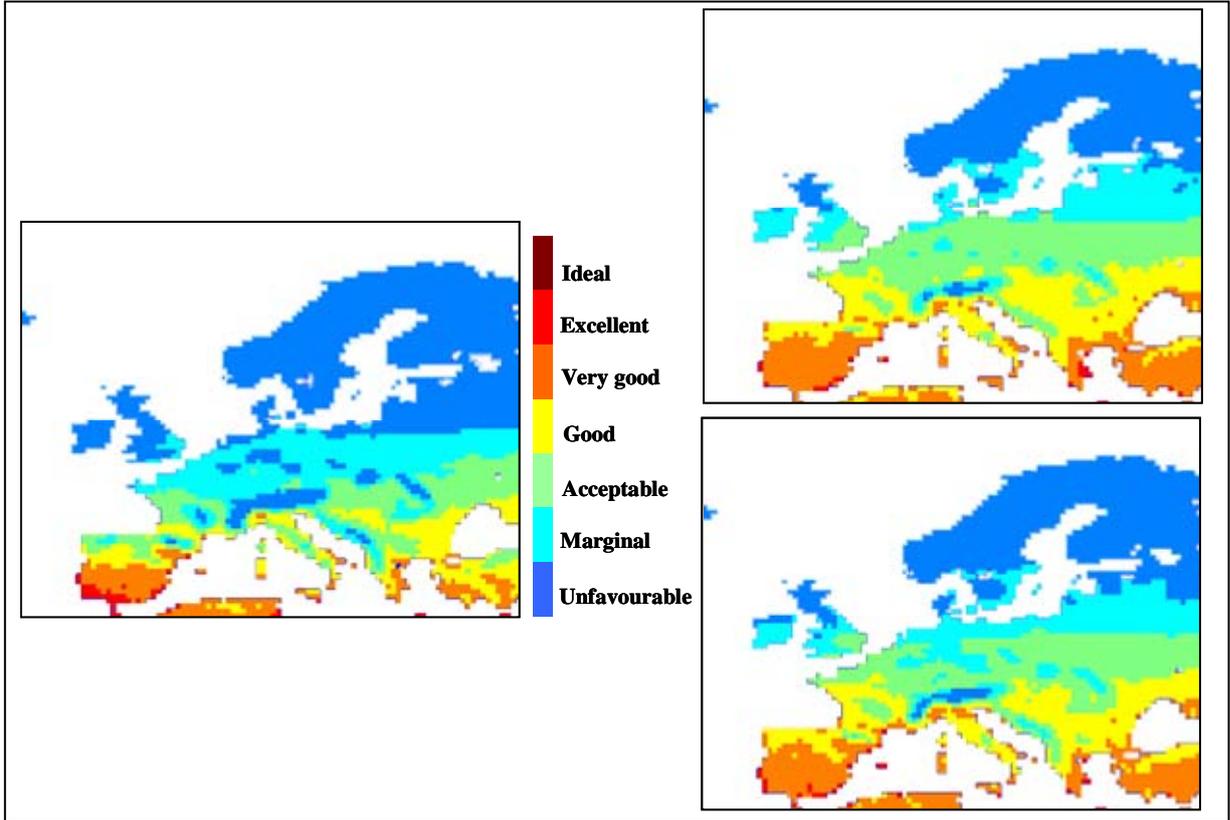


Figure 16. TCI scores in winter in the 1970s (left) and the 2080s (right), according to the HIRHAM model, A2 (top) and B2 (bottom) scenarios

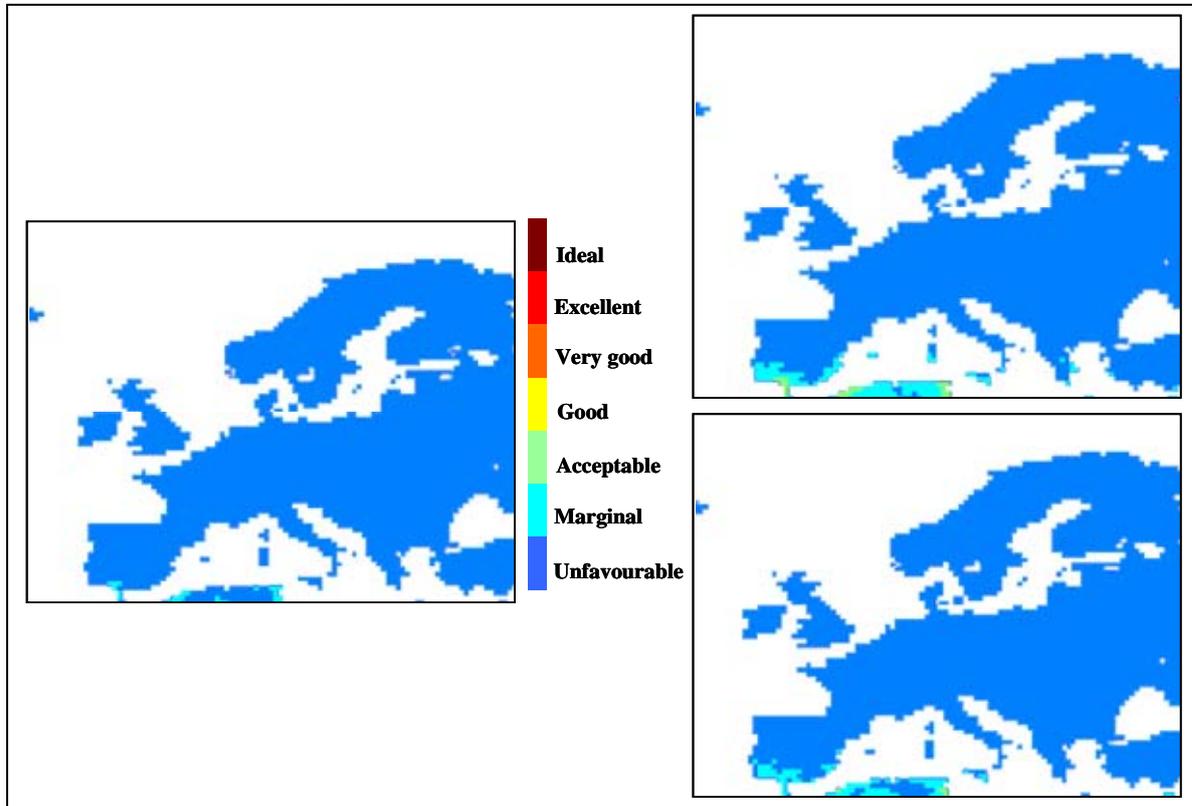
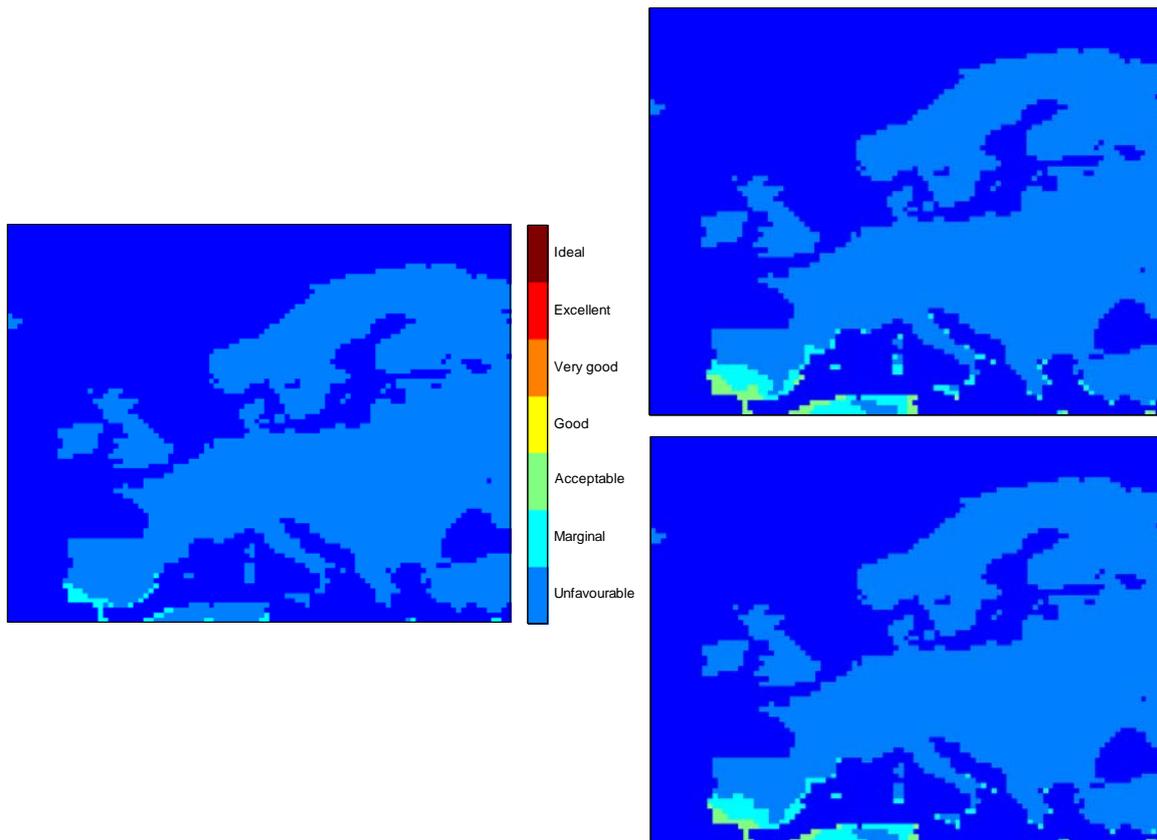


Figure 17. TCI scores in winter in the 1970s (left) and the 2080s (right), according to the RCAO model, A2 (top) and B2 (bottom) scenarios



3.2.3. Changes in Seasonality

The changes that have been discussed above have significant changes for the length of the ‘holiday season‘ (in a climatic sense) in Europe. This season length is defined here as the number of months with very good conditions (TCI>70), as described above. Currently, southern Europe has significantly more good months than northern Europe. Under the influence of climate change, this is projected to change, however. In both the HIRHAM and the RCAO model (see Figures 18 and 19), season length will become much more evenly distributed across Europe. The dominant trend in southern Europe is a decrease in good months in summer, whereas in northern Europe there will be an increase in good months in summer, spring and autumn. Interestingly, a coastal strip in southern Spain and Portugal is projected to maintain or even increase (HIRHAM-A2) its current season length.

Figure 18. Average number of months per year with very good conditions or better ($TCI > 70$), in the 1970s (left) and the 2080s (right), according to the HIRHAM model, A2 (top) and B2 (bottom) scenario

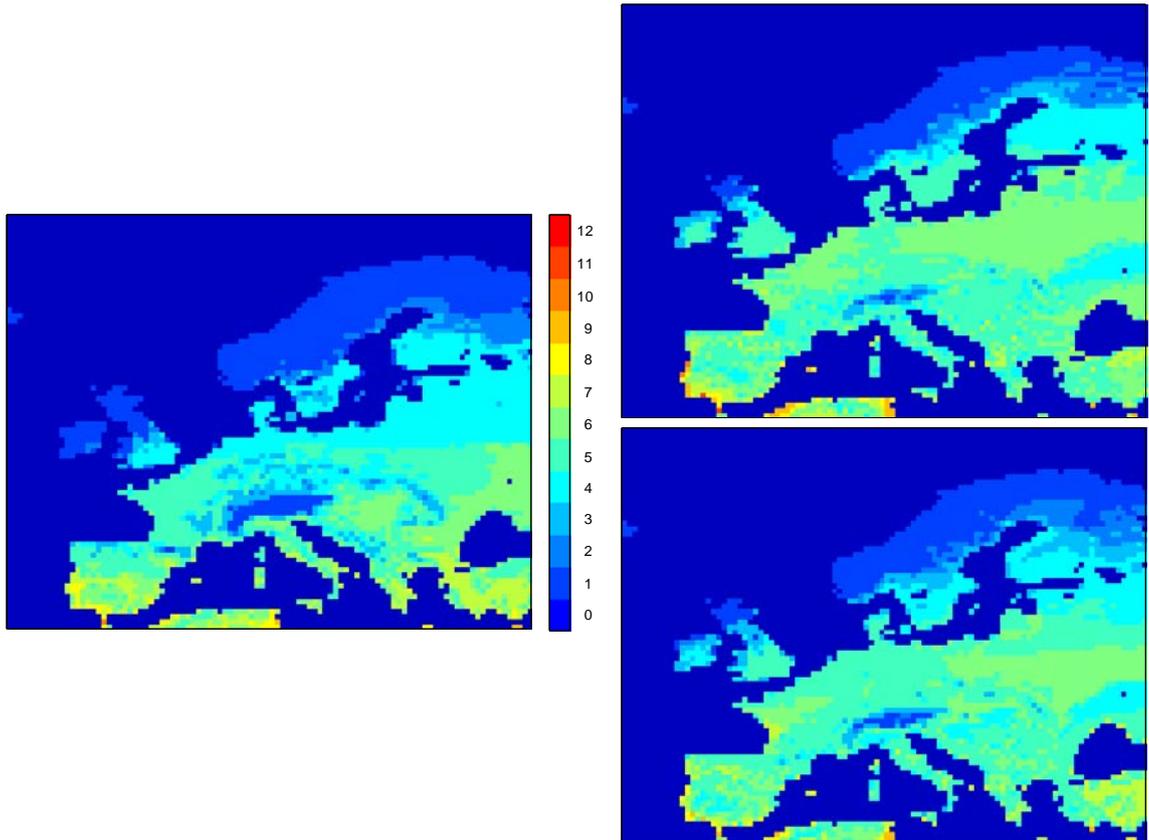
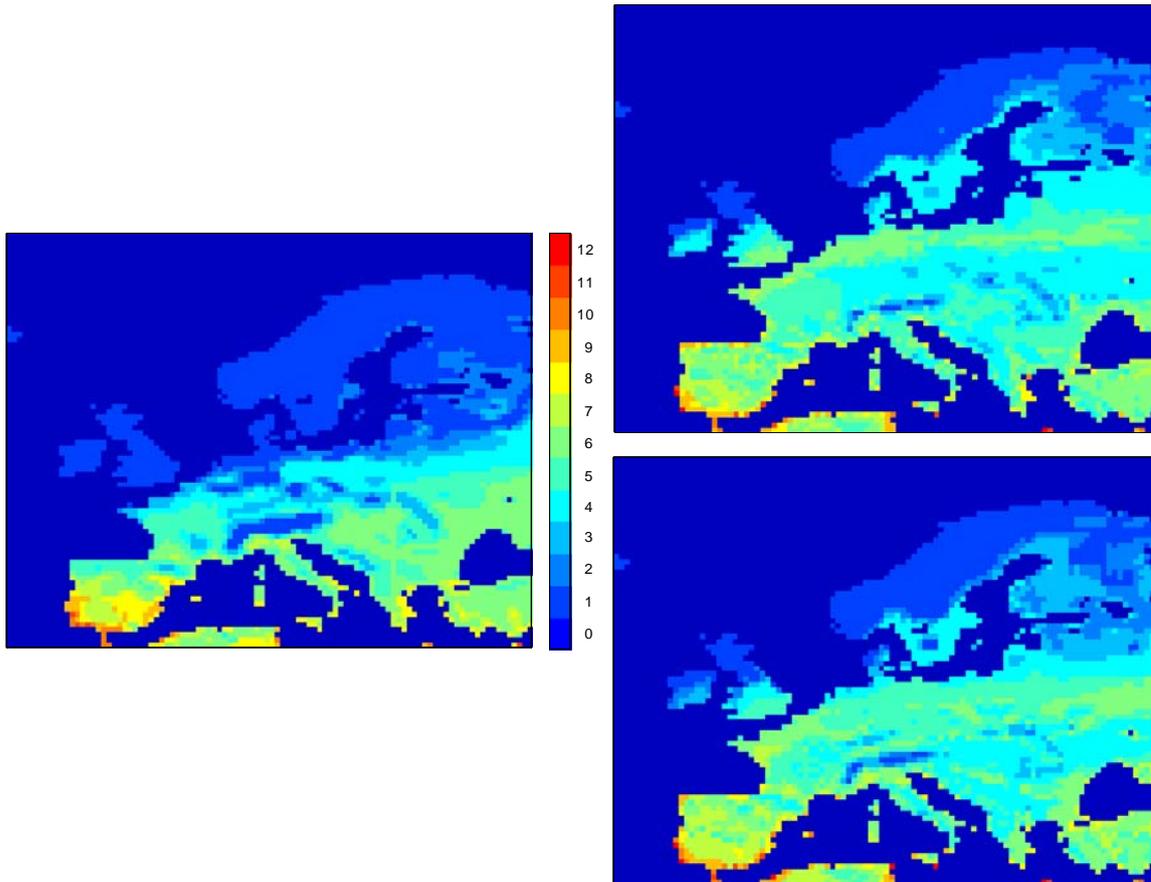


Figure 19. Average number of months per year with very good conditions or better ($TCI > 70$), in the 1970s (left) and the 2080s (right), according to the RCAO model, A2 (top) and B2 (bottom) scenarios



3.3. Freshwater and tourism

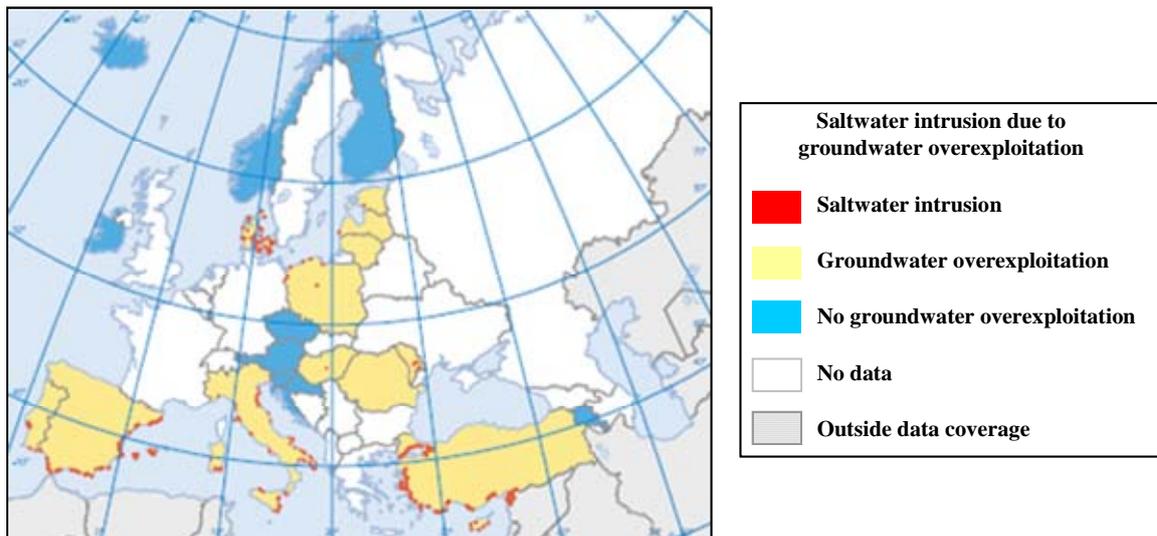
Tourism activities and facilities, such as establishments for accommodation, have direct impacts on the environment and its resources, presenting a number of challenges for the management of water supplies. The most popular tourism destinations in Europe are in general located around the Mediterranean, in those regions with warm climate and little rainfall mainly during the summer period. However, those regions are naturally subject to cyclical periods of drought.

The annual arrival of tourists increases the demand for water well beyond the normal requirements of the resident population and the capabilities of local water sources. When the amount of water available is insufficient to cover the necessities of every sector, conflicts about its use can arise. The seasonal character of coastal tourism and its geographical concentration (especially in Mediterranean countries where water is scarce), is an important

pressure at regional and local level and competes with other water users, especially agriculture. An increase in the level of water extraction together with the occurrence of several years of droughts has produced multiple problems in Southern European countries, especially sea water intrusion and conflicts between different users.

Sea water intrusion is a direct consequence of the overexploitation of aquifers (see Figure 20), and has serious implications for the water resources of a region, with tourism being an important element contributing to this phenomenon. The seasonal concentration of tourists during the summer months, when water is scarce already, leads to increased pressure on water resources in the coastal zone. Subsequently, withdrawal of water exceeding the recharge rate leads to overextraction and lowering of the groundwater table and therefore to the intrusion of seawater and the deterioration of water quality in coastal aquifers. García and Servera (2003) reported that 7 out of the 21 aquifer units in Mallorca have severe problems associated with salt-water intrusion, finding that those overexploited aquifers are located precisely in the most developed tourist zones.

Figure 20. Saltwater intrusion due to groundwater overexploitation



Source: EEA, 2003.

The scarcity of water intensifies competition between different users. In the case of the Mediterranean, the conflicts between tourism development and agriculture, especially in irrigated areas, have been the focus of attention in the last few years. Examples are Andalusia, Murcia and Valencia (Spain), where the use of water for golf courses and other tourist facilities has met with strong opposition from the agricultural sector.

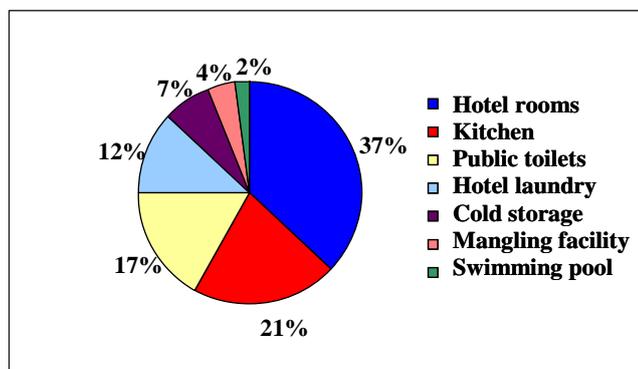
3.3.1. Water resources: present situation

Different studies have analysed the use of water by tourists and the facilities developed for tourism in several destinations. According to the EEA (2003) tourists consume 300 litres of water per day on average, with amounts up to 880 litres per day for those staying in luxury hotels, a quantity much higher than the use by local residents.

In the French province of Provence-Côte d’Azur the tourist population attains 1.7 million in summer, increasing the total population by 50%, and more than doubling water demand. In certain Greek islands (e.g. the Cyclades), water demand in summer can be 5 to 10 times as large as in winter. One of the consequences of this seasonality is the necessity of using infrastructures (production equipments and distribution systems) that are much larger than needed for the permanent population.

In their study about water resources and tourism on the island of Mallorca, Essex et al. (2004) refer to previous studies about water consumption by tourist in different regions. He reports that on Barbados tourists use 6 to 10 times more water than locals; on the east coast of Zanzibar a survey of 28 tourist accommodation businesses (accounting for 2570 beds) found that the average per capita water demand of tourists was 685 litres per day, which was about 15 times the average daily demand of a local resident. At the same time 15,000 cubic metres of water would typically supply 100 rural farmers for three years and 100 urban families for two years, yet only supply 100 luxury hotel guests for 55 days. Figure 21 provides some insight into the main components of water demand from tourism.

Figure 21. Water consumption by hotel per type of use



Source: Inter-Continental Hotels and Resorts, 1996

Figure 22 represents current water stress levels for European basins. Basins with severe water stress are concentrated in the Mediterranean region, with the exception of some areas around big northern European capitals. Figure 23 depicts the total volume of tourist arrivals in the NUTS2 regions. When comparing both maps the conclusion is that in general terms, those regions receiving the greatest numbers of tourists are also the regions where water stress is more significant.

Figure 22. Water stress levels in Europe under current conditions

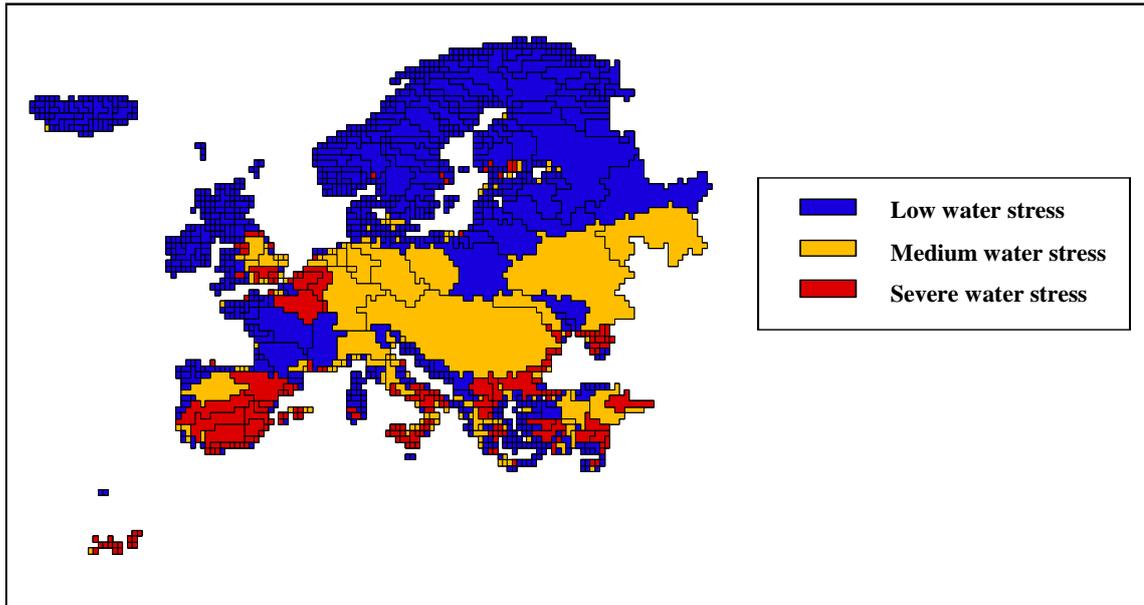
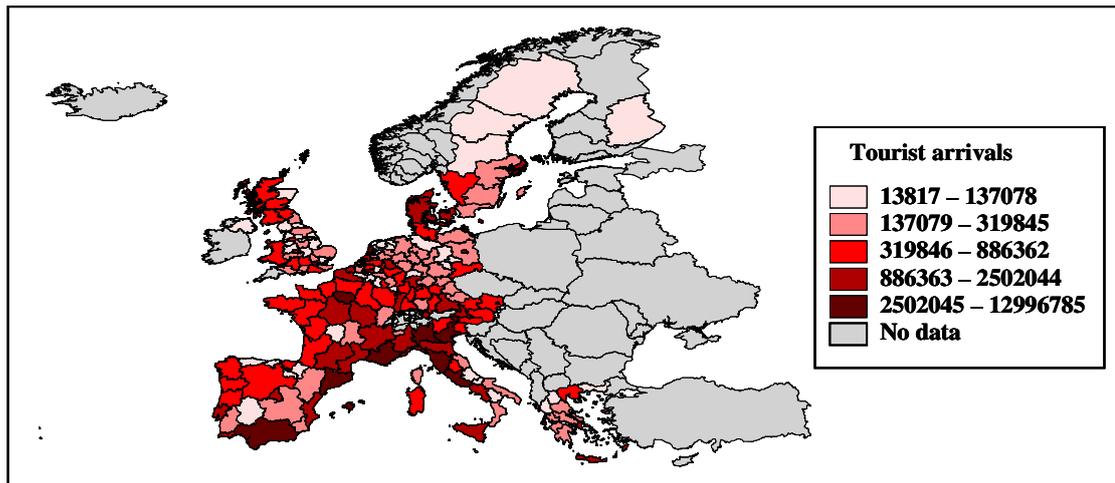


Figure 23. Tourist arrivals in NUTS 2 regions



The case of Spain provides an illustration of the resulting problems. The focus is on one of the Mediterranean countries since they are the most affected by water stress, and also suffer the highest tourism-related pressure on their water resources. The tourist market in Spain, as in the other Mediterranean countries, is characterised by a high spatial and temporal

concentration, with the highest densities of visitors found during the summer months when water resources are scarce and water demand from agriculture is high.

The phenomenon of seasonality in tourism amplifies the pressure on freshwater, endangering the sustainability of the water system. De Stefano (2004) reports that water consumption during the peak tourism month in 1999 in the Balearic Islands was equivalent to 20% of that used by the local population in a whole year and that water consumption has increased by about 80% since 1994. Margat et al. (2000) point out that the population size of 27 municipalities on the Costa Brava swells from 150.000 in winter to 1.1 million in Mid-August.

Table 4. *Evolution of water demand (Mm³/year) in Balearic Islands*

Sector	1980		1990		1995	
	Mm ³ /year	%	Mm ³ /year	%	Mm ³ /year	%
Urban	41.8	13.7%	63	19.5%	71.8	25%
Tourism	14	4.6%	22.5	7%	34.1	11.8%
Total Urban and Tourism	55.8	18.3%	85.5	26.5%	105.9	36.8%
Agriculture	249	81.7%	237	73.5%	182	63.2%
Total	304.8		322.5		287.9	

Source: Fayas et al. (1998).

The second-home market has had a tremendous growth along the entire Mediterranean Spanish coast. De Stefano reports that of every 100 houses built in Alicante, 60 are for the second-home market. Foreign tourists (80% from Germany and UK) own 240.000 houses in the province of Alicante, which is the province of Spain with the highest number of residents coming from other EU countries. The construction of second-homes is usually accompanied by the construction of residential complexes with gardens and swimming pools that need comparatively more water than flats with terraces. Moreover, attempts to attract tourists with higher purchasing power have been associated with the creation of water-demanding leisure facilities such as golf courses. It is expected that the number of golf courses in the province of Valencia will increase threefold in the coming 10-50 years, and that Murcia will host 39 golf courses within 10 years (De Stefano, 2004). In Mallorca the number of golf courses has increased from 5 in 1980 to 13 in 2000 and 22 in 2006 (Balearic Golf Federation, 2006), and another 16 are planned (Ecologistas en Accion, 2006). According to Essex et al. (2004) the water demand of the 269 hectares of golf courses in Mallorca in 1994 was 3.24 million m³.

The combination of water-intensive tourist activities and irrigation has led to the overexploitation of 20% of the aquifers (e.g. 25% in the Jucar river basin and 4% in the Balearic Islands) (De Stefano, 2004). Essex et al. (2004) report that the water table in the main aquifer of Mallorca had been lowered by 110 m during the period from 1973 to 1994, and drops of 4-6 meters were recorded for some aquifers between 1993 and 1994 alone (Essex et al., 2004). Aquifer overexploitation has led to saline intrusion in many aquifers of Spain, becoming a major problem that affects the quality of the freshwater supply and puts the sustainability and future of the tourism industry at risk.

3.3.2. Water resources: future

The exploration of future water availability and especially water stress is based on the work done by Alcamo et al. (2006). This study investigates different variables related to water resources in the future, “analyzing and comparing the impact of not only climate change and population but also changes in income, water use efficiency, electricity production and other socio-economic variables”. The work is derived from the scenarios A2 and B2 of the IPCC, and the climate models used are the ECHAM4 and HadCM3 general circulation models. The time frames included are 2020s and 2080s, although in this report only the results for the 2080s are shown. The resolution of the database is on a river basin scale.

Two indicators have been selected for the analysis of pressure on the water resources: the annual withdrawal-to-availability ratio (wta) and the water availability per capita. The first indicator is calculated by dividing the water extracted from surface or groundwater sources by the total annual water availability on a river basin scale.

$$\frac{\text{Total water withdrawals (mm/yr)}}{\text{Total water availability (mm/yr)}} \times 100$$

Water withdrawals encompass all withdrawals by the domestic, industry, irrigation, and livestock sectors. For current conditions the value of this parameter corresponds to the water withdrawn in 1995.

Water availability refers to the long term average potential water availability of the river basin calculated under consideration of the climate normal (1961-1990) and the future projections

(HadCM3 or ECHAM4 climate model; A2 or B2 scenario; 2020s or 2080s time frame). To calculate water availability, surface runoff and groundwater recharge are combined. Thus, reduction by use is not considered.

The withdrawals-to-availability ratio represents the intensity of pressure put on water resources and aquatic ecosystems by external drivers of change. The larger the volume of water withdrawn, used and discharged back into a river, the more it is degraded or depleted, and the higher the water stress. The division into categories of this indicator is done based on the work by Cosgrove and Rijsberman (2000), and is as follows:

Low water stress	$W_{ta} < 20\%$
Medium water stress	$20\% \geq W_{ta} < 40\%$
Severe water stress	$W_{ta} \geq 40\%$

For a detailed description of all the variables and the construction of the database, see Alcamo et al. (2006)

The available data do not allow for a tourism-specific study of water consumption. However, it is possible to study which regions will experience water stress and to what degree and compare those regions to the ones that have a large presence of tourism. Even if this methodology does not permit a quantitative evaluation of water consumption by tourists, it provides insight into the regions where pressure on water resources could be high and where conflicts between different users might arise as a consequence of water scarcity. The combination of water availability and tourism scenarios will therefore permit an exploration of the possible future relationships between both variables.

The analysis based on the work by Alcamo et al. (2006) shows that in general there is an increase in the number of river basins that experience severe water stress in the 2080s, with the largest increase taking place under scenario A2 (see Figure 24).

Figure 25 depicts the basins in which the variable “water availability per capita” decreases both in scenarios A2 and B2. As it can be seen coastal areas will be among the regions that are likely to suffer a decrease in the availability of water per capita. If the current trend in the number of visitors to the Mediterranean region continues in the future, a plausible image could be an increase of the pressure on water resources. In that case, the seasonality of the

tourism phenomenon together with its spatial concentration could reinforce the stress on the available water and its use and management. Therefore, water resources could have an important influence on future tourist development plans; the lack or scarcity of water could have an effect even greater than the consequences of climate on tourist comfort, substantially limiting the growth and sustainability of the sector in some areas.

Figure 24. *Water stress (withdrawals-to-availability) in Europe under current conditions (18a, left) and in 2080s according to the HadCM3 model in A2 scenario (18b, top right) and B2 scenario (18c, bottom right)*

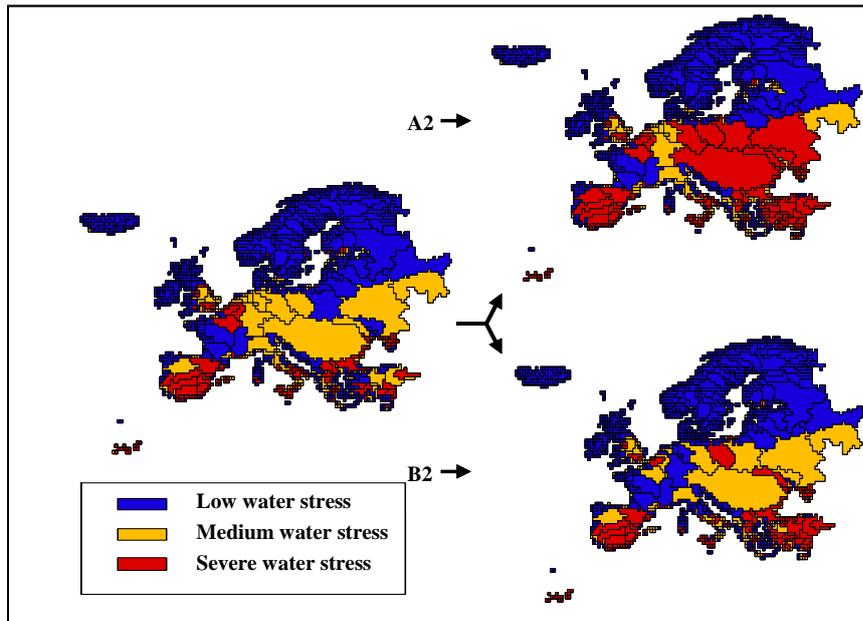
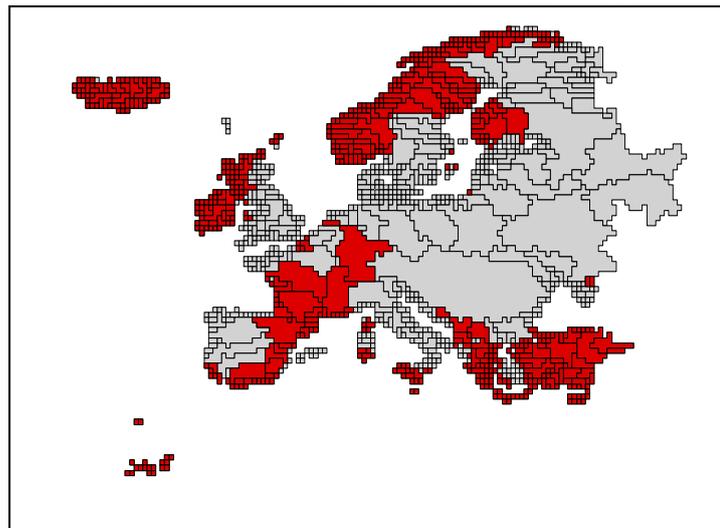


Figure 25. *River basins where the availability per capita decreases from current conditions to the 2080s both in scenarios A2 and B2 with the climate model HadCM3*



It is important to mention that maps like the one in figure 24 depict general patterns and hide monthly distributions. A temporal change in the arrival of tourists could be of importance for Mediterranean countries since a more even spread of arrivals over the months of the year

could counteract the negative effect of concentration during the summer months, when the demand for water is high and its availability limited. At the same time, changes in the spatial distribution of tourists will have consequences for the water resources of the new resorts, influencing the use and management of those resources and possibly affecting the development of more sustainable models of tourism.

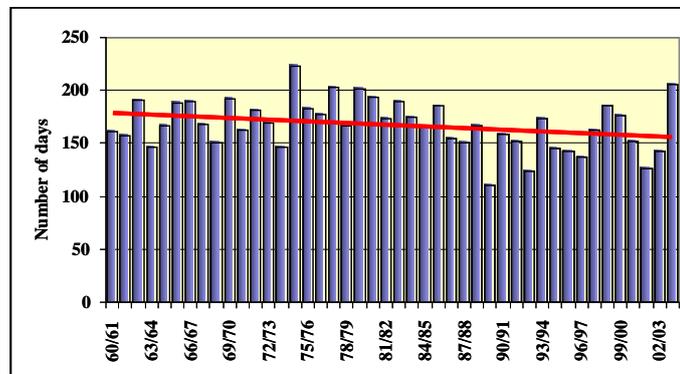
3.4. Winter sports

For winter sports, attention is focused on France and Austria, the dominant countries in the EU winter sports business. Relevant developments in the non-member state of Switzerland are also mentioned.

3.4.1. France

The recent evolution of snowfall in the mountain regions of France is represented in Figure 26. The data correspond to the number of days with snow, as measured by the meteorological station of Col de Porte (1320 meters), located in the Jura, for the last 40 years. The general tendency that can be observed for this and other stations is an important decrease in the number of days with snow, although there is still significant variability between consecutive years.

Figure 26. Annual number of days with snow in Col de Porte, 1960-2003



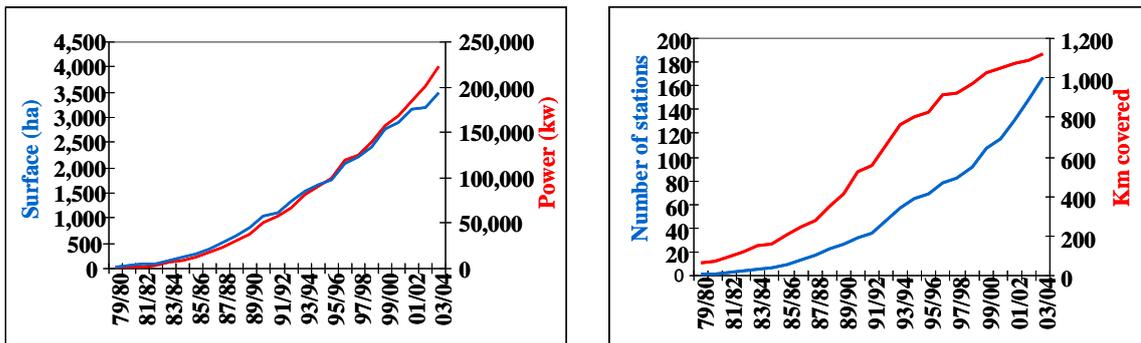
Source: SEATM (2004).

The decrease in the reliability of natural snow since the 1960s together with the inter-annual irregularity of its presence have led the ski businesses to adopt adaptation strategies such as the installation of snow making technology. The installation of this kind of infrastructures has been increasing since the first snow cannons were set up in the late 1970s. Since then, many resorts have seen the necessity of recurring to this kind of technology in order to guarantee the length of the snow season and the economic sustainability of the station (Figures 27 and 28).

The reduction in snowfall has been object of study by the French Meteorological Institute. Based on data for the last 50 years, Meteo France developed the CROCUS model, which calculates the snow-cover based on the meteorological parameters on the surface (temperature, humidity, wind, etc). Assuming a temperature increase of 1.8°C, the projections for stations located at 1500 meters of altitude indicated that the snow season (number of days with snow) will be 40 days shorter (Figures 29 and 30) than in current conditions.

Figure 27. Surface covered by snowmaking technology and power installed since 1979 (left)

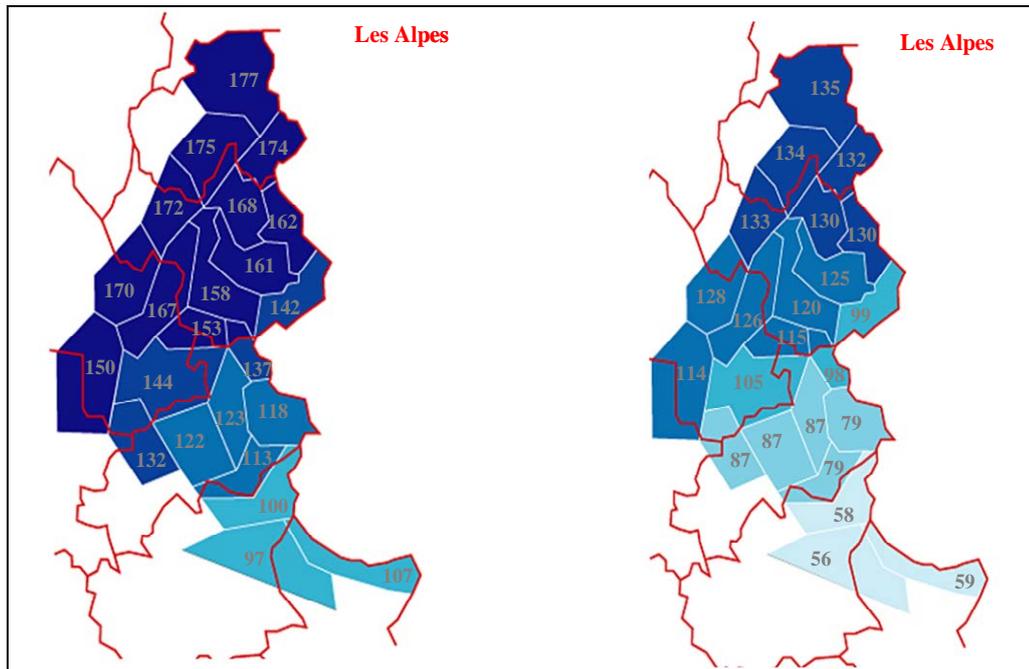
Figure 28. Number of stations with artificial snowmaking and kilometres covered since 1979 (right)



Source: SEATM (2004).

Figure 29. Mean length of the snow cover (in days per year) at 1500 meters in the Alps. Current situation (left)

Figure 30. Mean length of the snow cover (in days per year) at 1500 meters in the Alps. Situation with an increase of 1.8 degrees (right)



Source: SEATM (2004).

3.4.2. Austria

Tourism in Austria plays an outstanding economic role in comparison to other European countries (Feilmayr, 2004). Revenues of tourism add up to more than €14,2 billion, and the contribution to GDP is approximately 18%. Winter-sports tourism in Austria is as important as summer tourism. The number of bed nights spent in winter is lower than in summer, but the revenues during winter are 1 billion higher than during summer. Clearly, Alpine rural areas are highly dependent on winter tourism for their economic subsistence.

Past winter conditions stimulated the creation of low-lying ski resorts; an altitude range between 400 and 2800 meters was appropriate for business success (Breiling et al, 1999). The high Alpine zones with mountain peaks cannot be taken into considerations due to safety reasons or extreme climate conditions.

For Austria, Hantel et al. (2000) studied the variations in snow cover duration in relation to climate shifts. He found that in the most sensitive regions of Austria the length of the snow cover period may be reduced by about four weeks in winter if temperature rises by 1 degree.

The reduction in season length is smaller for higher-altitude stations. Adaptation is already in place in the Austrian ski industry. In 1991 there were 127 communities in Austria equipped with 250 snowmaking units (Walter, 2001). These units, for which US\$ 2 billion was invested, cover 20% of all skiing tracks.

3.4.3. Switzerland

Switzerland's 230 ski resorts cover 20% of the total ski area of Europe. Under the current climate conditions approximately 85% of them can be considered ski-reliable (Bürki et al, 2003). As shown in Table 5 and depending on the scenario considered, this percentage could drop to 63% as the snow line moves up to 1500 meters above sea level (masl) by 2030-2050. A shift to 1800 meters is considered a plausible scenario, which would leave only 44% of Swiss ski resorts snow reliable.

Table 5. Snow reliability of Swiss ski areas

Region	Number of ski resorts	1200 masl		Snow-reliability 1500 masl		1800 masl	
		No. %	No. %	No. %	No. %	No. %	No. %
Jura	15	4	27	1	7	0	0
Alps (Vaud + Frib.)	19	16	84	7	37	4	21
Valais	54	54	100	52	96	40	74
Bern (ex. Jura)	35	30	86	20	57	12	34
Central Switzerland	35	26	74	13	37	7	20
Ticino	8	8	100	3	38	2	25
Eastern Switzerland	18	11	61	6	33	3	17
Grisons	46	46	100	42	91	33	72
Switzerland	230	195	85	144	63	101	44

Source: Bürki et al. (2003).

4. Discussion and conclusions

This assessment shows that climate change is projected to have significant impacts on the physical resources supporting tourism in Europe. In the mountainous regions, snow reliability is very likely to decrease further, putting ski resorts at lower altitudes at risk. In summer, southern Europe will experience climatic conditions that are less favourable to tourism than the current climate. At the same time, countries in the North, which are the countries of origin of many of the current visitors of the Mediterranean, will enjoy better conditions in summer, as well as a longer season with good weather. In particular in southern Europe, the worsening situation resulting from deteriorating thermal conditions is further aggravated by increasing water shortages. Peak demand from tourism coincides with peak demand from agriculture, residential areas, the energy sector and nature. It also coincides with the summer dip in water supply, which will very likely be deepened by climate change.

The results presented here should be treated very carefully. First of all, snow reliability, water availability and thermal comfort are only three environmental issues that will be affected by climate change. Landscape, biodiversity, beach erosion, and deterioration of monuments are just a few examples of other factors that are affected by climate change, but are not assessed here. Secondly, in particular the analyses of the changes in TCI conditions are of a very general nature. Different tourism segments have very different climate requirements. The general approach taken here provides a first-order assessment, but more refined approaches will be needed in future studies. A more detailed analysis would require an appropriate level of insight into tourists' climate requirements, which relate to the third point of caution. Currently, our understanding of tourists' preferences with respect to climate and weather conditions remains very limited. Preferences are known to differ between tourism activities, and may also differ between tourists from different countries and cultures, but more empirical research is needed before segment-specific assessments can be done. Finally, there is still considerable uncertainty in our understanding of the climate system. In this assessment, different models and scenarios were used to cover part of this uncertainty range. The analyses showed that the use of multiple models and scenarios was appropriate. The results from the HIRHAM and the RCAO model differed considerably, although they generally coincided in the direction of change they predicted.

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Abstract

This document contains the results of the physical impact assessment for tourism within the context of the PESETA project. Tourism is a multi-billion euro industry that is highly dependent on climate resources. Climate change may provoke shifts in tourist flows, with large economic implications.

The report details the methodology applied and data used for the physical impact assessment for light outdoor activities and for winter sports. For the first category, the focus is on thermal conditions, for the second category on the availability of snow.

The assessment shows that climate change is projected to have significant impacts on the physical resources supporting tourism in Europe. In the mountainous regions, snow reliability is very likely to decrease further, putting ski resorts at lower altitudes at risk. In summer, southern Europe will experience climatic conditions that are less favorable to tourism than the current climate. At the same time, countries in the North, which are the countries of origin of many of the current visitors of the Mediterranean, will enjoy better conditions in summer, as well as a longer season with good weather. In particular in southern Europe, the worsening situation resulting from deteriorating thermal conditions is further aggravated by increasing water shortages. Peak demand from tourism coincides with peak demand from agriculture, residential areas, the energy sector and nature. It also coincides with the summer dip in water supply, which will very likely be deepened by climate change.

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