act Adapting to Climate change in Time

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THE ECONOMIC VALUATION OF CLIMATE CHANGE IMPACT ASSESSMENT

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THE CASE OF TOURISM IN BULLAS AND PATRAS

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CONTENTS

Paragraphs 1, 2, 3, 4 and partially 5 can be attributed to Giovanni Finocchiaro, paragraph 5.1.1 and 5.1.2 (including Annexes) to Alessio Capriolo.

1. Introduction

With its close connections to the environment and climate itself, tourism is considered to be a highly climate-sensitive economic sector similar to agriculture, insurance, energy, and transportation. Indeed, climate change is not a remote future event for tourism. Many impacts of a changing climate are even now becoming evident at different destinations around the world and climate change is already influencing decision-making in the tourism sector.

Many tourist activities depend on weather conditions and natural resources and most tourists have a high flexibility to adjust their holiday destinations (Schroter *et al.*, 2005). The interest in the relationship between weather and climate on the one hand and recreation and tourism on the other started around the 1950s (Scott *et al.*, 2006).

However, until relatively recently, climate was considered a more or less stable characteristc of destinations. It was assumed that climate could not account for any long-term trends in tourism demand (Abegg *et al.*, 1997). Nonetheless the climate change projections from the Intergovernmental Panel on Climate Change (IPCC) have led to a renewed interest in the relation between climate and the tourism sector. Peculiar of this relation is that it is driven by climate change at two different sites, that is, in the countries of origin as well as the destination countries.

In addition, tourism with its global economic and social value, its connections with development and sustainability and its strong relationships with climate has gained a relevant position in the actions against climate change led by United Nations. .

Although research on this topic has gained some attention in recent years, the influence of climate change on tourism has only been investigated in few studies, thus remaining poorly understood.

In this study we manly focus on coastal tourism, as winter tourism is not relevant to the cities involved in the project (Bullas and Patras).

2. Projected climate changes relevant for tourism

A correlation between tourism and in particular coastal tourism and some climatic variables is particularly evident.. Coastal zones are often subjected to significant anthropic pressures, which make them more vulnerable to the impacts of climate change, in particular, sea level rise (SLR) and an increased incidence of extreme weather events. Loss of valuable land due to SLR is one of the major impacts of climate change, even though tectonic movements, to some extent, mitigate the impacts. Together with land, also infrastructures and ecosystems may be lost due to the SLR, or damaged because of increased coastal erosion or extreme weather events. Extremely hot temperatures are likely to displace summer tourism away from coastal areas, and this trend is likely to be exacerbated by increasing shortage of water resources. The sea temperature is expected to increase, leading to northward shift of biodiversity and commercially valuable species (EEA, 2005), or invasion by alien species.

Besides, also other parameters are important, in particular for the comfort and safety of the tourist for example: intensity of radiation, reflected radiation, wind, and humidity.

3. Vulnerability of tourism to climate change

It is surprising that vulnerability of the tourism sector , received, so far, so limited attention . It has been implicitly, investigated, by studies addressing one of its three dimensions : exposure, sensitivity, and adaptive capacity.

In this document we try to structure a methodologyfor a comprehensive evaluation of tourism's vulnerability through an indicator based approach. Given the relative novelty of this effort the selection of indicators represents just a first attempt to frame future exercises.

3.1 Exposure

Although in literature there aren't specific indicators or methodologies to measure who and what (belonging to tourism sector) is mainly exposed to climate change, subsequently we try to provide some suggestions about potential indicator useful to this purpose.

Significant regional differences in present and expected climate change give rise to different exposure among human populations and natural systems to climate stimuli. In general, the degree of exposure of tourism to climate change depends on geographical location but also on the purpose of tourists visits, and many other socio-economical factors.

Based on the climatic variables that mainly concern now or in the future tourism sector, coastal and beach tourism will be the most exposed to climate change impacts.

Temperature increase, as a result of climate change, will occur with geographical and seasonal differences. Predictions for temperature increase could make the Mediterranean regions very hot, with the summer being more and more warm to the point of producing discomfort and losing touristic attractiveness. In this sense, touristic flows during the summer season will result among the most exposed to climate change.

Furthermore, tourist facilities and infrastructure will be exposed to higher frequency and intensity of extreme weather events such as flooding and storms, as well as to water shortages and drought periods. However, how extreme events that are relevant to tourism, will change in frequency and intensity is difficult to summarize in indicators. Potential measures of exposure to extreme weather events could be based, for example, on historic data and trend analysis.

Exposure to sea level rise is likely to cause flooding of some coastal areas and affect infrastructure and facilities (Mimura 1999; Parsons & Powell 2001), particularly in low lying coastal zone. Critical coastal infrastructure, communities situated close to the coast as well as sea ports will be exposed to coastal flooding, and storms may provoke impacts on maritime transport and related. Even small rises in sea level could result, in fact, in significant erosion and submersion of land, contamination of freshwater aquifers, biodiversity loss.

Also natural resources represent important factors for tourism and will therefore represent elements which are exposed to climate change and need to be taken into account: natural sites, protected areas, animal populations, plants, type and cover of forests and other facets of biodiversity.

Finally, the exposure of the tourist sector to climate change will be properly evaluated in terms of the number of the employees in the coastal/summer tourist sector.

Against this background exposure could be succesfully monitored by e.g.r:

- *share of tourist arrivals in the summer season*;
- *number of tourist facilities and infrastructure that might be affected by extreme weather events*;
- *number/area of tourist facilities and infrastructure located on low lying coastal zone*;
- *number/area of tourist protected areas and/or touristic natural sites*
- *number of employees in the coastal/summer tourism sector*.

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3.2 Sensitivity

3.2.1 Description

The sensitivity of the tourism sector to climate change has been usually addressed by using statistical methods (Bigano *et al.* 2006; Lise and Tol 2002; Maddison 2001) or by asking tourists how they would react to specific climate-related changes in a destination (Behringer *et al.* 2000; Braun *et al.* 1999; Scott *et al*. 2007a).

Detecting tourism sensitivity to climate is challenging as it involves many dimensions which are also linked to the purpose of tourist activity. If its main outcome is relaxation or recreation, then this canbe achieved through sightseeing, cultural and sport activities.

Thus weather i.e.the day-to-day variation of atmospheric conditions has to be firstly considered.

. Rain, wind, dust storm and fog disturb outdoor activities and occurrence of such events must be predicted and communicated to the hotels well in advance to enable them to take precautionary measures. As far as coastal tourism is concerned, water sports, snorkelling and recreational fishing are among the major attractions. Accordingly, there are several parameters linked to these which need to be carefully considered and predicted. Storm surges can be extremely dangerous even to the most able swimmer. Waves slightly higher than normal, has to be predicted and communicated to those responsible for the safety of tourists at sea.

A single casualty as a result of extreme weather may be bad publicity for the country and for the tourism industry.

Finally, there are some parameters more directly related to the comfort and safety of tourists which need to be also considered:

1. Temperature: This may appear simple but is vital as the traveller may often be subject to sudden change of up to 30-35 degrees. The body requires time to adjust to such abrupt changes.
2. Intensity of Radiation: Sometimes even though the temperature may be bearable, the radiation type and intensity at certain time of the day may be harmful because of the fragility of the skin, the eye and other body parts. Intense UV-B radiation, most particularly, is to be avoided else may lead to skin cancer and eye cataract.
3. Reflected radiation: Often tourists on the beach consider themselves protected under large umbrellas. Such may not be the case as equally intense radiation, capable of roasting the skin and likely to cause severe eye damage, is reflected by the sand. Salty water, added to it, makes it an ideal formula for getting sun-burnt.
4. Wind: Although slow winds are always welcome in the warm climates, it becomes a nuisance for outdoor activities above a certain speed. Its direction too is important considering that a soothing sea-breeze is pleasant at some time. However, this may not be the case at other times such winds may add to the discomfort of people especially as sea breezes are often laden with moisture –another source of discomfort. In the same way, wind could be a positive factor for recreational activities such as sailing, windsurf and kite surfing.
5. Humidity: High humidity is never welcome in warm climates. Already elevated temperatures combined with high relative humidity values may produce an uncomfortable atmosphere that may lead to dehydration and even fatality.

3.2.2 Indicators

Below we summarize some indicators proposed recently to evaluate the sensitivity of the tourism (beach tourism) sector to climate change (Sabine L. Perch-Nielsen 2009).
An indicator related to mean temperature increase, relevant but very coarse metric and not available on a global level, could be the *share of arrivals visiting for leisure purposes* (UN-WTO 2006). Assuming that, tourists visiting for business purposes or to see friends and relatives are less sensitive to changes in climate (Fagence and Kevan 1997).
Relatively to the sensitivity factors linked with the extreme events, only a very rough proxy has been found for the "robustness of beach tourism infrastructure and resources towards climatic extreme events". This proxy indicator, not specific for tourism is: *the percent of population annually affected by meteorological extreme events* (EM-DAT 2006). This indicator provides information on how well a country can cope with extreme events in general. Unfortunately, it represents not only the country's sensitivity, but also its current exposure and these two facets cannot be separated. For this indicator, in literature, the average of 10 years is taken in order to account for the low frequency of extreme events.
As regards the sensitivity factors linked with sea level rise, only one indicator has been found for the "proximity of tourism infrastructure and resources to maximum shoreline". This indicator is the *km of beach length to be nourished in order to maintain important tourist resort areas* (IPCC Response Strategies Working Group 1990) that is generally a very suitable indicator for this purpose.

3.3 Impacts

3.3.1 Description

There are three broad categories of climate change impacts that will affect tourism destinations, their competitiveness and sustainability (UNWTO-UNEP-WMO 2008):

1) ***Direct climatic impacts***. Changes in the length and quality of climate-dependent tourism seasons (e.g., sun-and-sea or winter sports holidays) could have considerable implications for competitive relationships between destinations and therefore the profitability of tourism enterprises. Studies indicate that a shift of attractive climatic conditions for tourism towards higher latitudes and altitudes is very likely. As a result, the competitive position of some popular holiday areas are anticipated to decline (e.g., the Mediterranean in summer) **jeopardizing a major sources of income**, whereas other areas (e.g. southern England or southern Canada) are expected to improve (Scott *et al*., 2007). Uncertainties related to tourist climate preference and destination loyalty require attention if the implications for the geographic and seasonal redistribution of visitor flows are to be projected (UNWTO-UNEP-WMO 2008).

   According to the IPCC increases in the frequency or magnitude of certain weather and climate extremes (e.g. heat waves, droughts, floods, tropical cyclones) are likely (IPCC 2007a; IPCC SREX 2012). Such changes will also affect the tourism industry through increased infrastructure damage, additional emergency preparedness requirements, higher operating expenses (e.g., insurance, backup water and power systems, and evacuations), and business interruptions.

   Indirect environmental change impacts. Several studies have examined the extent to which climate change can affect the economy of a country through its effect on environmental features (Uyarra et al., 2005). Changes in water availability, biodiversity loss, reduced landscape aesthetic, altered agricultural production (e.g., food and wine tourism), increased natural hazards, coastal erosion and inundation (caused by sea level rise), damage to infrastructure and the increasing incidence of vector-borne diseases will impact tourism to varying degrees. Hallegatte et al. (2008) report examples of indirect impacts and notes that coastal infrastructure designed to protect the city against storm surge, such as sea walls, may threaten the tourism industry because they deteriorate landscape, ecosystem health and beach leisure attractions (Lothian, 2006). Beach landscape degradation, marine ecosystem damage and loss of leisure activity (e.g. diving) would surely lead to a drastic reduction in tourism flows – or at least to a decrease in the willingness of tourists to pay – leading in turn to declining local incomes. The EU White Paper on Adaptation to Climate Change issued in April 2009 highlights that problems related to water supply can affect tourist destination and are becoming increasingly common in Mediterranean coastal areas. Coastal tourism will also be affected as a consequence of accelerated coastal erosion and changes in the marine environment and marine water quality, with less fish and more frequent jelly fish and algae blooms that determine adverse impact for recreational fishermen, snorkelers and divers.

Jelly fish and Algae Blooms

The presence of jellyfish and algal blooms in coastal waters and adjacent to beaches reduces the attractiveness of tourism for those beaches. These phenomena due to combination of higher water temperatures, overfishing and nutrient influxes. In the Mediterranean, algal blooms are boosted by nitrate and phosphate influxes from farming and human wastes. Climate change, including increasing sea temperatures and stratification may increase the impact and extent of this eutrophication in the Adriatic and Mediterranean Seas, as well as other enclosed seas like the Baltic and Black Seas. In the past, there have been several incidents of algae blooms in the Mediterranean: in the summer of 1989, the effects of eutrophication consisted in the appearance in Adriatic sea of large mats of a brown-colored, slimy, sticky, rotting and sometimes malodorous substance and its washing up on the beaches. The phenomenon reached its peak right in the middle of the tourist season, i.e. mid-July. As reported during the Seminar *"Coastal Tourism in the Mediterranean: Adapting to Climate Change" Cagliari (Sardinia-, Italy, 8-10 June 2009)*, the situation in 1989 appears to be the only one studied with reference to tourism aspect, even though there have been more recent algae blooms; in fact, little is known about the perception of tourists of such events. Tourists asked whether they would "seriously contemplate not spending a holiday along the Adriatic this summer"?, 35% of interviewed tourists stated yes. Another third of the tourists (34%) said they hoped it would get better, and 23% indicated that it was too late to change plans. Only 18% said that algae had no influence on their holiday, indicating that more generally, algae blooms may have a considerable impact on tourism. Incidences such as algae blooms are important for tourism, in that they are difficult to deal with, given that they affect the primary tourist attraction, i.e. the sun, sand and sea product.

Sources: Report on the Seminar "Coastal Tourism in the Mediterranean: Adapting to Climate Change" Cagliari (Sardinia), Italy, 8-10 June 2009; http://copranet.projects.eucc-d.de/files/000168_EUROSION_Climate_Change_and_Coastal_and_Beach_Management_in_Europe.pdf

In contrast to the varied impacts of a changed climate on tourism, the indirect effects of climate induced environmental change are likely to be largely negative. However, in some tourist sites, more favourable climatic conditions could have a positive impact on local economies if tourists respond to these changes by altering their choice of destination (Uyarra et al., 2005)

2) ***Indirect societal change impacts***. Climate change is thought to pose a risk to future economic growth and to the political stability of some nations. Any such reduction of global GDP due to climate change would reduce the discretionary wealth available to consumers for tourism and

> have negative implications for anticipated future growth in tourism. Climate change is considered a risk for national and international security that will steadily intensify, particularly under greater warming scenarios. International tourists are averse to political instability and social unrest, and negative tourism-demand repercussions for climate change security hotspots, many of which are believed to be in developing nations, are evident (Hall *et al.* 2004). (Scott *et al.* 2007).

Climate, the natural environment, and personal safety are three primary factors in destination choice, and global climate change is expected to have significant impacts on all three of these factors at the regional level.

3.3.2 Methodologies and indicators

In general there are two kinds of approaches to estimate the impacts of climate change: top-down and bottom-up. Several research studies within the first stream (*e.g.* Nordhaus, 1992; Nordhaus and Yang, 1996; Mastrandrea and Schneider 2004; Hitz and Smith, 2004; Stern, 2007) have estimated/ applied climate damage functions as reduced-form formulations linking climate variables to economic impacts (usually average global temperature to gross domestic product, GDP). An illustration is the recent update of the estimate of the damage of climate change in the US of the Stern review (Ackerman *et al.*, 2009). These authors assume that economic and non-economic damages of climate change are a function of temperature: $\underline{D = a\,T^N}$

where D refers to damages, T is the temperature increase, a is a constant and N is the exponent governing how fast damages rise. If N = 2, then 4° is four times as bad as 2°; if N = 3, then 4° is eight times as bad, etc.

Indeed, this branch of the literature provided early estimates of the order of magnitude of the effects of climate change in the world and large regions, as a function of the global temperature change (e.g. Fankhauser, 1994, 1995; Hitz and Smith, 2004; Tol, 2009).

Yet, for assessing impacts and prioritising adaptation policies such top-down approach has some disadvantages. Firstly, estimates are based on results from the literature coming from different, and possibly inconsistent, climate scenarios. Secondly, only average temperature and precipitation, are included not considering other relevant climate variables and the required time-space resolution in climate data. Thirdly, and because of the previous point, impact estimates lack the geographical resolution for adaptation policies. Indeed, aggregate or top-down impact estimates might hide variability of interest in the regional and sectoral dimensions.

Another strand of the literature has followed a bottom-up approach. This bottom-up or sectoral approach has been implemented in the EU PESETA project (http://peseta.jrc.ec.europa.eu/), where the physical effects of climate change are estimated by running high-resolution impact-specific models, which use common selected high resolution scenarios of the future climate.

Tourism Climate Index (TCI)

Addressing tourism and climate some global studies are available (Amelung *et al.* 2007; Hamilton *et al.* 2005), whereas others focus on specific countries (Hamilton, Tol, 2007) or destination types, such as ski areas (OECD, 2007), parks (Jones, Scott, 2006), and coastal zones (Moreno, Amelung, 2009; Moreno, Becken, 2009). Relatively few studies have specifically analyzed the potential impacts of climate change on the numbers of tourists visiting a specific country.

One of the key aspects in analyzing the impacts of climate change on the tourism sector is to express the impacts of climate change in a suitable physical indicator that can be used to model the attractiveness of the climate to tourists.

Some authors (e.g. Hamilton et al. (2005)) only summarize a single climatic aspect like temperature change. Alternatively, a composite indicator capturing a range of relevant climatic aspects can be used. The most commonly used of these indices is the Tourism Climate Index (TCI) developed by Mieczkowski (1985). This index is used also in the UE PESETA project and in particular in the section related to the physical impact assessment for 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 those general findings 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 in table 1.

Table 1: Sub-indices within the Tourism Climate Index

Sub-Index	Monthly Climate Variables	Influence on TCI	Weighting in TCI
Daytime Comfort Index (CID)	maximum daily temperature [in °C] & minimum daily relative humidity [%]	Represents thermal comfort when maximum tourist activity occurs	40%
Daily Comfort Index (CIA)	mean daily temperature [in °C] & mean daily relative humidity [%]	represents thermal comfort over the full 24 hour period, including sleeping hours	10%
Precipitation (P)	total precipitation [in mm]	reflects the negative impact that this element has on outdoor activities and holiday enjoyment	20%
Sunshine (S)	total hours of sunshine	rated as positive for tourism, but acknowledged can be negative because of the risk of sunburn and added discomfort on hot days	20%
Wind (W)	average wind speed [in m/s or km/h]	variable effect depending on temperature (evaporative cooling effect in hot climates rated positively, while 'wind chill' in cold climates rated negatively)	10%

Source: Based on Mieczkowski (1985)

The index is calculated as follows:

$$TCI = 2*[(4*CID) + CIA + (2*P) + (2*S) + W]$$

where CID = daytime comfort index, CIA = daily comfort index, P = 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.

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/m^2/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 to79) 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

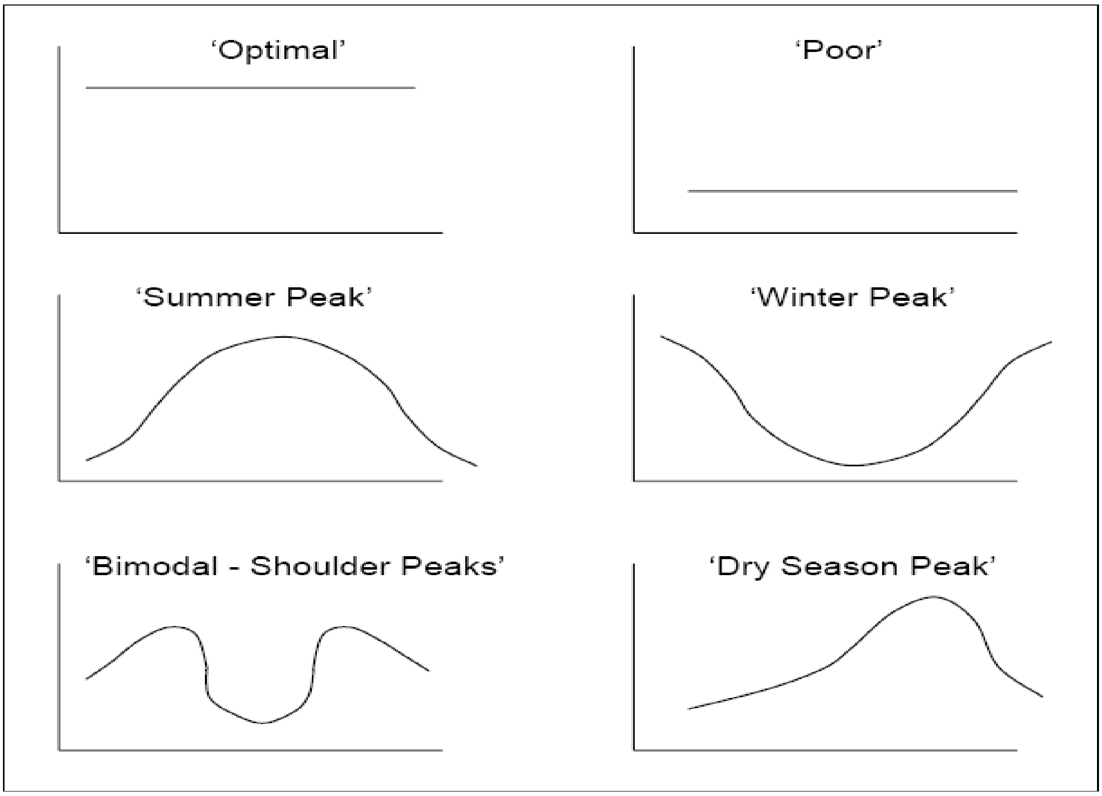
Source: Mieczkowski (1985)

Seasonal patterns are crucial for tourism behavior. These also can be captured by the TCI(Scott and Mcboyle (2001)). Table 4 and fig. 1 show the details.
A distribution qualifies as “optimal” if all monthly ratings are 80 or higher; it qualifies as “poor” if all monthly ratings are 40 or lower. If these conditions do not apply, there are four other options. The summer and winter peak distributions apply if the highest TCI ratings occur in summer or winter respectively. If the scores in spring and autumn are higher than in both summer and winter, the bimodal distribution applies. The ‘dry season peak’ is somewhat ambiguous, because the dry season can coincide with either the spring or the autumn season. Therefore, in this paper, the ‘dry season peak’ distribution is split up into spring peak and autumn peak. In a spring peak (autumn peak) distribution, the highest TCI scores occur in the spring (autumn) season, with autumn (spring) not coming in second place; otherwise the bimodal distribution would apply.
Note that the relationship between months and seasons is adjusted for the hemisphere that is considered. For example: in the northern hemisphere, the spring season is taken to encompass the months of March, April and May, while in the southern hemisphere, it is taken to encompass the months of September, October and November.

Table 4: Classification of TCI distributions

	All months	Spring	Summer	Autumn	Winter
Optimal	≥80	–	–	–	–
Poor	≤40	–	–	–	–
Summer Peak	–	–	1st highest TCI	–	–
Winter Peak	–	–	–	–	1st highest TCI
Bimodal	–	1st or 2nd highest TCI	–	1st or 2nd highest TCI	–
Dry season Peak	–	1st highest TCI (or Autumn)	–	1st highest TCI (or Spring)	–
Spring Peak	–	1st highest TCI	–	3rd or 4th highest TCI	–
Autumn Peak	–	3rd or 4th highest TCI	–	1st highest TCI	–

Source: Adapted from Scott and Mcboyle (2001): Dark shaded original category replaced by light shaded new categories



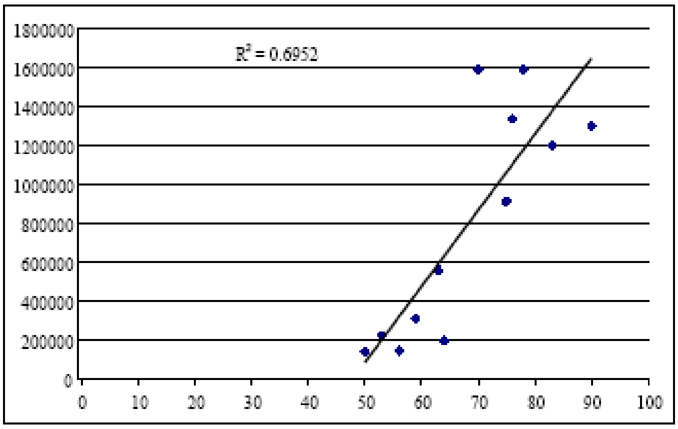
Source: Scott and Mcboyle (2001)

Figure 1: Conceptual tourism climate distributions

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 limitede.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.

Validating the performance of TCIs as a predictor for tourist demand remains however 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, 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.

This said, 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 2).



Source: EU PESETA project

Figure 2: 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 the PESETA project that TCIs can be effective indicators for the climatic attractiveness of tourist destinations.

Further, results of Peseta project provide simulated condition for summer tourism according to a High Emissions Scenario (IPCC SRES A2) for the 1961-1990 and 2071-2100.
In this scenario, TCI decrease remarkably in southern Europe suggesting that the suitability of the Mediterranean for tourism will decline during the summer months through reduction in peak summer tourism with related economic losses. Moreover, the PESETA project indicated significant potential shifts in the climatic suitability for tourism, with the belt of excellent summer conditions moving from the Mediterranean towards northern Europe. The reduction in attractiveness of current summer resorts is likely to be at least partially offset by increased opportunities for tourism in northern Europe. In the shoulder seasons (spring and autumn, not shown here), TCI scores are generally projected to increase throughout Europe and particularly in southern Mediterranean countries, which could compensate for some losses experienced in summer (EEA-JRC-WHO, 2008).

A second approach in analyzing the impacts of climate change on the tourism sector is to estimate the elasticity of tourism demand to its different determinants(such as climate, cultural setting, presence of historical sites, level of facilities, distance and travel costs, and so on (e.g. Crouch GI, 1995))
With regard to coastal tourism, climate change involves wheather condition and beach characteristics that are key factors for demand. Several investigations have considered how visitor numbers vary between locations in relation to beach characteristics (*e.g.*, Jedrzejczak, 2004; Tudor and Williams, 2006; Tzatzanis and Wrbka, 2002) and how numbers change at locations over time with weather conditions (*e.g.*, de Freitas, 1990; Dwyer, 1988). Coombes et al. (2009) have examined how visitor numbers may respond to modifications to both beach characteristics and weather conditions. The authors have quantified the effects of changes in temperature, precipitation, and sea level rise on visitor numbers at beaches for four climate change scenarios, using the case study of the East Anglian coastline.
There are finally examples where all these elements are compacted in a model of tourist behavior.

The most “famous” model of this typology is the *Hamburg Tourism Model* (Hamilton JM, et al., 2005)and its evolutions (Bigano A. et.al. (2007). The goal of this model is to describe, at a high level of geographic disaggregation, the reactions to climate change of tourist behaviour, both in terms of changes in their (domestic and international) numbers and in terms of changes in their expenditure decisions.

3.4 Adaptive capacity

The IPCC (2007b) has indicated that all societies and economic sectors will inevitability need to adapt to climate change in the decades ahead, and that adaptation is already occurring in many economic sectors, including tourism.

Adaptive capacity enables sectors and institutions to take advantage of opportunities or benefits from climate change, such as a longer growing season or increased potential for tourism (Adger et al. 2007).

The dynamic nature of the tourism industry and its ability to cope with a range of recent shocks, including SARS, terrorism attacks in a number of nations, or the Asian tsunami, suggests a relatively high climate change adaptive capacity within the tourism industry overall (UNWTO-UNEP-WMO 2008). The capacity to adapt to climate change (see Figure 3) is thought to vary between the components of the tourism value chain: tourists, tourism service suppliers, destination communities, tour operators subsectors of the tourism industry (Elsasser & Bürki 2002, Gossling & Hall 2006, Scott 2006, Becken & Hay 2007). Tourists have the greatest adaptive capacity (depending on three key resources; *money*, *knowledge* and *time*) with relative freedom to avoid destinations impacted by climate change or shifting the timing of travel to avoid unfavourable climate conditions. As such, the response of tourists to the complexity of destination impacts will reshape demand patterns and play a pivotal role in the eventual impacts of climate change on the tourism industry.

Tourism service suppliers and operators at specific destinations have less adaptive capacity. Large tour operators, who do not own the infrastructure, are in a better position to adapt to changes at destinations because they can respond to clients demands and provide information to influence clients’ travel choices. Destination communities and tourism operators with large investments in immobile capital assets (e.g., hotel, resort complex, marina, or casino) have the least adaptive capacity. The information requirements, policy changes and investments that are required for effective adaptation by tourism destinations require decades to implement in some cases, and so there is a need for rapid action for destinations predicted to be among those impacted by mid- century (UNWTO-UNEP-WMO 2008).

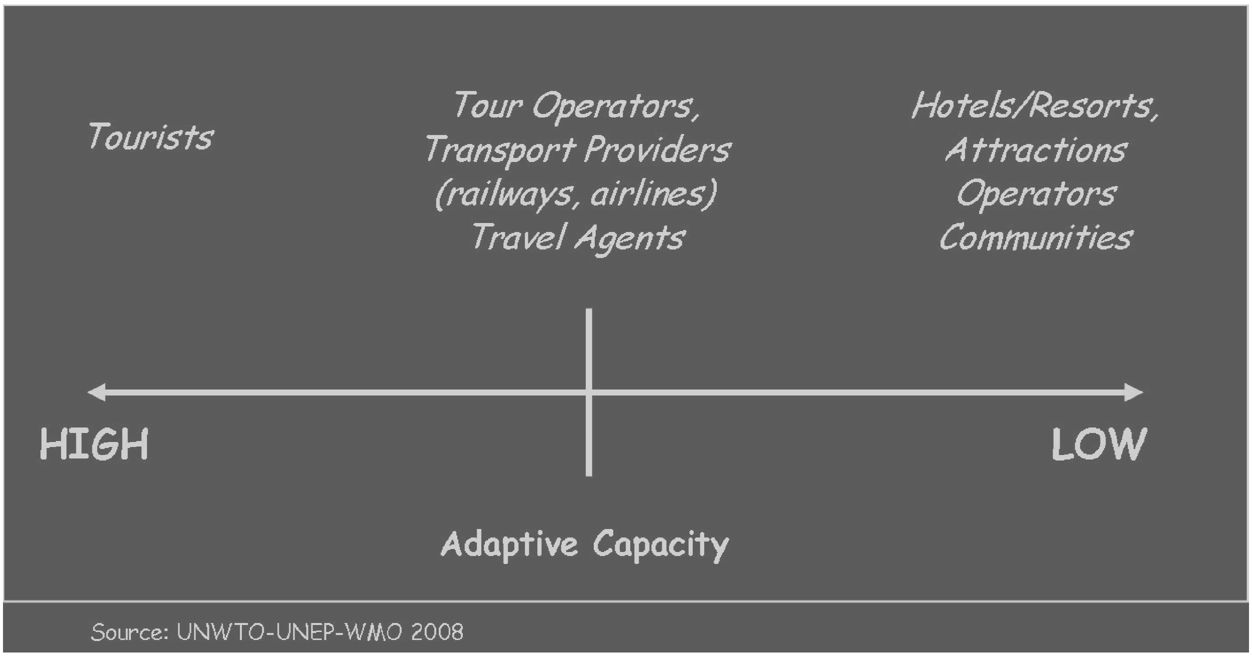


Figure 3: Relative Adaptive Capacity of Major Tourism Sub-sectors

The tourism sector has adapted its operations to climate zones world-wide. As Table 5 illustrates, a diverse range of technological, managerial, policy and behavioural adaptation measures are currently in use by tourism stakeholders to deal with climate variability at the destination level. Climate adaptations are rarely undertaken in isolation, but commonly involve multiple adaptations that are specific to the destination climate and its tourism products. The location specific nature of climate adaptation creates a complex mix of adaptations being practiced in the tourism sector across the globe.

Table 5: A Portfolio of Climate Change Adaptations strategies in the tourism sector

Type of Adaptation	Tourism Operators/ Businesses	Tourism Industry Associations	Governments and Communities	Financial Sector (investors/ insurance)
Technical	-Snowmaking -Slope contouring -Rainwater collection and water recycling systems -Cyclone-proof building design and structure	-Enable access to early warning equipment (e.g. radios) to tourism operators - Develop websites with practical information on adaptation measures	-Reservoirs, and desalination plants - Fee structures for water consumption -Weather forecasting and early warning systems	-Require advanced building design or material(fire resistant) standards for insurance - Provide information material to customers
Managerial	-Water conservation plans -Low season closures -Product and market diversification -Regional diversification in business operations -Redirect clients away from impacted destinations	-Snow condition reports through the media - Use of short-term seasonal forecasts for the planning of marketing activities (- Training programmes on climate change adaptation - Encourage environmental management with firms (e.g. via certification)	-Impact management plans (e.g., 'Coral Bleaching Response Plan') -Convention/ event interruption insurance -Business subsidies (e.g., insurance or energy costs)	-Adjust insurance premiums or not renew insurance policies -Restrict lending to high risk business operations
Policy	-Hurricane interruption guarantees - Comply with regulation (e.g. building code)	-Coordinated political lobbying for GHG emission reductions and adaptation mainstreaming - Seek funding to implement adaptation projects	-Coastal management plans and set back requirements -Building design standards (e.g., for hurricane force winds)	-Consideration of climate change in credit risk and project finance assessments
Research	-Site Location (e.g., north facing slopes, higher elevations for ski areas, high snow fall areas)	- Assess awareness of businesses and tourists and knowledge gaps	-Monitoring programs (e.g., predict bleaching or avalanche risk, beach water quality)	-Extreme event risk exposure
Education	-Water conservation education for employees and guests	-Public education campaign (e.g., 'Keep Winter Cool')	-Water conservation campaigns -Campaigns on the dangers of UV radiation	- Educate/inform potential and existing customers
Behavioural	-Real-time webcams of snow conditions -GHG emission offset programs	-GHG emission offset programs - Water conservation initiatives	-Extreme event recovery marketing	- Good practice in-house

Source: Adapted from UNWTO-UNEP-WMO 2008

In Moreno and Becken (2009) some examples of adaptive capacity indicators concerning "management capacity", "access to financing" and "institutional support" are illustrated: *number of resorts that are part of an early warning system, money invested into adaptation measures and technology, diversification of activities* and *marketing campaigns*. These indicators are quite general and could be properly adapted to different climate variable projections relevant for tourism such as mean temperature increase, as well as extreme weather events and sea level rise (Moreno A, Becken S, 2009). Furthermore, the *implementation level of sectoral plans including climate change* could represent another basic element for the evaluation of adaptive capacity.

3.5 Vulnerability assessment

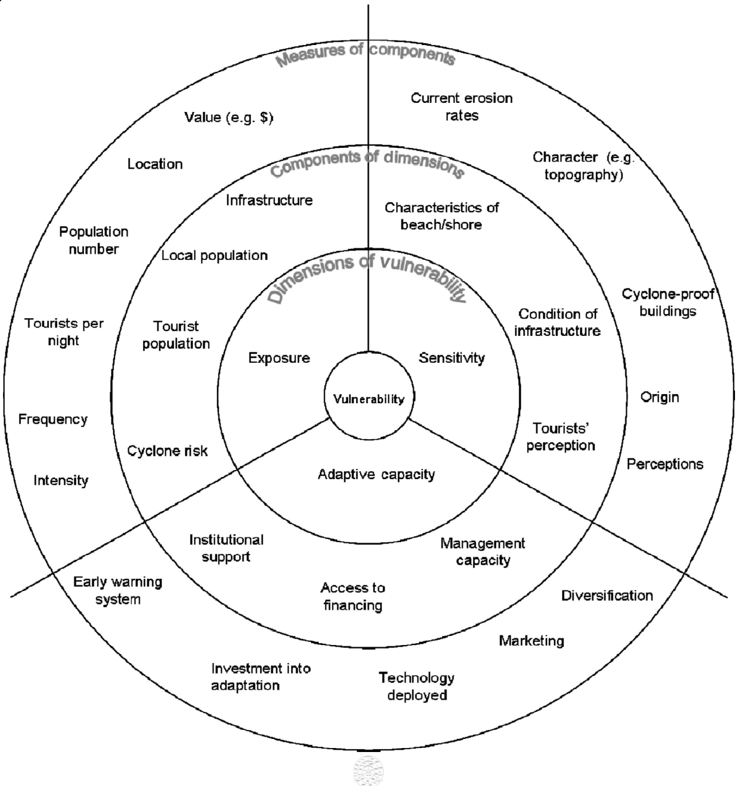
Tourism systems have been identified as complex systems, and the interactions between tourism and climate adds another layer of complexity. A tourist destination comprises a variety of stakeholders or agents, including tourism businesses, public sector organizations, community groups and non-governmental organization (NGOs). Moreover, the destination is characterized by different settings, both natural and cultural, a broad range of infrastructure and the kinds of activities that different types of tourists might engage in.

As a consequence, it should be recognized that a tourism destination is a complex system that consists of many different vulnerability situations. Each of these are characterized by different attributes of concern, hazards, stakeholders involved, timeframes considered and adaptive capacities.

The quantification of vulnerability to climate change requires consistent and structured methodologies. In some cases, the three dimensions of vulnerability (exposure, sensitivity and adaptive capacity) are not perfectly separable and need to be negotiated depending on the context of analysis.

Some attempts to assess vulnerability of tourism to climate change have been proposed in the past. Polsky et al. (2007) developed the vulnerability scoping diagram (VSD) as a tool for visualization and comparison between different vulnerability assessments. The diagram is composed of three layers: the innermost layer relates to the dimensions of vulnerability, namely exposure, sensitivity and adaptive capacity. The next layer specifies the components of each vulnerability dimensions, i.e. the “abstract characteristics” that typify the dimensions. Finally, the outermost layer shows the indicators that are used to measure the components.

Moreno and Becken (2009) developed a five-step methodology for assessing tourism’s vulnerability and applied the VSD in the framework of the third step specifically focusing the “vulnerability assessment” (Figure 4).



Source: Moreno and Becken, 2009

Figure 4: Vulnerability Scoping Diagram for the “beach-cyclone” sub-system

Another recent example of vulnerability assessment approach, developed at country level, is found in Perch-Nielsen S. L. (2009), where vulnerability of beach tourism is analysed by means of an index approach.
As regards vulnerability of community and ecosystem, IUCN (Herr D, Galland G. R., 2009) suggest to use Ecosystem-based Adaptation (EbA) in order to enhance resilience and reduce vulnerability by limiting exposure and building adaptive capacity.
In fact EbA is the sustainable management, conservation and restoration of ecosystems with the aim to assure the persistent provision of essential services that help people adapt to the negative impacts of climate change.

4. Conclusions

Scientific literature still reveals a key weakness of the vulnerability concept itself and points to the need for a broader concept and terminology. Extensive application of the vulnerability assessment framework to different tourism destinations is therefore required. What can be said in general is that coastal areas and leisure tourism in general, are among the most vulnerable tourist sectors. They are not only exposed and sensitive to climate change, but in many cases their adaptive capacity is low. Of course each case will have its specifities and will need to be analysed through each vulnerability component.
Knowledge about vulnerability to climate change will therefore play an important role in present and future management strategies of tourism destinations and will help policy makers and resource managers determine the areas of highest priority for early action.

5. Tourism impact assessment: Patras & Bullas

5.1 Patras

As suggested before ISPRA used the Tourism Climate Index (TCI) developed by Mieczkowski (1985) in order to assess the potentially occurring climate impact for tourism in Patras.

Operatively, the TCI has been calculated for the year 2010, as baseline year for Patras municipality. Although not in line with these climate data, also data on tourists arrivals for 2005 (the first available year, source: ADEP) and their monthly distribution in Patras (Achaia Prefecture) were considered and analysed by ISPRA. Approximately 70.1% of tourists arrivals is spread over the period April-October, that represents also the months when TCI scores more than 70 (comfort conditions for tourism activity are considered "Very good, excellent or ideal"). (Figure 5)

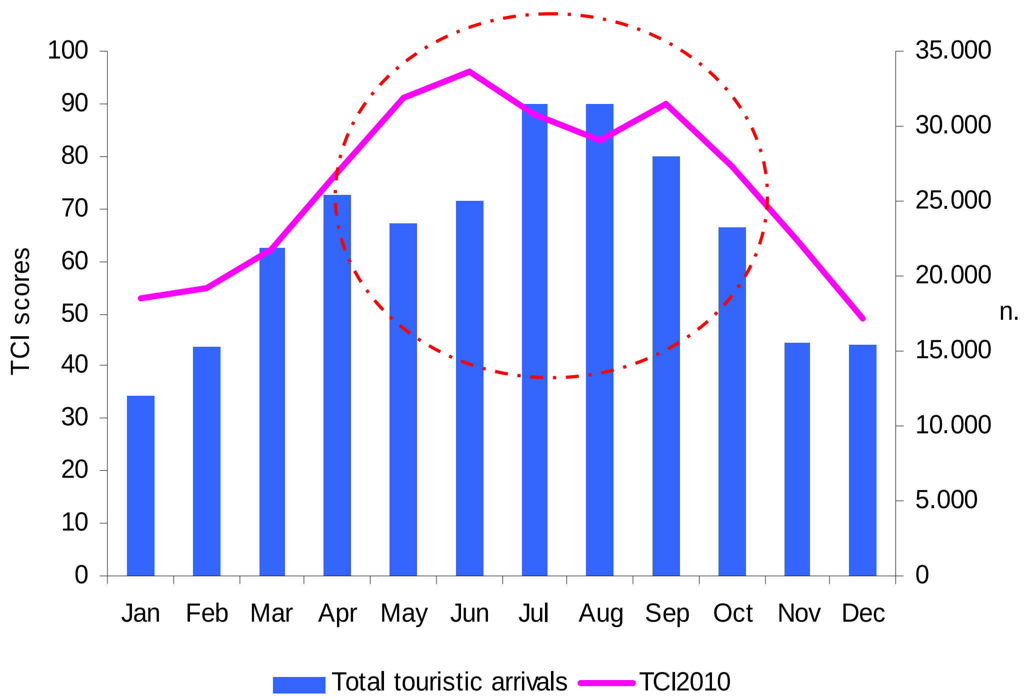


Figure 5: Monthly distribution of TCI 2010 and total and foreigners touristic arrivals in Patras (2005)

In addition, in order to illustrate the potential future changing of monthly comfort conditions, TCI scores have been calculated using temperature projections for Patras, extracted from the statistical downscaling elaborated by ISPRA, for the two periods 2046-2065 and 2081-2100 and from three different models. In particular, we used three models ("CLIM", "NN" and "SDSM") for the four seasons: Winter (December, January and February), Spring (March, April and May), Summer (June, July and August), and Autumn (September, October and November). Besides, we used precipitation projections for Patras, extracted from the RCM model SMHIRCA model, for 2100 and maintaining constant the value of 2010 for 2050. As for sunshine, wind and humidity for the period 2046-2065 we maintained the same values as in 2010, while for the period 2081-2100 we used the results indicated for the Western Greece according to a recent study of the Bank of Greece.

Comparing the different TCI scores, that have been obtained for the two periods in the future (2046-2065 and 2081-2100) and for the three models, and the baseline year, it may be observed in the graph (Figure 6) that the period from June to October shows lower TCI scores than the baseline year, becoming less climatically attractive. The other months maintain the same conditions or improve their climatic attraction. In general, TCI always scores at least “acceptable” climatic conditions. In conclusion in the future the climatic conditions of Patras will be always relatively comfortable for light outdoor touristic activities, although the summer season will become less climatically attractive than today.

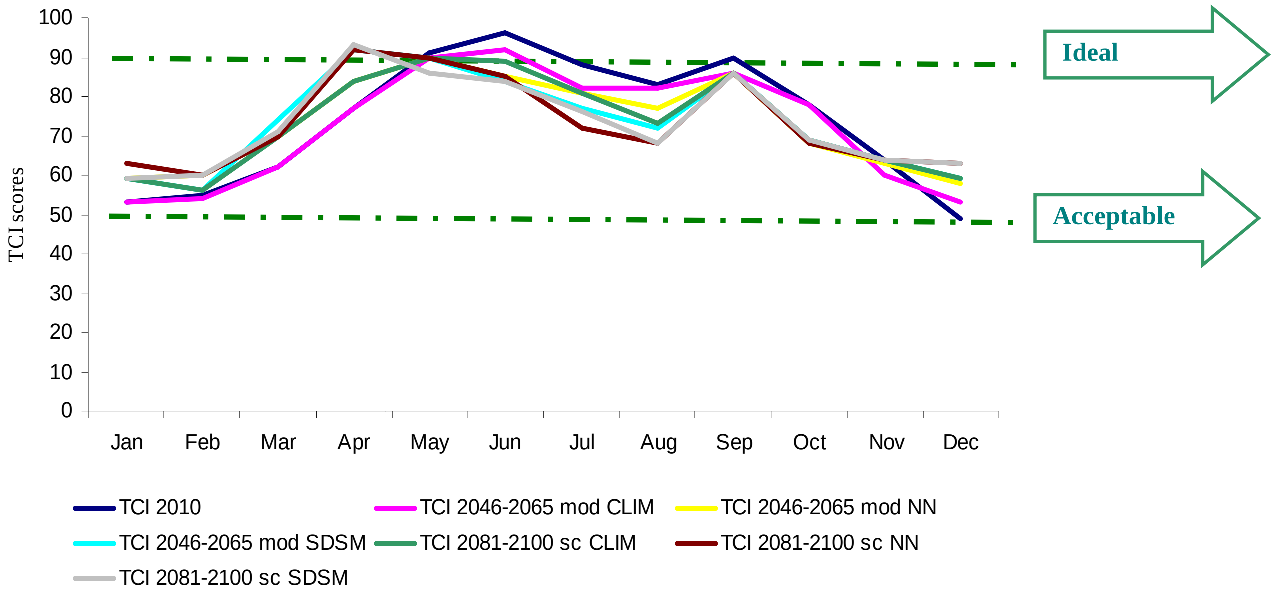


Figure 6: Comparison of TCI scores for the baseline year (2010) and for the future scenarios (2046-2065 and 2081-2100)

In order to assess the impact on future tourist arrivals in Patras, past correlation between TCI (for rather long time series) and arrivals should have been built up and the mathematical relationship among these variables estimated. The calibrated values of TCI in the future should have been placed in the algorithm to get the final impact on the arrivals. However due to lack of data on past arrivals in a sufficiently long time series, it was not feasible to follow this methodological option.

5.1.1 The Hamburg Tourism Model (HTM)

At this point an alternative model, the Hamburg Tourism Model (HTM) was used to assess the impact on tourist demand in Patras, being aware of the TCI outputs that put in evidence how tourism might partially depend on temperature change. The Hamburg Tourism Model[1] is an econometric simulation model of tourism flows to and from 207 countries, and is used to analyse scenarios of population and economic growth as well as climate change and climate policy. The core of the model consists of two econometrically estimated equations, respectively for arrivals (Equation (1)) and departures (Equations (2) and (3)). In these equations the variables are, respectively:

A	Total arrivals per year
G	Land area (km^2)
T	Annual average temperature (C°)
C	Length of coastline (km)
Y	Per capita income
D	Total national departures (abroad) per year
P	Population (in thousands)
B	The number of countries with shared land borders
H	Total domestic tourist trips per year
d	The destination country
o	The origin country

Arrivals are given by:

(1)
$$\ln A_d = \underset{0.97}{5.97} + \underset{0.96}{2.05} \cdot 10^{-7} G_d + \underset{0.07}{0.22} T_d - \underset{2.21}{7.91} \cdot 10^{-3} T_d^2 + \underset{3.03}{7.15} \cdot 10^{-5} C_d + \underset{0.09}{0.80} \ln Y_d$$
$$N = 139; R^2_{adj} = 0.54$$

Departures are determined by a two – step procedure. First, the HTM estimates the total tourists generated by a given country; then it divides tourists between those that travel abroad and those that stay within the country of origin. In this way, the model provides the total number of holidays as well as the trade-off between holidays at home and abroad.

Note that in order to cover not only international tourism flows but also *domestic* tourism, the HTM model requires an extensive global database of the amount of domestic tourism trips per country in the base year[2].

[1] The model was originally developed by Jackie Hamilton, David Maddison, and Richard Tol, with later additions by Andrea Bigano and Karen Mayor.

[2] For most countries, the volume of domestic tourist flows is derived using 1997 data contained in the Euromonitor (2002) database. For some other countries, it relies upon alternative sources, such as national statistical offices, other governmental institutions or trade associations. Data are mostly in the form of number of trips to destinations beyond a non-negligible distance from the place of residence, and involve at least one overnight stay. For some countries, data in this format were not available, and consequently the number of registered guests in hotels, campsites, hostels etc., or the ratio between the number of overnight stays and the average length of stay, were used. The latter formats underestimate domestic tourism by excluding trips to friends and relatives.

The number of tourists, that a country generates, depends on the size of the population and average income. Population numbers are measured in thousands. The share of domestic tourists out of total tourism depends primarily on the climate in the home-country and per capita income. Missing observations were filled using two regressions. Total tourist numbers, $D+H$, where H is the number of domestic tourists, were interpolated using

$$(2)\quad \begin{aligned} &\ln\frac{D_o+H_o}{P_o} = \underset{0.83}{-1.67} + \underset{0.10}{0.93}\ln Y_o \\ &N=63;\ R^2_{adj}=0.60 \end{aligned}$$

The number of tourists may exceed the number of people, which implies that people take a holiday more than once a year.

The ratio of domestic to total holidays was interpolated using

$$(3)\quad \begin{aligned} &\ln\frac{H_o}{D_o+H_o} = \underset{1.19}{-3.75} + \underset{0.42}{0.83}\cdot 10^{-1}\ln G_o + \underset{0.30}{0.93}\cdot 10^{-1}\ln C_o + \underset{0.32}{0.16}\cdot 10^{-1} T_o - \underset{1.11}{0.29}\cdot 10^{-3} T_o^2 \\ &+\left(\underset{0.12}{0.16} - \underset{1.24}{4.43}\cdot 10^{-7} Y_o\right)\ln Y_o \\ &N=63;\ R^2_{adj}=0.36 \end{aligned}$$

International tourists are allocated to all other countries on the basis of a general attractiveness index, climate, per capita income in the destination countries, the distance between origin and destination, etc. The annual mean temperature becomes a proxy of the climate. A number of other explanatory variables were included in the regression for reasons of estimate efficiency, but they were held constant in the simulation. The number of international tourists to a country is the sum of international tourists from the other 206 countries[3].

The core equations were estimated using 1995 data, and the model is further calibrated, so that the model almost perfectly reproduces the historical observations on the number of domestic tourists, international arrivals, and international departures. More convincingly, the model reproduces international arrivals and departures for the years 1980, 1985 and 1990; for arrivals, R^2 is always greater than 93%, and for departures, greater than 79%.

The model shows more in general that countries at higher latitudes and altitudes will become more attractive to tourists, to both domestic tourists and those from abroad, although the model also shows that the effect of climate change is much smaller than the combined effects of population and economic growth, at least for most countries. As a model, HTM presents several shortcomings. Its resolution is crude: it does not distinguish seasons, nor classifies tourists by age and income. Spatially, the model is restricted to countries, but it may be downscaled to regions or provinces, through a specific procedure. As a matter of fact, the Hamburg Tourism Model operates at a national scale, resolving domestic tourism in 207 countries and international tourism flows between those countries. However it is possible to look at a finer spatial resolution, by relying upon national and local data sources that provide tourists flows also for more restricted areas in given year. It is possible to allocate the national tourists flows estimated by HTM to sub-national areas splitting the allocation into a climate component, C, and an "all other factors" component, O that sums up all the remaining elements that might influence tourists flows. In the case we analysed for Patras, 1.5 % of all international tourists in

[3] See Bigano *et al*. (2005) for further details.

Greece visit Achaia province, where Patras is. The climate component associated to this tourists flow is equal to $C=0.22T-0.00791T^2$. The other component is set so that $C*O=1.5\%$, that is, $O = 0.033/(0.22T_{1995}-0.00791T_{1995}{}^2)$. O is held constant over the simulation period, while C changes with respect to the climate variations in Patras, that were calculated by ISPRA, either referring to the outputs of Global Circulation Models, or using the statistical downscaling results (as reported in the "Mediterranean Baseline Scenario"). As the values of C change due to climate change, also the touristic arrivals quota will vary.

As shown in details in the annexes, the national results of HTM were downscaled for the province of Achaia (to whom Patras belongs) by using the only available data provided on tourism arrivals (2005 for the whole province). As climate varies from one region to another one, this would lead to a regionally differentiated pattern of climate change impacts on tourism.

The growth rate of tourism demand (2005-2100) at national level in Greece was estimated by HTM for different developing scenarios with and without climate change:

Table number:**Scenarios**	**Growth rate of tourism demand**
A1B with CC	**204**
A1B without CC	**297**
B1 with CC	**153**
B1 without CC	**209**
A2 with CC	**130**
A2 without CC	**204**

A minimum and a maximum scenario has been considered for each emission scenario just taking into account the minimum and maximum value of temperature.

As far as A1B scenario is concerned:

Table number:

Global Circulation Models	**Temperature [°C]**
A1B (Intermediate emission scenario) - CNRM	**2,9 (maximum)**
A1B (Intermediate emission scenario) - INGV	**1,4 (minimum)**
Statistical downscaling - Mean annual temperature 2100	**Temperature [°C]**
NN	**1,725 (maximum)**
CLIM	**1,275 (minimum)**

Change in percentage of tourists in Greece and Patras (% variation with - without climate change) at 2100

Minimum scenario

GREECE	**-23,43**
Patras (Achaia)	**-19,77**
Rest of GREECE	**-23,48**

Maximum scenario

GREECE	**-23,43**
Patras (Achaia)	**-11,48**
Rest of GREECE	**-23,61**

As far as B1 scenario is concerned:

Global Circulation Models	Temperature [°C]
B1 (Optimistic scenario) – CNRM	1,9
Statistical downscaling - Mean annual temperature 2100	Temperature [°C]
NN	1,725 (maximum)
CLIM	1,275 (minimum)

Change in percentage of tourists in Greece and Patras (% variation with - without climate change) at 2100

Maximum value downscaling

GREECE	**-18,12**
Patras (Achaia)	**-12,51**
Rest of GREECE	**-18,21**

Minimum value downscaling

GREECE	**-18,12**
Patras (Achaia)	**-11,36**
Rest of GREECE	**-18,23**

As far as A2 scenario is concerned:

Global Circulation Models	Temperature [°C]
A2 (Pessimistic scenario) – CNRM	3,6
A2 (Pessimistic scenario) – INGV	2,0
Statistical downscaling - Mean annual temperature 2100	Temperature [°C]
NN	1,725 (maximum)
CLIM	1,275 (minimum)

Change in percentage of tourists in Greece and Patras (% variation with - without climate change) at 2100

Minimum scenario

GREECE	**-24,34**
Patras (Achaia)	**-17,51**
Rest of GREECE	**-24,45**

Maximum scenario

GREECE	**-24,34**

Patras (Achaia)	**-6,43**
Rest of GREECE	**-24,62**

As it is evident from each simulation in the different scenarios analysed, tourists arrivals are expected to decrease in 2100 in all the Greece and this general reduction will be partially allocated to Patras area depending on the differential between the mean temperature of the country and the mean value in Patras. The larger the differential will be (with the mean temperature in Greece higher than the one in Patras), the less the decrease in arrivals will be in Patras with respect to the rest of Greece.

The HTM may represent surely an interesting method to estimate somehow the dynamics of tourists demand even in such a small area like Patras over a year timeframe. Nevertheless it does not say a lot about the seasonality of the related flows, which is an important factor to assess the real impact on tourism business and plan effective adaptation policies to redirect tourists towards more comfortable periods.

5.1.2 Tourism-related economic activity and economic valuation of future impact at present price

The importance of Achaia prefecture in the tourism of Greece has been declining. Between the years 2005 and 2007 there was a severe reduction in the tourism spending in Achaia by more than 50%.

Year	**2005**	**2006**	**2007**
Tourism spending	121.442.521	108.452.799	56.938.528

Table: Tourism spending in Achaia prefecture

Taking into account the 2007 value, the **maximum loss** that may be predicted in
A1B scenario is equal to: 56.938.528* (-19,77%) = 11256746,9856 €
B1 scenario is equal to: 56.938.528* (-12,51%) = 7123009,8528 €
A2 scenario is equal to: 56.938.528* (-17,51 %)= 9969936,2528 €

ANNEXES

A1B Maximum scenario

Step1 Base year	Tourists 2005	Temp (°C) (annual mean) in 2005	Temp Index	Share of tourists not related to climate	Temperature increase 2100-2005
GREECE	17843622				
Area of Patras	268348				1,725
Rest of Greece	17575274				2,9
	Share (2005)				
GREECE	1,000				
Area of Patras	0,015	15,161	1,517	0,010	
Rest of Greece	0,985	17,7	1,416	0,696	

Step 2 2100 with climate change	Tourists 2100	Temp (°C) in 2100	New Temp Index	New share of tourists	Number of tourists per area
GREECE	54244611				
Area of Patras		16,886	1,459	0,014	943078,8635
Rest of Greece		20,6	1,175	0,818	53301532,02
Total				0,832	54244610,88

Step 3 2100 without climate change	Tourists 2100	Temp (°C) in 2100	Temp Index	New share of tourists	Number of tourists per area
GREECE	70839179				
Patras		15,161	1,517	0,015	1065341,56
Rest of Greece		17,7	1,416	0,985	69773837,78
Total				1,000	70839179,34

Step 4 decrease of tourists in Greece and in the area of Patras (var % with - without climate change) in 2100

GREECE	**-23,43**
Area of Patras	**-11,48**
Rest of Greece	**-23,61**

A1B Minimum scenario

Step1 Base year	Tourists 2005	Temp (°C) (annual mean) in 2005	Temp Index	Share of tourists not related to climate		Temperature increase
GREECE	17843622					
Area of Patras	268348					1,275
Rest of Greece	17575274					1,4
	Share (2005)					
GREECE	1,000					
Area of Patras	0,015	15,161	1,517	0,010		
Rest of Greece	0,985	17,7	1,416	0,696		

Step 2 2100 with climate change	Tourists 2100	Temp (°C) in 2100	New Temp Index	New share of tourists	Number of tourists per area
GREECE	54244611				
Area of Patras		16,436	1,479	0,015	854760,2872
Rest of Greece		19,1	1,316	0,916	53389850,59
Total				0,930	54244610,88

Step 3 2100 without climate change	Tourists 2100	Temp (°C) in 2100	Temp Index	New share of tourists	Number of tourists per area
GREECE	70839179				
Area of Patras		15,161	1,517	0,015	1065341,56
Rest of Greece		17,7	1,416	0,985	69773837,78
Total				1,000	70839179,34

Step 4 decrease of tourists in Greece and in the area of Patras (var % with - without climate change) in 2100	
GREECE	**-23,43**
Area of Patras	**-19,77**
Rest of Greece	**-23,48**

B1 Maximum scenario

Step1 Base year	Tourists 2005	Temp (°C) (annual mean) in 2005	Temp Index	Share of tourists not related to climate	Temperature increase 2100-2005
GREECE	17843622				
Area of Patras	268348				1,725
Rest of Greece	17575274				1,9
	Fraction (2005)				
GREECE	1,000				
Area of Patras	0,015	15,161	1,517	0,010	
Rest of Greece	0,985	17,7	1,416	0,696	

Step 2 2100 with climate change	Tourists 2100	Temp (°C) in 2100	New Temp Index	New share of tourists	Number of tourists per area
GREECE	45144364				
Area of Patras		16,886	1,459	0,014	725438,9
Rest of Greece		19,6	1,273	0,886	44418925
Total				0,900	45144364

Step 3 2100 without climate change	Tourists 2100	Temp (°C) in 2100	Temp Index	New share of tourists	Number of tourists per area
GREECE	55136792				
Area of Patras		15,161	1,517	0,015	829195,3
Rest of Greece		17,7	1,416	0,985	54307597
Total				1,000	55136792

Step 4 decrease of tourists in Greece and in the area of Patras (var % with - without climate change) in 2100

GREECE	**-18,12**
Area of Patras	**-12,51**
Rest of Greece	**-18,21**

B1 Minimum scenario

Step1 Base year	Tourists 2005	Temp (°C) (annual mean) in 2005	Temp Index	Share of tourists not related to climate	Temperature increase 2100-2005
GREECE	17843622				
Area of Patras	268348				1,275
Rest of Greece	17575274				1,9
	Share (2005)				
GREECE	1,000				
Area of Patras	0,015	15,161	1,517	0,010	
Rest of Greece	0,985	17,7	1,416	0,696	

Step 2 2100 with climate change	Tourists 2100	Temp (°C) in 2100	New Temp Index	New share of tourists	Number of tourists per area
GREECE	45144364				
Area of Patras		16,436	1,479	0,015	735027,2
Rest of Greece		19,6	1,273	0,886	44409336
Total				0,900	45144364

Step 3 2100 without climate change	Tourists 2100	Temp (°C) in 2100	Temp Index	New share of tourists	Number of tourists per area
GREECE	55136792				
Area of Patras		15,161	1,517	0,015	829195,3
Rest of Greece		17,7	1,416	0,985	54307597
Total				1,000	55136792

Step 4 decrease of tourists in Greece and in the area of Patras (var % with - without climate change) in 2100	
GREECE	**-18,12**
Area of Patras	**-11,36**
Rest of Greece	**-18,23**

A2 Maximum scenario

Step1 Base year	Tourists 2005	Temp (°C) (annual mean) in 2005	Temp Index	Share of tourists not related to climate	Temperature increase 2100-2005
GREECE	17843622				
Area of Patras	268348				1,725
Rest of Greece	17575274				3,6
	Share (2005)				
GREECE	1,000				
Area of Patras	0,015	15,161	1,517	0,010	
Rest of Greece	0,985	17,7	1,416	0,696	

Step 2 2100 with climate change	Tourists 2100	Temp (°C) in 2100	New Temp Index	New share of tourists	Number of tourists per area
GREECE	41040331				
Area of Patras		16,886	1,459	0,014	763289,0508
Rest of Greece		21,3	1,097	0,763	40277041,55
Total				0,778	41040330,6

Step 3 2100 with climate change	Tourists 2100	Temp (°C) in 2100	Temp Index	New share of tourists	Number of tourists per area
GREECE	54244611				
Area of Patras		15,161	1,517	0,015	815777,92
Rest of Greece		17,7	1,416	0,985	53428832,96
Total				1,000	54244610,88

Step 4 decrease of tourists in Greece and in the area of Patras (var % with - without climate change) in 2100	
GREECE	**-24,34**
Area of Patras	**-6,43**
Rest of Greece	**-24,62**

A2 Minimum scenario

Step1 Base year	Tourists 2005	Temp (°C) (annual mean) in 2005	Temp Index	Share of tourists not related to climate		Temperature increase 2100-2005
GREECE	17843622					
Area of Patras	268348					1,275
Rest of Greece	17575274					2
	Share (2005)					
GREECE	1,000					
Area of Patras	0,015	15,161	1,517	0,010		
Rest of Greece	0,985	17,7	1,416	0,696		

Step 2 2100 with climate change	Tourists 2100	Temp (°C) in 2100	New Temp Index	New share of tourists	Number of tourists per area
GREECE	41040331				
Area of Patras		16,436	1,479	0,015	672930,4438
Rest of Greece		19,7	1,264	0,879	40367400,16
Total				0,894	41040330,6

Step 3 2100 without climate change	Tourists 2100	Temp (°C) in 2100	Temp Index	New share of tourists	Number of tourists per area
GREECE	54244611				
Area of Patras		15,161	1,517	0,015	815777,92
Rest of Greece		17,7	1,416	0,985	53428832,96
Total				1,000	54244610,88

Step 4 decrease of tourists in Greece and in the area of Patras (var % with - without climate change) in 2100	
GREECE	**-24,34**
Area of Patras	**-17,51**
Rest of Greece	**-24,45**

5.2 Bullas

First of all, and in order to get an overview of the current situation, the TCI index has been calculated for the year 2010, as baseline year for Bullas municipality, and as it is shown in the next figure.

According to this graph, Bullas achieves higher TCI scores between April to October but above all in May and June (rating=ideal) and in September and October (rating= Excellent). As for tourist flows, the real data obtained from the Bullas Tourist office show that tourists arrive in this region above all in autumn (September-October) and early spring (March).

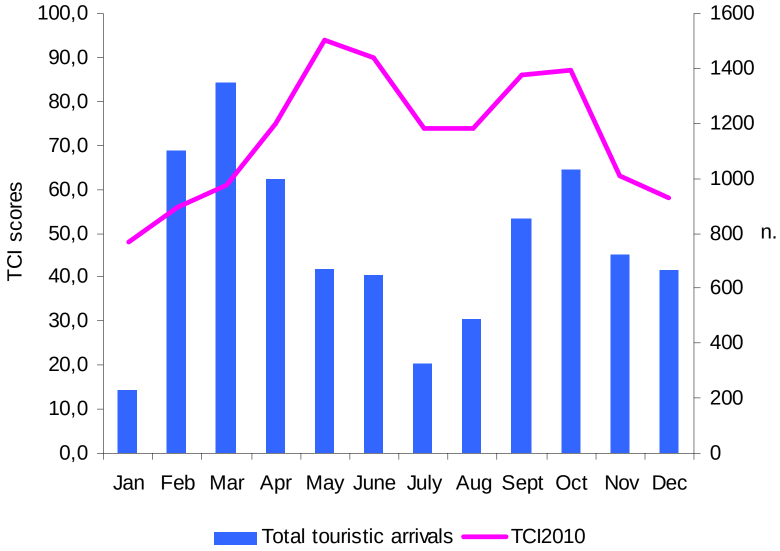


Figure 7: Monthly distribution of TCI 2010 and total and foreigners touristic arrivals in Bullas (2010)

In addition, and in order to illustrate the potential future change of monthly comfort conditions, TCI scores have been calculated considering precipitation, sunshine, wind and humidity as constant variables (in these cases predictions are unreliable) and using temperature projections for Bullas, extracted from the statistical downscaling elaborated by ISPRA, for two periods 2046-2065 and 2081-2100 and for different scenarios.

In details for the period 2046-2065 we used as maximum values the results obtained with the model “NN” for Winter (December, January and February), the results obtained with the model “SDSM” for Spring (March, April and May), the results obtained with the model “NN” for Summer (June, July and August), and the results obtained with the model “SDSM” for Autumn (September, October and November).

For the same period but as minimum values we used the results obtained with the model “CLIM” for Winter (December, January and February), for Spring (March, April and May), for Summer (June, July and August), and for Autumn (September, October and November).

For the period 2081-2100 we used as maximum values the results obtained with the model “NN” for Winter (December, January and February), the results obtained with the model “SDSM” for

Spring (March, April and May), the results obtained with the model "NN" for Summer (June, July and August), and the results obtained with the model "SDSM" for Autumn (September, October and November).

Always for the period 2081-2100 we used as minimum values the results obtained with the model "CLIM" for Winter (December, January and February), the results obtained with the model "CLIM" for Spring (March, April and May), the results obtained with the model "SDSM" for Summer (June, July and August), and the results obtained with the model "CLIM" for Autumn (September, October and November).

The different TCI scores for the two different periods and two scenarios (maximum and minimum) are illustrated in the graph (Figure 8). With the increase of temperature and the decrease of precipitation (which has not been considered in the statistical downscaling models, but values can be derived from RCM climatic models), for the future (2046-2065 and in 2081-2100) the months between June and September show less attractive climatic conditions, compared to the same months of the baseline year 2010 (which are not anyway the most comfortable months during the year). In synthesis, climatic conditions of the summer period will worsen significantly in the future.

The remaining months will maintain the same conditions, with the peak of climatic comfort in May.

In general, climatic conditions show always TCI scores higher than 50 (acceptable) except in January (about 48-49 TCI score) and during the summer period for the maximum scenario of 2081-2100 in July (49) and August (41).

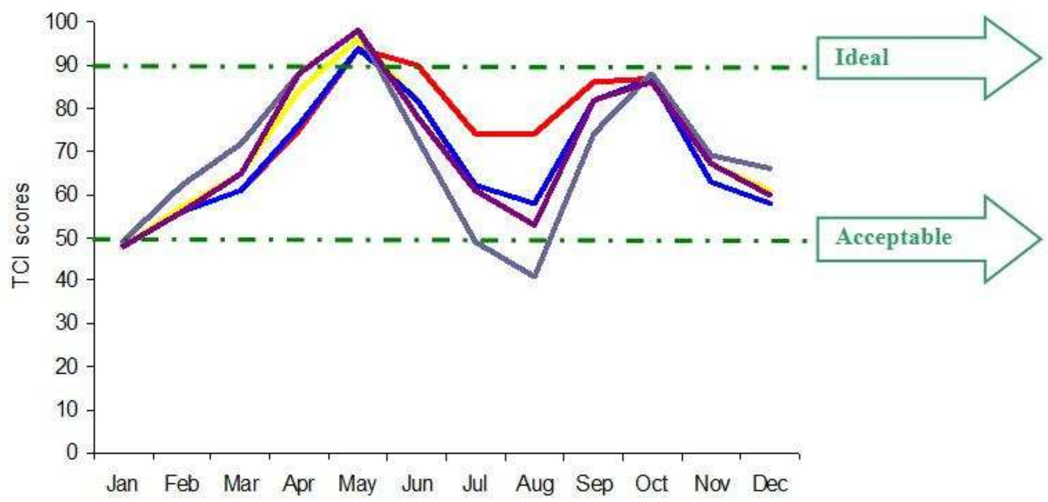


Figure 8: Comparison of TCI scores for the baseline year (2010) and for the future scenarios (2046-2065 and 2081-2100)

As illustrated in the figure 8 the worsening of climatic conditions will occur during the summer season, while Spring and Autumn will have excellent and even ideal climatic conditions. Furthermore, as summer is the period in which the lowest tourist flows are registered, the impact of climate change on tourism in Bullas will be likely scarcely significant.

In general it's useful to underline that the climatic conditions of Bullas are by no means the only attraction in the area. Attractive landscapes, cultural heritage, wine tourism and traditional lifestyles, among other factors, make Bullas an interesting tourist destination.

Moreover, tastes and fashion are unstable over extend periods of time. The modern habit of sunbathing, for example, was not part of popular culture until relatively recently. Many things may change over the next decades that increase or decrease the relevance of the climatic resources for tourism in general and of the TCI index in particular. Sunbathing is for example now seen as a potential health risk.

For this reason, tourist developments are shaped by an amalgam of factors, including political, economic growth, technological advances, and demographics. In the day-to-day practice of the tourist industry, climate factors are overwhelmed by all kinds of other influences that require immediate action: fashion, trends, terrorism, etc. The weather's effects on the climatic resources for tourism will perhaps not be so evident, but the compound effect of years of slow change can have quite dramatic long-lasting effects.

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THE CASE OF THE WINE IN THE CITY OF BULLAS

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The Impact Assessment of climate change on wine production and quality

In order to examine the climatic effects on wine quality, Bullas vintage ratings, provided by the Municipality, were used (from 1970 to 2008). The ratings are based on 6 categories with general meanings of 0 Disastrous, 20 Very bad, 40 Bad, 60 Good, 80 Very good, 100 Excellent (a score of 0 or 20 has never been given). Average growing season temperatures were used as a climate factor and were taken by ISPRA's model simulations.
To account for potential non-climate trends in vintage ratings (i.e., better production technology) the following econometric regression model approach was applied in the climate/vintage ratings analysis (G.V. Jones et al., 2005):

$$R_t = a + b * temp_t + c * trend + \varepsilon_t$$

where R_t and $temp_t$ represent the vintage rating in points and the average growing season temperature in °C for year t. To account for quality improvements that are independent of climatic changes the model introduces a trend variable *trend*. The trend variable begins with the value 1 in 1970 and continues in one-unit steps.

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	74.000	76.975		.961	.343
Temp	-.999	4.314	-.062	-.231	.818
Trend	.673	.384	.469	1.750	.089

Table 1 Results

The full model is not statistically significant (R2=0,18): both the average growing season temperature in °C for vintage (temp) and the trend variable (trend) do not make a significant contribution to predicting vintage ratings. The time series data are not sufficiently long and the consequence is that the model does not make in evidence any significant correlation between the raising temperature and a worsening in the quality of the local wine.

The outcomes of the model might be higly dependent on the available data quality, but apart from the insufficient length of the time series, there might be other relevant factors undermining the robustness of this findings. First, seasonal and extreme temperature effects are very important in wine production and they have been taken into account just partially, including an average gorwing seasona temperature. Secondly, linked to this point, even though, in the period examined, temperature remained always in a tolerable range for grapes. But this does not mean that there are no temperature thresholds above which effects are disruptive. Thirdly, the analysis does not really isolate wine producer autonomous adaptation, but just the trend variable to explain a general improvement. Consequently increasing temperature might have not impacted the quality of wine simply because wine producers protected their grapes, and/or modified the timing of their harvest behavior reacting to temperature changes.

Year	*Rating*	*Temp*	*Trend*
2008	80	16.54	39
2007	60	16.45	38
2006	80	17.22	37
2005	80	16.30	36
2004	100	16.56	35
2003	80	17.16	34
2002	60	16.86	33
2001	60	17.21	32
2000	80	16.36	31
1999	80	17.37	30
1998	100	16.69	29
1997	60	16.69	28
1996	80	15.96	27
1995	60	17.28	26
1994	80	16.96	25
1993	80	15.29	24
1992	60	15.55	23
1991	80	15.83	22
1990	80	16.66	21
1989	60	16.64	20
1988	60	16.30	19
1987	80	16.53	18
1986	40	15.80	17
1985	60	15.82	16
1984	60	15.25	15
1983	60	16.37	14
1982	60	16.09	13
1981	60	16.16	12
1980	60	15.58	11
1979	40	15.83	10
1978	80	15.59	9
1977	60	15.54	8
1976	60	15.00	7
1975	80	15.13	6
1974	100	15.05	5
1973	80	15.32	4
1972	40	14.64	3
1971	40	14.89	2
1970	40	15.93	1

Table 2 Temp and trend data

References

Jones, G.V., White, M.A., Cooper, O.R., and Storchmann, K., (2005). Climate Change and Global Wine Quality. *Climatic Change*, 73(3): 319-343.

THE CASE OF HEALTH VULNERABILITY TO CLIMATE CHANGE IN PATRAS

Authors
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CONTENTS

Introduction

It is largely recognized that environmental consequences of climate change, already observed and expected, will affect human health both directly (e.g. effects of thermal stress or direct injuries from floods) and indirectly through increased risk of climate-sensitive diseases (e.g. water-related or vector borne diseases, cardiovascular and respiratory diseases) mediated by changes in water-,air-, food quality and quantity, agriculture practices, ecosystems, and living environment. This direct and indirect exposures can cause death, disability, and suffering[4].

Vulnerability and adaptation (adaptive capacity?) need thus to be assessed to ensure effective risk management of the current and potential effects of climate variability and change on physical, social and psychological well. Differences in impacts of climate hazards across exposed people are determined by many factors including the severity of the hazard itself, the population that is exposed to the hazard and the coping capacity of the exposed individuals and community to the hazard. In general, the vulnerability of a population to a health risk depends on the local environment stability and quality, the effectiveness of multidisciplinary governance, the quality of the public health infrastructure and social services , the access to relevant local information on extreme weather threats (see Fig.1).

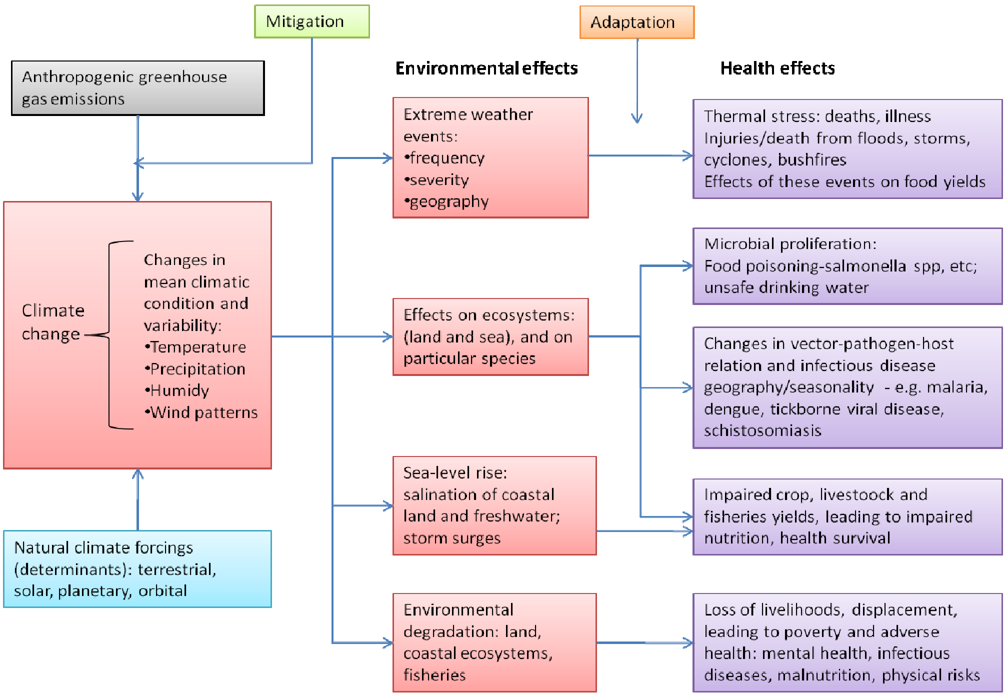

Fig. 1. ***Diagram of pathways by which climate change affects health and well being modifying influences of environmental, social and health-system factors. (Source: Anthony J McMichael, Rosalie E Woodruff, Simon Hales, 2006[5] Adapted by ISPRA)***

Populations, subgroups and systems that cannot or will not adapt are more vulnerable, as are those that are more susceptible to weather and climate changes. Furthermore some population groups need a special attention because of their special vulnerability : children, pregnant women, elderly, disabled people, people temporarily or permanently living in community such as residential homes or with low socio economic status are generally more susceptible to adverse health effects, especially for heat and weather-related illness and death, vector borne and zoonotic disease, waterborne and food borne illnesses.

[4] Confalonieri, U., B. Menne, R. Akhtar, K.L. Ebi, M. Hauengue, R.S. Kovats, B. Revichand A. Woodward,2007 :Human health. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working GroupII to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Lindenand C.E.Hanson,Eds.,CambridgeUniversityPress,Cambridge,UK,391-431.

[5] Anthony J McMichael, Rosalie E Woodruff, Simon Hales, 2006. Climate change and human health: present and future risks. Lancet 2006; 367: 859–69

Understanding a population’s capacity to adapt to new climate conditions is essential to reinforce ability of mitigation and adaptation measures to reduce adverse social and health impacts, and it requires cooperation among public health action and other sectors commitment.
Health impact assessment performed by health experts is a policy tools to identify the climate change problem (concerns of vulnerable groups) and its context also in order to prioritize actions, to describe the current situation (health burdens and risks) and whereas possible, predict future impacts, but also to identify key partners and governance issues(e.g. available information) including research needs for the assessment. There are still some level of uncertainty in methods and models, specially for future impacts, although research and empirical experience is growing more and more.
However precautionary principle and the already changing environment require a proactive attitude from all sectors. Indeed many of climate and environmental determinants of health fall outside areas of direct action and governance of the health sector. Efficiency of cross cutting and multi-sector prevention measures depends on mainstreaming of health issues in other sector policies since earliest stages of any vulnerability assessments and strategy planning.

Effectively targeting prevention or adaptation strategies requires understanding which demographic or geographical sub-populations may be most at risk and where additional interventions are needed, having also in mind that improving the capacity to cope with current climate variability will facilitate the capacity to cope with long-term climate change and that increasing the adaptive capacity of a population shares similar goals with sustainable development .
Furthermore many features make urban environment and urban population more vulnerable to the two major determinants of climate change such as thermal anomalies and changes in weather patterns:

2) Urban areas [6] concentrate people and buildings into a relatively small area, then even a relatively contained weather event (storm, intense rain, heat wave, air stagnation) or increased risk factors (increase number of vectors carrying diseases such as mosquitoes) can affect a large number of people
3) Urban people show a high dependence from stability and performance of water and energy distribution, common infrastructures and services such as transportation systems to move people and goods, communication systems, sewers and waste removal systems.

4) Urban economy may largely rely on touristic resort and economic activities very depending from stability of environmental systems and climate variables such as quality of bathing waters and coastal environment, local food safety and production, weather and seasonal patterns .

5) Urban and suburban areas host several crucial health and social services (such as hospitals, residential homes, schools and kindergarten) and a large variety of vulnerable groups (such as elderly, children, economically disadvantaged communities, disabled). Increased risk of climate-sensitive diseases will result in a heavy social financial burden.

6) Urban built environment elements enhance *per se* vulnerability to climate and weather hazards of health relevance:

- Asphalt, concrete and other hard surfaces:

[6] The Clean Air partnership (May 2007). Cities preparing for climate change- A study of six urban region.

- absorb sun radiation, favouring the urban heat island effect, which exacerbates heat waves and puts pressure on electricity generation and distribution systems;
- prevent absorption of rainfall, creating runoff that carries pollution to local water bodies (lakes, streams, etc.);
- can cause overwhelming of storm water systems during heavy precipitation events.

- Combined sewers carrying both storm water and sewage:
    - lost lasting or intense precipitation cause overflows of untreated pollutants that impair quality of local water bodies, suitable for bathing, agriculture and human consumptions purposes,
    - intense rain or floods may cause rodents migration outside sewage network increasing the risk of diseases such as leptospyrosis
    - impaired manholes drainage will favour breeding sites for dangerous and annoying urban mosquito .
- Concentration of people in urban areas will affect healthy environment :
    - act as environmental pressure on vegetation and green spaces, worsening heat island effects, storm water runoff, air pollution from transportation;
    - creates a large demand for water, straining local water supplies and making them more vulnerable in drought conditions increasing the risk of water-related disorders.
    - increase vulnerability to blackouts when electricity demands are high and when storms occur due to centralized power sources, longer distribution lines, interconnected grid
- Urban sprawl and competition for building sites lead to construction in vulnerable areas such as floodplains or steep slopes.
- Poor maintenance of green public and private areas (including school garden) will facilitate presence of allergenic weeds , "pollen thunderstorm"(see paragraph 2.3) and harmful insects.

With this in mind, this report wants to help focussing on some of the health-related adaptation activities, providing:
a) A brief summary of health impact assessment methodologies to be performed by health experts;
b) An overview of potential health risks for climate sensitive environmental systems organized along climate stressors, including a suggested list of indicators to warrant basic information on population exposure to those risks, to support impact assessment studies and , last but not least, to identify vulnerable population groups that may be most at risk;
c) A first list of adaptations options of health relevance organized by domain (urban planning, water management etc) to facilitate governance;
d) A practical example of climate-change health risk and economic assessment for the greek city of Patras.
The aim is to reinforce awareness of local policy makers on the health relevance of many measures, including availability of sufficient information to warrant such activities, to strengthen institutional capacity for preventive measures, planning, preparedness and environmental health risk management. In a word copying with changes which are already before our eyes.

1. Health Impact Assessment: concepts and available methodologies in climate change scenarios

According to most quoted definitions[7], vulnerability to climate change is the degree to which geophysical, biological and socio-economic system are susceptible to, and unable to cope with, adverse impacts of climate change. The term “vulnerability” may refer to the vulnerable system itself or to the mechanism causing the impacts. Key vulnerabilities are associated with many climate-sensitive systems, including, for example, food supply, infrastructure, health, water resources, coastal systems, ecosystem, global bio-geochemical cycle, ice sheets and modes of oceanic and atmospheric circulation.

According to WHO the vulnerability of human health to climate change is a function of[8]:

1. sensitivity, which includes the extent to which health, or the natural or social systems on which health outcomes depend, are sensitive to changes in weather and climate (the exposure–response relationship) and the characteristics of the population, such as the level of development and its demographic structure.

2. the exposure to the weather or climate-related hazard, including the character, magnitude and rate of climate variation and changes in environmental climate-sensitive systems.

3. the adaptation measures and actions in place to reduce the burden of a specific adverse health outcome (the adaptation baseline), the effectiveness of which determines in part the exposure–response relationship.

Being sensitivity best described by HIA (health impact assessment procedures) this chapter will briefly illustrate some general concepts and methodologies.

The evidences of sensitivity of population health to weather and climate are based on five main types of empirical study: [9]

1. Health impacts of individuals extreme events (e.g. , heat waves, floods, storms, droughts, extreme cold);
2. Spatial studies where climate is an explanatory variable in the disruption of the disease or the disease vector;
3. Temporal studies assessing the health effects of inter-annual climate variability, of short term (daily, weekly) changes in temperature or rainfall, and of long-term (decadal) changes in the context of detecting early effects of climate change;
4. Experimental laboratory studies and field studies of vector, pathogen, or plant (allergen) biology;

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[7] Schneider, S.H., S. Semenov, A. Patwardhan, I.Burton, C.H.D. Magadza, M.Oppenheimer, A.B. Pittock, A. Rahman, J.B. Smith, A. Suarezand F.Yamin, 2007: Assessing key vulnerabilities and the risk from climate change. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L.Parry, O.F.Canziani, J.P.Palutikof, P.J. vander Lindenand C.E.Hanson, Eds., Cambridge University Press, Cambridge,UK,779-810.

[8] Sari Kovats,Kristie L. Ebi and Bettina Menne. 2003. Methods of assessing human health vulnerability and public health adaptation to climate change. WHO 2003

[9] Confalonieri, U., B. Menne, R. Akhtar, K.L. Ebi, M. Hauengue, R.S. Kovats, B. Revichand A. Woodward,2007 :Human health. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working GroupII to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Lindenand C.E.Hanson,Eds.,CambridgeUniversityPress,Cambridge,UK,391-431.

5. Intervention studies that investigate the effectiveness of public-health measures to protect people from climate hazards.

1.1 Health Impact Assessment (HIA) of climate change[10]

Health Impact Assessment (HIA) has been defined as "a combination of procedures, methods and tools by which a policy, program or project may be judged as to its potential effects on the health of a population, and the distribution of those effects within the population"[11]
Thus, HIA can be a useful tool to a range of stakeholders when considering multiple outcomes to be optimized to attain population wide benefits.
The different stakeholder concerns can be generally grouped into economic, political, quality of life, or ethic.
Therefore, key components that are important to include into the multi-stakeholder HIA process are: equity/democracy, sustainability, and ethical use of evidence. Human health is central to all these stakeholder interests, being essential to the quality of life, being viewed by many as a fundamental human right, and being central to many economic impacts and political actions.
Identifying and quantifying systematically the many pathways through which climate change can affect health is challenging. The following aspects have indeed to be addressed:

- The absence of an appropriate comparison group
- The long-time period over which human actions affect climate
- The large number of health outcomes potentially affected by climatic change
- The numerous non-climatic influences on each of these outcomes.

There are models that already provide quantitative measures of future risks from climate change.
Particularly widespread are epidemiological methodologies, often used to identify and quantify the relationships between exposure and response on population[12]. Examples are:

- *Ecological studies*: used to quantify the relationships between exposure and response for a range of climate-sensitive diseases. In this case the exposure is defined at the population level rather than the individual level. Group-level relationships are investigated through spatial and temporal variation in exposure and outcome. Usually we can take advantage of large aggregated DB of health outcomes.
- *Time–series methods* have been developed to estimate the proportion of disease in a population that is attributable to weather: the day-to-day or week-to-week variation in exposure to weather. Temperature and daily mortality have been shown to be strongly associated, as have temperature and cases of diarrhoea risk assessment methods to estimate the population at risk or the population-attributable fraction

Independently on the approach , there are several elements of confounding and noise in the data, not always easy to be removed from the analysis. It is worth noting for instance that the quoted studies do not consider the different degrees of exposure of the population to the climate change as well as the different sensitivity of groups within the sample.

[10] S Kovat et al.l "Method assessing human health vulnerability and public health adaptation to climate change" WHO, 2003
[11] Confalonieri UEC. 2000. Environmental change and human health in the Brazilian Amazon. Glob. Change Hum. Health 1:174–83
[12] Sari Kovats, Kristie L. Ebi and Bettina Menne. Health and Global Environmental Change "Method assessing human health vulnerability and public health adaptation to climate change" WHO 2003

It is thus recommended to insulate the effects of climate changes on health from other factors that determine the burden of disease such as the population growth, aging and socio-economic development.

At the simplest level, the burden of disease attributable to climate change can be calculated as:

Attributable burden = (estimated burden of disease under climate change scenario) – (estimated burden of disease under a baseline climate, such as that in 1961–1990).

Using this scenario-based approach, nothing changes in the future world except the climate.

For instance the World Health Organization (WHO) has developed a Comparative Risk Assessment (CRA) based on this approach to quantify the burden of diseases from specific risk factors and to estimate the benefit of realistic interventions that remove or reduce these risk factors (see note 10).

The burden of disease was estimated based on one "business-as-usual" scenario (projected emissions with no policy on climate) and two scenarios in which greenhouse gas emissions are reduced and greenhouse gas concentrations have stabilized at some acceptable level. The aim is to consider the potential benefits of reducing the risk factors rather than taking adaptive actions to reduce impacts:

The choice of model depends on several factors, such as the purpose of the study and the type of data available. Integrated health risk assessment uses any or all of these methods to forecast the potential impact of global climate change and other major environmental changes (such as population growth or urbanization) and policy responses upon human health. However, quantitative modelling is only one possible approach for describing future vulnerability to the potential health effects of climate changes.

Alternatively in more sophisticated exercises climate change can be also coupled with other kind of scenarios.. Scenarios are not intended to predict future worlds or future climates, but they usually provide:
• Plausible and often simplified descriptions of how the future may develop based on a coherent and internally consistent set of assumptions about driving forces and key relationships;
• Hypothetical sequences of events constructed for the purpose of focusing attention on causal processes and decision points;
• Archetypal descriptions of alternative images of the future, created from mental maps or models that reflect different perspectives on past, present and future developments.

It's worth it to mention following type of scenarios:

Climate scenarios
Climate scenarios are plausible representations of future climate that have been constructed for use in investigating the potential impact of climate change. Many national climate scenarios have been specifically constructed for national impact assessment. The scenarios used in the assessment should incorporate both "high" emissions (leading to upper limits of the projections of changes in climate) and scenarios in which emissions are reduced by specific climate policies (mitigation).

Population scenarios

Population projections are available from a variety of national and international sources. National population projections are available from a central government agency in most countries. These are likely to include age-specific and other relevant demographic information.

Socioeconomic scenarios

Adaptation to climate change will take place in a dynamic social, economic, technological, biophysical and political context that varies over time and location and across communities. It is essential that adaptation be included in estimates of future impact. Adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities or to cope with the consequences. These features of communities and regions that appear to determine their adaptive capacity include economic resources, technology, information and skills, social infrastructure, social institutional development and equity in terms of the arrangements governing the allocation of power and access to resources.

Table 1. Advantages and disadvantages of scenarios	
The scenarios are useful because: - Can help to image a range of possible future; - Are powerful frameworks for using both data and model produce output in combination with quantitative knowledge elements; - Exploring future possibilities that go beyond conventional thinking may result in surprising and innovative insight	*The disadvantages in using scenarios:* - Scenarios are often developed from a narrow disciplinary-based perspective, resulting in a limited set of standard economic, technological and environmental assumption. - Many scenarios have a "business-as-usual" character, assuming that current condition will continue for decades. - The set of assumptions made for different sectors, regions or issue are often not consistent with each other. - Key assumptions and underlying implicit judgment and preference are not made explicit.
Source: adapted from S Kovat et al.l "Method assessing human health vulnerability and public health adaptation to climate change" WHO, 2003	

The CRA methodology uses a standardized quantitative assessment framework and a single comparative mortality and morbidity measure to compare the disease burden across health risk factors. The assessment generated estimates of the numbers of deaths and disability adjusted life years (DALYs) attributable to each risk factor in the year 2000 along with expected changes in exposures and associated relative risks of disease outcomes for several time points between 200 and 2030.

Comparative risk assessment involves four stages:

(a) Identifying climate-sensitive health outcomes, (b) Quantitative estimates, (c) Scenarios based climate change exposure assessment, (d) Estimating attributable and avoidable burden of disease.

IDENTIFYING CLIMATE SENSITIVE HEALTH OUTCOMES

Health Impact, determined by global climate change, could occur trough different exposure pathways (extreme heat waves, floods, droughts, etc); they could also be influenced by warmer air temperatures that could modify air pollutants and aeroallergens.

Less-direct health impacts may result from climate-related alteration of ecosystems or water and food supplies, which in turn could affect infectious disease incidence and nutritional status. Finally, sea-level rise could lead to massive population displacement and economic disruption.

QUANTITATIVE ESTIMATES

CRA approach requires the construction of models; they are usually generated on the basis of measurements of the health effects of observed variations in climate over time, (relationships between climate and disease or geographic range , or both).

The most important source of uncertainty in the assessment is extrapolating short term or geographic relationships between climate and disease to the process of long-term climate change; instead gradual climate shift may be less or more severe.

To accurately compare health risks attributed to climate change we must adopt a summary measure of population health, such as:

- Potential years of life lost measures the years of life lost due to premature death.
- Disability- adjusted life-years (DALYs) measures combine effects of mortality and morbidity [13]
- Quality-adjusted life-years (QALYs) measures combine mortality and the quality of life gained[14]

The WHO has a database of DALYs and the cost of select intervention to gain DALYs.

The limits of DALY is that the assessment restrict only to well-characterized and quantified disease burden and exclude other likely outcomes of climate change. To resolve model discrepancies for the same health outcome, selection should be made on the basis of validation against historical data, biological plausibility and applicability to other regions.

SCENARIO-BASED CLIMATE CHANGE EXPOSURE ASSESSMENT

Any human activities (fossil fuel combustion or deforestation) presumably influence global climate. Climate change exposures are based on global climate scenarios: internally consistent representations of future climatic conditions.

These are generated by applying a range of levels of anthropogenic forcing from GHG emissions to computer models representing human and natural influences on the global climate. Output data consist of grid maps of climate variables, such as temperature, precipitation, and humidity at varying spatial resolution.

ESTIMATING ATTRIBUTABLE AND AVOIDABLE BURDENS OF DISEASE

CRA approach needs to link the change in exposure measurement to the change in health outcome. A relative risk or proportional change can then be calculated under each of the various future climate scenarios. Multiplying this relative risk by the total burden of disease that would have been expected to occur in the absence of climate change it is possible to estimate the disease burden attributable to climate change.

As said many health outcomes are multi-factorial and need additional considerations on non-climatic factors such as economic development or demographic trends. Non-climatic effects can be partly addressed by stratifying relative risk estimates separately for populations with clearly different baseline disease burdens and vulnerabilities.

The main limitation of the CRA approach in relation to policy making, further to the analytical difficulties in quantifying health impacts of climate change, is that this method does not consider the full range of implications of a policy or an intervention, but
measures directly the burden associated with a specific risk.

Assessing health outcomes in relation to climate change is a complex task that must accommodate the multiple types of uncertainty that compound across the antecedent environmental and social changes (See table n°4).

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[13] It is calculated as the present value of the future years of disability-free life that are lost as the result of the premature deaths or cases of disability occurring in a particular year.

[14] This is calculated by estimating the total years of life lost to disease or gained by treatment and weighing each year with a quality-of-life score (from 0, representing the worst health possible to either 1 or 100, representing the best health possible) to reflect the quality of life in that year

Table 2. Source of uncertain in relation to health impact assessment	
Problems with data	• Missing components or errors in data • "Noise" in data associated with bias or incomplete observations • Random sampling error and biases(non representativeness) in a sample
Problem with models	• Known processes but unknown functional relationships or errors in structure of model • Known structure but unknown or erroneous values of some important parameters • Known historical data and model structure but reasons to believe that the parameters or model or the relationship between climate and health will change over time • Uncertainty regarding the predictability of the system or effect • Uncertainty introduced by approximating or simplifying relationships within the model
Other source of uncertainty	• Ambiguously defined concepts or terms • Inappropriate spatial or temporal units (such as in data on exposure to climate or weather) • Inappropriateness of or lack of confidence in the underlying assumptions • Uncertainty resulting from projections of human behavior (such as future disease patterns or technological change) in contrast to uncertainty resulting from "natural" sources (such as climate sensitivity)
Source: adopted from McCarty et al 2001 p 127	

These methodologies (HIA and CRA) need several data and models (such as climate change scenarios or DALYs) and need expensive and time-consuming epidemiological studies. Since the inter-correlation between health and climate changes is already known, the precautionary approach could be used to eliminate or further reduce potential damages.

To understand the efficiency of preventive measures already in place much of available information in several sectors could be used in order to mitigate the impact of climate changes on human health and to facilitate ad-hoc improvement of the coping capacity.

1.2 Geographical information system[15]

Geographical information systems are extremely important tools in assessing the impact of climate change also in the field of health. A geographical information system is essentially a system for linking geographical information (such as the geographical coordinates of a specific point or the outline of a defined administrative region) to some information about that location (such as the number of people killed in floods in that region in a given year). For investigating climate effects, any geographical information system should contain:

- geographical information defining the study points or areas, such as the latitude and longitude of the study points or digitized geo-referenced outlines of administrative regions;
- information about the distribution of the exposure (climate) in space and time, such as the mean and standard deviation of precipitation for specific points or administrative regions;
- information about the health effects of this exposure, such as the incidence or prevalence of climate-sensitive outcomes in the corresponding time and place; and

15 *S Kovat et al.l "Method assessing human health vulnerability and public health adaptation to climate change" WHO, 2003*

- information about possible determinants of vulnerability to climate change, such as average income or housing quality.

Such a system allows:

- the different kinds of information for each time and place to be linked;
- trends in exposure, modifying factors and outcomes in space and time to be mapped; and
- the linked data to be exported in a format that allows appropriate statistical analysis, ensuring that any correlations drawn between the exposure data and the outcome data are based on data drawn from the same place at the same time.

2. Developing information to assess health vulnerability to climate change.

This chapter will provide an overview of potential health risks from climate variability and change together with a suggested list of indicators organized according to the two largest groups of determinants related to climate change, namely thermal anomalies (thermal stress) and adverse weather events (floods, drought, windstorm, storm surges, etc) useful to:

- monitor population exposure to identified environmental health risk,
- support impact assessment studies,
- identify vulnerable population groups for the correspondent risk.

Suggested example of indicators shown here are valid specifically for adaptation policies, and we excluded indicators related to mitigation policies (reducing greenhouse gases, risks due to ozone depletion etc.).
The majority of this first list of indicators have been deliberately expressed in a generic form, without any strict computational formula to allow construction of indicator according both to information locally available in existing information systems (health, environment and other sectors) and to field experts judgment (e.g. anomalies of the pollen season can be monitored with early flowering rather than quantitative aspects such as the spread and intensity of the phenomenon).
Single paragraphs are organized according to health risk , a summary table is provided in the annex together with suggested adaptation measures. However should be always kept in mind that many climate stressors influence same health determinant and that their combination act synergistically, for instance: warmer temperature facilitate early onset of pollens and, at the same time, ground level ozone concentration is temperature dependent and it has also, *per se*, an irritating action on respiratory airways which may trigger allergic crisis.

2.1 Direct effects of heat and heat-waves

Physiological and biometeorological studies have shown that high and low temperatures affect health and well-being. Global warming may lead to more extreme heat waves during the summer while producing less extreme cold spells during the winter.[16]. High temperatures cause well described clinical syndromes such as heat stroke, heat exhaustion, heat syncope and heat cramps.
Epidemiological studies have described seasonal fluctuation in mortality and morbidity temperature related. Most temperate countries have a stronger seasonal pattern.
Over the next century, heat waves are likely to become more common and severe. Cold mortality is a problem but it's likely to decline with milder winter. [17] Particular subgroups of the population such as those with heart problems or in medical treatment with psychotropic drugs, the elderly, the very young and the homeless can be specially vulnerable to extreme heat. In urban areas due to heath island effects temperature could be higher of several degrees and this should be considered in

[16] U.S.EPA http://www.epa.gov/climatechange/effects/health.html
[17] Alcamo, J., J.M. Moreno, B. Nováky, M. Bindi, R. Corobov, R.J.N. Devoy, C. Giannakopoulos, E. Martin, J.E. Olesen, A. Shvidenko, 2007: Europe. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 541-580

planning urban adaptation measures (ad hoc urban temperature monitoring intervention to mitigate heat island effects).

Among most quoted epidemiological method for estimating the impact of temperature on mortality are time–series studies of daily mortality which follows methods developed for air pollution impact assessment studies. These methods are considered sufficiently rigorous to assess short-term (day-to-day or week- to-week) associations between the environmental exposure and mortality if adjustment is made for longer-term patterns in the data series. The relationship between temperature and mortality can be derived using a regression model that quantifies the extent to which day-to-day variability in deaths is explained by variation in temperature.
Quantifying temperature-related mortality requires daily counts of deaths, ideally grouped by cause of death, and temperature measured at a similar temporal and geographical resolution.
Studies of heat-wave events can be used to inform the adaptation assessment including use of cost – benefits analysis of adaptation measures for heat waves such as HHWS (Heat Health Watch/Warning Systems)[18] .

Indicator of maximum and minimum temperatures (day and night temperature) and their time series are very important in monitoring the probability of heat related problem. Increasing temperatures directly raise body temperature, and increased humidity slows cooling of the body by decreasing sweat evaporation. Along with maximum temperatures, night-time (minimum) temperatures are important to track for public health effects, because physiologic recovery from daytime heat is hampered if temperatures during the night do not decrease sufficiently. Apparent temperature, or the use of a heat index, which combines humidity and temperature, is important in looking at mortality effects. Demographic information of people exposed to heath island phenomena is important in planning urban adaptation measures.

	Exposure	**Impact**	**Socio economic vulnerabilities**
Thermal stress, heat and heat waves	➢ Maximum and minimum temperature (time series) ➢ Heat index (apparent temperature) ➢ Percentage and demographic distribution of population living in urban areas at risk of heat island phenomena	Heat related mortality excess Increase of hospital admission for cardiovascular and respiratory disorders	Elderly (>65) Infant (<1 year) Children pregnant women People with chronic disease Patient taking psychotropic drug Low socioeconomic status Socially isolated people Lack of heat wave early warning

18 Cambiamenti climatici e strategie di adattamento in Italia. Una valutazione economica. A cura di Carlo Carraro. Il Mulino

2.2 Influence of temperature on air quality

Climate change may increase summer episodes of photochemical smog due to increased temperatures[19]. Weather conditions influence air quality via the transport and/or formation of pollutants (or pollutant precursors), biogenic emissions (such as pollen production) and anthropogenic emissions (such as those caused by increased energy demand). Sunlight and high temperatures, combined with other pollutants such as nitrogen oxides and volatile organic compounds, can cause ground-level ozone to increase. Respiratory disorders may be exacerbated by warming-induced increases in ground-level ozone. Ground-level ozone can damage lung tissue, and is especially harmful for people affected by allergies, asthma and other chronic lung diseases. Concentration of pollutants interact with pollen enhancing risk of allergic crisis. In urban areas, the main source of primary air pollutants is motor vehicles. The concentrations of air pollutants are seasonal and may vary during the day. During winter in temperate countries, air pollution episodes are often caused by stagnant weather conditions. Unlike winter smog episodes, summer ozone episodes affects larger region. Early warning system for Ozone alarm threshold are recommended as requested by law in many countries including Italy.

Many studies have been undertaken that quantify the relationship between air pollutants and health outcomes, mortality and morbidity, in a variety of populations[20]. Among them two mayor health assessment were conducted in Italy based on collaborative project between APAT-ISPRA and WHO[21].
The most complete estimates of both attributable numbers of deaths and average reductions in life span associated with exposure to air pollution are based on cohort studies.
Modelling current and future pollutant concentrations is complex. Future emissions are estimated using linked models of energy use and economic activity. Atmospheric chemistry models need to be linked to emissions projections to estimate future air quality at the appropriate geographical and temporal resolution. Research is needed on the potential effects of climate change on air quality, including the effects on daily levels, seasonal patterns and changes in geographical distribution

Air mass stagnation events, which increase O_3 production and will increase in frequency as weather conditions favourable to heat waves increase, are another important indicator. The U.S.A. National Climatic Data Center (NCDC) has proposed climate impact indicators that include an air mass stagnation index. A stagnation day is defined as one with sea-level geostrophic wind[22] < 8 m/sec, 500 millibars (mb) wind < 13 m/sec, and no precipitation (Wang and Angell 1999), and although not directly related to pollutant emissions, air stagnation days can exacerbate the effects of existing air pollution.[23]

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[19] Alcamo, J., J.M. Moreno, B. Nováky, M. Bindi, R. Corobov, R.J.N. Devoy, C. Giannakopoulos, E. Martin, J.E. Olesen, A. Shvidenko, 2007: Europe. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 541-580

[20] http://www.euro.who.int/en/what-we-do/health-topics/environmental-health/air-quality/publications

[21] WHO – Europe. 2006 Health Impact of PM_{10} in 13 Italian Cities.
WHO- Europe. 2002 Health Impact Assessment of Air Pollution in the eight major Italian Cities

[22] Air under the influence of both the pressure gradient force and Coriolis force tends to move parallel to isobars in conditions where friction is low (1000 meters above the surface of the Earth) and isobars are straight. Winds of this type are usually called geostrophic winds. A geostrophic wind flows parallel to the isobars. The Coriolis effect is a (fictitious) force which acts upon any moving body (an object or an parcel of air) in an independently rotating system, such as the Earth. In meteorology, the horizontal component of the Coriolis force is of primary importance, as the most well known application of the Coriolis force is the movement or flow of air and ocean currents across the Earth. (www.weatheronline.co.uk)

[23] English et al. , 2009. Environmental Health Indicators of Climate Change for the United States: Findings from the State Environmental Health Indicator Collaborative. Environmental Health Perspectives Volume 117 N° 11 November 2009

The indicator suggested is O_3 daily average concentration. There are 24 consecutive 8-hour averages (8-hour rolls) that can possibly be calculated for each day. The daily maximum 8-hour average concentration for a given day is the highest of the 24 possible 8-hour averages computed for that day. EU target value set for the protection of human health is 120 microgram/m^3 O_3 daily maximum 8-hourly average, not to be exceeded more than 25 times a calendar year[24].

Thermal stress, and air quality	➢ Air mass stagnation ➢ Air quality data weighted on population ➢ O_3 daily average concentration ➢ Increase of anthropogenic emissions	Increase of hospital admission for cardiovascular and respiratory disorders	Elderly (>65) Infant (<1 year) Children People with chronic disease Low socioeconomic status Lack of early warning for Ozone episodes

2.3 Thermal anomalies, pollens and allergy risk

Pollen phenology is changing in response to observed climate change, especially in central Europe and at a wide range of elevations. Earlier onset and extension of the allergenic pollen season are likely to affect some allergic disease.[25]

Evidence is growing that changes in air circulation and weather patterns might facilitate the geographical spread of pollen species to new areas as they become climatically suitable. Warming is likely to further cause both an earlier onset and a larger extension of the flowering and pollen season for some species (such as weeds) that cause allergic reactions in already sensitive people. A warmer climate is expected to promote the growth of the moulds, weeds, grasses, and trees. Ragweed has been observed to grow faster and bloom earlier in urban areas where effects of climate change are enhanced compared with rural areas for higher temperatures related to heat island effect and higher pollution level of CO_2.[26] Some species, such as ragweed[27] and mugwort[28], show particular risks for health and require land-use measures, maintenance of public and private green areas or eradication.

Climate changes particularly affect species that bloom in late winter and spring. Many specific studies have actually highlighted in the last few years a growing anticipation in the blooming period of many allergenic plant species and families, such as Birch, *Compositae*, *Urticaceae*, *Graminaceae*, *Juniperus ashei* and *Cryptomeria japonica*[29].Changes in weather patterns (e.g. intense urban windy storm) may facilitate so called “pollen thunderstorm”, that is the sudden release of large quantity of pollens and allergenic microgranules from physical cracking of pollens.

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24 EEA, http://themes.eea.europa.eu/IMS/IMS/ISpecs/ISpecification20080701123452/full_spec

25 Alcamo, J., J.M. Moreno, B. Nováky, M. Bindi, R. Corobov, R.J.N. Devoy, C. Giannakopoulos, E. Martin, J.E. Olesen, A. Shvidenko, 2007: Europe. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 541-580

26 U.S. EPA http://www.epa.gov/climatechange/effects/health.html

27 Ambrosia, also called bitterweeds or bloodweeds

28 Artemisia vulgaris (mugwort or common wormwood)

29 ISPRA 2010. Cambiamenti climatici e salute: criticità e proposte progettuali per una strategia d’adattamento ambientale

Monitoring anomalies in pollen season or in pollen loads (if available or through modelling) and distribution (above all in public location like schools and urban green) like the presence of specific allergenic species like ragweed, could be useful to support healthy urban green planning, land measures and appropriate seasonal medical treatment of allergies.

Stressor	Exposure	Impact	Socio economic vulnerabilities
Thermal anomalies and allergic pollens	6 Anomalies in pollen season 7 Anomalies in distribution of allergenic plants (urban green - schools, leisure environments)	8 Incidence of allergic population 9 Increase in anti-allergic drugs use (out patients) 10 Loss of working/school days 11 Increase in hospital admissions for asthma or allergic crisis	Infant (<1 year) Children Green public areas or community spaces with bad maintenance standard.

2.4. Climate change and vector borne disease

Climate change may both alter the distribution of vector species and their population depending on whether conditions are favourable or unfavourable for breeding places (such as vegetation, host or water availability) and reproductive cycle. Factors responsible for determining the incidence and geographical distribution of vector-borne diseases are complex and involve many demographic and societal as well as climatic factors. Temperature can also influence the reproduction and maturation rate of the infective agent within the vector organism and the survival rate of the vector organism, thereby further influencing disease transmission. For instance vectors, such as mosquito, flies or ticks, that do not regulate their internal temperatures are therefore sensitive to external temperature and humidity..

Transmission requires that the reservoir host, a competent vector and the pathogen shall be all present in an area at the same time and in adequate numbers to maintain transmission.
Changes in average temperature and humidity patterns favour the distribution of arthropods, potential vectors of viral, bacterial and parasitical diseases[30]. Changes in tick distribution consistent with climate warming have been reported in several European location[31]. Future changes in tick-host habitats and human-tick contacts may be important for disease transmission. An increased risk of localised outbreaks is possible due to climate change but only if suitable vectors are present in sufficient numbers.
This issue is not only relevant to developing countries, but also to the developed world. Western Countries, including Italy and other EU Countries, for instance are considered at risk for viral diseases such as West Nyle Fever, Dengue and Chikungunja due to the increasing presence of the mosquito vector *Aedes aegypti* and the emerging vector *Aedes albopictus*.
Climate effects on vector-borne disease should be analysed as a whole, combining climate data with concurrent measurements of the vectorial capacity and infection rate of vectors, abundance and infection rate of reservoir hosts (if any) and the infection rate and eventual health effects on humans.
The relationships between climate and disease distribution and transmission have been investigated for many vector-borne diseases, including the development of predictive models . Predictive models can be broadly classified in biological (based on aggregating the effect of climate on the individual components of the disease transmission cycle) or statistical (derived from direct correlations between geographical or temporal variations in climate and associated variation in disease incidence or distribution, either in the present or recent past).
Increase in quantity and distributions of vectors either now or in the recent past constitute indirect evidence that they have been, or could be, affected by climate change.
Many vectors are collected using a variety of different trapping methods, applied with varying effort over time and space, so that obtaining standardized measurements of abundance is often difficult. Therefore most studies centre on analysing patterns of presence versus absence (that is, distributions), which are relatively more robust and less data-intensive. The correlation between climatic variables and the distribution of vectors may be analysed using either explicitly statistical techniques or semiquantitative climate-matching methods such as in the CLIMEX model[32].

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30 U.S. EPA http://www.epa.gov/climatechange/effects/health.html

31 http://www.cdc.gov/climatechange/effects/vectorborne.htm
http://www.ecdc.europa.eu/en/healthtopics/Pages/Climate_Change_Vector_Borne_Diseases.aspx

32 Sutherst, R. W., and G. F. Maywald. 1985. A computerised system for matching climates in ecology. Agric. Ecosyst. Environ. 13: 281–299. CrossRef, CSA
Sutherst, R. W. 1998. Implications of global change and climate variability for vector-borne diseases: generic approaches to impact assessments, Int. J. Parasitol. 28: 935–945. CrossRef, PubMed, CSA
Sutherst, R. W. 2004. Global change and human vulnerability to vector-borne diseases. Clin. Microbiol. Rev. 17:136–173. CrossRef, PubMed see also http://www.climatemodel.com/climAppl.htm

Surveillance data for human cases of vector borne infectious diseases and disease vectors and reservoirs, are recommended indicators. The assessment of the arthropod diffusion risk is a priority in preventing vector-transmitted diseases, both endemic and recently introduced. This is possible through:

- *geo-referenced and quantitative knowledge of the species and of the environmental reservoirs of infection identifying and locating vector arthropod populations, both native and allochthonous, involved in the transmission of: plasmodes (Anopheline mosquitoes), leishmanias (Phelbotomes), arboviruses (tiger mosquito and ticks), filarials (tiger mosquito), rickettsias and bacteria (ticks); and*
- *constant monitoring of the dynamics of vector species populations and of possible reservoirs with respect to the progress of climate events,*
- *efficiency of eco-compatible biological methods that control the vector*

Unplanned vector control campaign may lead to further impairment of environmental quality. Personal protection methods should be part of information campaign and environmental friendly

	Exposure	**Impact**	**Socio economic vulnerabilities**
Thermal anomalies and changes in vector distribution	• Anomalies in vector distribution • N° of environmental vector control campaign (N°/years)	12 Human cases of vector borne infectious diseases 13 Increase in personal protection products sales (lotions, sprays, mosquito nets etc.)	Coastal/urban population Low socioeconomic status Lack of information campaign on personal protection methods

mosquito net should be used in private and public places to avoid exposure.

2.5 Climate change and Harmful algae blooms (HABs)

A worldwide increase in cyanobacterial (blue-green algae) sources has been observed in both coastal and freshwaters. Algal blooms may occur in freshwater as well as marine environments.
An algal bloom or marine bloom or water bloom is a rapid increase in the population of algae in an aquatic system. Toxic blooms (HABs) occur when algal species produce neurotoxins, usually when stressed or dying. Many studies suggested increased temperatures and salinity stratification resulting from climate change combined with human activities, primarily through nutrient runoff, are important factors related to the increase of HABs.
Blue-green algae (cyanobacteria) are any of a number of species of microscopic bacteria that are photosynthetic. They occur naturally in surface waters. When conditions are optimal, including light and temperature, levels of nutrients (i.e., phosphorous and nitrogen, and the ratio of the two), and lack of water turbulence, blue-green algae can quickly multiply into a bloom.
Blue-green algae blooms are likely to occur more often in warmer months. When some blooms occur in water bodies, exposure to the blue-green algae and their toxins can pose risks to humans, pets, livestock and wildlife. Exposure may occur by ingestion, dermal contact, and aspiration or inhalation.

Risks to people may occur when recreating in water in which a blue-green algae bloom is present, or from the use of drinking water that uses a surface water source in which a blue-green algae bloom is present.

Human exposure to HABs can cause eye and skin irritation, vomiting and stomach cramps, diarrhoea, fever, headache, pains in muscles and joints, and weakness. [33]

When toxic blue-green algae blooms occur in water supply systems is needed a specific treatment for the blooms that does not merely kill the algae, since rupturing of the blue-green algal cells can release their toxins, and treatment may not be entirely effective in removing toxins. In Italy a contamination of algal bloom in water supply system as been found in Puglia[34].

H*armful Algal Blooms* (HABs) can also cause human pathologies through the consumption of contaminated shellfish. Seawater warming can therefore contribute to increasing cases of sea food contamination such as for instance ciguatera, an intoxication caused by ciguatoxin (toxin produced in particular by the microalgae *Gambierdiscus toxicus*). [35]

Information campaign for the population and early warning systems are key preventive measures. Health impact assessment will rely on recorded cases and outbreaks.

Potential exposure indicators include monitoring intensity, frequency, duration and distribution of HABs, ad hoc monitoring of water supply system and HABs recorded cases.

Environmental stressor	Exposure	Impact	Socio economic vulnerabilities
Thermal stress	Algal blooms monitoring (frequency, duration and distribution) Cyanobacteria in drinking water	HABs recorded cases (*amnesia, diarrhoeal, skin and eye irritation, numbness, liver damage, respiratory paralysis)*	Coastal population Touristic resort Lack of early warning system and public information Bad maintenance of water supply network

2.6 Climate change and increased risk of waterborne and foodborne diseases

2.6.1.Food safety and food-borne diseases

Climate change combined with the way in which food is produced, distributed and consumed, can potentially influence food safety and occurrence of food borne diseases. A statistical association between diseases and temperature changes in the short term suggests that foodborne diseases shall be influenced by climate change in the long term. In the cCASHh report[36] (*Climate Change and*

[33] English et al. , 2009. Environmental Health Indicators of Climate Change for the United States: Findings from the State Environmental Health Indicator Collaborative. Environmental Health Perspectives Volume 117 N° 11 November 2009

[34] UNPRECEDENTED CYANOBACTERIAL BLOOM AND MICROCYSTIN PRODUCTION IN A DRINKING WATER RESERVOIR IN THE SOUTH OF ITALY. References: Luca Lucentini , Massimo Ottaviani , Sara Bogialli , Emanuele Ferretti , Enrico Veschetti , Rosa Giovanna , Concetta Ladalardo , Matteo Cannarozzi De Grazia , Nicola Ungaro , Rosaria Petruzzelli , Gianni Tartari , Licia Guzzella, Marina Mingazzini, Diego Copetti . (not yet published)

[35] ISPRA 2010. Cambiamenti climatici e salute: criticità e proposte progettuali per una strategia d'adattamento ambientale

[36] The pan-European project Climate Change and Adaptation Strategies for Human Health (cCASHh) , funded under the European Union's 5th Framework Programme, aims to provide the scientific basis for the development of indicators for, and response strategies to climate variability and change within the health sector. Included in cCASHh is an assessment of the potential impact of weather and climate on the incidence of foodborne disease in Europe.

Adaptation Strategies for Human Health in Europe) epidemiological studies were conducted to describe and quantify the effect that environmental temperature has on foodborne diseases. According to observatiosthe number of cases of salmonellosis increases by 5-10% for each 1°C of raise in weekly temperatures, for average temperatures above 5 °C. About one third of salmonellosis transmission cases in England, Wales, Poland, Netherlands, Czech Republic, Switzerland and Spain can be caused by temperature changes.
Cases of food poisoning can even be related to meteorological conditions of unexpected heat that can increase bacterial replication (e.g. more cases of food poisoning were reported during unusually hot summers both in the UK and in Australia). Other pathogens are temperature sensitive. *Vibrio parahaemolyticus* and *Vibrio vulnificus* are responsible for non viral infections related to the consumption of fish in the USA, Japan and South East Asia. Their abundance depends on the salinity and the temperature of coastal waters. In 2004, a great epidemic occurred due to the consumption of oysters contaminated by *V. parahaemolyticus*, which was related to the presence of unusually high temperatures in the coastal waters of Alaska.[37]
Microscopic filamentous fungi can develop on a large variety of plants and can lead to the production of highly toxic chemical substances, commonly called mycotoxins. The most widespread and studied mycotoxins are metabolites of some types of mould such as *Aspergillus*, *Penicillium* and *Fusarium*. Contamination caused by fungi can take place during almost all the stages of the food chain (harvesting, storage and transport). The colonization and diffusion of fungi are favoured by environmental conditions and nutritional components, as well as other factors such as attacks by infesting insects. The biosynthesis of mycotoxins is influenced by quite unique conditions, such as: climate and the geographical location of the cultivated plants; farming practices; storage.
Increased risk of food contamination by infesting species (especially flies, rodents and cockroaches) is also temperature sensitive. The activity of flies is mainly influenced by temperature rather than by biotic factors. It is probable that in temperate countries, which have warmer climate conditions and milder winters, the quantity of flies and other infesting species will increase during the summer months and there will be an early appearance in spring[38].
Some cases of food borne diseases can also be associated to extreme climate events since rain and floods can favour the spread of pathogens. For example, fresh fruit and vegetables can be contaminated by water-borne pathogens such as the protozoes *Cyclospora* and *Cryptosporidium spp*. Seafood can also be contaminated by enteric bacteria and viruses that can survive water treatment plants, specially if there is a contaminated overflow during floods or intense rain period.
During flood lack of water for hygiene use in emergency will also facilitate oro-faecal transmission diseases.

The suggested indicators include monitoring of food samples to reveal possible contamination by fungi, mould and pathogens (e.g.salmonella, campylobacters, V vulnificus e V cholera, micotoxins), as well as tracking outbreaks of food borne diseases in the population to manage and prevent other possible contamination.

37 ISPRA 2010. Cambiamenti climatici e salute: criticità e proposte progettuali per una strategia d'adattamento ambientale
38 ISPRA 2010. Cambiamenti climatici e salute: criticità e proposte progettuali per una strategia d'adattamento ambientale

Environmental stressor	Exposure	Impact	Socio economic vulnerabilities
Thermal anomalies	Increase/N° of food samples contaminated by mould, fungi and pathogens (e.g.*salmonella, campylobacters, V vulnificus e V cholera, micotoxins)*	Outbreaks of foodborne diseases	Community residence people (schools, hotels, elderly homes, summer camps) Low socioeconomic status Lack of ad hoc food safety monitoring plan in extremes

The chemical security of waters and food during long periods of drought is also worth considering. A higher concentration of chemical pollutants in waters used for human consumption is assumed (since a water shortage is followed by a poor dilution effect). Furthermore, vegetable infestation and temperature increases both lead to a higher use of pesticides (which have an increased degradation with higher temperatures) and a more frequent utilization of new chemicals compounds [39].

It is suggested to monitor any increase in the use of pesticides or in the presence of samples of food contaminated by chemicals, as well as the presence of acute toxic disorders in farmers or

Environmental stressor	Exposure	Impact	Socio economic vulnerabilities
Thermal anomalies and chemical safety	• Increase of pesticide use • Increase/N° of food samples contaminated by chemicals	14 N° of acute toxic disorder in farmers or workers	Infant (<1 year) Children pregnant women Lack of ad hoc food safety monitoring plan in extremes

Adaptation measure should regard also review of food and water monitoring and control for pathogens and chemicals under critical condition of extreme weather events.

2.6.2 Water safety and water-borne diseases

Climate change is also likely to affect water quality and quantity in Europe, and hence the risk of contamination of public and private water supplies. [40]
More frequent extreme rainfall events could lead to increased surface water turbidity and higher numbers of bacteria and pathogens in surface water. This would create a greater challenge for water treatment works, particularly where direct river abstraction is used.
Heavy rainfall can cause abnormal changes in the direction of flow of water through both surface and underground channels. Microbial contaminants present in biosolids or manures applied to agricultural land may be transferred to surface water sources more rapidly than under conditions of

[39] ISPRA 2010. Cambiamenti climatici e salute: criticità e proposte progettuali per una strategia d'adattamento ambientale

[40] Alcamo, J., J.M. Moreno, B. Nováky, M. Bindi, R. Corobov, R.J.N. Devoy, C. Giannakopoulos, E. Martin, J.E. Olesen, A. Shvidenko, 2007: Europe. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 541-580

more 'normal' rainfall. The contamination of surface water sources used for drinking water production by storm drain overflow may be brief, with a bolus of infected water being followed by substantial dilution as a result of the excess water flow[41].

Diseases such as cholera and salmonella, which are transmitted through contaminated food or water, could become more widespread because of increased flooding. Both extreme rainfall and droughts can increase the total microbial loads in freshwater and have implications for water quality and outbreaks of diseases. [42]

Cryptosporidiosis[43] is the most significant waterborne disease associated with the public water supply in the UK. The spring peak in cases of cryptosporidiosis is likely to be associated with spring rainfall and high levels of contaminated manure on the land, especially from lambs . These relationships show that rainfall may have played an important role in sporadic cases of the disease in the springtime.[44]

Suggested indicators are the n° of contaminated water samples (chemical and biological), the N° of period with intermitted water supply and the incidence of outbreaks of water related diseases (water

Environmental stressor	Exposure	Impact	Socio economic vulnerabilities
Adverse weather events (floods)	• Increased n° of contaminated water samples (chemical and biological) • N° of period with intermittent water supply	Outbreaks of water related diseases (water borne, food-borne, hygiene behaviour)	Community residence people (schools, hotels, elderly homes, summer camps) Low socioeconomic status Lack of ad hoc monitoring plan in extremes Lack of health surveillance

Changes in the distribution of rainfall may increase drought risk. One consequence of drought would be a failure of the domestic water supply, resulting in a need for standpipes and other methods of water delivery. The potential health effects of this would include water related diseases. Access to sufficient water for the elderly, disabled and other vulnerable groups would be a concern. Localized water shortages may be particularly important .[45]

A potential increase in drought could substantially affect water resources and sanitation in situations where water supply is effectively reduced. This could lead to an increased concentration of pathogenic organisms in raw water supplies. Additionally, water scarcity may require using poorer-quality sources of fresh water, such as rivers, which are often contaminated. All these factors could increase the incidence of diseases. Epidemiological assessment should be used to quantify this risk.

The health consequences of drought include diseases resulting from lack of water. In times of shortage, water is used for cooking rather than hygiene. In particular, this increases the risk of faecal-oral (primarily diarrheal) diseases and water-washed diseases (such as trachoma and scabies).

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41 Department of Health/Health Protection Agency, 2008. Health Effects of Climate Change in the UK 2008: An update of the Department of Health Report 2001/2002.

42 Alcamo, J., J.M. Moreno, B. Nováky, M. Bindi, R. Corobov, R.J.N. Devoy, C. Giannakopoulos, E. Martin, J.E. Olesen, A. Shvidenko, 2007: Europe. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 541-580

43 http://www.ecdc.europa.eu/en/healthtopics/Pages/Climate_Change_Water_Borne_Diseases.aspx

44 Department of Health/Health Protection Agency, 2008. Health Effects of Climate Change in the UK 2008: An update of the Department of Health Report 2001/2002.

45 Department of Health/Health Protection Agency, 2008. Health Effects of Climate Change in the UK 2008: An update of the Department of Health Report 2001/2002.

Another concern is the use of unsafe new sources of water (such as untreated waste water) for human activities such as irrigation. These practices lead to an increased risk of infectious diseases by use of food contaminated by unsafe water.

The indicators suggested are : Length and severity of drought periods and the number of contaminated water and food samples by chemicals

Environmental stressor	**Exposure**	**Impact**	**Socio economic vulnerabilities**
Adverse weather events (drought)	• Length and severity of drought periods	• Increased n° of contaminated water and food samples (chemicals)	Community residence people (schools, hotels, elderly homes, summer camps) Low socioeconomic status Lack of water management plan in extremes Lack of health surveillance plans

Since long term effects of chemical exposure is hard to quantify, health impact assessment of food and water borne diseases generally are referred to acute intoxication generally manifested by diarrhoeal disorders. The potential impact of changes in rainfall on waterborne disease is very important. However, little epidemiological research has addressed the role of rainfall in either triggering individual outbreaks or in the overall burden of waterborne disease.
Time–series methods can be used to quantify an association between variation (daily, weekly or monthly) in diarrhoea outcomes and environmental temperature. The effect of high temperatures may be only apparent after 1–2 weeks, as delay is inherent between the time of infection, the onset of symptoms and when disease is recorded through routine surveillance. An appropriate environmental monitoring plan may accelerate these proxies acting as early warning system to anticipate health risk.
Other factors should be considered for assessment:

- Health data may be available from routine surveillance (laboratory-confirmed cases by pathogen) or the records of infectious intestinal illness at primary care clinics or hospitals.
- The date of onset of illness (or admission) should be reasonably accurately recorded, and data should be available at the weekly or daily resolution. Analysis of aggregate monthly data may lead to overestimate of a temperature effect because the potential to control for the effects of non-climate factors (such as seasonal confounding) is limited.
- If the model is based on a relationship derived from a different population, then justifying this extrapolation is important, especially if the other population differs in climate and the burden of diarrhoeal disease.
- A climate relationship with a specific diarrhoea pathogen can be used to estimate the effects on the total burden of diarrhoeal disease if information is also obtained on (1) their relative contribution to overall disease incidence and (2) equivalent data on climate-sensitivity and relative prevalence for all other diarrhoea pathogens.

Information on water borne and food borne outbreaks and incidence can be found at ECDC website (http://www.ecdc.europa.eu) and, for Italy, the National Health Institute (www.iss.it *)*
To summarize several potential mechanisms will increase the risk of water and food borne diseases:

- Heavy precipitation causing sewers to overflow and people come into contact with pathogens and faecal matter.

- Heavy rainfall causing contamination of surface or coastal water if the sewers are used as storm drains.
- Heavy rainfall leading to agricultural runoff contaminated with livestock faeces into surface water, which reaches the public water supply or direct contact with humans.
- Heavy rainfall leading to failure in a wastewater-treatment plant.
- Drought reducing the amount of surface water and groundwater, leading to increasing concentrations of pathogens and the use of alternative sources of water that are less potable.

Table 5. Summary table on pathogens and health significance (source: Pond* et al.*, in Menne* et al. *(2010))

	Pathogen	**Weather influences**	**Health significance***	**Relative infective dose***	**Infection caused**
Viruses:	Norovirus GGI and GGII Sapovirus Hepatitis A virus Rotavirus Enterovirus Adenovirus Avian influenza virus#	Storms can increase transport from faecal and wastewater sources Survival increases at reduced temperatures and sunlight (ultraviolet) * Changes in seasonality	High High High High High High Low	Low Low Low Low Low Low unknown	Gastroenteritis Gastroenteritis Hepatititis Gastroenteritis Gastroenteritis Respiratory&intestinal influenza
Bacteria:	Pathogenic *Escherichia coli* *Campylobacter jejuni, C. coli* *Helicobacter pylori* *Legionella pneumophila* *Vibrio cholerae* *Vibrio parahaemolyticus*# *Vibrio vulnificus*# *Vibrio alginolyticus* *Toxic cyanobacteria*	Enhanced zooplankton blooms Salinity and temperature associated with growth in marine environment	High High High High High Medium Low Low Medium	Low Moderate Unknown High High High Low Unknown Moderate	Gastroenteritis Gastroenteritis Stomach&duodenal ulcer Pneumonia Cholera Wound infections, otitis and lethal septicaemia, gastroenteritis, respiratory dysfunctions, allergic reactions
Protozoa	Cryptosporidium spp.	Storms can	High		

:	Giardia spp *Naegleria fowleri*# *Acanthamoeba* spp.#	increase transport from faecal and waste water sources Temperature associated with maturation and infectivity of Cyclospora	High Low Low	Low Low High Unknown	Gastroenteritis Gastroenteritis Meningoencephalitis Keratitis, blindness
Taxa labelled with # are considered potentially emerging. *according to WHO-report "Emerging Issues in Water and Infectious Disease", 2003.					

2.7 Disaster management in extreme weather events

As already mentioned climate change is likely to increase the risk of mortality and injuries from wind storm, flash floods and coastal flooding. The elderly, disabled, children, ethnic minorities and those on low income are more vulnerable and need special consideration.
Sea-level rise can have a wide variety of impacts causing flooding, land loss, salinitation of ground water and the destruction of residential houses and infrastructures including water supply and sanitation networks, desalinisation plans and health infrastructures. Coastal flooding related to sea-level rise could affect large populations. Under some scenarios up to 1.6 million of people each year in the Mediterranean, northern and western Europe, might experience coastal flooding by 2080 [46]**.**
Weather disasters affect human health by causing considerable loss of life. Extreme weather events cause death and injury directly. Following disasters, deaths and injuries can occur as residents return toclean up damage and debris.
The non fatal effects of natural disasters include:
• physical injury;
• increases in respiratory and diarrhoeal diseases because of crowding of survivors, often with limited
shelter and access to potable water;
• effects on mental health that may be long lasting in some cases;
• increased risk of water-related diseases from disruption of water supply or sewerage systems; and
• exposure to dangerous chemicals or pathogens released from storage sites and waste disposal sites into flood waters.
Bereavement, property loss and social disruption may increase the risk of depression and mental health problems. Substantial indirect health impact can also occur because of damage to the local infrastructure and services (such as damage to hospitals and roads) and population displacement.
The total health impact of a disaster is difficult to quantify, because injuries and secondary effects are poorly reported and communicated.
Current vulnerability to weather disasters needs to be described in terms of total and age-specific mortality and morbidity.

Epidemiological studies of flood events can be undertaken in relation to the following outcomes to compare incidence in the pre- and post-flooding situations:
• injuries
• infectious diseases, especially skin, gastrointestinal and respiratory infections; and

46 Alcamo, J., J.M. Moreno, B. Nováky, M. Bindi, R. Corobov, R.J.N. Devoy, C. Giannakopoulos, E. Martin, J.E. Olesen, A. Shvidenko, 2007: Europe. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 541-580

• mental disorders: increases in common anxiety and depression disorders.

Routine surveillance may provide data on episodes of infectious disease both before and after a flood.

As indicators in this area of concern it's suggested to provide hazard maps weighted on population for all kind of event that have probability to happen (floods/sludge, landslides, storm surges, sea level rise, droughts). Hazard maps can also be obtained by simply overlapping spatial maps of areas at risk with maps of population living in the area of interest. Another indicator should be the number of events (flash floods/ sludge, landslide, intense rainfall, windstorm or storm surges) occurring in the area of interest .Other useful indicator suggested to monitor extreme impacts and preparedness are the number of people requiring medical assistance/ hospitalization(physical injuries and post traumatic stress disorders), N° of deaths and N° request of damage restore of socio -economic activities (crops, tourism, schools, hospitals, etc) and residential damages. All this indicators show the resilience and coping capability of the system to extreme events.

Environmental stressor	Exposure	Impact	Socio economic vulnerabilities
Adverse weather events (floods, drought, windstorm, storm surges, etc)	• Hazard maps weighted on population (floods/sludge, landslides, storm surges, sea level rise, droughts) • N° of flash floods/ sludge, landslide, intense rainfall, windstorm, storm surges.	• N° of people requiring medical assistance/ hospitalization (physical injuries and post traumatic stress disorders) • N° of deaths • N° request of damage restore of socio - economic activities (crops, tourism, schools, hospitals, etc) and residential damages	Elderly (>65) Infant (<1 year) Children People with disabilities (including obesity) Resilience of water supply and sanitation systems Lack of early warning systems

Adaptation measures should include risk reduction management in disaster.

2.8 Global warming and Avalanches

These events should be expected to impact settlements, infrastructural elements, resources and the environment, resulting in human and financial losses. Long term temperature change affects the volume of glacier ice in mountain regions. Glacier ice loss due to global warming has been identified as an important factor in the occurrence of a range of catastrophic processes, such as outburst floods and rock avalanches. With respect to predicted temperature increases, further glacier ice loss will result in continued debuttressing of mountain slopes leading to slope deformation and, in some cases, catastrophic failure.

Snow avalanches are mainly ruled by temperature fluctuations, heavy precipitations and wind regimes, so that climate change is likely to modify the frequency and magnitude of both ordinary and extreme events .

As indicator are suggested *hazard maps weighted on population for areas that have probability to experience avalanches. Hazard maps can also be obtained by simply overlapping spatial maps of areas at risk with maps of population living in the area of interest and touristic resort nearby .*

Environmental stressor	**Exposure**	**Impact**	**Socio economic vulnerabilities**
Thermal stress	• Events monitoring system (n°/year) • Hazard maps	15 Injuries and deaths	Local mountain communities and touristic resorts Lack of early warning and public information

2.9 Wildfires

Increased temperatures will result in an increased frequencies of wildfires that, in turn, will elevate particulate matter levels. Large-scale wildfires and biomass burns have also been known to increase ground-level O3 concentrations. The smoke, particulate matter, and O_3 precursors from fires can affect local populations as well as those at long distances from the fire's origin[47].

Besides direct injuries there would be an increase of acute respiratory diseases.

Environmental stressor	Exposure	Impact	Socio economic vulnerabilities
Thermal stress	• Frequency, severity and distribution of wildfires	16 N° of people requiring medical assistance/ hospitalization 17 Loss of private property and touristic attraction	Elderly (>65) Infant (<1 year) Children People with disabilities (including obesity) Community residence people (schools, hotels, elderly homes, summer camps) Building vulnerability

47 English et al. , 2009. Environmental Health Indicators of Climate Change for the United States: Findings from the State Environmental Health Indicator Collaborative. Environmental Health Perspectives Volume 117 N° 11 November 2009

3. Climate and Health: Adaptations measures in urban area

A) Urban Planning

Public information on climate-related health threats and prevention.

Awareness of emerging health risk is a key tool for effective preventive measures. Any efforts should be put in place to make individuals and vulnerable groups, stakeholders and policymakers aware about potential health effects, and able to address specific risks associated with climate change (e.g. for the prevention of heat illness, of vector borne/food-borne disease, etc.). Communication to be effective needs to be tailored to specific groups, and conducted together with public health experts [48].

Messages should empower people to access and use necessary health resources. Since frightening scenarios may elicit despair and helplessness, it is important to design messages that minimize these responses leading to constructive behaviors. These communication steps must continue throughout the adaptation process, and can include periodical organization of workshops and conferences, distribution of factsheets, implementation of websites and other tools, etc. Educational programme in school are highly recommended.
Information on health risks should be also part of background knowledge of environmental , climate professionals and utilities managers.

Intervention to reduce heat island effects and heat related health impacts
Cities can take various actions to address urban heat island issue.
Among these, parks, street trees, and green roofs can help surface temperatures reduction in cities, creating at the same time more walkable, liveable communities. Trees provide cooling shade, and can significantly reduce home energy costs. In addition, vegetation helps to improve local air quality. Other options are represented by: i) cool roofs, that use light-colored roofing materials that reflect heat rather than absorbing it; ii) green roofs, that use living vegetation to reduce heat; iii) cool pavements, that include the use of more reflective light-colored materials instead of black asphalt, as well as the use of permeable pavements.

Another important way of reducing heat-related mortality is implementing a weather-based heat-wave warning system. In Italy, like many other European Countries, the Ministry of Health is dedicating a lot of resources to the heat wave management providing information materials and supporting the national heat waves surveillance and alarm system for the 27 cities that joined the network (www.salute.gov.it) .
Integrated with proper response, emergency heat warning systems can reduce population vulnerabilities, increase resilience to future extreme events, and help identify vulnerable populations.

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[48] H. Frumkin, J. Hess, G. Luber, J. Malilay, M. McGeehin (2008). Climate change: the public health response. American Journal of Public Health, 98(3): pp. 435-445

Intervention to reduce air pollution impacts.

Especially in warmer season all efforts should be made to warrant effective management of air quality and ozone episodes strengthening those measures already in place . These measures may include:

- maintaining strict regulation of air pollutants also by traffic restrictions;
- reducing exposures to combustion products (e.g. trough actions such as regulations/controls on diesel trucks, increased car fuel efficiency, etc.);
- increase community bike/walkability together with green areas planning
- improve public transportation planning adequate number of personnel also in summer holidays period;
- Provide information to public on risky behavior such as sports/outdoor activities in hot weather.

It's important to improve and maintain effective warning systems both for air quality and ozone .

Intervention to prevent impacts from increased risk of vector-borne diseases.

The primary adaptation measure to limit the spreading of infectious disease are prevention programs that reduce the specific vulnerability (e.g., avoiding/mitigate exposure to mosquitoes) including educational programme and public information, health surveillance and tracking systems to identify emergence of potential threats, and planning accurate sustainable vector control programme outside outbreak emergencies. Elements of such a strategy include[49]:

- Monitoring of vector density and factors influencing disease transmission and diffusion;
- Dissemination of information and strengthen research on sustainable vector control;
- strengthening local capacity for assessing the social, cultural, economic and environmental factors that lead to increased vector density and increased transmission of disease;

Informatoin is in the end essential : epidemic early warning systems combine clinical data such as emergency department and outpatient clinic syndromic surveillance with climate data, vector biology data, clinical laboratory data, veterinary data, telephone hotline call tracking, pharmaceutical use data, and other data[50].

An appropriate environmental monitoring and biodiversity assessment could be helpful to anticipate outbreak occurrence.

It is also important matching these actions with an effective public information on individual protective tools such as mosquito network, personal repellent and management of private manholes, standing water in saucers, gully hole, etc. to be extended also to vulnerable communities like schools, residential homes etc .

Intervention to reduce health impacts in disasters.

Disaster risk reduction preparedness should be part of adaptation strategies and should include:

- create preparedness plans for scenarios that are not currently planned for (e.g. major flooding by sea level rise and storm surges , saline intrusion, etc.) also by using integrated risk map weighted on population, crucial infrastructure and economic activities;
- work cross-sector with health and emergency preparedness entities to identify and refine scenarios;
- develop and improve effective early warning systems, especially for regions that have not yet adopted it;

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[49] World Health Organization Europe (2003). Health and global environmental change. Series n.1. Methods of assessing human health vulnerability and public health adaptation to climate change.

[50] H. Frumkin, J. Hess, G. Luber, J. Malilay, M. McGeehin (2008). Climate change: the public health response. American Journal of Public Health, 98(3): pp. 435-445

- improve effective protection and emergency response systems;
- improve effective coordination among alert systems and emergency personnel responding to public health emergencies.
- improve Land-use planning and zoning to avoid (or to protect) the allocation of buildings, infrastructure and basic services (e.g. school, hospital etc.) in flood or landslide prone areas.

Finally it must be kept in mind that people not aware of risks can slow down the emergency operations.
In disaster critical conditions community ability to cope with it relies also on preventive information campaign that should be organized also for communities such as schools, hospitals, residential homes.
Avoiding exposure to the hazard by keeping hazard zones free of intensive economic use or highly populated settlements is highly recommended.

The communication strategy, based on a multidisciplinary approach, should be part of the risk disaster management and adaptation plans for extreme weather events in order to share knowledge among different actors,

- Specific communication activities should be planned (before, during and after the event) and targeted at different groups at risk (e.g. the elderly, children, communities).
- Public authorities must be mainly responsible for elaborating and delivering the messages.
- The media are a key partner in communication.
- Communication should be a long-lasting and institutional process and not only a contingency tool.

B) Water supply and sanitation system (WSS)

In normal conditions water supply and sanitation are made to prevent pollution of water bodies and to prevent hygiene related diseases. Under extremes or adverse weather conditions they become an important source of pollution.
The resilience of WSS is a challenging vulnerability under climate change scenarios for both technical and regulations aspects. Generally WSS are very sensitive to changes in water loads, sea level rise, storm surge and energy blackout (windstorms) can further impair their functioning. Crucial infrastructure such as water treatment plans and water supply systems are often hitted by extremes.
Although is well known that pollution discharge from WSS is a major health determinant for bathing and drinking water , generally water quality monitoring is not due in condition of extreme weather according to present European regulations. Only the recent EU Flood directive is somehow addressing the issue. Regulations are also lacking for the safe use of new sources of water through several techniques including aquifer recharge with reclaimed water . Furthermore usual water and land use management adaptation strategies do not include, in the practice, consultation with utilities managers .
Due to the relevance of the issue Guidelines on Water Supply and Sanitation in extreme events are to be finalized by the Task Force on extreme Weather events[51] within the framework o the Protocol Water and Health to the UNECE Water Convention leaded by Italy (Ministry of Environment/ISPRA) .

[51] http://www.unece.org/env/water/meetings/documents_TFEWE.htm

Recommended actions are:

- Include WSS management into water and climate adaptation strategies
- Provide effective water bodies monitoring during heat waves, intense rain and/or drought events;
- effective monitoring and inventories of condition and capacity of water distribution systems and of treatment systems
- provide local regulations for safe use of new sources of water;
- reinforce ability of water supply with alternative techniques such as rain harvesting and/or reclaim and reuse of treated waste water

Other measures at urban and peri-urban level include:

- ***Sustainable urban drainage systems implementation.***
- use of permeable surfaces (e.g. in parking lots or roads) to reduce stormwater runoff, thus reducing the risks of flooding and pollution outflows, reducing the risk of stormwater systems overwhelming during heavy precipitation events , and increase recharging of ground aquifers;
- use of green roofs to increase on-site retention of stormwater;
- increase the use of stormwater retention ponds, constructed wetlands and swales providing surveillance for potential risk of increase of vector borne diseases .

C) Energy

Strategies referred to managing energy demand include:

- reduce vulnerability to blackouts from hydropower loss, storms and floods informing population on health threats in emergency (e.g. food contamination without refrigeration, electric shock etc) ;
- reduce urban heat and energy demand for air conditioning, especially during heat waves, increasing street trees and urban parks/green areas planning and maintenance, and increasing green roofs and high-albedo surfaces;
- decrease energy needs for cooling building by improving energy saving techniques, specially in crucial infrastructures such as schools, hospitals and residential homes providing safe indoor air quality standards ;

D) Transportation.

Adaptation to climate change of transportation sectors (public and private) and related infrastructures to mitigate injuries to people and settlements are generally shared with usual adaptation measures that here are briefly summarized[52]:

3) evaluation of the vulnerability of port facilities and associated infrastructures due to changes in water level, increased wave activity, storm surges, etc.;
4) relocation of coastal road, rail lines and all the other infrastructures that could be subjected to sea-level rise, storm surges, etc.;
5) assessment and retrofitting of vulnerable transportation infrastructure systems such as culverts, tunnels, bridges, subway entrances, dykes, etc.;
6) ensuring that critical components, such as switch gear or substation, are above flood levels;

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[52] The Clean Air partnership (May 2007). Cities preparing for climate change- A study of six urban region.

7) ensuring the availability of alternative routes in case of disruption and/or need of evacuation.

E) Infrastructures and basic services.

Strategies regarding improving adaptation to climate change for infrastructures and basic services (such as hospital, school, etc.) include:

- taking into account of the increased risks of flooding, heat waves, intense storms and storm surges, wind speed and other climate change/extreme events effects on building design and development;
- designing drainage systems and entrance thresholds at the best to cope with more intense rainfall, possibility of flooding, etc.;
- improve natural ventilation to reduce heat gain during summer/heat waves;
- using ground-floor spaces for flood compatible use, such as car parking, or raise ground floor above flood level in areas potentially vulnerable to floods;
- utilizing green roofs to insulate against heat gain and reduce stormwater runoff.
- Develop disaster management plan shared with local communities
- Provide adequate green space management to mitigate allergic risk
- Extend use of mosquito network in risky areas
- Provide educational and information campaign for personnel and people living in community buildings.

Table 5. Suggested example of adaptation measures[53] for no-health sectors
(Source: The Clean Air Partnership, 2007[54], adapted by ISPRA)

Suggested example of adaptation measures[55] for no-health sectors		
Sector or system		
Urban Planning	**Public information on climate-related health threats and prevention.**	Support public health awareness campaign addressing specific risks associated with climate change (e.g. for the prevention of heat illness, of vector borne/food-borne disease, etc.) tailored to specific groups, including vulnerable populations (e.g. outdoor workers , people living in communities, social services professionals, people with chronic illness, etc.) including environmental , climate professionals and utilities managers Provide information to public on risky behavior such as sports/outdoor activities in hot weather. Educational programme in school are highly recommended
	Intervention to reduce heat island effects	Increased street trees and tree canopy coverage Increased parks and green spaces(avoid allergenic species!) Green roofs, light coloured roofing materials Management of reflective building and road surface (high albedo) Heat alert and early warning systems
	Intervention to reduce air pollution impacts	Strengthen air quality management Air quality and ozone alarm and warning system
	Interventions to prevent vector-borne diseases	Early detection and warning systems (vectors density, transmission risk) Planning /Guidelines for sustainable mosquito control Information campaign for use of protection devices (mosquito network) and management of green areas for public and vulnerable communities (schools , residential homes)
	Include disaster risk reduction strategy into adaptation plans	• Reinforce preparedness plans by using integrated risk map weighted on population, crucial infrastructure and economic activities; • work cross-sector with health and emergency preparedness bodies to identify and refine scenarios; • develop and improve effective early warning systems and effective coordination among alert systems . • improve Land-use planning and zoning to avoid (or to protect) the allocation of buildings, infrastructure and basic services (e.g. school, hospital etc.) in flood or landslide prone areas.

[53] No ad hoc mitigation measures were considered
[54] The Clean Air Partnership (2007). Cities preparing for climate change – A study of six urban regions (http://www.cleanairpartnership.org/pdf/cities_climate_change.pdf)
[55] No ad hoc mitigation measures were considered

		• Plan, organize and manage risk communication campaign • provide ad hoc environmental ad hoc monitoring plan post-event to mitigate exposure to contaminated biota
Water supply and sanitation (WSS)	**Include WSS management into water and climate adaptation strategies**	- Provide effective water bodies monitoring during heat waves, intense rain and/or drought events; - assess water supply capacities in emergency - provide local regulations for safe use of new sources of water; - reinforce ability of safe water supply with alternative techniques such as rain harvesting and/or reclaim and reuse of treated waste water; safe acquifer recharge;
	Sustainable urban drainage systems implementation.	18 use of permeable surfaces (e.g. in parking lots or roads) to reduce stormwater runoff, 19 use of green roofs to increase on-site retention of stormwater; 20 increase the use of stormwater retention ponds, constructed wetlands and swales providing preventive measures for potential risk of increase of vector borne diseases
Energy	**Intervention to reduce health risk from energy blackouts**	Information campaign for public and communities Invest in distributed energy systems (cogeneration) and local renewable energy
	Intervention to reduce energy demand providing indoor air quality standards	improve energy saving techniques, specially in crucial infrastructures such as schools, hospitals and residential homes providing safe indoor air quality standards
Transportation	**Intervention to reduce health hazards from infrastructures vulnerabilities**	vulnerability assessment of port facilities and coastal roads, rail lines and other infrastructure subject to sea level rise , increased wave activity, storm surges etc.
		Assess vulnerability transportation infrastructure systems (culverts, tunnels, bridges, subway entrance, etc.)
		Ensure alternative routes are available in case of disruption and/or need for evacuation
		Ensure critical components (switch gear, substation) are above flood levels
Infrastructures and basic services	**Reinforce resilience to climate change for infrastructures of essential social services (such as hospital, school, residential homes etc.)**	Increase environmental monitoring of community food, drinking water and bathing waters in extremes conditions
		Design drainage systems and entrance thresholds to cope with more intense rainfall, use ground-floor spaces for flood-compatible use such as car parking, or raise ground floor above flood level
		Design buildings for improved natural ventilation and reduce heat gain in summer
		Reinforce local sustainable measures to control vector diseases risk (e.g. mosquito net in community building)
		Utilize green roofs to insulate against heat gain and reduce stormwater runoff

CLIMATE CHANGE AND HEALTH RISK SCENARIOS FOR THE CITY OF PATRAS

This chapter illustrates an example of risk assessment for population exposure to heat waves under climate change- , prepared for the city of Patras in July 2011. Data availability was not enough for an extensive study, nonetheless the likelihood of the results, even if proxies, are sufficient to be a forewarning for preventive action and preparedness.

1. Temperature variation and population exposure

The PHEWE project (Assessment and Prevention of acute Health Effects of Weather conditions in Europe), analyzed the health effects of meteorological conditions during warm and cold seasons in 15 cities: Athens, Barcelona, Budapest, Dublin, Helsinki, Ljubljana, London, Milan, Paris, Prague, Rome, Stockholm, Turin, Valencia, and Zurich. [56]

The focus was on the effect of apparent temperature on mortality. Apparent temperature is a measure of relative discomfort due to combined heat and high humidity (Steadman, YEAR). It can be calculated as a combination of air temperature (temp) and dew point (dew),according to the following formula :

$$AT = -2.653 + 0.994\ temp + 0.0153\ (dew)^2 .$$

The relationship between the last four day average, maximum apparent temperature (lag 0–3) and log (natural logarithm) mortality rates was investigated. An **excess of risk for exposures to apparent temperature above a threshold** that varies among cities, was detected. The threshold is the value of apparent temperature, which corresponds to a change in the effect estimate. For a V-shaped curve, this is the value of apparent temperature associated with the minimum mortality rate.

City-specific results were pooled into 2 groups defined on the basis of meteorological and geographic criteria (Figure 1):

1. “Mediterranean” cities: Athens, Rome, Barcelona, Valencia, Turin, Milan, and Ljubljana.
2. “North-continental” cities: Prague, Budapest, Zurich, Paris, Helsinki, Stockholm, London, and Dublin.

The curves remained fairly constant until a threshold AT and then rapidly increased with a heat effect apparently stronger in Mediterranean than in north-continental cities. Using minimum apparent temperature as exposure indicator, the combined curve was similar in shape, but, as expected, with a minimum around lower apparent temperature values[57].

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[56] M. Baccini, A. Biggeri, G. Accetta, T. Kosatsky, K. Katsouyanni, A. Analitis, H. Ross Anderson, L. Bisanti, D. D’Ippoliti, J. Danova, B. Forsberg, S.Medina, A. Paldy, D. Rabczenko, C. Schindler and P. Michelozzi ,2008. Heat Effects on Mortality in 15 European Cities (Epidemiology • Volume 19, Number 5, September 2008)

[57] M. Baccini, A. Biggeri, G. Accetta, T. Kosatsky, K. Katsouyanni, A. Analitis, H. Ross Anderson, L. Bisanti, D. D’Ippoliti, J. Danova, B. Forsberg, S.Medina, A. Paldy, D. Rabczenko, C. Schindler and P. Michelozzi ,2008. Heat Effects on Mortality in 15 European Cities (Epidemiology • Volume 19, Number 5, September 2008)

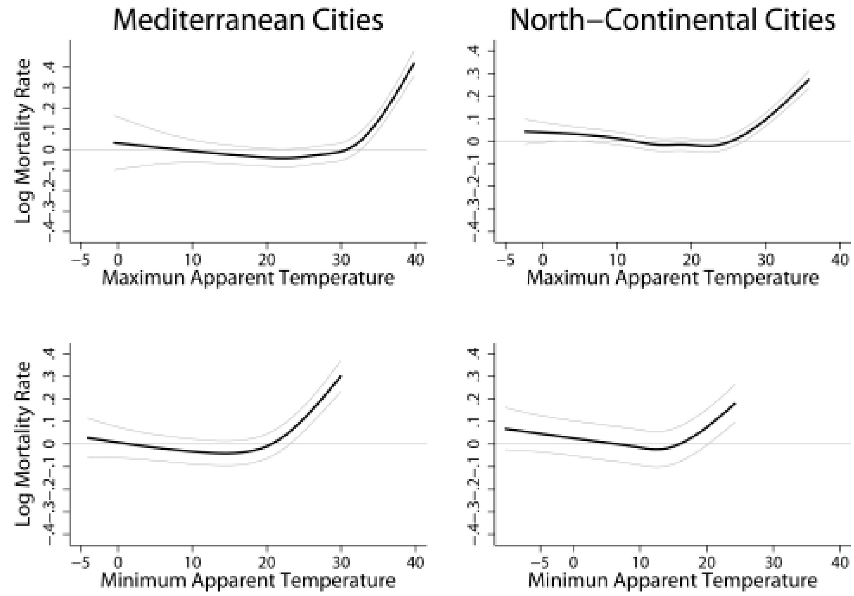


***Figure 1.** The figure show how, over the threshold value, the natural logarithm of the mortality rate climb rapidly, specially in Mediterranean cities.*

Heat effect are reported as "**percent change in mortality associated with a 1°C increase in maximum apparent temperature above the city-specific threshold"**. City-specific and overall meta-analytic estimates of thresholds and percent change are reported in Figure 2. For Ljubljana, Stockholm, and Zurich estimated thresholds were just below 22°C whereas for Athens, Milan, and Rome estimates were over 30°C.

The overall meta-analytic **value of the threshold** was 29.4°C (95% credibility interval [CrI] =25.7 to 32.4) for Mediterranean cities (excluding Barcelona) and about 6 degrees lower for North-continental cities (23.3°C; 22.5 to 24.0).

Overall meta-analytic **percent change per degree** of above-threshold apparent temperature equaled 3.1 (0.6 to 5.7)and 1.8 (0.1 to 3.6) for Mediterranean and North-continental cities, respectively.[58]

[58] M. Baccini, A. Biggeri, G. Accetta, T. Kosatsky, K. Katsouyanni, A. Analitis, H. Ross Anderson, L. Bisanti, D. D'Ippoliti, J. Danova, B. Forsberg, S.Medina, A. Paldy, D. Rabczenko, C. Schindler and P. Michelozzi ,2008. Heat Effects on Mortality in 15 European Cities (Epidemiology • Volume 19, Number 5, September 2008)

TABLE 2. Regional Meta-Analytic Estimates and City-Specific Estimates of Threshold and Percent Change in Natural Mortality Associated With a 1°C Increase in Maximum Apparent Temperature Above the City-Specific Threshold

	Threshold (°C) (95% CrI/CI)[a]		% Change (95% CrI/CI)[a]	
Region				
North-continental	23.3	(22.5 to 24.0)	1.84	(0.06 to 3.64)
Mediterranean	29.4[b]	(25.7 to 32.4)	3.12	(0.60 to 5.72)
City				
Athens	32.7	(32.1 to 33.3)	5.54	(4.30 to 6.80)
Barcelona	22.4[c]	(20.7 to 24.2)	1.56	(1.04 to 2.08)
Budapest	22.8	(21.9 to 23.7)	1.74	(1.47 to 2.02)
Dublin	23.9	(20.7 to 27.1)	−0.02	(−5.38 to 5.65)
Helsinki	23.6	(21.7 to 25.5)	3.72	(1.68 to 5.81)
Ljubljana	21.5	(15.0 to 28.0)	1.34	(0.32 to 2.37)
London	23.9	(22.6 to 25.1)	1.54	(1.01 to 2.08)
Milan	31.8	(30.8 to 32.8)	4.29	(3.35 to 5.24)
Paris	24.1	(23.4 to 24.8)	2.44	(2.08 to 2.80)
Praha	22.0	(20.4 to 23.6)	1.91	(1.39 to 2.44)
Rome	30.3	(29.8 to 30.8)	5.25	(4.57 to 5.93)
Stockholm	21.7	(18.2 to 25.3)	1.17	(0.41 to 1.94)
Turin	27.0	(25.2 to 28.9)	3.32	(2.53 to 4.13)
Valencia	28.2	(23.7 to 32.7)	0.56	(−0.35 to 1.47)
Zurich	21.8	(16.5 to 27.0)	1.37	(0.49 to 2.25)

[a]95% credibility interval for regional meta-analytic estimates and 95% confidence interval for city-specific estimates.
[b]Excluding Barcelona.
[c]Mean apparent temperature.

Figure 2. *For the city of Athens the average percent change in natural mortality per degree (1°C) of* $Tapp_{max}$ *over the threshold of 32.7°C is +5.54%. E.g. a raising of 2°C over the threshold is expected to increase the risk of mortality of 11.08%*

. The overall meta-analytic estimates of percent change **in cardiovascular mortality** per degree of above-threshold temperature were 3.7 (0.4 to 7.0) for Mediterranean cities and 2.4 (-0.1 to 5.3) for North-continental cities. Higher associations were found between heat and **mortality due to respiratory diseases**, with estimated percent changes equal to 6.7 (2.4 to 11.3) and 6.1 (2.6 to 11.1) for Mediterranean and North-continental cities, respectively.[59]

The effect of heat was particularly large in the elderly. **For people aged 75 and older, we estimated that a 1°C increase in maximum apparent temperature above the threshold was associated with an increase in mortality for all natural causes of 4.2% for the Mediterranean region and of 2.1% for the north-continental region.** The same effect estimates were 8.1% and 6.6%, respectively, when only deaths for respiratory causes were considered.[60]

59 M. Baccini, A. Biggeri, G. Accetta, T. Kosatsky, K. Katsouyanni, A. Analitis, H. Ross Anderson, L. Bisanti, D. D'Ippoliti, J. Danova, B. Forsberg, S.Medina, A. Paldy, D. Rabczenko, C. Schindler and P. Michelozzi ,2008. Heat Effects on Mortality in 15 European Cities (Epidemiology • Volume 19, Number 5, September 2008)

60 M. Baccini, A. Biggeri, G. Accetta, T. Kosatsky, K. Katsouyanni, A. Analitis, H. Ross Anderson, L. Bisanti, D. D'Ippoliti, J. Danova, B. Forsberg, S.Medina, A. Paldy, D. Rabczenko, C. Schindler and P. Michelozzi ,2008. Heat Effects on Mortality in 15 European Cities (Epidemiology • Volume 19, Number 5, September 2008)

TABLE 3. Overall Meta-Analytic Percent Changes (95% Credibility Intervals) in Mortality for All Natural, Cardiovascular, and Respiratory Causes, in All Ages and by Age Group, Associated With a 1°C Increase in Maximum Apparent Temperature Above the City-Specific Threshold

	Mediterranean Cities		North-Continental Cities	
Age; yrs	% Change	(95% CrI)	% Change	(95% CrI)
Natural mortality				
All	3.12	(0.60 to 5.73)	1.84	(0.06 to 3.64)
15–64	0.92	(−1.29 to 3.13)	1.31	(−0.94 to 3.72)
65–74	2.13	(−0.42 to 4.74)	1.65	(−0.51 to 3.87)
75+	4.22	(1.33 to 7.20)	2.07	(0.24 to 3.89)
Cardiovascular mortality				
All	3.70	(0.36 to 7.04)	2.44	(−0.09 to 5.32)
15–64	0.57	(−2.47 to 3.83)	1.04	(−2.20 to 4.92)
65–74	1.92	(−1.49 to 5.35)	1.50	(−1.12 to 4.62)
75+	4.66	(1.13 to 8.18)	2.55	(−0.24 to 5.51)
Respiratory mortality				
All	6.71	(2.43 to 11.26)	6.10	(2.46 to 11.08)
15–64	1.54	(−3.68 to 7.22)	3.02	(−1.55 to 7.42)
65–74	3.37	(−1.46 to 8.22)	3.90	(−0.16 to 8.92)
75+	8.10	(3.24 to 13.37)	6.62	(3.04 to 11.42)

Figure 3. *In Mediterranean cities, for example, there will be a risk of 4,2% of deaths above the baseline natural mortality rate, for each degree of $Tapp_{max}$ over the threshold that will be reached.*

Episode analyses of heat waves have documented a comparatively **higher impact on mortality than on morbidity (hospital admissions) in European cities**. Objectives of the PHEWE project were also to evaluate the impact of high environmental temperatures on hospital admissions during April to September in 12 European cities participating in the project. For each city, time series analysis was used to model the relationship between maximum apparent temperature and daily hospital admissions for cardiovascular, cerebrovascular, and respiratory causes by age (all ages, 65–74 age group, and 75+ age group). [61]

For respiratory admissions, there was a **positive association** that was heterogeneous between cities. For a **1°C increase in maximum apparent temperature above a threshold, respiratory admissions in the 75+ age group increased by +4.5%** (95% confidence interval, 1.9–7.3) in Mediterranean cities and +3.1% (95% confidence interval, 0.8–5.5) North-Continental cities. In contrast, the association between temperature and cardiovascular and cerebrovascular admissions tended to be negative and did not reach statistical significance. [62]

Results from the PHEWE project showed that in Europe the impacts on morbidity in terms of hospital admissions are not consistent with the effect observed on mortality. Higher temperatures do not appear to be associated with a significant increase in admissions for cardiovascular disease, as seen in the United States, while a positive association between high temperatures and hospital admissions for respiratory causes was observed in most of the cities (Michelozzi et al., 2008). These results suggest that during periods of high temperature **many deaths occur rapidly before**

[61] P. Michelozzi , G. Accetta, M. De Sario , D. D'Ippoliti , C. Marino , M. Baccini ,A. Biggeri , H. Ross Anderson, K. Katsouyanni , F. Ballester , L. Bisanti , E. Cadum ,B. Forsberg , F. Forastiere , P. G. Goodman , A. Hojs , U. Kirchmayer , S. Medina ,A. Paldy , C. Schindler, J. Sunyer , and C. A. Perucci , on behalf of the PHEWE Collaborative Group, 2009. High Temperature and Hospitalizations for Cardiovascular and Respiratory Causes in 12 European Cities. (Am J Respir Crit Care Med Vol 179. pp 383–389, 2009)

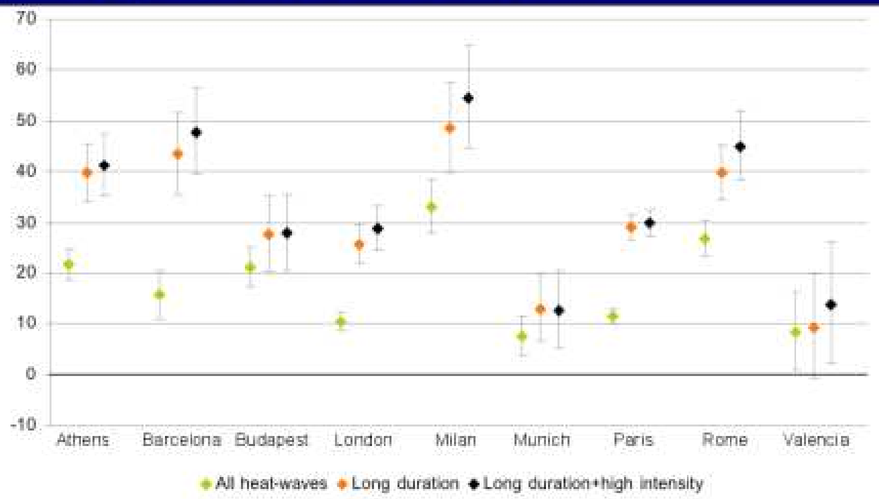
[62] P. Michelozzi , G. Accetta, M. De Sario , D. D'Ippoliti , C. Marino , M. Baccini ,A. Biggeri , H. Ross Anderson, K. Katsouyanni , F. Ballester , L. Bisanti , E. Cadum ,B. Forsberg , F. Forastiere , P. G. Goodman , A. Hojs , U. Kirchmayer , S. Medina ,A. Paldy , C. Schindler, J. Sunyer , and C. A. Perucci , on behalf of the PHEWE Collaborative Group, 2009. High Temperature and Hospitalizations for Cardiovascular and Respiratory Causes in 12 European Cities. (Am J Respir Crit Care Med Vol 179. pp 383–389, 2009)

receiving medical treatment or admission to hospital, and this may be particularly true for acute events which are more common within the cardiovascular diagnostic group (Norris, 1998). These results may be important when planning preventive strategies to reduce heat-related mortality among susceptible population groups. [63]

2. Heat waves projection and population exposure

In the EuroHEAT project a heat-wave was defined as a **period when maximum apparent temperature (Tapp max) and minimum temperature (T min) are over the 90th percentile of the monthly distribution for at least two days**. Applying this definition, during the heat-wave episodes **the percentage increase of mortality estimated ranged from 7.6% to 33.6% in nine European cities.** Results show a high heterogeneity of the effect between cities and populations. [64]
Heat-waves characterized by long duration and high intensity have the highest impact on mortality. Each heat-wave was also characterized by intensity and duration. The impact of heat-waves characterized by longer duration (more than four days) was 1.5–5 times higher than for short heat-waves.
The results of studies published in Europe between 1993 and 2003[65] from several European cities indicate that **high values of both Tapp max and T min were associated with an increase in mortality and the impact of heat-waves characterized by longer duration was 1.5–5 times higher than for short heat-waves** (Fig. 4). **The heat-wave effect was stronger in the elderly**. The highest increase was observed in Athens, Budapest, London, Rome and Valencia, in persons in the 75+ age group. In all cities, females were at higher risk than males. In the EuroHEAT study, heat-waves of higher intensity and duration were generally more dangerous. Moreover, the first heat-wave of the summer appeared to be more dangerous in only some cities (Athens, Budapest and Munich). For subsequent heat-waves, those occurring after a short time interval generally had less effect than those occurring after three or more days . [66]

Fig. 4. Effect of heat-waves with different characteristics on total mortality among people aged 65+ (% increase and 90% CI)



Source: Matthies et al. (2008).

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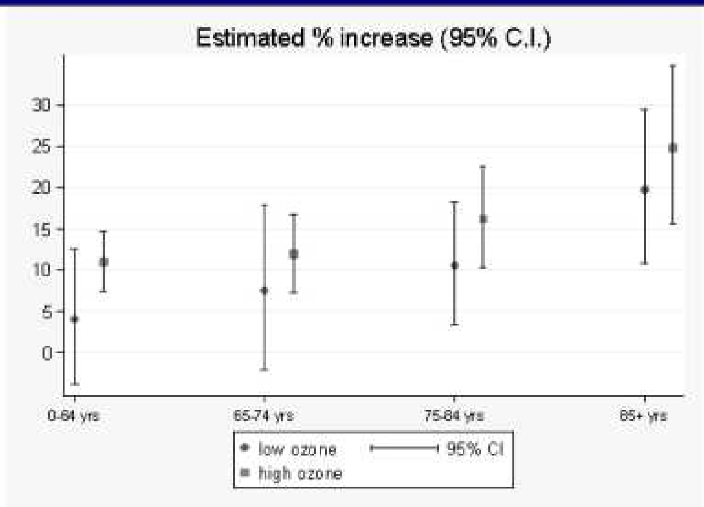
[63] World Health Organization 2009. Improving public health responses to extreme weather/heat-waves – EuroHEAT
[64] World Health Organization 2009. Improving public health responses to extreme weather/heat-waves – EuroHEAT
[65] Kunst et al., 1993; Ballester et al., 1997; Michelozzi et al., 2000; Basu & Samet; 2002, Hajat et al., 2002, Pattenden et al., 2003
[66] World Health Organization 2009. Improving public health responses to extreme weather/heat-waves – EuroHEAT

Figure 4. *The figure show that for example for an average heat waves in Athens is expected an increase (%) in all natural mortality between 20 and 25%, in Milan between 30 and 35% and Barcelona around 15%. In are considered heat waves of long duration and high intensity the % increase in total mortality (n° of death above the baseline) rises considerably.*

There is **increasing evidence for a synergistic effect on mortality between high temperatures and ozone concentrations**. Analyses of daily mortality, meteorological and air pollution data from nine European cities (1987–2004) in EuroHEAT confirmed that the effects of heat-wave days are much larger for older age groups, and this remains after adjusting for air pollutants (Analitis & Katsouyanni, in press). The effects of heat-wave days on mortality were greater when ozone or PM 10 levels were higher, particularly among the elderly (75–84 years). The **total daily number of deaths in this age group increased by 16.2% on heat-wave days with high ozone levels and 14.3% on days with high PM 10 levels**, respectively, **compared to an increase of 10.6% and 10.5% on days with low levels of ozone** (Fig. 5)**and PM 10**. The effects of heat-wave days with high ozone levels were less evident for those people in the 85+ age group (Fig. 5). The fact that the interaction appears less for those in the 85+ age group may be a result of them spending more time indoors where ozone is much lower.[67]

Figure 6 shows the exposure of Greece urban population to Ozone air pollution, increasing over the last three years of the time series. The indicator shows the population weighted yearly sum of maximum daily 8-hour mean ozone concentrations above a threshold (70 microgram Ozone per m3) at the urban background stations in agglomerations. Human exposure to elevated ozone concentrations can give rise to inflammatory responses and decreases in lung function.

Fig. 5. Percent increase in the total daily number of deaths in days with a heat-wave and a "low" or "high" level of ozone, adjusting for barometric pressure, wind speed, calendar month, day of the week, holiday and time trend (results from random effects meta-analysis)



Low ozone: at the 25th percentile of the overall distribution of ozone
High ozone: at the 75th percentile of the overall distribution of ozone

Figure 5*. Percent increase in the total daily number of deaths with an heat wave and a low or high level of ozone.*

67 World Health Organization 2009. Improving public health responses to extreme weather/heat-waves – EuroHEAT

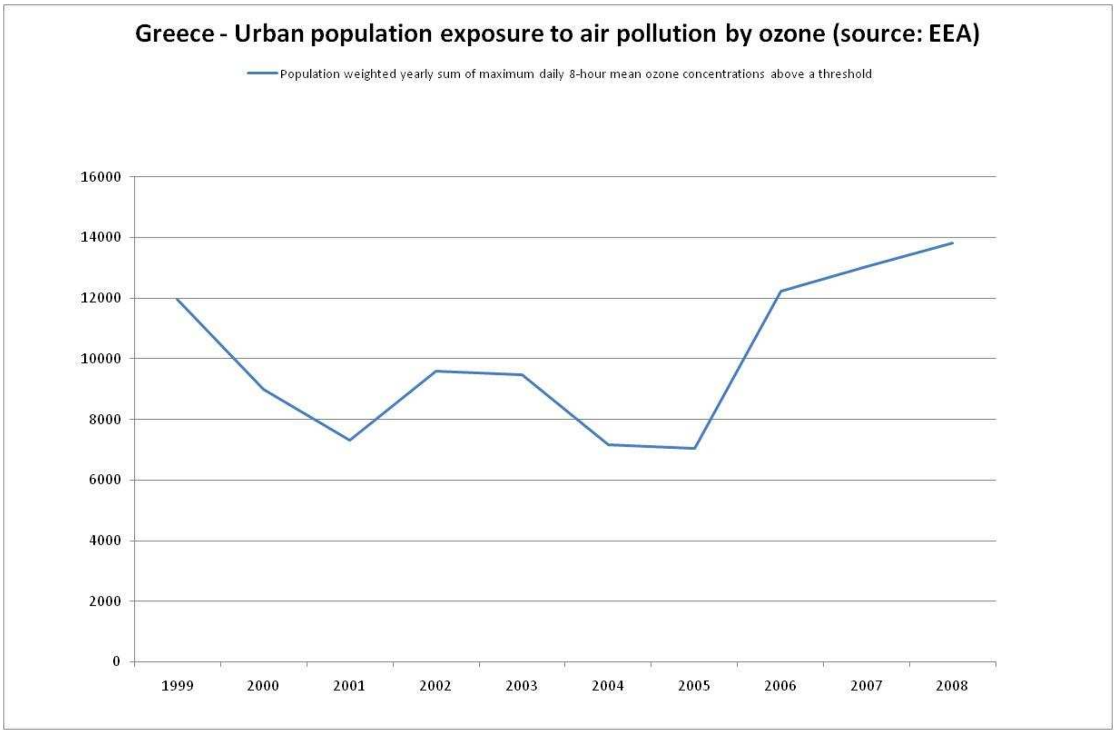


Figure 6*. Greece urban population exposure to Ozone (1999-2008) .Source EEA*

Building on the methodology of the PHEWE study (where the impact of high apparent temperature on mortality was quantified in terms of **attributable number of deaths)**, in the EuroHEAT project, future impacts of heat were estimated for temperature projections from the SRES of the Intergovernmental Panel on Climate Change (IPCC, 2000).
The pattern of the average **daily number of attributable deaths over the warm season** was also studied . For most cities, attributable deaths are concentrated during the hottest months (July–August). A moderate impact was observed also during June. Projections for the year 2030 under the SRES scenarios are reported in the table of figure 6.[68]

68 World Health Organization 2009. Improving public health responses to extreme weather/heat-waves – EuroHEAT

Table 4. Actual impact of heat and projections for 2030 of the average number of attributable deaths per year (80% credibility intervals) calculated under the B1, A1B and A2 SRES scenarios, by city

City		B1 $\Delta T=0.54$	A1B $\Delta T=0.84$	A2 $\Delta T=1.02$
Athens	230 (172, 290)	316	376	415
Barcelona	290 (212, 374)	319	338	350
Budapest	399 (346, 463)	457	490	511
Dublin	0 (0, 1)	0	1	1
Helsinki	11 (6, 17)	14	17	18
Ljubljana	13 (1, 34)	13	15	15
London	142 (99, 185)	183	206	220
Milan	95 (70, 123)	116	130	139
Paris	423 (57, 488)	500	546	574
Prague	72 (53, 92)	84	93	98
Rome	388 (339, 440)	470	520	552
Stockholm	21 (13, 30)	19	21	22
Turin	121 (80, 168)	136	148	156
Valencia	72 (29, 123)	56	59	61
Zurich	29 (18, 41)	32	35	37

Source: A Biggeri, unpublished data, 2008.

Figure 7*. In the figure the actual average number of deaths attributable to heat waves is immediately on the right of the city name (e.g. for Athens is 230) , then the three forecast of IPPC scenarios.*

3. Baseline climate scenario - part i climate trends and projections [69]

The temperature and heat waves future trends for Patras were assessed starting from temperature time series covering a period of 44 years (from 1960 to 2003), long enough for a proper estimate of the annual and seasonal trends.
Temperature projections were extracted from the gridded fields generated by three Regional Climate Models (RCMs) and two high-resolution Global Climate Models (GCMs). T**he results for the RCMs are available only for the "intermediate" emission scenario A1B**; for the GCMs, the results are also available for the A2 (pessimistic) and B1 (optimistic) scenarios.
According to the three RCMs, the **rise of the mean air temperature** during the last decade of the century is estimated to be between 3.5 °C (RM5.1) and 4.0 °C (RACMO2), with a **warming more**

69 Franco Desiato, Andrea Toreti, Guido Fioravanti, Piero Fraschetti, Walter Perconti (ISPRA, Climate and Applied Meteorology Unit)

pronounced in summer (between 4.5 °C and 5.1 °C) and less in spring (between 2.4 °C and 3.0 °C).
The warming predicted by the GCMs in the A1B scenario is lower than the prediction by the RCMs (1.4 °C and 2.9 °C for INGV and CNRM models, respectively). In the **A2 scenario, the GCMs estimate a warming between 2.0 °C and 3.6 °C,** while in the **B1 scenario the global CNRM model predicts a warming of 1.9 °C.** This means that the two opposite scenarios (i.e. A2 and B1) introduce an uncertainty in the variation of mean temperature of about 1.0 °C wide.

SCENARIO	MEAN TEMPERATURE Variation 2100				
	WINTER (DJF)	SPRING (MAM)	SUMMER (JJA)	AUTUMN (SON)	ANNUAL
PATRASSO					
A1B					
CNRM	**+2.3**	**+2.6**	**+3.7**	**+2.8**	**+2.9**
INGV	**+0.5**	**+1.2**	**+2.0**	**+1.8**	**+1.4**
A2					
CNRM	**+2.6**	**+3.7**	**+4.7**	**+3.3**	**+3.6**
INGV	**+1.2**	**+1.8**	**+2.5**	**+2.8**	**+2.0**
B1					
CNRM	**+1.5**	**+1.8**	**+2.7**	**+1.5**	**+1.9**
INGV					

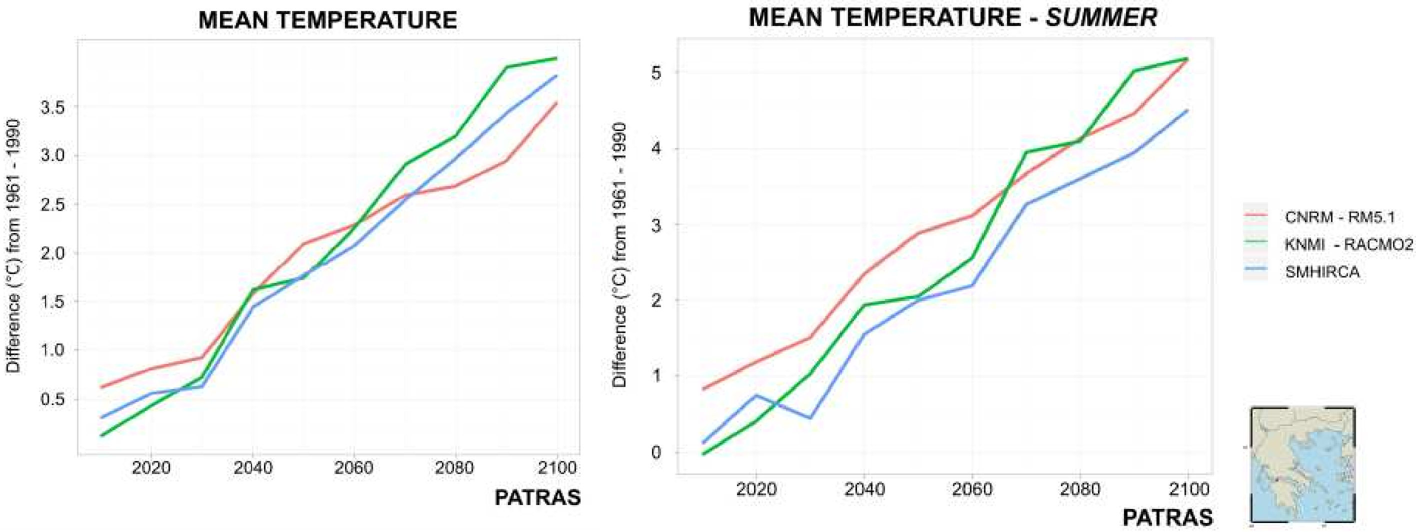
Figure 8. *Seasonal and annual mean temperature variation predicted by GCMs (°C)*

MODELS	MEAN TEMPERATURE Variation 2100				
	WINTER (DJF)	SPRING (MAM)	SUMMER (JJA)	AUTUMN (SON)	ANNUAL
PATRAS					
CNRM-RM+5.1	+2.6	+3.0	+5.1	+3.4	+3.5
KNMI-RACMO2	+3.6	+2.8	+5.1	+4.4	+4.0
SMHIRCA	+3.6	+2.4	+4.5	+4.8	+3.8

MODELS	MAXIMUM TEMPERATURE Variation 2100				
	WINTER (DJF)	SPRING (MAM)	SUMMER (JJA)	AUTUMN (SON)	ANNUAL
PATRAS					
CNRM-RM+5.1	+3.0	+3.0	+5.1	+3.1	+3.6
KNMI-RACMO2	+3.4	+2.9	+5.4	+4.2	+4.0

MODELS	MINIMUM TEMPERATURE Variation 2100				
	WINTER (DJF)	SPRING (MAM)	SUMMER (JJA)	AUTUMN (SON)	ANNUAL
PATRAS					
CNRM-RM+5.1	+2.5	+2.8	+5.2	+3.6	+3.5
KNMI-RACMO2	+3.7	+2.7	+5.1	+4.7	+4.0

Figure 9. *Seasonal and annual mean, maximum and minimum temperature variation predicted by RCMs (°C)*



3. Baseline climate scenario - part ii statistical downscaling of temperature time series for ancona, bullas and patras[70]

In this work a heatwave is defined as a period in which maximum temperature exceeds the thirty-year 95 th percentile for at least three days (Kuglitsch et al., 2010). Table 2 shows the projections for the average intensity (HWII), length (LWII) and number (NWII) of heatwaves in the periods 2046-2065, 2081-2100. The projections are presented as anomalies with respect to the 1961-1990 climatological means calculated using the E-OBS data set. HWII is the average intensity of a heat wave (in °C), namely the average of the temperature exceeds with respect to the reference threshold during the heatwave event. LWII is the average number of days of each heatwave event. Finally, NWII is the average number of heatwaves.

__Figure 11.__ Mean variation for Average intensity, length and number of heat waves (2046-2065, 2081-2100)

Table 2: Mean variation (2046-2065, 2081-2100) for HWII, LWII, NWII with respect to the climatological values (1961-1990)

		HWII		LWII		NWII	
		2046 - 2065	2081 - 2100	2046 - 2065	2081 - 2100	2046 - 2065	2081 - 2100
ANCONA							
	CLIM	2.8	16.7	3	12.3	0.4	1.6
	NN	55.6	132.7	30.1	54.3	1.6	3
	SDSM	30.1	57.2	12.4	23	1.6	2
BULLAS							
	CLIM	3	14	3.8	14.3	0.6	1.9
	NN	26.9	77.6	16.1	50.6	1	3
	SDSM	16	28.7	9.7	19.4	1.1	2.1
PATRAS							
	CLIM	-0.6	16.1	1	14	-0.03	2.1
	NN	34.1	74.1	20.1	41.1	1.4	2.6
	SDSM	14.8	36.4	7.3	19.5	0.7	1.8

70 Fabiana Baffo (Fondazione ENI Enrico Mattei), Franco Desiato, Guido Fioravanti, Piero Fraschetti, Walter Perconti, Andrea Toreti (ISPRA, Climate and Applied Meteorology Unit)

4. Climate change risk assessment for the city of patras

The risk assessment for the city of Patras, is based on the results of European researches, mainly the PHEWE and EUROHEAT projects, complemented by the above mentioned ISPRA study on temperature and heat waves prediction.
In what follows, climate projections are related to the A1B intermediate scenario, representative of a "central climate case", stemming from the Regional Climatologic Model run, more focused on the area of interest.
Differently from the current analysis, the results from the European project PHEWE and EuroHeat, consider the apparent temperature (AT), which differs from effective Temperature (T) as shown by the formula:

$AT = -2.653 + 0.994*T + 0.0153*(dew)^2$

Apparent temperature is often higher than effective temperature because humidity increase the perception of heat. We will still use the effective temperature as reference and in this particular case, and because Mediterranean cities(like Patras) have often quite high rates of humidity during the summer season, the results using the apparent temperature would be indeed higher than using effective temperature. Of course with these assumption results obtained should be considered only as an approximation.
On the other hand, the PHEWE and EuroHeat projects study also the city of Athens. This gives us confidence in extending some of the projects' results to the case of Patras which is in the same geographical region and give us the opportunity to be more close to a good proxy.
Due to the absence of a specific threshold value for Patras, as it is defined by PHEWE research, we can perform only a proxy risk analysis as if Patras had similar threshold values as overall Mediterranean cities, using the percent change per degree values that refer to the Mediterranean cities.
We should also consider the temperature variations , computed by ISPRA experts, compared to the baseline of summer maximum temperatures of the available time series, to set our analysis toward a more likely future scenario. **In the case of Patras the average of maximum temperature in summer** (time series 1986-2003 from the climatic station of Araxos, near Patras) **is 30.6°C that we assume as baseline of Patras maximum summer temperature (baseline summer Tmax)**.
For the heat waves issue, although the definitions used in the EuroHEAT project and the ISPRA study are slightly different, the results of the analysis of the data lead us to qualitative conclusions that have likewise high probability, even if to be considered as approximation (proxy).

4.1. Key results from the studies

Percent change in mortality associated with a 1°C increase in maximum apparent temperature above the city-specific threshold (The overall meta-analytic value of the threshold is 29.4°C) Fonte: PHEWE project, EuroHEAT project		
Percent change per degree (1°C)in **mortality for all natural causes-** Mediterranean cities	Mediterranean cities+ 3.1	Population Over 75: +4.22
Percent change per degree (1°C) **in mortality** for **cardiovascular causes** -Mediterranean cities	All ages population + 3.7	Population Over 75: +4.66
Percent change per degree (1°C) **in mortality** for **respiratory causes** - Mediterranean cities	All ages population: +6.71	Population Over 75: +8.10
Percent change per degree (1°C) in hospital **admissions** for **respiratory causes** - Mediterranean cities	All ages population: 2.1	Population Over 75: +4.5%

Climate Trend and Projections for the city of Patras - Fonte: ISPRA - Patras baseline summer Tmax 30.6°C		
Mean air temperature variation predicted by RCMs (2100)	Annual: between 3.5 °C (RM5.1) and 4.0 °C (RACMO2)	Summer: between 4.5 °C (SMHIRCA) and 5.1 °C(RM5.1 and RACMO2)
Maximum air temperature variation predicted by RCMs (2100)	Annual: between 3.6 °C (RM5.1) and 4.0 °C (RACMO2)	Summer: between and 5.1 °C(RM5.1) and 5.4 °C (RACMO2)
Mean temperature variation predicted by GCMs (2100)	Annual: between 1.4 °C (INGV) and 2.9 °C (CNRM)	Summer: between +2.0 (INGV)e +3.7 (CNRM)

Table 1. Summary of the results of PHEWE study on Percent change in mortality associated with a 1°C increase in maximum apparent temperature above the city-specific threshold and ISPRA study on Climate Trend and Projections for the city of Patras

Percent risk increase in mortality/admission related to Patras projection variations in Max summer temperature Mediterranean cities – RCMs models		
Summer Maximum air temperature variation predicted by RCMs (2100): between +5.1 °C (RM5.1) and +5.4 °C(RACMO2) over the summer baseline Tmax		
Percent change	All ages population	Population Over 75
% change in mortality for all natural causes	+ 3.1	+4.22
Risk Increase - mortality all natural causes(%)	**+19.5 to +20.5**	**+26.6 to +27.9**
% change in mortality for cardiovascular causes	+ 3.7	+4.7
Risk Increase - mortality for cardiovascular causes (%)	**+23.3 to +24.4**	**+29.6 to +31.0**
% change in mortality for respiratory causes	+6.71	+8.1
Risk Increase - mortality for respiratory causes(%)	**+42.3 to +44.3**	**+51.0 to +53.5**
% change in respiratory admissions	+ 2.1	+4.5
Risk increase - respiratory hospital admission	**+13.2 to +13.9**	**+28.4 to +29.7**

Table 2. Percent risk increase in mortality/admission related to Patras projection variations in Max summer temperature

According to the maximum temperature projection (in this case we used maximum summer temperature variation), the maximum baseline value of 30.6°C and using as proxy the results (%of increase above the threshold of 29.4°C) from the two European research studies, we could estimate that the risk of an increase in mortality (natural, cardiovascular causes, respiratory causes) is very high, being the lower value +13.2% of deaths above the baseline mortality rates.

Effect of heat waves on total mortality among people aged over 65, for some Mediterranean cities			
%increase in total mortality (people over 65)	**Al heat waves**	**Long duration**	**Long duration +high intensity**
Athens	Between 20 and 25	Around 40	Slightly over 40
Barcelona	Between 10 and 15	Between 40 and 45	Between 45 and 50
Rome	Between 25 and 30	Around 40	Around 45
Valencia	Between 5 and 10	Slightly above 10	Around 15
Actual impact of heat and projection for 2030 of the average number of attributable death per year for IPPC scenarios, for some Mediterranean cities			
City	**Actual average n° of attributable death**	**A1B scenario 2030 attributable death**	**B1/A2 scenarios**
Athens	230	376	316/415
Barcelona	290	338	319/350
Rome	388	520	470/552
Valencia	72	59	56/61

Table 3 Summary of the results of EuroHEAT study on Effect of heat waves on total mortality and Actual impact of heat and projection for 2030

Mean variation (2046-2065, 2081-2100) for average intensity, length and number of heat waves, for the city of Patras						
	Average intensity (HWII)		Length(LWII)		Number(NWII)	
	2046-2065	2081-2100	2046-2065	2081-2100	2046-2065	2081-2100
CLIM	-0.6	16.1	1	14	-0.03	2.1
NN	34.1	74.1	20.1	41.1	1.4	2.6
SDSM	14.8	36.4	7.3	19.5	0.7	1.8

Table 4. Summary of the results of ISPRA study on mean variation (for average intensity, length and number of heat waves, for the city of Patras

The main finding highlighted by these summary tables, is that the number of heat waves will increase specially during the period 2018-2100, in number average intensity and length.. Accordingly the city's population will run a growing risk of higher mortality in the next decades.

We should strongly highlight at this point, that a real risk and impact assessment should be based on ad hoc data, and through a specific epidemiological study dedicated to the Municipality of Patras. In our case, the only possibility for a risk analysis was at best an approximation. We have used data from important studies and made some assumption to the purpose of the risk assessment, that are not too far from reality, but still are supposition, so that any quantitative results cannot be considered as fact. Qualitative statement results of our analysis, on the other hand, are a very good proxy of real future scenarios.

5. The Economic Valuation of future impact at present price

In 2006 the frequency for people that were hospitalized for respiratory diseases was 14,5 patients per 1000 inhabitants, while for cardiovascular diseases was 3,84 patients per 1000 inhabitants. The mean average days of hospitalization was 3,84 days and the mean cost per hospital bed was 110€ per day (all of these data were extracted by annual statistical reports from the Hellenic Statistical Authority for Achaia Prefecture).

Total population	Cardio Vascular Diseases	Respiratory Diseases
11.776	7.168	4.608

Considering the risk increase with regard to respiratory diseases hospital admission in table 2 (+13.2 to +13.9), and the portion of population currently affected, a future estimate of the additional number of people potentially at risk can be calculated:

4.608* 13,2 % = 609,63 additional people
4.608* 13,9 % = 640,512 additional people

And through this one it is possible to estimate approximately the additional expenses due to hospital admission for respiratory diseases:

610 people*110€*3,84 days= 257664 €
640 people*110€*3.84 days = 270336 €

Unfortunately the number of days lost for health problems x average daily wage are not available at the Statistical Authority.

According to the data presented by the Municipality of Patras, total deaths in the last year available (2009) have been 3067. If we apply the numbers ISPRA has above estimated for **incremental deaths** we obtain that:
the range for risk increase in mortality for cardiovascular causes would be between:

Min	(3067 * 23.3 %) =714,611
Max	(3067 * 24.4 %) = 748,348

the range for risk increase in mortality for respiratory causes would be between:

Min	(3067 * 42.3 %) =1297,341
Max	(3067 * 44,3 %) = 1358,681

	Year 2008			Year 2009		
	No of Deceased			No of Deceased		
Age of the deceased	SUM	Male	Female	SUM	Male	Female
SUM	**3030**	**1583**	**1448**	**3067**	**1614**	**1453**
<1 year	**9**	**5**	**4**	**11**	**6**	**5**
1 year	1	0	0	1	1	0
2 years	1	0	0	1	0	0
3 >>	0	0	0	0	0	0
4 >>	0	0	0	0	0	0
5-9 >>	1	1	0	2	1	1
10-14 >>	2	1	1	2	1	1
15-19 >>	6	5	1	6	5	2
20-24 >>	11	9	2	13	10	2
25-29 >>	17	14	3	17	14	4
30-34 >>	18	13	5	20	15	5
35-39 >>	21	16	5	21	15	7
40-44 >>	33	23	10	34	24	9
45-49 >>	51	35	16	51	36	16
50-54 >>	72	49	22	73	51	23
55-59 >>	102	71	31	103	72	30
60-64 >>	145	99	46	144	101	43
65-69 >>	182	122	60	174	115	59
70-74 >>	328	201	127	316	195	120
75-79 >>	500	274	227	495	278	217
80-84 >>	622	294	329	651	309	342
>85	909	351	558	932	366	567

Even taking into account the most precautionary value sets in PESETA study (see the box below), the cost associated to the additional deaths estimated would be in a range between:

Min	1,1 mio € * (714+1297) = 2212,1 mio €
Max	1.1 mio € * (748+1358) = 2316,6 mio €

BOX. The Value of Statistical Life

According to Aldy and Viscusi (2003) the compensating wage method usually produces higher VSL in a range of USD 4-9 million. It consists of a revealed preferences approach (hedonic wage) where the average risk of mortality is evaluated by a wage premium. This last reflects the "wage-risk trade-offs" of workers with similar jobs in different environmental conditions. Estimates below the USD 5 million value usually come from studies using the Society of Actuaries data. These report wages from workers who have self-selected themselves into jobs that are an order of magnitude riskier than the average. There are also some studies yielding estimates beyond USD 12 million, but these did not estimate the wage-risk trade-off directly or their authors reported unstable estimates. Estimates with this methodology are available only for small segment of the population and usually refer only to current risk of accidental deaths (e.g. no deaths caused by air pollutants after a latency period are considered). Estimates of roughly USD 1 million are produced by averting behaviour approaches. These Stated Preference Methods directly ask individuals how much they would be willing to pay to compensate for a small reduction in risk. The lower estimates compared with compensating wage methods may reflect several characteristics of these studies that distinguish them from the labour market studies. First, some product decisions do not provide a continuum of price-risk opportunities (unlike the labour market that does offer a fairly continuous array of wage-risk employment options) but rather a discrete safety decision. Second, the types of products considered in some studies may induce selection based on risk preferences. Third, several studies are based on inferred, instead of observed, price-risk trade-offs. This methodology has been also applied in the PESETA study. A contingent valuation survey in which people of various ages – including elderly persons – have been asked to report their willingness to pay (WTP) for a reduction in their risk of dying has been conducted in UK, France and Italy. The results yielded exactly EUR 1.1 million.

At the same time Tol used a more pragmatic approach based on labor productivity, and the value of a death has been evaluate 200 times the average annual per-capita income of the country.

Viscusi, W.K., Aldy, J.E., 2003. The value of a statistical life: a critical review of market estimates throughout the world. Journal of Risk and Uncertainty 27 (1), 5 –76.

Tol, R.S.J., 2002a. New estimates of the damage costs of climate change, Part I: benchmark estimates. Environmental and Resource Economics 21 (1), 47–73.

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HEALTH VULNERABILITY TO THERMAL ANOMALIES, ADVERSE WEATHER EVENTS AND NATURAL DISASTERS: SUMMARY TABLE							
Climate/environ mental stressor	**SENSITIVITY** *Examples of confidence level or degree of climate sensitive diseases/health hazards (Source: IPCC, WHO)*	**EXPOSURE** *Examples of exposure Indicators to hazards*	**IMPACTS** *Examples of of health, socio-economic impact indicators*	**COPYING CAPACITIES** *Examples of Governance mains/preparedness*	**VULNERABILITY** *Examples of - vulnerable groups - governance, socio-economic determinant*	**ADAPTATION OPTIONS** *Examples of Measures of no-health sectors to be undertaken with consultation with public health experts*	**RISKS** *How likely the impact will occur? (source: IPCC, WHO)*
THERMAL ANOMALIES (temperature warming, temperature extremes)	**<u>Medium confidence</u>: increased heat wave-related deaths** **<u>High confidence</u> bring some benefits to health, including fewer deaths from cold** **<u>High confidence</u>: increase cardio-respiratory morbidity and mortality associated with ground-level ozone**	➢ Maximum and minimum temperature (time series) ➢ Heat index (apparent temperature) ➢ Percentage and demographic distribution of population living in urban areas at risk of heat island phenomena - Air mass stagnation - Air quality data weighted on population - O3 daily average concentration - Increase of anthropogenic emissions	- Heat related mortality excess - - Increase of hospital admission for cardiovascular and respiratory disorders	Heat Early warning systems Health Surveillance system for heat wave Measures to reduce urban heat Island effects through creating green spaces. information and modeling capacities (trained personnel, technical tools, information sharing and disseminating tools)	- Elderly (>65) - Infant (<1 year) - Children - pregnant women - People with chronic disease - Patient in medical treatment with psychotropic drug - Low socioeconomic status - Socially isolated people - Community settlements (schools, residential homes etc) - Lack of heat wave early warning - Lack of early warning for Ozone episodes	Public information on climate-related health threats and prevention specially for vulnerable groups Intervention to reduce heat island effects . Intervention to strengthen urban air pollution management	**<u>Virtually certain</u> Reduction of human mortality and morbidity from exposure to cold temperature** **<u>Very likely</u> Increased risk of heat-related mortality , especially for the elderly, chronically sick, very young and socially-isolate people**
Food safety (pathogens)	**<u>Medium confidence</u>: increase the**	Increase/N of food samples contaminated by mould, fungi and	- Outbreaks of foodborne diseases	Ad hoc measures of food control in food chain in	- People living in communities (schools, hotels, elderly homes,	Increase pathogens monitoring of community food, drinking water and	

	burden of diarrhoeal diseases	pathogens (e.g. *salmonella*, *campylobacters*, *V. vulnificus* e *V. cholera*, *micotoxins*)		extremes/adverse weather events Generally few monitoring data	summer camps) - Low socio-economic status	bathing waters in extremes conditions Educational programme in school are highly recommended	
Food safety (chemical hazards)		- Increase of pesticide use - Increase/N of food samples contaminated by chemicals	- N of acute toxic disorder in farmers or workers	Strengthened measures of food control in food chain Generally few monitoring data	- Infant (< 1 year) - Children - Pregnant women	Increase chemicals monitoring of community food, drinking water and bathing waters in extremes conditions	
Biodiversity changes		- Algal blooms monitoring (frequency, duration and distribution) - Cyanobacterial presence in drinking water	-HABs-related recorded cases (*amnesia, diarrheal, numbness, liver damage skin and eye irritation, respiratory paralysis*)	Monitoring measures and early warning system Data from specific monitoring	-Coastal population -Touristic resort -Lack of early warning system and public information -Bad maintenance of water supply network	Increase environmental monitoring of community drinking water and bathing waters and sea-food in extremes conditions	
Biodiversity changes	**<u>High confidence</u>** : **Changes in species/seasonal distribution of some allergenic pollen species**	- Anomalies in pollen season - Anomalies in distribution of allergenic plants (urban green–schools, leisure environments)	- Incidence of allergic population - Increase in anti-allergic drugs use (out patients) - Loss of working/school days - Increase in hospital admissions for allergic crisis	Improve pollen monitoring with emerging species Build connection between environmental monitoring and health professionals (timing of medical treatment)	- Infant (< 1 year) - Children - Green public areas or community spaces with bad maintenance standard	Review of protocol of urban green management specially in public and schools environment Identify local plants with low allergenic activity in urban planning	
Biodiversity changes	**<u>Medium confidence</u>** : **Changes in distribution of some infectious disease vectors** **<u>High confidence</u>: continue to change the range of some infectious disease vectors**	- Anomalies in vector distribution - N° of environmental vector control campaign (N°/year)	- Human cases of vector borne infectious diseases - Increase in personal protection products sales (lotions, sprays, mosquito nets, etc.)	Comprehensive guidelines for vector control Management, information and modeling capacities (trained personnel, technical tools, information sharing and disseminating tools)	- Coastal/urban population - Low socioeconomic status - Lack of information campaign on personal protection methods specially in communities	Interventions to prevent vector-borne diseases Early detection and warning systems (vectors density, transmission risk) Planning /Guidelines for sustainable mosquito control Information campaign for use of protection devices (mosquito network) and management of green areas for public and vulnerable communities (schools , residential homes))	

Avalanches		Events monitoring system(N°/year)	- Injuries and deaths	Effective post-event emergency relief Hazard maps feasible with appropriate cartography	- Local mountain communities and touristic resorts Lack of early warning and public information	Alarm system and information campaign Disaster preparedness planning	
Wildfires	**High confidence: increase the number of people suffering from death, disease and injury from fires**	- Frequency, severity and distribution of wildfires	- N of people requiring medical assistance/hospitalization Loss of private properties and touristic attraction	Alarm system Emergency response systems	- Elderly (< 65) - Infant (< 1 year) - Children - People with disabilities (including obesities) - People living in community (schools, hotels, elderly homes, summer camps) - Building vulnerability	Wildfires control preparedness And information campaign	
ADVERSE WEATHER EVENTS (floods/sludge, landslides, storm surges, sea level rise, droughts)	**High confidence: increase the number of people suffering from death, disease and injury from heatwaves, floods, storms, and droughts**	- Hazard maps weighted on population (floods/sludge, landslides, storm surges, sea level rise, droughts) - N of flash floods/sludge, landslide, intense rainfall, windstorm, storm surges	- N of people requiring medical assistance/hospitalization (physical injuries and post traumatic stress disorders) - N of deaths - N request of damage restore of socio-economic activities (crops, tourism, schools, hospitals, etc) and residential damages	Events monitoring system Structural and non-structural measures Early warning system Disaster preparedness planning Effective post-event emergency relief Hazard maps feasible with appropriate cartography	- Elderly (> 65) - Infant (< 1 year) - Children - People with disabilities (including obesities) Resilience of water supply and sanitation systems Lack of early warning systems	Reinforce resilience to climate change for infrastructures of essential social services (such as hospital, school, residential homes etc.) Intervention to reduce health hazards from infrastructures vulnerabilities Sustainable urban drainage systems implementation. Include WSS management into water and climate adaptation strategies	**Very likely** **Increased risk of deaths, injuries and infectious, respiratory and skin diseases water- and foodborne diseases;** **Likely** **Increased risk of deaths and injuries by drowning in floods; migration related health effects , post-traumatic stress**

							disorders
(food and water quality)	**Medium confidence : increase the burden of diarrhoeal diseases**	- Increased N of contaminated water samples (chemical and biological) - N of period with intermitted water supply - - Length and severity of drought periods	- Outbreaks of water related diseases (water borne, foodborne, hygiene behaviour) - Increased n of contaminated water and food samples (chemicals)	Strengthened measures of water and food control Provision of safe drinking water and sanitation in emergencies	-Community residence people (schools, hotels, elderly homes, summer camps) - Low socioeconomic status Lack of water management plan in extremes Lack of health surveillance plans	- Provide effective water bodies monitoring during heat waves, intense rain and/or drought events; - assess water supply capacities in emergency - provide local regulations for safe use of new sources of water; - reinforce ability of safe water supply with alternative techniques such as rain harvesting and/or reclaim and reuse of treated waste water; safe aquifer recharge;	**Likely** **Increased risk of food and water shortage; increased risk of water- and foodborne diseases**

THE CASE OF CULTURALE HERITAGE IN ANCONA

Authors

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CONTENTS

Introduction

The assessment of Climate Change effects on Cultural Heritage, carried out by ISPRA and by IsCR, (Italian Institute for Conservation and Restoration) was realized to identify the potential risk for cultural objects in Ancona.
This work was finalized firstly to classify those monuments that could be mostly subjected to the deterioration processes and subsequently to define the opportune adaptation strategies for the protection of artworks in Ancona.
The method for evaluating the potential weathering hazard on Cultural Heritage was based on The Risk Map of Cultural Heritage, a project realized by IsCR in 1996 (Accardo *et alt*, 2002).

1. The Risk Map of Cultural Heritage

The Risk Map of Cultural Heritage is one of the first Italian instruments describing the potential risk level affecting Italian Cultural Heritage (Accardo G., Giani E., Giovagnoli A., 2003).
By this methodology, information concerning the distribution and characteristics of the architectural and archaeological monuments in Italy, are collected.
The purpose of the Risk Map was to identify the space/time distribution of the risk in order to plan the maintenance activities and to reduce the potential restoration works certainly more expensive and invasive.
Calculation of risk indicators was based on the acquisition of the following information:

- climatic and environmental parameters (that contribute to deterioration phenomena)
- distribution of cultural properties
- territorial hazard (impact defined through the damage quantification)
- vulnerability of the single items (its conservation condition)

Processing the above mentioned parameters and applying specific *damage functions*, the risk indicators, related to the deterioration of materials due to climate and environmental factors, can be calculated.

2. Risk indicators

The risk described in the Risk Map is subdivided in three levels (Accardo G., Cacace C., Rinaldi R. 2005):

1) Territorial Risk (R_t), concerning the state of susceptibility to a weathering process of an aggregate of monuments located in a specific area.
This indicator can be calculated correlating the territorial danger with the characteristics of the aggregate population of monuments.

$$R_t = n \bullet TH \qquad (1)$$

TH = Territorial Hazard estimated for urban area; n =number of monuments placed in municipal territory

2) Individual Risk (R_i), that indicates the state of susceptibility to a weathering process of a single cultural object. This indicator can be calculated correlating territorial hazard (at urban level) with the conservation condition of monument (vulnerability).

$$R_i = V_k \bullet TH \qquad (2)$$

TH = territorial hazard estimated for urban area; V_k = vulnerability of the single property

3) Local Risk (R_l), that indicates the state of susceptibility to a weathering process of a single item, estimating the territorial hazard in the area near the monument

$$R_l = V_k \bullet TH_j \qquad 3)$$

TH_j = territorial hazard estimated near the monument; V_k = vulnerability of the single property

In this study territorial and individual risk indicators were estimated in Ancona.

2.1. Territorial hazard

The decay of a monument is mainly due to climatic and environmental conditions of the area where the item is placed (*territorial hazard*); the effects usually depend on composition and nature of materials constituting cultural heritage. In this study, the territorial hazard is represented by the dissolution of limestone materials (material loss expressed as surface recession, R) (Bonazza A. et al, 2009).
For elaborating this parameter the damage function[71] (4) was applied (De la Fuente D et al, 2011):

$$R = 4 + 0.0059 \cdot SO_2 \cdot RH_{60} + 0.054 \cdot [H^+] \cdot Rain + 0.078 \cdot HNO_3 \cdot RH_{60} + 0.0258 \cdot PM_{10} \qquad (4)$$

This approach decribes the impacts produced by the synergistic action of atmospheric pollution and climatic factors on stone materials; on the other hand, it does not provide information about the effects of intense precipitation events, because the applied algorithm (4) considers the total annual quantity of precipitation. The effects of the intense rainfall were not estimated for Ancona because we have evaluated the possible damage functions that could better describe the relation between the dose (frequency of rainy days, rainy periods, etc.) and the response (material decay).

2. 2 Vulnerability

The vulnerability of a cultural object represents the variable that indicates its level of exposure to environmental/territorial hazard in relation with its conservation condition (Cacace C., Ferroni A.M., 2006). Vulnerability depends on sensitivity of monuments to climatic and environmental conditions; it can be calculated using specific statistical algorithms. Information, acquired through a data sheets model, is elaborated in order to obtain data on conservation condition of 12 architectural and decorative elements (foundations; vertical structures; horizontal structures; roofing structures; vertical links; indoor paving; outdoor paving; claddings; indoor decorations; outdoor decorations; outdoor openings; indoor openings).
The conservation condition of a monument can be obtained analysing six types of damage: generic damage; material decay; moisture; biological deterioration; surface deterioration; lacunae, missing fragments/pieces.
Each type of damage is classified according to its seriousness, extent and urgency; the algorithm using for calculation of vulnerability [72] is:

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[71] R = surface recession (µm/anno); SO_2, HNO_3, PM_{10} = dioxide sulphur, nitric acid, particular matter concentrations (µg/m^3); Rh_{60} = relative humidity when RH>60 otherwise 0; [H+] = H+ concentrations (mg/l); Rain = amount of precipitation (mm/anno). Unlike to PM10 and SO2 concentrations, the nitric acid (HNO3) concentrations are not usually measured by air quality monitoring stations, so they are estimated starting from nitrogen dioxide (NO2) and ozone (O3) concentrations, Relative Humidity (RH) and temperature (T) by the following formula: HNO3 = 516•e-3400/(T+273) ([NO2]•[O3]•Rh)0.5.

[72] INDvul (k) = vulnerability index of k- monument; m = number of variables used for quantifying the superficial conservation condition in relation with the urgency, seriousness and extent; n = number of variables for which information is not available P_j = weight of j –variable; Q_{ji} = i- value of j –variable; cost/m = updated constant in relation with updated weight of variables

$$INDvul(k) = \Sigma (P_j \bullet Q_{ji}/(m-n) \bullet (cost/m)) \qquad (5)$$

The correlation between vulnerability and territorial hazard provides the potential risk level of the considered object. Higher vulnerability values correspond to worse conservation conditions.

3. Results

In this section territorial hazard data, vulnerability information, territorial and individual risk assessment were reported.

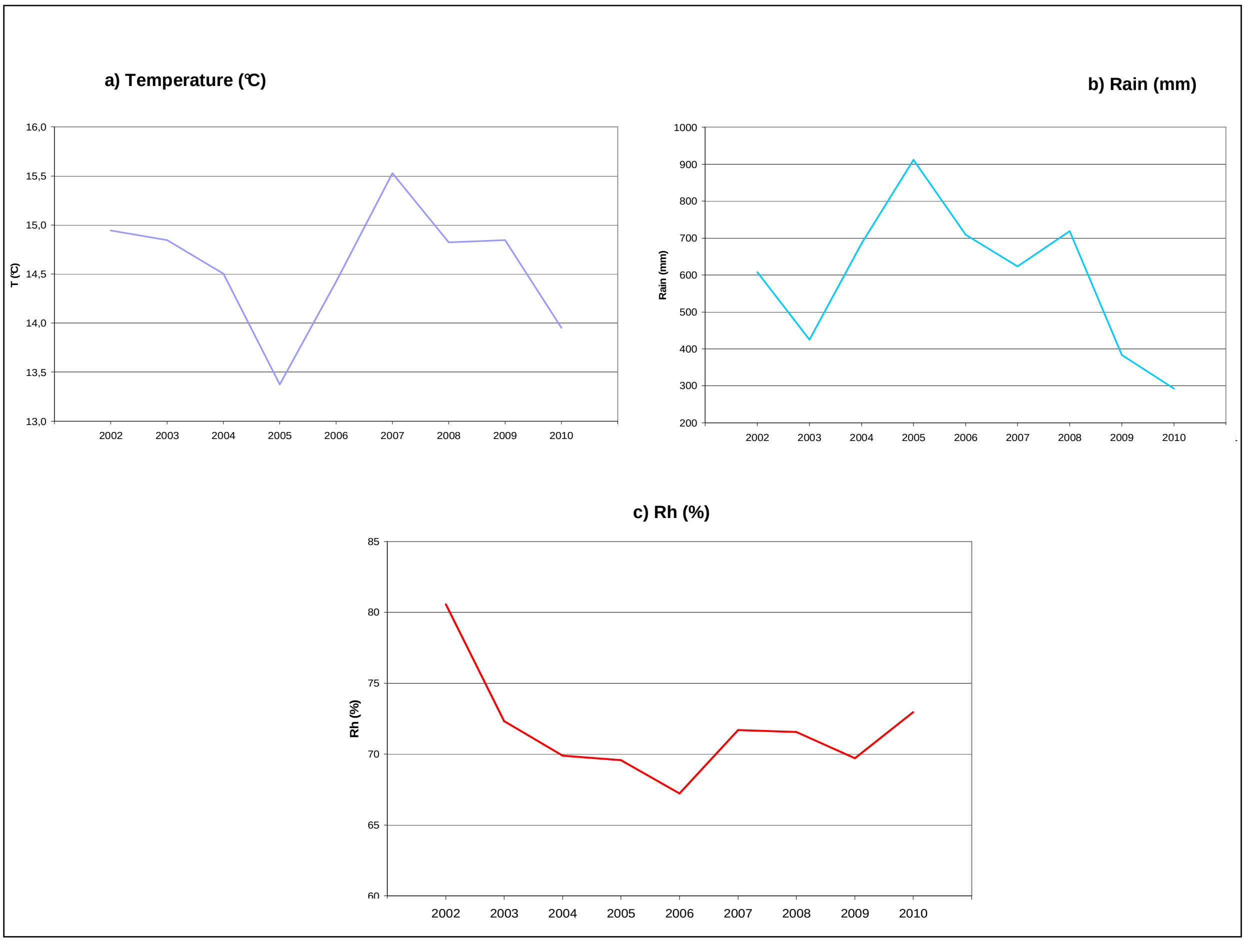
Territorial hazard

In this work territorial hazard, represented by material loss, was analyzed for calcareous monuments in the current and in the future scenarios.

Current scenario

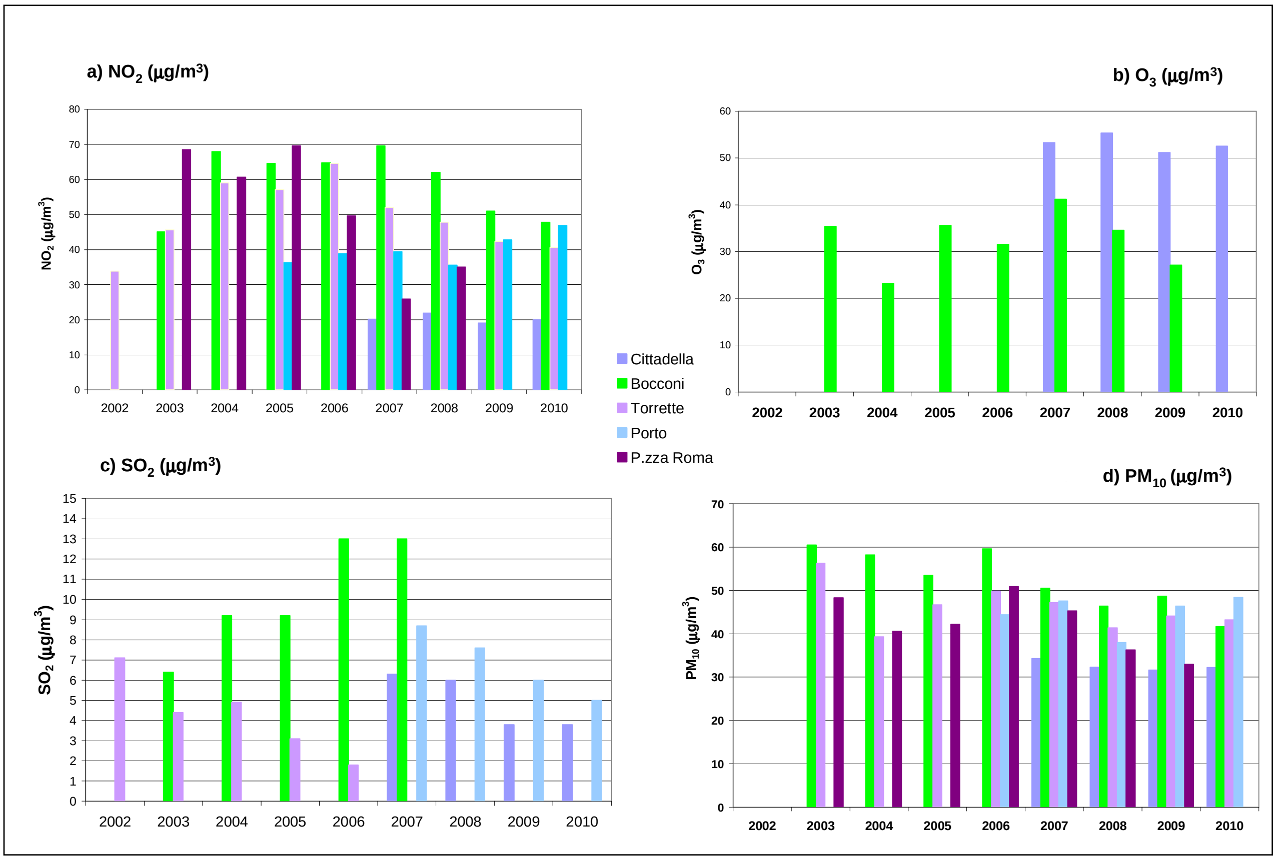
In the current scenario data concerning annual values of precipitation, temperature and relative humidity, that were recorded in the meteorological station in Ancona- Falconara from 2002 to 2010, were collected (fig.1).

Fig.1: a) Temperature (°C); b) Rain (mm); c) Relative Humidity (%) in 2002-2010



Moreover, in this study nitrogen dioxide (NO_2), ozone (O_3), particular matter (PM_{10}) and sulphur dioxide (SO_2) concentrations from 2002 to 2010 were gathered (fig.2).

Fig.2: a) NO_2, b) O_3, c) SO_2 and d) PM_{10} concentrations from 2002 to 2010



For elaborating surface recession in the future scenario, precipitation and temperature trends from 2010 to 2100[73] calculated in relation to the period from 1961 to 1990, were used (Desiato F. *et al*, 2010). The pollutant concentration trend estimated for 2011-2030 were elaborated supposing the pollutant concentrations maintain the current decrease trend[74] (Cattani G. *et al*, 2010). The dissolution of calcareous objects, was estimated using the equation (4) in the current and in the future scenarios.

In the current scenario, the surface recession was obtained next to two air quality monitoring stations (Bocconi and Cittadella) from 2003[75] to 2010. Bocconi is an urban traffic station while Cittadella is a background urban station. Surface recession values were included between 6 and 8.2 µm per year. The highest values are calculated next to Bocconi (table 1).

Table 1: Surface recession (2003-2010)

	Bocconi	Cittadella
2003	7,3	
2004	7,4	
2005	7,5	
2006	7,2	
2007	8,2	6,7
2008		6,7
2009		6

[73] Precipitation and temperature trends from 2010 to 2100 were estimated in relation to the period 1961- 1990

[74] Air pollutant trends were estimated until 2030 without evaluating pollution trend to 2100 because the future concentration trends could be characterized by approximation that is too large.

[75] The surface recession in 2002 wasn't elaborated because the air pollution data were not enough

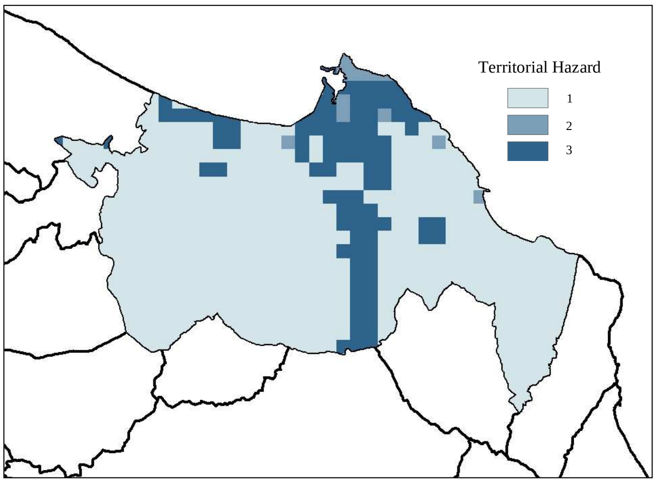
2010		6,3

Since the acceptable deterioration rate fixed by literature is 8 µm per year (UNECE ICP Materials Programme) the values obtained for Ancona are lower than the tolerable levels.

To obtained surface recession/territorial hazard at municipal level, data elaborated close to Bocconi and Cittadella stations were correlated with information about the land use in Ancona[76].

The surface recession estimated in Bocconi (7-8 µm per year) was attributed to those areas characterized by car and marine traffic (harbour and city centre), while the material loss calculated in Cittadella (between 6-7 µm per year) was associated to the green urban areas; the surface recession values lower than 6 µm per year were attributed to green background areas. Territorial hazard results were subsequently divided in 3 classes: from class 1 corresponding to the lowest hazard to class 3, the highest (fig.3).

Fig.3: Territorial Hazard at municipal level in the current scenario



Future scenario

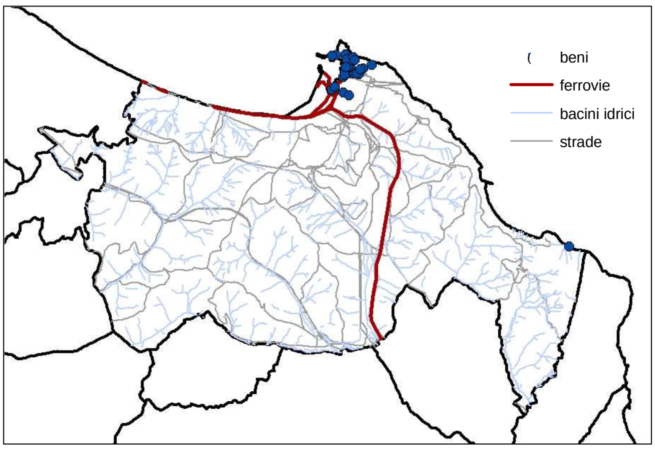
In the future scenario precipitation and pollutant decreases were predicted.

Foreseen precipitation and air pollutant concentrations decreases should cause a slight reduction of the damage for cultural objects in Ancona.

Vulnerability

The fig. 3 shows the distribution of 125 monuments recorded in the Risk Map of Cultural Heritage .

Fig. 4: Distribution of architectural objects and archaeological sites in Ancona



[76] For elaborating surface recession at municipal level, geostatistical interpolation techniques are usually applied. But in this case, since the input data that are necessary for interpolation were not enough, the correlation between available data and use land in Ancona is considered an acceptable approximation to represent the surface recession in the whole municipal area.

The study of vulnerability was realized for 25 architectural objects and for 2 archaeological sites. The results indicate: 1) superficial alterations and humidity damage are the main deterioration forms observed on the items; 2) vulnerability is generally medium-high for architectural monuments while it is high for archaeological sites.
The monuments, that are characterized by worse conservation conditions, are Tempio di S. Rocco, Porta Farina, Chiesa del Gesù, Chiesa del SS. Sacramento and Mole Vanvitelliana.

Risk

The risk indicators were elaborated correlating vulnerability with territorial hazard (that was represented, in this case, by surface recession).
In the current scenario the risk is more considerable for those monuments characterized by higher vulnerability values.
In the future scenario the territorial hazard could decrease because annual precipitation and pollutant concentrations should reduce.
As concerns vulnerability component, it's not possible to know its future trend since conservation condition of a monument will depend on the appropriate maintenance activities. If those monuments characterized by high vulnerability are subjected to monitoring and maintenance interventions, an improvement of their conservation condition might be verified.

Conclusions

The correlation between the monument vulnerability with territorial hazard in each area permits the calculation of territorial and individual risk.
The assessment of these indicators allows to individuate the most aggressive areas for monuments and their potential risk level.
To maximise the adaptive capacity of artworks, the planning of rigorous and frequent maintenance activities is suggested in order to improve the conservation condition of the cultural heritage and to reduce the restoration actions, that usually are more expensive and invasive than maintenance works.

The Economic Plan of maintenance activities

The decay phenomena analysis realized in this study, provided indications relating to the appropriate conservation activities that should be implemented to preserve cultural heritage in Ancona.
For example, the planning of maintenance activities and corresponding budget for *Loggia dei Mercanti* was reported in table 1.
This elaboration represents an challenge to evaluate the possible costs of maintenance activities that should interest the most damaged parts of the building.
The suggested interventions were quantified on the base of the *Prezziario per il Restauro dei Beni Artistici* (Dei, Roma 2003) prescinding from provisional works and considering, for the operations on the bricks, the costs of the operations on limestone materials with siliceous component.

Table 1: Loggia dei Mercanti: plan of maintenance activities and corresponding costs

n. price list	**Operation**	**Interested surface (mq)**	**Unit price**	**Total price**
5051 b	**Disinfection by the application of biocide and manual removal of superior vegetation:** the burdens relating to fixing of surrounding surfaces that are in danger of falling, on every kind of stone objects situated in external environment, are not included	2	€ 41,97	€ 83,94
15056 a	**Disinfection from heterotroph and/or autotrophs microorganism by the application of biocide and subsequent mechanical removal**	10	€ 92,47	€ 924,70
15061 a c	**Removals of superficial cohesive deposits, concretions, incrustations and soluble stains through water spraying using atomization system**	25	€ 159,58 € 143,98	€ 3599,55
15063 a	**Removals of superficial cohesive deposits, incrustations, concretions through the application of inorganic salt, carbonate and ammonium carbonate solutions;**	15	€ 273,69	€ 4105,35
Total price				**€ 8713,54**

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THE CASE OF SLOW LANDSLIDES IMPACT IN ANCONA

Authors

D. Spizzichino, A. Capriolo and F. Di Gioia

CONTENTS

Introduction

The assessment of Climate Change impacts on geological hazard (slow landslides), developed by ISPRA jointly with Ancona Municipality, was carried out in order to identify future impact scenarios on specific segments of social infrastructure (residential and commercial buildings) and the best adaptation measures in case of action. All the economic evaluation has been implemented starting by the output of local impact assessments report.

Through this approach it has been possible to estimate future costs of inaction (expected damage) that such a kind of events will have on the assets taken into account and also the costs (adaptation measures) for risk and vulnerability.

1. Methodology

The main scope of analysis was to identify the future space distribution of building (in the municipality of Ancona) affected by slow landslide and compare the related costs (value of buildings) with the landslide risk reduction costs, in order to plan adaptation policies to Climate Change.
The analysis was based on the collection of the following data:

- Future urbanized area worst case in 2100 scenario) affected by slow landslide in the Ancona municipality **(H=spatial hazard);**
- **Different land use in** urban area classified and derived from Corine Land Cover project 2006 (**E = Exposed Elements**);
- The building vulnerability was supposed constant in this stage (**V = Vulnerability =1**);
- Building value (**estimated cost per m^2**) derived by the *Italian Real Estate Observatory Market.*

By Geo-Processing (through spatial analysis) the above mentioned input data, the expected future costs due to landslide risk affecting urbanized area were calculated in 2100. The adaptation costs were estimated considering the total costs necessary for landslide risk reduction (superficial and deep slow landslide restoration works).

2. Urbanized area in the Ancona municipality affected by slow landslide in the year 2100.

The urbanized area affected by future slow landslide (Tab.1 and fig.1), was taken from the Local Impact Assessment Report (Life Act 2011).

Tab1. Climate Change impact and trends analysis – Summary table for the impact at municipal level using CLC2006. (Local Impact Assessment Report, LIFE ACT 2011).

Ancona municipality Surface in Km²
124,43

		Area affected by landslide (2011)			Area affected by landslide (2100) FLSB		
Level 3	CODE_06	AREA_km²	% municipal area	% Vs Land cover	AREA_km²	% municipal area	% Vs Land cover
Continuous urban fabric	111	0,001	0,001	0,16	0,002	0,00	0,29
Discontinuous urban fabric	112	1,567	1,259	14,13	2,402	1,93	21,66
Industrial or commercial units	121	0,113	0,091	2,86	0,189	0,15	4,78
Port areas	123	0,000	0,000	0,01	0,066	0,05	4,77
Green urban areas	141	0,688	0,553	33,03	0,842	0,68	40,38
Sport and leisure facilities	142	0,000	0,000	0	0,031	0,03	7,19
Non-irrigated arable land	211	15,674	12,596	22,45	21,984	17,67	31,49
Vineyards	221	0,653	0,525	33,76	0,909	0,73	46,98
Complex cultivation patterns	242	4,109	3,302	30,92	5,733	4,61	43,14
Land principally occupied by agriculture, with significant areas of natural vegetation	243	1,102	0,886	13,9	1,692	1,36	21,34
Broad-leaved forest	311	1,510	1,214	37,41	1,926	1,55	47,71
Coniferous forest	312	0,129	0,104	10,27	0,200	0,16	15,94
Mixed forest	313	0,414	0,333	15,76	0,653	0,52	24,87
Transitional woodland-shrub	324	0,830	0,667	30,64	1,035	0,83	38,20
TOTAL		26,84	21,57	21,71	37,752	30,34	30,53


Fig.1. Urbanized area affected by landslide in the worst scenario (2100)

3. Economic assessment for the residential and commercial building

For the economic assessment of commercial and residential building, indexes (tab.1) published by the Real Estate Market Observatory (fig. 2 and 3) from *Agenzia delle Entrate* was adopted.

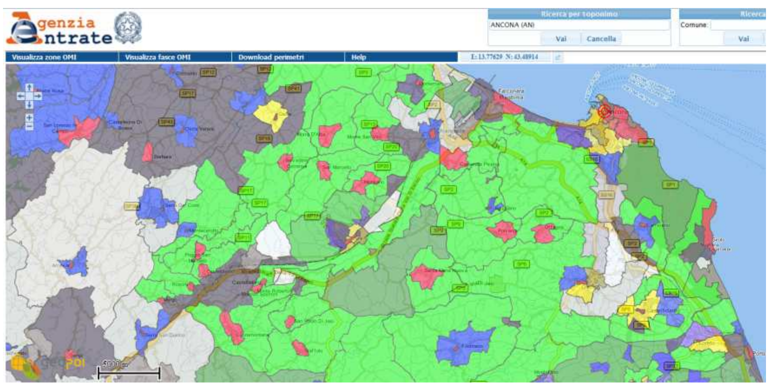

Fig.2. Real Estate Market zones division (as of second half of 2012).

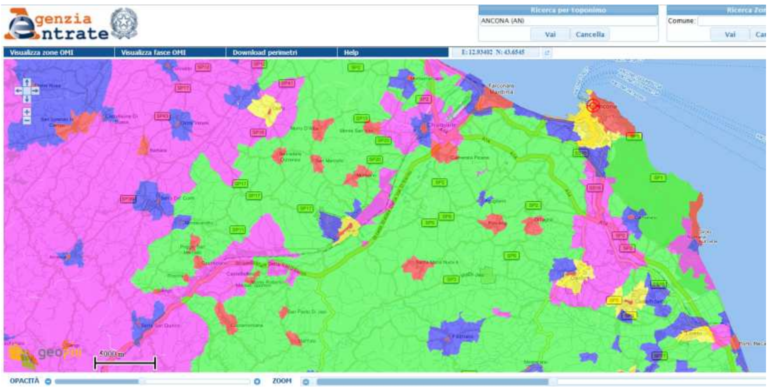

Fig.2. Real Estate Market bands division (as of second half of 2012).

Average costs for every single zone/ are available (obtained from the real market sales) useful for the unit cost definition (tab. 2).

Table 2 Estimates of the real estate market for different areas and for different uses.

Zone	number of residents	residential average cost euro/m2	commercial average cost euro/m2	office average cost euro/m2
B1	3759	€ 2,000.00	€ 2,325.00	€ 2,175.00
B2	0	€ 2,041.67	€ 2,275.00	€ 2,225.00
B3	0	€ 2,075.00	€ 2,275.00	€ 2,225.00
B4	656	€ 2,537.50	€ 2,000.00	€ 2,000.00
B5	584	€ 2,566.67	€ 1,850.00	€ 1,925.00
B7	898	€ 1,375.00	€ 1,975.00	€ 2,000.00
C1	54	€ 1,322.50	€ 1,900.00	€ 1,500.00
C2	1105	€ 1,641.67	€ 2,050.00	€ 1,725.00
C3	1927	€ 1,233.33	€ 1,700.00	€ 1,900.00
C4	762	€ 1,691.67	€ 1,800.00	€ 1,850.00
C5	0	-	-	-
D1	1171	€ 1,716.67	€ 1,600.00	€ 1,675.00
D2	301	€ 1,537.50	€ 1,625.00	€ 1,850.00
D3	953	€ 1,450.00	€ 1,275.00	€ 1,425.00

4. Future damage estimate for the residential and commercial building due to slow landslides.

In order to estimate the total direct costs due to the loss of residential and commercial areas because of future landslides (year 2100), the urbanized area potentially affected by landslide was moltiplied by the unit cost derived by the observatory.

In order to estimate the total cost, the urbanized affected area (depending on the type of destination code) was multiplied by the unit value taken from the Market Observatory, assuming a standard building composed by four floors (ground floor for commercial/office destination).

Tab3. Total loss estimate for residential and commercial building (2100).

Ancona municipality SKm Surface (Km2) **124,43**	**Corine land cover 2006**	**Urban area affected by landslide in the 2100 (Km2)**	**total loss cost 2100**
	Continuous urban fabric	0,00	€ 18.920.000,00
	Discontinuous urban fabric	2,40	€ 19.213.039.792,00
	Industrial or commercial unit	0,19	€ 377.111.778,00
	Port areas	0,07	€ 131.520.000,00
	total	**2,66**	**€ 19.740.591.570,00**
	Residents	**Urban area affected by landslide in the 2100**	**%**
	102.926,00	15.333,00	15

5. Adaptation polices and related estimated costs

With regard to the adaptation costs from landslides impacts within the Ancona municipality, a site specific analysis was carried out. All the technical literature (e.g. regional price list of works, guideline of restoration works and countermeasures) has been taken into account in order to provide the unit cost of measures for slow landslide (type 1 superficial landslide and type 2 deep landslide). Calibration of cost has then been made on real cases available on the project database ReNDiS[77] developed by ISPRA from 1999. This analysis has identified the costs of measures (per m^2) that can be applied in order to reduce the urban area affected by landslide risk. The following table 4 shows the main works usually adopted for the slow landslide and their relative costs.

Table 4 Measures cost estimate adopted for slow superficial landslide (type 1) and slow deep landslide (type 2)

Type 1		
main works		cost euro/m2
cleaning of weeds		€ 8.00
escavation		€ 5.00
drainage systems		€ 7.00
protection from erosion		€ 20.00
superficial retaining works (walls, gabions)		€ 20.00
bioengineering		€ 10.00
	tot	**70**

Type 2		
main works		cost euro/m2
cleaning of weeds		€ 8.00
escavation		€ 5.00
drainage systems		€ 26.00
protection from erosion		€ 18.00
deep retaining works (piles,anchors, bulkhead)		€ 25.00
bioengineering		€ 8.00
	tot	**90**

The above values were multiplied by urban area affected in the future (year 2100) by landslides. The maximum total costs that the municipality of Ancona should support (in order to reduce the

[77] http://www.rendis.isprambiente.it/rendisweb/

future impact that these phenomena will have on urban areas) is listed below (table 5). The analyses produce an average cost of 280 (million euro).

Table 5 Total cost for landslide risk reduction in the Ancona Municipality

m^2	3,500,000.00	Urban area affected by future landslide (year 2100) equal to 3% of the entire territory)
€	254,000,000.00	Min cost of measures
€	315,000,000.00	Max cost of measures
€	280,000,000.00	Average cost of measures

6. Benefit cost analysis and conclusions

From the above analysis it is quite clear that the inaction cost (damage caused by slow landslide in the future) that the municipality of Ancona will have to incur without adaptation plan are much greater than the costs of landslide risk reduction (table 6). More in detail the adaptation costs are 1.6 % of the total inaction costs referred to the complete loss of property, giving evidence that adaptation cost are lower than cost of inaction.

Table 6 Cost/benefit inaction/adaptation

Expected damage of total exposed elements (year 2100)	Percentage of adaptation respect the inaction
€ 19,740,591,570.00	**1.6 %**
Adaptation costs (risk reduction measures)	
€ 315,000,000.00	

The treatment of the temporal dimension has not considered benefits (avoided costs) as emerging from gradual adaptation during the reference period 2011-2100. The analysis is unable to predict the time when the various landslides would be triggered and consequently to establish when costs are avoided. However the study provides an estimate, in the presence of different climate scenarios (increase in average seasonal precipitation), of the total perimeter of the surface that in 2100 will presumably slide down.

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