IMPACTS OF CLIMATE CHANGE ON ALL EUROPEAN ISLANDS

Final Report

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KEY MESSAGES

European islands represent a major but often underrepresented part of the EU and its Member States. There are more than 50,000 islands on the European Continent, 500 islands are larger than 20 km^2 and they have a total area of over 700,000 km^2 or more than 7 per cent of Europe's surface area. The Outermost Regions are geographically situated outside of Europe and together with the Overseas Countries and Territories have the largest marine domain in the world with a combined Exclusive Economic Zone over 15 million km^2.

- **European islands face very concrete risks as a result of a changing climate** as a result of higher temperatures, changed rainfall regimes, weather extremes, and sea level rise. Climate related risks are not limited to specific regions or countries but that it is an issue for all islands. Empirical evidence for all five case studies shows that climate change is not an abstract threat that may occur in the future but it is a concrete risk with the consequences of which many islands are faced with now.

- **Islands' infrastructure including its most critical components such as airports, sea ports and highways is often located near the coast and hence particularly vulnerable to sea level rise and flooding**. In addition to transport infrastructures, water supply and energy systems are faced with particular challenges. Investment costs for future proofing, maintenance and damage repair cost are expected to grow significantly. For example, the flooding and intensive rainfalls in February 2010 in Madeira caused damage costs of more than € 1 billion.

- **European Islands' dependence on imports for food and water is likely to increase with climate change as is the costs.** Decreasing rainfall and salinization in combination with continuously increasing demand is creating a situation where water shortages become most precarious. Already now, small islands rely on imports of fresh water to meet their water needs during periods of low rainfall. For example, the cumulative cost of climate change for drinking water supply has been estimated for Greece as between 0.9 % of GDP to 1.3% of GDP for the period 2041-2050.

- The agriculture sector is in many islands crucial for minimising the island's dependence on food imports and an important source of foreign revenues from the export of agricultural products. **In the long term most islands will be faced by decreased crop production and at the same time higher costs for water irrigation**. Existing experience underlines that there can be major impacts, for example in 2013 alone olive oil production on Crete decreased by up to 70 per cent as the result of a combination of warm southern winds and increased temperatures.

- **Many islands are strongly dependent on revenues from the tourism industry with a share in the island's GDP of 20 per cent or even higher, yet tourists' motivation to visit islands can be compromised by climate related effects** – heat, fires (as seen in Greece), flooding (e.g. Madeira) health risks and biodiversity loss (as seen in French Polynesia). For example, there is high interdependence between tourism and biodiversity for the **Netherlands Antilles,** with many visitors coming specifically for the diving and coral reef-watching. The costs of climate change in the Netherlands Antilles estimated future costs to be as high as US$4 billion (€3 billion) already in 2020 and to increase to between US$9.2 (€6.8) and US$11.7 (€8.6) billion in 2050[i].

- **The fishing industry will face a risk of lower catches for many islands,** which will result in decreasing trade in fishing products and worsening islands' trade balance. A temperature increase of coastal waters will shorten the reproduction period of temperate water fish species, decreasing the natural recruitment of young fish, resulting in a decrease of exploitable stock. Risks also exist for other marine industries. For example, in **French Polynesia**, i**n 2008, pearl cultivation provided over three quarters of Polynesian export revenues which in 2012 was equivalent to about EUR 58 million and employment for about 5000 people**. Climate change could undermine the profitability of this industry.

- Besides physical, energy, water and food security there is also a **significant increase in the risk of vector-borne viruses such as malaria and dengue** fever which proliferate when dramatic changes in temperature and precipitation patterns occur. **In Reunion a mosquito-borne infection touched 35% of the population and led to a dramatic drop in tourist numbers between 2005 and 2006**. In Madeira the presence of mosquitos was first reported in 2004.

- **70 % of Europe's biodiversity is located on islands which include 43 Ramsar sites and 8 World Heritage sites. The loss of islands' unique biodiversity could be huge**. Between January and March 1996, following unusually warm water temperatures, **the corals of New Caledonia suffered a bleaching episode with coral mortality rates of as high as 90 per cent**. The degradation of the corals as a result of bleaching and storm damage could also destroy the physical barrier which shelters Atolls from heavy ocean swell. Atolls are among the most complex and fascinating geological structures of the planet.

- **An ultimate consequence of climate change impacts on islands will be migration.** The exact impacts of climate change on migration are hard to quantify: the important decision on whether or not to relocate is based on a complex interplay between many factors, in which environmental concerns may matter to varying degrees. Given that the predominant reason for environmental migration is economic, damage to the key economic sectors as a result of climate change is likely to lead to migration.

- **The consequences of climate change impacts on European islands will not be limited to the islands and their inhabitants** but will go well beyond the islands' borders. The challenge of climate change impacts is beyond most islands' capacities to address on their own and hence requires a strengthened cooperation between the islands and the mainland as well as between North and South to minimise the consequences and increase the benefits of early action for all. **The engagement of EU policies and programmes is essential to respond to the challenge of reducing risks and impacts of climate change on European islands.**

1 INTRODUCTION

1.1 Rationale for this study

Climate change poses significant risks to many if not all European islands with associated impacts in several key areas including security, migration, and biodiversity. Climate risk is a particular challenge to islands as their pressure absorption capacity and territorial redeployment abilities are usually lower than on the mainland. Climate change is likely to have increasingly important implications for the relationship between these islands and the EU main continent in the years to come, in particular in terms of trade flows of specific products and natural resources.

The EU islands represent an enormous diversity in terms of their size, geology, climate, altitude, biodiversity, population and local economy. Common features of the islands are their limited accessibility, isolation, dependence on a limited number of economic sectors and small internal markets. The particular situation of island regions and related challenges are acknowledged in the Lisbon Treaty.

The majority of islands have a weaker economic performance than the mainland with an average GDP per capita 80 per cent below the EU average.[ii] The economically best performing islands are those specialised in activities such as tourism (e.g. the Balearic islands, Cyprus, and some Greek islands) and those focused on international trade through, for example, transport or energy (e.g. shipping in the Åland islands, crude oil and gas production in Shetland and Orkney).

Many islands are home to an outstanding diversity of landscapes, ecosystems and species. This diversity is particularly threatened, because of the higher exposure to natural hazards, including the impacts of climate change, which constitute a key risk for European islands. In many cases islands have a lower capacity to absorb external shocks compared to mainland locations, which will only aggravate the issue. The relevance of sea level for Europe as a whole and islands in particular is underlined by the fact that between 1950 and 2000 the population living in European coastal municipalities doubled to more than 70 millions inhabitants. The total value of economic assets located within 500 meters from the coastline was estimated to be between EUR 500 and 1000 billion in 2000.[iii]

The main objective of this study is to understand the concrete climate change related risks facing European islands and to evaluate the costs of inaction in key areas such as security, migration, and biodiversity loss. The potential consequences of impacts in these principal areas on trade between islands and the main EU continent will also be examined. Ultimately the study is to raise awareness among policy-makers at the EU level and citizens on how climate change already affects and is likely to affect European islands in the future. The study points to the possible costs of climate change impacts for individual EU Member States and the EU as a whole.

The report is structured as follows. After an introduction to the definition and classification of European islands and the particular status of outermost regions in EU policy-making, we present the methodological approach. Section 2 provides an overview on climate trends European islands are faced with at present and in the future. Section 3 assesses the consequences of climate change on different sectors and areas most relevant to European islands. Section 4 summarises the implications for trade, security and migration. Section 5 concludes drawing together the key insights from this report.

1.2 European islands: definitions and classifications

Islands of relevance for this study can be grouped into three main categories:

- **European islands** which are geographically situated within Europe and are part of EU Member States. These islands can be differentiated into three different areas: Mediterranean, Baltic, and Northern European and Arctic Islands.
- **Outermost Regions (ORs)** which are fully part of the EU, but are geographically situated outside of Europe.
- **Overseas Countries and Territories (OCTs)** which are closely associated with four EU Member States (Denmark, France, the Netherlands, and the United Kingdom) and the EU as specified in the Lisbon Treaty but are not part of the EU territory or directly subject to EU law.

There are more than 50,000 *European islands* of which around 500 are larger than 20 km^2. Estonia alone is estimated to have a total of 1,520 islands.[iv] In the European Union there are 362 islands each with a permanent population of more than 50 inhabitants.[v]

The *Outermost Regions (ORs)* of the EU are composed of:

- the Canary Islands (an autonomous community belonging to Spain)
- Madeira and the Azores (autonomous regions of Portugal)
- Martinique, Guadeloupe, French Guiana, La Réunion, Saint-Martin and Saint-Barthélemy (overseas "departments" or "collectivities" of France).

Their particular situation in terms of their geographical and economic realities such as remoteness, small size and dependence on a small number of products has been recognised by the EU since 1999.[vi]

Similarly, most of the 21 *Overseas Countries and Territories (OCTs)* are remotely located. The Danish overseas territory is Greenland, the French overseas territories include French Polynesia and New Caledonia, the Dutch overseas territories include the Netherlands Antilles and the UK overseas territories include Bermuda, the Cayman Islands, and the Falkland Islands.

European overseas entities (i.e. ORs and OCTs) cover a land area of 4.4 million km^2, equivalent to that of the continental European Union and have the largest marine domain in the world with a combined Exclusive Economic Zone of over 15 million km^2.[vii] These overseas entities can be clustered in the following regions (,the most relevant islands are noted within the brackets):

- Caribbean (Guadeloupe, Martinique, Netherlands Antilles, Aruba, Bermuda, Cayman Islands, British Virgin Islands, Anguilla, Montserrat);
- Indian Ocean (Reunion Island, Mayotte);
- Macaronesia (Azores, Madeira, Canary Islands);
- Pacific (French Polynesia, New Caledonia);
- Polar and Sub-Polar (Greenland, Falkland Islands); and
- South Atlantic (Saint Helena).

The situation of islands in general and of outermost regions in particular is acknowledged in the Lisbon Treaty. Article 174 of the Treaty on the Functioning of the European Union stipulates that "Among the regions concerned, particular attention shall be paid to rural areas, areas affected by industrial transition, and regions which suffer from severe and permanent natural or demographic handicaps such as the northernmost regions with very low population density and island, cross-border and mountain regions."

The Outermost Regions form an integral part of the EU and are covered by EU law along with the other rights and duties associated with EU membership.[viii] The legal grounding of the concept of 'Outermost Regions' was laid down at the Treaty of Amsterdam in 1997, and was further reinforced by the Treaty of Lisbon. The Lisbon Treaty acknowledges the special nature of the European Outermost Regions and the need for undertaking specific actions to foster their development (Articles 107 (3) (a) and 349 TFEU). Article 349 of the Treaty on the Functioning of the European Union stipulates that specific measures are warranted '*taking account of the structural social and economic situation [of European Outermost Regions], which is compounded by their remoteness, insularity, small size, difficult topography and climate, economic dependence on a few products, the permanence and combination of which severely restrain their development*'.

The Cohesion Policy framework sets out to support convergence and coherence of the Outermost Regions with the EU and also to assist the process of Outermost Regions' economic development, such as though implementing strategies to improve competitiveness, fiscal policies and reduce reliance on imported commodities[1]. The measures enforced by the above-mentioned Article 349 in the Treaty of Lisbon refer to state aids and access to structural funds and to horizontal European Union programmes, which are customised to the special circumstances and determinants of ORs.

Structural and Cohesion Funds are allocated to Outermost Regions by means of specific financial instruments, including the European Agricultural Fund for Rural Development (EAFRD), which sustains agricultural initiatives under Pillar 2 of the Common Agricultural Policy (CAP). Regional policy plays also a pivotal role in designing and implementing adjusted climate change mitigation and adaptation programmes, which receive dedicated funding from the European Regional Development Fund (ERDF). EUR 7.8 billion from EU Structural Funds were earmarked to Outermost Regions in the period 2007-2013 through ERDF, EAFRD, the European Social Fund (ESF), European Fisheries Fund (EFF), plus other measures such as POSEI (Programme of Options Specifically Related to Remoteness and Insularity).[ix]

In addition to Structural Fund programmes, other European initiatives were rolled out to address the specificities of these regions, such as Natura 2000, BEST (Voluntary scheme for Biodiversity and Ecosystem Services in Territories of the EU Outermost Regions and Overseas Countries and Territories) as part of DG Environment programmes, and CIP (Competitiveness and Innovation Framework Programme), initiated by DG Research.[2]

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[1] http://www.lisbon-treaty.org/wcm/the-lisbon-treaty/treaty-on-the-functioning-of-the-european-union-and-comments/part-7-general-and-final-provisions/592-article-349.html

[2] http://ec.europa.eu/regional_policy/activity/outermost/index_en.cfm#10

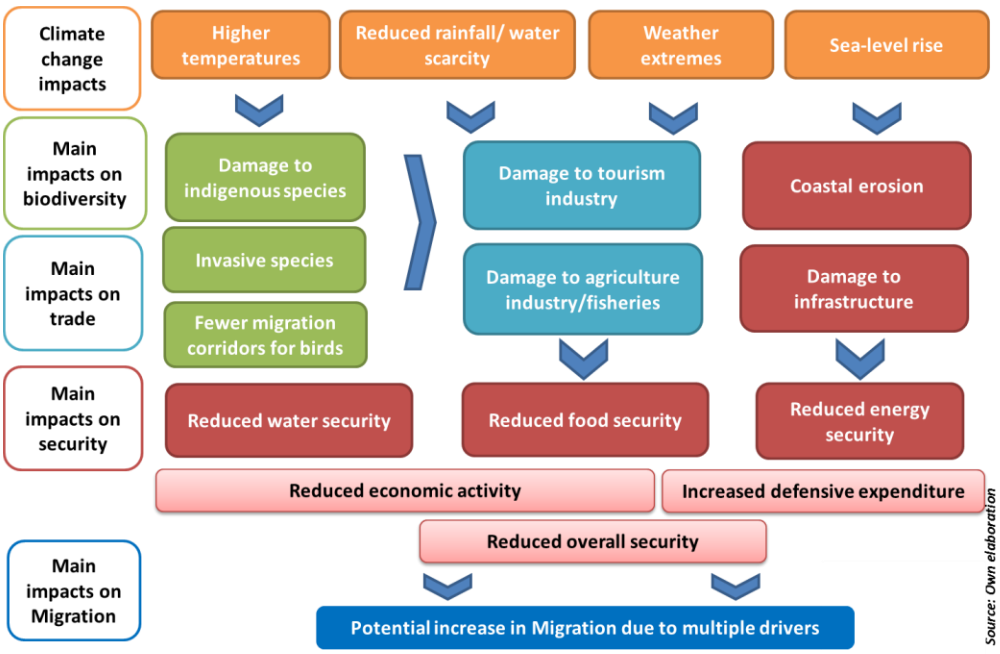
Since October 2008, the Commission's policy paper on 'The Outermost regions – an asset for Europe) came up with two main strategic objectives to be achieved, which concentrate on tackling new challenges in ORs (eg demographic pressure. climate change) and making best use of the regions' assets. Two years later, at the initiative of DG REGIO, the First Forum for Outermost Europe was organised with the aim to provide a platform for nurturing active partnerships and exchange of views between the European Commission, the European Parliament, Member States and Outermost Regions.[3]

European islands are dispersed over a vast geographical area: from the Arctic in the Northern hemisphere to the subtropical regions off the North-West African coast. These European Islands, together with the Outermost Regions and the European Overseas Countries and Territories cover every ocean basin, and extend from polar to tropical latitudes. European islands, ORs and OTCs stretch across the bio-geographical regions of Arctic, Atlantic, Pacific, Boreal, Continental, Mediterranean, Macaronesian and Indian Ocean, and cover all climatic zones (polar, temperate, arid, tropical, Mediterranean, and mountains). Some of these islands even benefit from different micro-climates within their mainland due to variations in topographic conditions.

1.3 Methodological approach and structure of this report

Figure 1 sets out the conceptual approach of this report. It illustrates the key impacts of climate change on islands and how this relates to issues pertaining to biodiversity, security, migration and trade. It is important to note that the potential impacts of climate change depend on the specific characteristics of the island and can be both negative and positive.[x]

Figure 1: Impacts of climate change on islands



Source: Own elaboration

[3] *Ibid.*

This report is based on a thorough and systematic review of existing literature on the risks and impacts of climate change on European islands. Given the scope of the report's subject a case study approach was used. Building on desk research, a long list of potential case studies was compiled. Based on this list five islands or island regions were selected for an in-depth analysis of the above identified climate change impacts on the islands' key sectors.

The case studies were selected based on the following criteria:

- **Geographic coverage**: Selected cases should reflect a balanced geographic coverage to the extent possible, including cases in the Northern and Southern hemisphere, different ocean locations, and linked with different EU Member States.
- **Climate zone:** Selected cases should represent a diversity of climatic zones so as to illustrate the impacts of climate change in different areas.
- **Biodiversity**: Selected cases should include at least one island of particular importance for biodiversity, *i.e.* a biodiversity hotpot.
- **Security:** Selected cases should represent a diversity of the key security risks the selected islands are predominantly faced with (infrastructure, water, food, or energy security).
- **Migration:** To the extent possible, selected cases should include at least one island experiencing high levels of migration, recognising that this can be due to various factors including economic prospects, unemployment etc. Thus climate change is likely to be one factor among several.
- **Data availability:** the cases should be relatively well documented (e.g. subject of national/international studies), qualitative and quantitative data easily available and/or experts can be contacted to obtain useful information.

Table 1 provides an overview of the 5 case studies and how they address the above-identified criteria. Two case studies (Macaronesia and Greek islands) are located in the Northern Hemisphere, five case studies (La Reunion, Netherlands Antilles and French Polynesia/New Caledonia) are located in the Southern Hemisphere. The selected case studies cover all major climate zones except for the arctic climate zone. The research for this report showed that the impacts of climate change on islands in the arctic climate zone have not been assessed in great detail so far.[4] This may be due to the fact that these islands may benefit from climate change in the short term for example in terms of longer vegetation periods.

Table 1: List of case studies

Island/ cluster of islands	Geographic location	Climate zone	Category of European island[5]	Most relevant climate impact	Focus area(s)
Northern Hemisphere					
Macaronesia (Azores, Madeira (Portugal);	Atlantic Ocean, Macaronesian	Oceanic, subtropical	OR	Weather extremes	Tourism, Biodiversity,

[4] Several islands located in the arctic climate zone have been contacted for this study (see Annex I).
[5] According to the three main categories introduced in section 1.1 of this report as follows: European island: geographically situated within Europe; OR: Outermost Region; OCT: Overseas Countries and Territories.

Canary Islands (Spain))	region	climate		Higher temperatures	Infrastructure
Greek islands such as Rhodes and Crete (Greece)	Mediterranean	Mediterranean	European islands	Higher temperatures Changed precipitation	Tourism Infrastructure
Southern Hemisphere					
La Reunion (France)	Indian Ocean	Tropical	OR	Weather extremes Changed precipitation Sea level rise	Biodiversity Agriculture
Netherlands Antilles (The Netherlands)	Caribbean Islands	Tropical	OCT	Weather extremes, Changed precipitation, Sea level rise	Biodiversity Tourism
French Polynesia / New Caledonia (France)	Pacific Ocean	Tropical	OCT	Weather extremes, Changed precipitation, Sea level rise	Biodiversity Agriculture

The location of the five case studies is visualised in Figure 2.

Figure 2: Location of the five case studies

Map source: www.nationsonline.org

The in-depth analysis of the five case studies was carried out using on desk-based research based on a common template for all case studies. Each case study captures the key features of the island(s) or island region, the most relevant climate trends experienced in the past and projected for the future as well as their expected consequences on key sectors and areas. Particular emphasis was put on concrete risks and impacts that can be quantified or illustrated so as to serve as examples when communicating climate risks European islands are facing.

In addition to desk research local experts were contacted to identify additional documents and data. For each case study at least one interview with a local expert was conducted to ensure that the key impacts and their implications are covered (see Annex I for list of experts contacted and for a list of interviews that were conducted for each case study). The research for this report was carried out between June and September 2013. Where case studies included economic values these were converted to Euros to facilitate comparability, using the 1 October 2013 currency exchange rate.[6]

The five case study reports with an in-depth analysis are attached to this report (see Annex II). This report provides a synthesis and summary of the key insights gained from the five case studies.

[6] US$1.3554/€ European Central Bank, http://www.ecb.europa.eu/stats/exchange/eurofxref/html/eurofxref-graph-usd.en.html

2 OVERVIEW OF KEY CLIMATE CHANGE RELATED RISKS FACING EUROPEAN ISLANDS

This section summarises the climate change impacts on European islands. It begins by summarising key climate trends at a global level before focussing on the specific climate trends for European islands building on the information gathered for the five case studies. Projections on future climate change are often based on the scenarios as developed by the International Panel on Climate Change (IPCC). Most commonly used scenarios are the 'B2 scenario' and the 'A2 scenario' which reflect different assumptions on key global developments that influence greenhouse gas emissions and hence climate change. The 'B2 scenario' builds on a world where local solutions to social and environmental issues are pursued, with moderate global population growth and technological change. The 'A2 scenario' is based on a very heterogeneous world with stronger population growth and a more fragmented approach. More details and the implications in terms of temperature change and sea level rise at global level are summarised in Table 2.

Table 2: Summary of IPCC scenario assumptions

	Temperature Change		Sea Level Rise
	*C at 2090-2099 relative to 1980-1999		m at 2090-2099 relative to 1980-1999
Case	**Best Estimate**	**Likely Range**	**Model-based range excluding future rapid dynamical changes in ice flow**
Constant Year 2000 concentrations	0.6	0.3-0.9	NA
B1 scenario	1.8	1.1-2.9	0.18-0.38
The B1 scenario family describes a convergent world with the same global population that peaks in mid-century and declines thereafter, with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.			
A1T scenario	2.4	1.4-3.8	0.20-0.45
The A1 scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. A1T has technological emphasis on non-fossil energy sources.			
B2 scenario	2.4	1.4-3.8	0.20-0.43
The B2 scenario family describes a world in which the emphasis is on local solutions to social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.			
A1B scenario	2.8	1.7-4.4	0.21-0.48
(See A1T scenario.) The A1B scenario is distinguished by a technological development in both fossil intensive and non-fossil energy sources.			

A2 scenario	3.4	2.0-5.4	0.23-0.51
The A2 scenario family describes a very heterogeneous world. The underlying theme is self reliance and preservation of local identities. Fertility patterns across regions converge very slowly which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.			
A1F1 scenario	4	2.4-6.4	0.26-0.59
(See A1T scenario.) The A1F1 scenario is distinguished by a technological development in fossil intensive energy sources.			

Source: IPCC (2007)

2.1 Global climate trends to date

"Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level" [xi]

Since the late 1970s, despite annual variability, an evident trend of elevated global temperatures can be distinguished, and the effects of climate warming have been attributed to increased concentrations of greenhouse gases (GHGs). Over the same period, more protracted and severe droughts have been recorded across the world, especially in the tropical and sub-tropical regions, as a result of changes in precipitation patterns associated with warmer air temperatures. In the decade between 2002 and 2011, the global average temperature increased by 0.77 °C to 0.80 °C compared with the pre-industrial average temperature.[xii]

Rising sea levels has been a global concern, and since the year 1990 the phenomena became more apparent, with a reported increase in sea levels by around 20 centimetres and increasing average annual sea level rise. According to the IPCC, the increased intensity of hurricanes in the North Atlantic since the 1970s is closely correlated with the elevated sea temperature.[xiii] As such, the projected warming of tropical seas is expected to lead to an intensification of tropical cyclones across the tropical region, with sub-regional variations.

Globally, the number of great inland flood disasters between 1996 and 2005 has doubled as compared to the decade between 1950 and 1980, while economic losses have climbed by a factor of five.[xiv] Although the main drivers of such natural disasters are deemed to be human-induced (eg land-use change and demographic pressure on fragile zones), the vulnerability of these regions is expected to increase in the future due to climate change.

A consistent warming trend has been experienced in all small-island regions. For instance, in the Caribbean, Indian Ocean and Mediterranean regions, results show a warming of between 0 to 0.5 °C per decade for the period between 1971 and 2004. In the South Pacific region there was an increase in the annual number of hot days and warm nights between 1961 and 2003. Projections for the future predict a gradual warming of surface air temperature.

Global sea levels have increased by about 20 centimetres since 1900; the consequences for beaches are not always the same across the world but have proven very impactful in certain regions. For example, a study of 200 beaches on nine islands of the Caribbean between 1985 and 1995 shows that 70% of beaches studied were eroded[xv]. The most important climate trends are summarised in Table 3.

Table 3: Summary of climate trends

Key climate impacts	Empirical evidence to date	Expected future changes
Higher temperatures	Globally, the decade between 2002 and 2011 was 0.77 °C to 0.80 °C warmer than the pre-industrial average temperature. Over the same period, temperatures in the European land area were 1.3 °C above the pre-industrial level.	Global average temperature is projected to be between 1.1–6.4 °C higher by 2100 taking climate model uncertainties into account. Land temperature in Europe is projected to increase between 2.5 °C and 4.0 °C by 2071–2100.
Changed precipitation	Precipitation changes across Europe show more spatial and temporal variability than changes in temperature.	Continued precipitation increases in northern Europe (most notably during winter) and decreases in southern Europe (most notably during summer). The number of days with high precipitation is projected to increase.
Weather extremes	Higher variability and frequency of storms.	Despite some uncertainty for mainland Europe, weather extremes are expected to worsen for the Caribbean.
Sea level rise	Tide gauges show a global mean sea-level rise of around 1.7 mm/year over the 20th century. Satellite measurements show a rise of around 3 mm/year over the last two decades.	Projections of global mean sea-level rise in the 21st century range between 20 cm and about 2 m by the end of the century. If the Greenland ice sheet were to melt completely, then on its own this would lead to a sea level rise of around 7 m. Current projections are that this would not happen this millennium.

Source: Mainly based on EEA (2012, p19), complemented with additional information from the literature review

In addition to these key climate impacts there are a number of specific climate trends such as an increase in sea surface temperature and ocean acidification. These are addressed if and where relevant in the report.

2.2 Key climate trends relevant for European islands

Based on the in-depth analysis carried out for the five case studies, the most relevant climate change impacts on temperature, precipitation, weather extremes and sea level rise are summarised the following sub-sections. Table 4 and Table 5 recap the specific climate change impacts based on empirical evidence of past climate change impacts and on projected climate change impacts from the five case studies carried out for this report.

2.2.1 Higher temperatures

The empirical evidence for all five case studies shows an increase in temperature over the last decades. Climate scenarios for the five case studies project a further increase in temperature of more than 1°C and even up to 3°C for the Mediterranean Sea. Higher temperatures are expected globally but are likely to be most pertinent for the Mediterranean islands in the summer when temperatures are already at high levels[xvi]. On the Greek islands, reduced rainfall is predicted to elongate the dry-season by twenty days each year between 2021 and 2050[xvii]. A recent study on the French overseas territories and climate change shows that during the last 40 years, temperatures have risen by +0.65°C to +1.5°C, depending on the territory. Climate modelling suggests a temperature rise between +1.4°C and +3°C by the end of this century in the French overseas territories[xviii].

2.2.2 Changed precipitation pattern

Precipitation patterns have changed over the last decades on all regions assessed. While some islands such as the Azores, parts of La Reunion and French Polynesia and New Caledonia register higher annual average precipitation levels, the Canary Islands, the Greek Islands as well as the Netherlands Antilles have been faced with lower mean precipitation rates. It is expected that average rainfall will increase for the Azores and French Polynesia, whereas the other islands are expected to be faced with reduced rainfalls which may be even significant as in the case of the Greek islands.

2.2.3 Weather extremes

Changes in temperatures and precipitations patterns are in many cases linked to a higher number of weather extremes in the form of more frequent extreme temperatures or extreme rainfalls constituting a serious threat to human health and the environment. For example, for some Greek islands it is projected that the number of days over 35°C (labelled as 'heat wave days') will increase by about 10 between 2021 and 2050.[xix] For La Reunion as well as French Polynesia and New Caledonia, both located in a tropical climate zone, it is expected that the number of cyclones will decrease but their associated precipitation will intensify.

2.2.4 Sea level rise

Sea level rise is a common phenomenon for all island regions analysed for this report. Satellite data indicates that the Mediterranean sea level has risen by 2.6 cm overall between 1992 and 2008, other islands report also steady average sea level rise over the last decades. As for projections on future sea level rise, some Greek islands may be faced with a rise in sea level of up to 1 m. For La Reunion a rise of between 20 and 60 cm is projected, while the region of the Southern Pacific may be faced with a sea level rise close to the global average of 0.35 m by the end of the century. In French overseas territories where sea levels had been rising from under 3 mm/year to over 5 mm/year over the last 20 years, rises between 40 and 60 cm, even up to 1 m in extreme cases by the end of this century are projected.[xx]

It is important to note that in general there is increased probability of low probably events with high impact such as weather extremes with devastating consequences for islands. Extreme weather events that may have occurred once in century may occur once in a decade.

Table 4: Empirical evidence on climate change impacts

Key climate impacts	Macaronesia	Greek islands	La Reunion	Netherlands Antilles	French Polynesia / New Caledonia
Higher temperatures	Between 1981 and 2010 for all 3 archipelagos average temperature increase ranged from 0.30 to 0.38 °C per decade exceeding global temperature rise by up to 0.10 °C per decade. [xxi]	The Eastern Mediterranean Sea is warming substantially, particularly the Aegean and eastern Ionian seas.	In the period 1969-2008, the average temperature on Reunion Island has increased by 0.62°C.[xxii] Most significant temperature rise took place over the austral autumn, in the months of March, April, and May.	Data from the late 1950s to 2000 has shown that the number of very warm days and nights in the Caribbean is increasing dramatically and very cool days and nights are decreasing	In French Polynesia, the observed increase in temperature was about 1.05C.[xxiii] In New Caledonia the minimal temperatures have increased by 1.2°C and the maximal temperatures have increased by +0,9°C.[xxiv]
Changed precipitation	Precipitation data illustrates a higher frequency of rainfall for Azores. There is also a slightly negative trend for precipitation in the Canary Islands, with frequent yearly precipitation lower than 500 mm after 1990.[xxv]	Mean precipitation has fallen.	The Western and South Western and Southern areas were characterised by reduced precipitations and increased droughts, whereas the closer to the East, the higher the average precipitation rate.	There is a trend towards an overall decrease in precipitation, with prolonged dry spells having occurred over the past few decades. The number of heavy rainfall events is increasing.	Since the mid of the 1970s annual rainfall has increased by 50 to 100%.[xxvi]
Weather extremes	Increasing number of significant weather events were recorded in the Canary Island, although the severity of the events has not changed.[xxvii]	Warm temperature extremes in the summer period have increased.	No clear tendency was observed with respect to the frequency of extreme precipitations. The number of storms increased in the summer season, and decreased in the autumn period.	While the islands located in the Southern part of the Netherlands Antilles are protected from tropical storms, the Northern islands are affected by an increased number of tropical storms.	From 1878 to 1969, 29 cyclones and strong tropical depressions (STD) have been recorded, while 44 cyclones and STD have been observed between 1969 and 2007.
Sea level rise	n.a.	Satellite data indicates that the Mediterranean sea level has risen by 2.6 cm overall between 1992 and 2008.	Between 1993 and 2011, the sea water level increased with 5 to 9 mm/year.	n.a.	In French Polynesia an increase of about 7.5 cm has been observed in Tahiti between 1975 and 2005.

Source: Literature reviewed for the case studies (see Annex II to this report for the full case studies), Note: n.a. = no specific data/information available

Table 5: Projected climate change impacts

Key climate impacts	Macaronesia	Greek islands	La Reunion	Netherlands Antilles	French Polynesia / New Caledonia
Higher temperatures	In Azores temperature increase by between 1 ºC and 2 ºC for the period up to 2070-2100. In Madeira overall increase in the average temperature between 2 ºC and 3 ºC. For Canary Islands, average temperature rise of 1 ºC.	With a predicted global temperature increase of 2°C, the corresponding warming in the Mediterranean Sea is expected to be between 1-3°C.[xxviii]	An increase in temperature between 1.5 and 2.8 °C.[xxix]	In the Caribbean, the air temperature by 2080 is projected to rise by 2 ºC following a low scenario and 3.3 ºC following a high scenario[xxx]. Temperatures on the ABC-islands are expected to rise over the coming decades	In the South Pacific, IPCC projects an average increase in surface temperatures of 1.8C by 2100.[xxxi] In New Caledonia The minimal and maximal temperatures could increase by between +1,4 °C and +2,7 °C.[xxxii]
Change in precipitation	At the Azores, increase in rainfall.[xxxiii] For Madeira a significant reduction (about 30%) in annual precipitation.[xxxiv] For the Canary Islands average precipitation may decrease by between 10% and 15% for the same period.[xxxv]	Precipitation is expected to decrease substantially. Total water potential is expected to decrease by between 14 per cent (Scenario B2) and 22 per cent (Scenario A2).[xxxvi]	Precipitation expected to be reduced by between 6 and 8 per cent by the end of the 21st century. A decrease in precipitation during the austral winter.	In the Caribbean decreased rainfall in the - rainy season, which will become shorter, and precipitation increase during the summer months, June-August[xxxvii].	Details from global projections suggest an increase of rainfall in the range of 5-15% for most islands. For New Caledonia lower precipitation is expected in particular during winter.[xxxviii]
Weather extremes	n.a.	The number of days over 35°C (labelled as 'heat wave days') on some Greek islands will increase by about 10 between 2021 and 2050.[xxxix]	Projections show a decrease in the number of cyclones in conjunction with an increase in their associated intense precipitations.	Overall, a larger number of intense precipitation events are expected in the Caribbean, conducting to more severe and frequent flash flood episodes[xl].	Intensification of cyclones in all tropical regions, with stronger maximum winds and more abundant punctual rainfall. [xli] Total number of cyclones may decrease.[xlii]
Sea level rise	Average rise of 0.35m.	Sea level rise is predicted to reach 0.25m (Scenario B2) and as much as 1m (Scenario A2) by 2100. The Greek islands likely to be most strongly affected include Lemnos, Samos, Rhodes, Crete and Corfu.	Sea level is expected to continue rising at variable rates, at ± 2 mm/year, or 20-60 cm in a century according to IPCC projections.	Sea levels rise of between 0.16 and 0.87 meters by 2100 expected.	In the region of the Southern Pacific, the increase in the sea level by the end of the century is in the same range as the global average (0.35 meters).[xliii]

Source: Literature reviewed for the case studies (see Annex II to this report)

3 CONSEQUENCES OF CLIMATE CHANGE IMPACTS ON KEY AREAS AND SECTORS OF EUROPEAN ISLANDS

Islands, whether located in the Southern or Northern Hemisphere, are most exposed to the consequences of the above-described climate trends. Several characteristics of islands explain the particular risk they are facing as a result of a changing climate. Islands' infrastructure, population, and economic activity is in many cases concentrated near to the coast which increases the exposure to climate change impacts such as sea level rise and weather extremes. The nature of climate change impacts will vary across islands depending on their location, the level of coastal development and infrastructure, the diversification of the economy, the type of tourism (international versus national, exclusively seaside, biodiversity etc.), the health of ecosystems (coral reefs, beach, mangroves, etc.) and their responses to climate change[xliv].

This chapter assesses the consequences of climate change for the following areas and sectors that are for many islands of critical importance for their environmental, economic and social well-being: infrastructure, agriculture, tourism, and biodiversity. For each area the chapter provides examples to underline the devastating impacts many islands are already faced with and are expected to be faced with in the future.

How climate change impacts affect key areas and sectors is provided in Table 6. For each area and sector the most relevant direct consequences are listed. It is worth noting that there can be strong interactions between different areas and sectors as illustrated in Figure 1. These are not captured in the table. These consequences are elaborated in more detail in this chapter with concrete examples from the case studies.

Table 6: Main negative consequences of climate impacts on key areas and sectors

Area/ sector	Higher temperatures	Changes to precipitation pattern	Weather extremes	Sea-level rise
Agriculture	Plant disease and pest outbreaks; Animal diseases	Droughts lead to land degradation and lower crops yield; Soil erosion; Damage to crops	Damage to crops and animals; Damage to arable land and relevant infrastructure	Loss of arable land; Salinisation of irrigation and freshwater systems
Tourism	Changes to seasonality; Heat stress for tourists; Increased need for air conditioning resulting in higher costs; Changes to tourist attractions.	Water shortages for tourists linked to competition for water between tourism and other economic sectors including agriculture	Risk of damage and interruption to tourism infrastructure; Perceived higher risk which may discourage potential tourists	Loss of beach area; Risk of damage to tourist infrastructure often in costal zones (e.g. hotels, restaurants)
Biodiversity	Proliferation of invasive species; Degradation of conditions for animal reproduction.	Aridification increases the risk of forest fires which is a significant threat to very biodiversity rich ecosystems	Temporary destruction of birds' shelters and reduction of their food; Erosion of beaches / loss of habitats.	Erosion of beaches / loss of habitats.
Energy infrastructure	Impact on energy generation, transmission and distribution; Increases demand for air-conditioning resulting in higher costs.	Affects energy generation, transmission and distribution as well as shipping routes;	Affects energy generation, transmission and distribution as well as shipping routes; In particular, transmission and distribution if not underground.	Near-coastal construction might need to be moved.
Transport infrastructure	Overheating : infrastructure can become temporarily unusable; Construction process will become more costly, and maintenance will have to happen more often.	Dry soil in combination with sudden heavy rainfall can cause mudslides and flooding that can damage transport networks.	Port facilities / maritime transport are likely to be affected; Increased risk of direct infrastructure damage.	Bridges and transport lines/infrastructure near the coast have to be elevated/relocated; Surface instability due to higher sea-levels can cause damage.
Water supply infrastructure	Increased demand for water during warm periods for consumption and irrigation etc. can cause (temporary) water scarcity.	Lower freshwater supply; Reduced soil moisture, surface waters, and groundwater supply. Reduced groundwater recharge capacity.	More intense storms could overwhelm the sewer system's collection capacity, with more flooding and more untreated sewage spilled into waterways.	Contamination of freshwater aquifers; Increased evaporation and saline intrusion from sea-level rise; Disruption to treatment process.

Source: own compilation based on literature reviewed

3.1.1 *Infrastructure*

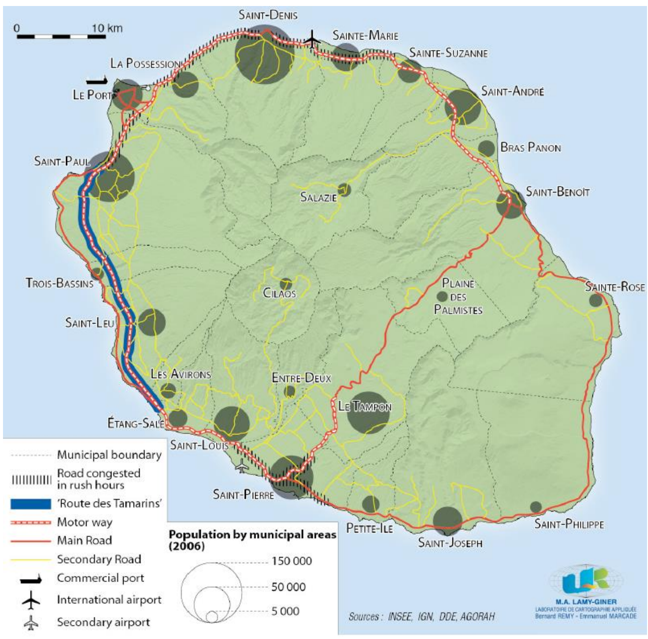
Climate change is expected to have significant impacts on insular infrastructure and all its components including:

- **transport** including roads, airports and ports, and
- **water** supply and water treatment,
- **energy** supply, distribution and demand,
- the **built environment**.

On islands, economic and social activity is usually centred near the coastline, where the highest concentration of larger settlements is found. In addition most of the critical infrastructure is located near the coast including transportation hubs such as airports or highways[xlv]. At the same time given their particular location, functioning **transport infrastructure** such as airports and sea ports are of particular importance for islands across all key economic sectors. In addition to the need to transport economic goods for trade and provide tourists with reliable infrastructure, most islands' **energy infrastructure** is highly dependent on imported fossil fuels. Extreme weather events therefore not only pose a risk to the islands' physical infrastructure but also to the transport routes to the island.

The particular situation of the transport infrastructure is well illustrated by the situation in **Reunion Island**. As many other islands, **Reunion**'s low-lying areas concentrate 82 per cent of the population and have a per capita density that is three to four times bigger as compared to the island average[xlvi]. Projected sea level rise and more frequent extreme weather events constitute an important threat to the island's infrastructure. Vital infrastructure (eg road, maritime, air transport as shown in Figure 3), installations and facilities that support local communities will be at severe risk.

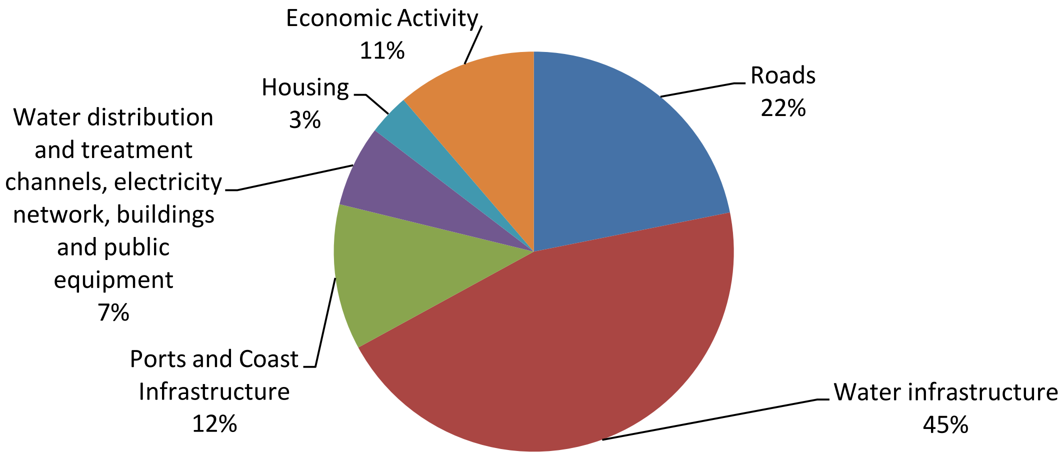
Figure 3: Transport infrastructure in Reunion Island



Source: Lamy-Giner (2011)[7]

In terms of possible costs that islands will be faced with as a result of future climate impacts past experience related to extreme weather events can provide a very useful indication. In **Madeira**, floods and mudslides due to heavy and sudden rainfall in February 2010 led to considerable destruction of transport infrastructure (roads), housing, electricity, port infrastructure, and tourist facilities[xlvii]. Costs of the flooding were € 1,080 million most of which related to damages to the water infrastructure followed by the road infrastructure (see Figure 4). These costs are material losses only and do not include human and natural biodiversity and habitats losses. These costs of around € 1 billion constitute about 20 per cent of Madeira's GDP which was € 5.2 billion in 2010[8].

Figure 4: Illustration of funds allocated following the flooding damage of 2010 in Madeira



Source: Personal Communication

The water supply infrastructure is also under increased pressure as a result of climate change. Decreasing rainfall and the expected decline in the quality of aquifers through salinization, sewage and chemical spillage, in combination with continuously increasing demand is creating a situation where water shortages become most precarious[xlviii]. Already now, small islands rely on imports of fresh water to meet their water needs during periods of low rainfall – at considerable costs. Desalination is similarly a costly means of water provision.

Water supply is already an issue for many Greek islands. For example, water reservoirs on **Greek islands** were at their lowest level in July 2008 with imports of water resources via tankers costing €11 million that year, a 10 per cent increase over the amount of water imported in 2007.[xlix] Water supply problems in tourist resorts are increasingly common and are expected to increase further as temperatures increase and the summer period lengthens. For example, the Aegean islands have more than 15 million overnight stays per year and on some islands the population over the summer period is 30 times greater. This leads to increased demands for water which are met through importation of water from the

[7] http://shimajournal.org/issues/v5n2/h.%20Lamy-Giner%20v5n2%2086-105.pdf
[8] Direção Regional de Estatística da Madeira

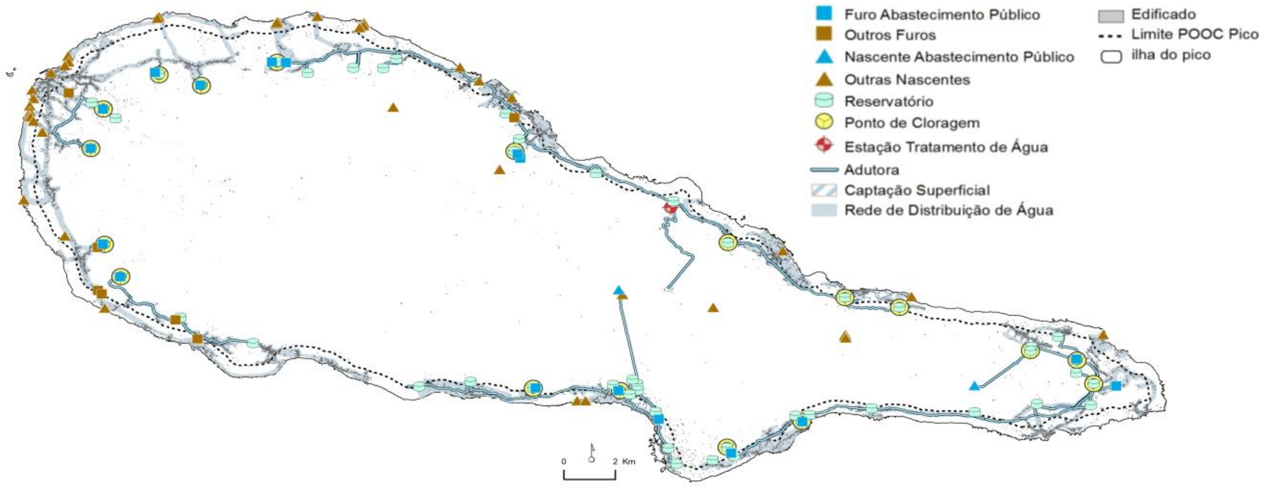
mainland by tankers and through desalination.[l] The cumulative cost of climate change for drinking water supply has been estimated for the period 2041-2050 to be 0.89 per cent under the A1B IPCC scenario and 1.32 per cent of GDP under the A2 IPCC scenario. For the period 2091-2100 could increase to as much as 1.84 per cent of GDP, ie €4.28 billion.[li] Kouroulis et al (2013) assessing a range of climate scenarios and their implications for water availability for the island of Crete for the period 2000-2050 point to a significant water insufficiency. Depending on the scenario the estimated deficit ranges from 10% to 74%. If it is assumed that all climate scenarios considered for this study are equally probable, 'average water availability is expected to drop from 93% during 2000–2050 to a devastating 70% of the observed average […], which is already insufficient to cover current demand'[lii].

The already experienced and expected further increase in pressure on the water supply system has also ramification for the agriculture sector. On the island of Crete, the increasing salinity of groundwater reserves has implications for crop cultivation, especially along the coast[liii] (see section 3.1.2). Water resource loss is expected to lead to a 1.69 per cent decline in GDP for Greece in a high-impact climate change scenario[liv].

Effects of climate change are expected to have an important impact on the water supply infrastructure in **Madeira** where precipitation is expected to decrease significantly. Firstly, flooding is a frequent phenomenon due to the steep slopes in Madeira's territory and small watersheds. Highest concentration of population is near river shores, increasing their vulnerability to "flash flooding". Secondly, there may be a water quality issue for irrigation. "Levadas" are man-made channels, with an extension of around 1400km, which transport water from high (where fountains collect the water) to lower altitudes (below 600m) where the agricultural land is concentrated, thanks to the steep slopes that keep the water running. The purpose is to be able to bring water from locations with water surplus to places where water needs are higher.[lv] Decrease in precipitation may endanger this system and water pumping to these channels may become very if not costly. Furthermore, the sea level rise may increase the risk of sea water intrusion in watersheds and available drinkable water may decrease by 30 per cent until 2050 and up to 50 per cent until 2100.[lvi]

For the **island of Pico, in Azores**, an assessment of the potential impacts of climate change was carried out. Sea level rise that increases the probability of flooding and causes material damage has already motivated the reinforcement of slopes ("taludes") at the coast to prevent infrastructure damage. The number of extreme weather events (droughts, heavy precipitation and intrusion by the sea) are likely to grow, putting at risk the quality of life of the island's population mostly living nearby the coast.[lvii] Figure 5 illustrates the extent to which the coastal water distribution network (grey lines) and other freshwater sources in the coastal area under at risk as a result of sea level and weather extremes. The island of Pico has already problems with contamination of underground water by saltwater sources, putting at risk freshwater quality for human consumption.[lviii]

Figure 5: Water distribution network in the island of Pico for the coastal area



Source: Costa, S., Melo, C. (2011): plano de ordenamento da orla costeira da Ilha do Pico, Volume 6, Avaliação ambiental estratégica, Relatório ambiental

Saltwater intrusion is an important threat for most islands. It was already observed in the low-lying plains of Reunion Island's Western Coast[9], and the forecasted increase in sea level will further accelerate this process in certain cultivated areas, potentially leading to the contamination of soil, landward groundwater and drinking water sources. Reduced precipitations regime will have negative effects on crop yields, especially for species less tolerant to saline conditions.

Coastal erosion and land loss is likely to affect all infrastructure components. For the Hersonissos region on Crete alone the identified threats as a result of sea level rise mean that 470 ha and 520 ha for 50cm and 100cm of sea level respectively could disappear.[lix] This is however only one point in case. It has been estimated that sea level rise will flood 15 per cent of the total area of coastal wetlands in Greece.[lx] This is a particular problem for Greece as around 85 per cent of the population resides within 50km of the coastline.[lxi]

The estimated total long-term financial loss due to a sea level rise of both 0.5m and 1m on different land uses in the Greek coastal zone is huge until 2100. The total discounted costs as a result of sea level rise have been calculated to be equal to 2 per cent of the Greek GDP (in 2010 prices).[lxii] Under the IPCC's A2 scenario Greece may lose 3.5 per cent of the country's total land surface.[lxiii] By adopting appropriate adaptation measures land loss could be reduced to 0.5 per cent, while the expenditure on coastal protection would be equivalent to 0.02 per cent of Greek GDP. Greek authorities' project that 0.5m SLR by 2100 will flood 15 per cent of the current total area of coastal wetlands in Greece with estimated economic losses exceeding €350 million.[lxiv]

Replacement costs for buildings and other infrastructure due to sea level rise in the Caribbean region could be between US$960 million (€708 million) to US$6.1 billion (€4.5

[9] ONERC (2012) and SRCAE (2012)

billion) on an annual basis.[lxv] Table 7 below illustrates the predicted value of the land loss in the Netherlands Antilles due to rising sea levels:

Table 7: Predicted value of land loss in the Netherlands Antilles due to sea level rise

Country	*A2 Scenario*	*B2 Scenario*
Curaçao		
Total Land Area (km^2)	444	444
Land Loss (km^2)	8.8	4.4
Value of Land Loss (US$ million)	616	308
Bonaire		
Total Land Area (km^2)	294	294
Land Loss (km^2)	5.8	2.9
Value of Land Loss (US$ million)	406	203
St. Maarten		
Total Land Area (km^2)	34	34
Land Loss (km^2)	0.68	0.34
Value of Land Loss (US$ million)	47.6	23.8
St. Eustatius		
Total Land Area (km^2)	21	21
Land Loss (km^2)	0.42	0.21
Value of Land Loss (US$ million)	29.4	14.7
Saba		
Total Land Area (km^2)	13	13
Land Loss (km^2)	0.26	0.13
Value of Land Loss (US$ million)	18.2	9.1

Source: ECLAC pp. 15, 2010b

Hurricane events are often associated with coastal flooding, which impacts on capital investment assets and infrastructural facilities. The estimated damage and losses incurred by hurricanes in the Netherlands Antilles over the period 1950 to 2008 are considerable and summarised in Table 8.

Table 8: The economic impacts of the most important hurricanes in the Netherlands Antilles (1950-2008)

Hurricane(Year)	**Damage bill**	**Damages**
Hugo (1989)	US$ 10 million (€7.4 million)	Extensive environmental and physical damages, the islands of St. Eustatius and Saba remained nearly bare of all vegetation. Considerable material damage, including buildings, energy networks and infrastructure, harbour facilities.
Luis (1995)	US$1 billion (€0.74 billion) (direct and indirect costs)	Devastated 90% of all construction, transport and communication networks were disrupted, major damage was caused to the coast and coastal installations
Georges (1998)	US$70 - 80 million (€52 – 59 million)	Buildings, energy and communication infrastructure were severely damaged.
José (1999)	7.5 - 8.5 million US$ (€5.5 – 6.3 million)	The hurricane was associated with a heavy rainfall, which triggered a severe flooding in the low-lying areas of the island and caused extensive material damage.
Lenny (1999)	n.a.	Hurricane associated with mud slides and severe flooding, as well as swells that caused severe beach erosion and coastal damage to port facilities.

Omar (2008)	n.a.	Severe coastal flooding devastated coastal facilities, buildings and infrastructure. The storm surge hit strongly Saint Nevis largest tourism resort, hurting the island's economy and employment rate[10].

Source: Own compilation based mainly on MDNA&A (2010)[lxvi] and source cited in the text

3.1.2 Agriculture

Agriculture is of importance for many islands either for subsistence agriculture to minimise the island's dependence on often costly good imports or for exporting agriculture products. Subsistence agriculture provides food security locally, while cash crops such as sugarcane and bananas are exported[lxvii].

The impacts of climate change on the agriculture sector will vary across different islands depending on their location and the occurrence of particular climate related impacts. In mid- to high-latitude regions higher temperatures and elevated CO_2 concentrations will slightly increase crop yield in the short-term, however in the long-term further warming is projected to cause an increasingly negative effect. In dry and low-latitude areas even a slight warming will result in decreased crop production. More frequent extreme weather events, including heat waves, droughts and flooding, will reduce crop production and pose a threat to livestock productivity. Heat waves are projected to decrease crop yields due to heat stress and more frequent wildfires. Droughts will result in land degradation, increased risk of livestock deaths and wildfires, while heavy precipitation events are expected to cause soil erosion and damage crops. Increased weather extremes might also promote plant disease and pest outbreaks. In addition, warmer temperatures will affect the spread of animal diseases. In addition, sea level rise is projected to impact low-lying coastal agricultural areas and cause salinization of irrigation water and freshwater systems[lxviii].

The ability to produce specific cash crops on islands will be affected and will result in an increased dependence on food imports. The increase in the frequency of extreme weather events will affect the stability of food supplies and access to food. In addition, climate change impacts on ecosystem services will have significant negative consequences on subsistence agriculture on small islands[lxix].

The case studies show how the agricultural sector of islands has already been negatively affected. **Greece** has seen its annual production of olive oil decline by half since 2001. Climate change is thought to be an important factor contributing to this decline as a result of higher temperatures drought and related water scarcity[lxx]. The production of olive oil may not be possible in certain areas in the future or cultivation techniques will need to change (e.g. shifting farms to higher altitudes, changing planting patterns etc.)[lxxi]. Unfavourable weather conditions in summer 2013 affected the production of olive oil on **Crete** causing a decrease of up to 70 per cent. A combination of warm southern winds and increased temperatures over extended periods caused the olives to dehydrate and fall prematurely. The Cretan Association of Olive Oil Producers (SEDIK) estimated income losses of €150-200 million. SEDIK is currently seeking some form of support / assistance from the Greek

[10] http://www.imf.org/external/pubs/ft/scr/2009/cr09180.pdf

Government and the EU[lxxii]. The loss of agricultural land between 2040 and 2050 is predicted to reach a worrying 19 per cent on Greek islands[lxxiii].

For **Crete** it is expected that the combination of higher temperatures and reduced rainfall will seriously impact cultivated crops due to higher evapotranspiration losses and water scarcity[lxxiv]. Iraklion on Crete is considered to be one of the most important agriculture areas in the country, employing close to 80,000 workers.[lxxv] As a result of the climate trends for Greek islands (and the Mediterranean region as a whole) the length of the dry season (where precipitation is less than 1mm per day) is expected to increase to around 10 days in southern part of Iraklion in Crete and by 15-20 days in the northern part of Iraklion.[lxxvi] At the same time, water demand for agriculture is projected to continue, thus increasing competition between different water users.[lxxvii]

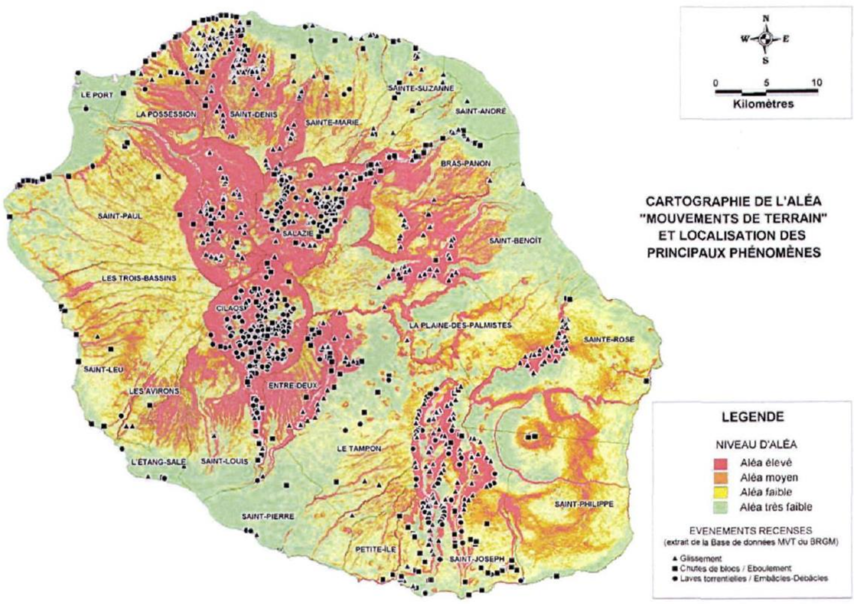
While the adoption of specific crop management techniques may help to reduce some of the negative effects on agricultural production, such options could require up to 40 per cent more water for irrigation which may not be available given expected pressures on water resources in the region[lxxviii]. While increasing the efficiency of irrigation in the agriculture sector can help to reduce water withdrawals, it will not be sufficient to compensate for expected climate change impacts on water stress in the Mediterranean region.[lxxix]

At the **Azores** animal farming is an important sector, especially for dairy production that accounts for a third of Portugal's production. If water supply is compromised due to lower average precipitation and lands become drier and eroded due to extreme temperatures and heavy rainfall, the area available for grazing will decrease and the dairy production may be negatively impacted, affecting Azores' trade balance.

Climate change is expected to have significant impacts in **Madeira**'s agriculture sector, both positive and negative. The main products of the island are banana, wine and potato but the island's topography is not ideally suited for agriculture, as it is composed of big slopes and the installation of greenhouses difficult.[lxxx] As the average temperature increases, it approaches the optimal value for the production of these products and most likely it will cause an increase in productivity and potential production area of the banana and potato, with uncertain effects in the wine production. However, with a decrease in water availability and expansion of production, water stress in agriculture is likely to increase, especially in the Southern area and in high altitudes, possibly requiring an increase in agriculture imports. [lxxxi] As far as fishing is concerned, the change in patterns of sea currents may change the traditional routes of pelagic fish (between 0-200 m), namely tuna (*Thunnus sp*), that accounts for 40% of the catch in Madeira, and may also change the recruitment of young black scabbard fish (*Aphanopus carbo*) (between 600-1200m), that supposedly migrates from the north Atlantic, also accounting for 40% of the annual catch in Madeira. A temperature increase of coastal waters will shorten the reproduction period of temperate water fish species, decreasing the natural recruitment of young fish, resulting in a decrease of exploitable stock of several fish of temperate waters for commercial purposes.

Experience from **Reunion Island** shows how an island's topography, changes in land-use and expected climate change may negatively affect the agriculture sector. Reunion Island's mountainous topography is characterised by rivers and streams that form an East-West longitudinal pattern. Landslides and erosion risks are high in some areas along the rivers, on escarpments and ravines, where the soil is sensitive to intense rainfalls and water exposure, conditions under which landslides occur. As illustrated in Figure 6 below, the regions most prone to natural disasters are situated on the Northern and North-Eastern Coast, where precipitations increased significantly over the last decades.

Figure 6: Map of landslides Reunion Island and their degree of risk



Source: Bastone and La Torre, 2011[lxxxii]

In the rugged landscapes of ravines or river banks, healthy tropical forests are crucial in maintaining ecosystems regulating services such as the stability of soils and land cover, as well as preventing natural disasters[lxxxiii]. On Reunion Island, the loss of soil from agricultural land on slopes was already signalled in 1993 by Perret, who estimated that **around 20 t of soil matter per hectare and per year was washed away after heavy rainfalls**. This phenomenon is even more accentuated on the Western coast of Reunion Island, where the use of tree fallows was abandoned to make space for agricultural cultivations, thus discouraging erosion control and macrofauna restoration[lxxxiv]. Sub-regional climatic changes, including the greater rainfalls in the Northern and North Eastern coastal areas, further impaired fragile and unstable soils, impacting agricultural production. In the past 50 years, the **increased number of droughts** in the Western and South-Western coastal zones harmed crops and caused a **decline in yields**; however, although no studies were performed on the economic impacts of climatic changes on agricultural production, it is clear that the incomes of farmers continue to be unstable because of natural calamities.

Another example is **Martinique** where in 2003 a serious drought resulted in a fall of banana production by 24%. Yields in 2003 were 15 tonne per hectare lower than in 2002 (59 t/ha in 2003 compared to 74 t/ha in

Tropical islands cyclones and hurricanes have already caused serious damage and future projections show that a warmer climate will increase the peak wind speed and the mean and peak intensity of such cyclones[lxxxv]. Examples of the most devastating tropical cyclones and hurricanes in recent years, which had serious impacts on the agricultural production of islands, are shown in Table 9.

Table 9: Examples of impacts of extreme weather events on the agricultural sector

Location	Name of cyclone/hurricane	Year	Impacts on agriculture
Guadeloupe	Cyclones Tomas and Earl	2010	The cyclone in combination with a serious drought and the eruption of Montserrat resulted in reduced banana and melon production. Banana yields were 23.5 per cent lower than in 2009 (29,000 tons of damage). 1824 tons of melon were lost, which was a 40 per cent decline in exports[lxxxvi].
Martinique	Cyclone Tomas and Iris	2010	The cyclone caused losses in the production of sugar cane, banana, fruits and vegetables[lxxxvii].
Martinique	Cyclones Omar and Emily	2011	The cyclone resulted in significant soil loss with negative consequences for the agricultural sector.
Martinique and Guadeloupe	Hurricane Dean	2007	The banana plantations of Martinique and Guadeloupe were completely destroyed, which resulted in 115 million euros in economic losses[lxxxviii]. In addition, 30 per cent of planted areas of sugar cane, vegetables and horticulture were damaged[lxxxix].
French Polynesia	Hurricane Oli	2010	The hurricane resulted in serious economic damage in the agricultural sector as many fields were drenched in the sea water[xc].

Source: own compilation based on literature reviewed

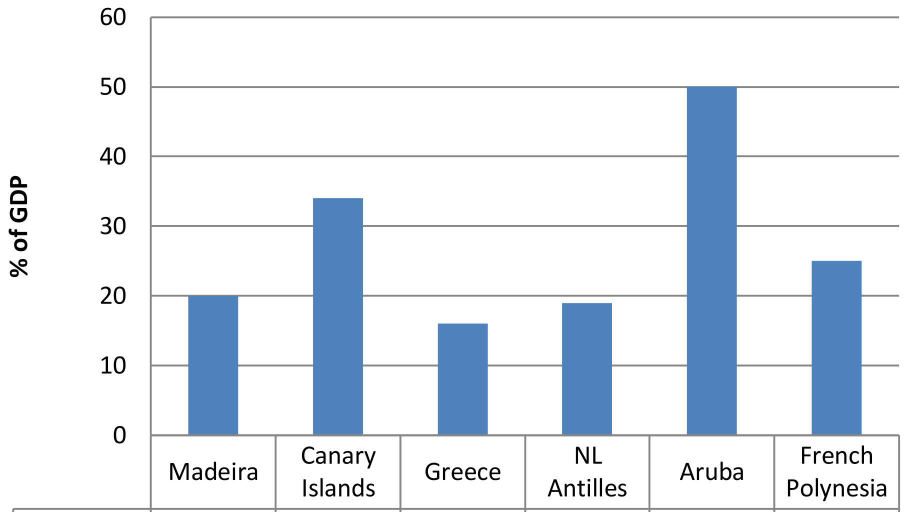
Climate change impacts on diseases and parasites will have also a significantly negative impact. For example in the **Caribbean islands** due to intensive monoculture cultivation, banana production is already constrained by two parasites which threaten the root system of the plantations. The impact of these parasites on bananas is expected to worsen as a result of climate change[xci].

Rising sea levels will also have negative impacts on coastal agriculture through inundation and soil salinization[xcii]. For instance, in **Wallis and Futuna** sea level rise is likely to have significant impacts on taro, a starch-rich root plant. This plant plays an important role in subsistence agriculture and is usually grown on flood plains next to coastal banks. In recent years, farmers have noticed that due to an incursion of sea water to their fields saline infiltration has increased. This can seriously damage crops as high levels of salinity can completely destroy taro cultivations[xciii].

3.1.3 Tourism

Tourism is a key economic sector in many European islands and a significant contributor to GDP and employment. Figure 7 shows that tourism contributes 20 per cent to Madeira's GDP, 34 per cent to the Canary Islands' GDP and as much as 50 per cent in the case of Aruba which is part of the Netherlands Antilles. In Greece the tourism sector provides around 20 per cent of total employment which is likely to be much higher in some of the Greek islands.

Figure 7: Contribution of the tourism sector to GDP



	Madeira	Canary Islands	Greece	NL Antilles	Aruba	French Polynesia
% of GDP	20	34	16	19	50	25

Source: case studies (see Annex II to this report). Note: The data for Greece covers Greece as a whole. Greek islands make up 40% of the total share.

Climate change is expected to have both direct (e.g. temperature, hours of sunshine, humidity, duration of the tourist season, operating expenses) and indirect impacts (e.g. impacts on biodiversity, sea temperature, types of activities) on the tourism sector in many islands[xciv]. Climate change can adversely affect the tourism industry through *inter alia*: changes in temperature and rainfall; rising sea levels, inundation and flooding which lead to a loss of coastal amenities and beach erosion; extreme weather events which cause damage or disruption to tourist facilities and infrastructure; water shortages; and an increased incidence of vector-borne diseases. The latter may negatively affect the perceived level of security of a tourist destination and result in lower number of visitors. Moreover, the attractiveness of many islands to tourists is closely linked to its natural resources (beaches, coral reefs, forests, etc.), thus climate change impacts on biodiversity and the marine environment will have an effect on tourist demand. For example, increases in sea water temperatures can contribute to coral bleaching which have an impact on sea-related tourist activities such as diving. Climate plays an important role in determining the length of tourism seasons, as well as their quality.[xcv]

These impacts are expected to influence tourists' destination choices (e.g. reducing demand for worst affected islands, reduced demand for diving holidays) and require additional investments (e.g. for the replacement of damaged facilities and infrastructures), thus implying significant economic costs for the sector.

The tourism sector in the **Mediterranean region** is expected to face less favourable conditions in summer given predicted increases in temperature. For example, the results of the CIRCE project ('Climate Change and Impact Research: the Mediterranean Environment') suggest that expected climate change will decrease tourism flows from the north of Europe to the south and increase flows within the north of Europe.[xcvi] These impacts are likely to become increasingly important in the long-term. An increasing number of 'hot days' and 'tropical nights' are likely to result in increasing discomfort among tourists and affect their choice of tourist destination in mid-summer.

The number of so-called ‘hot days’ with temperatures above 35^{o}C is expected to increase more significantly in certain areas, for example, **Iraklion on Crete** is expected to see a 10-15 day increase, Rhodes is expected to have smaller increases of around 10 days.[xcvii] At the same time the number of ‘tropical nights’ with temperatures above 20^{o}C is also expected to increase across Greece with island sites affected even more than continental areas. For example, Rhodos and the city of Chania on Crete are expected to experience a sum of 40 additional tropical nights in the future.[xcviii] High temperatures coupled with increased humidity levels near the sea will add to the discomfort of tourists and may serve to discourage visitors, particularly during certain periods. Together with the increase in hot days and tropical nights, the higher humidity will add to discomfort of tourists an may serve to deter potential visitors to the islands[xcix]. At the same time, more than 30 additional summer days are expected in coastal areas of Crete (Chania and Rethymno). This could lead to an extension in the tourism season by as much as one month per year in these areas with a ‘lengthening and a flattening’ of the Greek tourism season expected by 2030.[c] Such a longer tourism season will help to spread demand (for energy, water etc.) more evenly and thus alleviate pressures on summer water supply and energy demand.[ci]

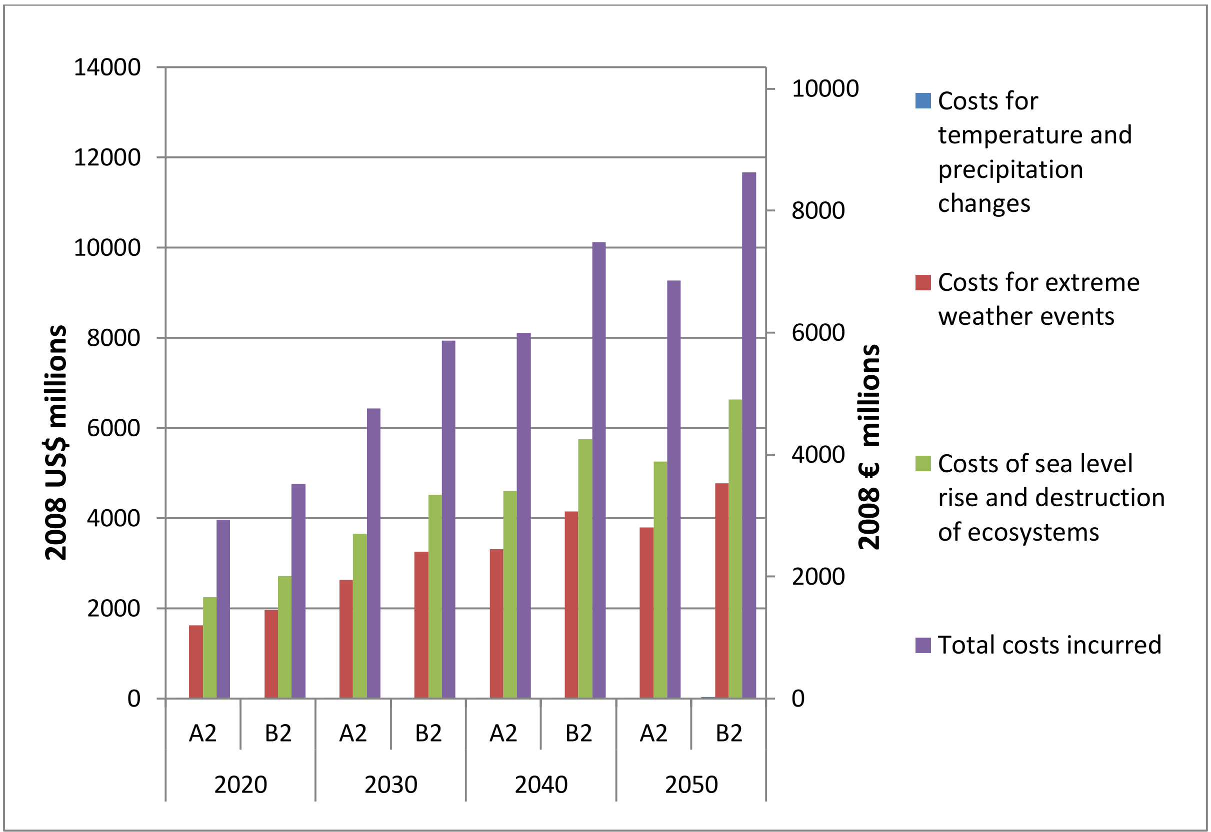
Natural disasters affect the tourists’ perception of security and negatively affected the image of a region and ultimately deter tourists from visiting the region. Such disasters include forest fires, heavy rainfalls and storms. Forest fires in **Greece** in August 2007 were the worst for several decades and demonstrated the country’s vulnerability to fire as a result of its dry climate.[cii] Extensive forest fires can result in a considerable shortfall in tourist receipts.[ciii] After heavy rainfalls and flooding in **Madeira** in February 2010 (see 3.1.1) tourist numbers decreased by 10.1 per cent resulting in a fall of 14 per cent in revenues. This had significant impacts on the population employed by sectors related to tourism. There was a 7 per cent increase in unemployment in tourist relevant sectors in 2010 alone.[civ,cv]

Tourist destinations such as **Madeira** where tourism is strongly motivated by landscape, security and health conditions are likely to be strongly affected by indirect climate impacts. Besides the damage to the physical infrastructure climate change has already increased the probability of spreading of epidemics. The presence of the mosquito *Aedes aegypti,* which was first reported in 2004 and explained by higher temperatures, could seriously damage the tourist sector. The mosquito is a vector species of dengue fever and yellow fever. Although the mosquito’s population is not yet infected with viruses, there is a significant risk that this will happen in the future.[cvi] Diseases spreading, thermal comfort of tourists and natural disasters impact the feeling of security of tourists.[cvii]

The interdependence between tourism and biodiversity has been very well examined for the **Netherlands Antilles**.[cviii] Many visitors come to the Netherlands Antilles specifically for the diving and coral reef-watching experience[cix], as a result of which negative climate change impacts on biodiversity will also affect the tourism sector. A study on the costs of climate change in the Netherlands Antilles estimated future costs to be as high as US$4 billion (€3 billion) already in 2020 and to increase to between US$9.2 and 11.7 billion (€6.8 – 8.7 billion) in 2050[cx]. The study quantified the costs of changes in temperature and precipitation but also extreme events (frequency and intensity), sea level rise and the destruction of ecosystems (particularly coral reef loss) due to ocean acidification (see above) on the basis of two climate scenarios, the International Panel on Climate Change’s A2 and

B2 scenarios (see section 2). The cost of extreme weather events are assessed in terms of the potential damage to the tourism industry. The cost of sea level rise is examined with respect to loss of beach and tourism infrastructure along the coast and combined with the costs of coral reef loss due to rising sea levels and ocean temperatures.[11] The highest costs are related to sea level rise and the destruction of ecosystem (see Figure 8**Error! Reference source not found.**).

Figure 8: Costs of Climate Change to the tourism sector in the Netherlands Antilles (2008 US$ millions)



Source: Own compilation based on ECLAC, 2010b. Note: Total costs incurred a reported from the referenced report and do not reflect the sum of the individual costs reported in the table.

Climate change is also expected to significantly increase the cost of insurance for the tourism industry. For example, because of sea level rise, extreme weather events, and other consequences of climate change, the Association of British Insurers predicts that insurance premiums will rise in the **Caribbean** between 20 and 80 per cent by the middle of the century with private sector insurance possibly becoming an ineffective option due to high costs.[cxi] In some cases insurance company may not be willing to cover certain climate risks which may lead to additional costs for local governments. For instance, in Curacao cases have been reported where damage costs to hotels located close to the coast as result of

[11] The latter is calculated on the assumption that tourists spend around 30 per cent of their total expenditure on sea related activities and that this expenditure will not occur anymore as a result of sea level rise, loss of beach and coastal tourism infrastructure a well as coral reef destruction (ECLAC, 2010b).

flooding that were not covered by insurance companies were partially borne by the government.[12]

3.1.4 *Biodiversity*

Both land-based and marine biodiversity of islands will be affected by climate change. According to the Millennium Ecosystem Assessment[cxii] climate change is the second greatest threat to biodiversity, changing species through:

- Shifting habitats,
- Changing life cycles, and
- The development of new physical traits.

The principal effects of climate change will likely include further losses to coral reef systems, erosion of coast and beaches, salinization of ground water sources, losses in hilltop vegetation and flora, soil humus losses and erosion, increases in various disease vectors, changes in ocean currents, fishing and migration and a stronger foothold for invasive species.

The impacts of climate change on the biodiversity of islands are a particular concern. Islands and their surrounding near-shore marine areas constitute of unique ecosystems often comprising many plant and animal species that are endemic (found nowhere else on Earth)[cxiii]. While islands cover only 5 per cent of global land area, they host 20 per cent of the world's vascular plant species and 15 per cent of all mammal, bird and amphibian species.[cxiv] The EU's outermost regions and overseas countries and territories host more endemic species than the entire European continent.[cxv] For example, both UK offshore islands and French islands host important numbers of seabird species.[cxvi] Moreover, islands are characterised by a high share of coastal lines with important coastal habitats – 70 per cent of Europe's biodiversity is located on islands which include 43 Ramsar sites and 8 World Heritage sites. The French overseas *collectivités* are home to 80 per cent of French biodiversity and over 98 per cent of the vertebrate fauna and 96 per cent of the vascular plants specific to France.[cxvii] Moreover there are five global biodiversity hotspots on European islands. For example, New Caledonia alone hosts a number of endemic species that is comparable to the entire European continent.[cxviii] Islands with high biodiversity, including most of the EU's overseas entities, are also exceptionally vulnerable to the threat of invasive alien species, which can have a disproportionate impact on local livelihoods, culture and economic opportunities.[cxix]

Over the past century, island biodiversity has been subject to intense pressure from invasive alien species, habitat change, over-exploitation, and, increasingly, from climate change and variability, natural and environmental disasters, land degradation and pollution. Biodiversity can be particularly vulnerable on small and fragile islands. While ecosystems have always adapted to change, climate induced changes at an unprecedented rate pose a particular challenge to islands' ecosystems. At the same time islands' unique biodiversity is often the fundamental basis for key economic sectors such as agriculture and tourism, thus climate

[12] Personal communication

change impacts on biodiversity have a direct or indirect impact on a number of economic sectors.

The uniqueness of many island species' also adds to their vulnerability - of the 724 recorded animal extinctions in the last 400 years, about half were island species. Species that have evolved on islands have done so free from competition from large numbers of other species and are, therefore, susceptible to invasions by alien species. Populations of island fauna and flora tend to be naturally small, and species often become concentrated in specific small areas, where they are subject to various natural and anthropogenic pressures that endanger their survival. In addition, they are often highly specialised[cxx].

Marine biodiversity is a critical feature of many small islands. The types of impacts will vary according to the island climate zones and the ecosystems present. Tropical islands will suffer from coral bleaching (associated with ocean temperature rise and acidification) and the loss of mangrove and seagrass habitats (due to saltwater intrusion and warmer water) - both ecosystems serve as critical nursery habitats for commercially important fish (see below).[cxxi] Polar islands are less thoroughly studied in terms of ocean acidification, but recent research indicates that cold water corals are also at risk from ocean acidification.[cxxii] Additionally, polar islands could see reductions in fish, seabirds, and other marine animals due to habitat loss, or the introduction of invasive alien species that previously found the water temperatures uninhabitable.[cxxiii]

Climate warming will exacerbate the expansion of biological invasions, as temperature increases will most likely lead to the migration of some species towards higher altitudes. This will entail a reconfiguration of mountainous habitats, which will seriously affect the equilibrium of ecosystems and the health of native and indigenous species. Also, the increase in the frequency and intensity of extreme weather events such as heavy marine swells and prolonged droughts (leading to forest fire incidents) will pave the way for exotic species invasion in disturbed habitats or habitats with a weakened resilience[cxxiv]. Climate change is deemed to favour the accelerated spread of opportunistic and alien species, but the degree of such influence is still not clear and, in this respect, a better understanding of the biological limits of the species populations would be necessary.

For instance, mangroves serve as a critical nursery habitat for many commercially viable fish species, in addition to protecting shorelines from extreme weather events and erosion.[cxxv] Climate change is expected to affect these habitats through sea level rise and flooding, elevated sea surface temperatures, and ocean acidification.[cxxvi] Melanesia, where **New Caledonia** is located, is expected to bear the brunt of mangrove loss in the Pacific due to sea level rise: while the entire loss of mangroves in the Pacific is expected to reach about 13 per cent, 83 per cent of that amount will be lost in Melanesia alone.[cxxvii]

Sea level rise also poses a threat to marine organisms such as sea turtles. The six species of sea turtles that nest in the Caribbean are all listed as endangered or critically endangered by CITES, due to both habitat loss and capture by fishermen.[cxxviii] Climate change is another factor placing turtles at risk, in part because of the habitat loss associated with sea level rise, as well as coastal development and seawall construction.[cxxix] A 2005 report by Fish et al calculated the potential lost nesting area in **Bonaire** to be between 23 and 52 per cent depending on the predicted sea level rise.[cxxx]

Among **Macaronesian islands** (e.g. Azores, Madeira) biodiversity loss is a significant challenge due to the inversion of the trade wind that could affect the relict Laurel forest. Whereas some Arctic islands will benefit from milder conditions and a longer growing season with the opportunity to grow new crops, although marine species are affected by changing temperatures and an increased frequency of severe storms as well as coastal erosion constitutes a threat to local communities and in particular the fisheries industry on these islands.

Together with the Canary Islands, **Madeira** is a major hotspot of biodiversity of the Mediterranean area and of the world. Due to the increase in the average temperature, *Laurissilva (Teucrium abutiloides*), timber oriented forests and invasive alien species may expand in altitude and will occupy the areas currently occupied by other fauna and flora species that may become endangered, such as the *Urzais* (*Erica maderensis*) or the *Freira da Madeira* (*Pterodroma madeira*).[cxxxi] A decrease in precipitation may threaten Madeira's natural ecosystems, namely a large area of protected humid forest, and the small rivers and ground water systems that depend greatly of the precipitation captured in high grounds.[cxxxii]

The consequences of changes in temperature and precipitation were experienced in the **Canary Islands** (Lanzarote) in 2004 when 100 Million Pilgrim Crickets (Desert Locusts) landed on the coast. These crickets need high temperatures and strong droughts to expand their lifetime and heavy rains for massive reproduction. In 2004, West Africa and the Canary Islands met these climate requirements and the crickets were brought to the coast of the Canary Islands due to the south-eastern winds. The crickets devoured around 1% of crop land and a significant amount of pesticides were used against them, causing damage to endemic species. Although these plagues are rare, climate change can increase their frequency.

The consequences of climate change on marine and terrestrial biodiversity are even more pertinent for **New Caledonia and French Polynesia**. Between January and March 1996, following unusually warm water temperatures, the corals of New Caledonia suffered a bleaching episode. Around Nouméa, the rate of coral mortality was as high as 80 per cent, reaching as high as 90 per cent on some shallow reefs (Richer de Forges and Garrigue, 1997). However, the affected areas were very limited in size. The coral reefs were also damaged by the tropical storms. The hurricane Erica in 2003 had a significant impact on the reef formations and the fish populations in the park. The fragile coral formations diminished significantly, resulting in a loss of habitat for the fish populations. The wealth of commercially-exploited fish and butterfly fish was seriously affected. Twenty months after the hurricane, the reefs had not regenerated; the broken corals had turned into debris and were being colonized by algae. The corals of New Caledonia are not adapted to tropical storms of such intensity; the immediate impacts of these events on the reefs are very serious and profoundly degrade the reefs in the short and medium term. Intensification of tropical storms in the region, as predicted by the IPCC, could irreversibly modify the coral formations and the species' composition of New Caledonia (Wantiez, 2005).

The degradation of the corals as a result of bleaching and storm damage could also destroy the physical barrier which shelters Atolls from heavy ocean swell. Atolls are among the most complex and fascinating geological structures of the planet. These ring-shaped tropical islands, which sometimes exceed 10 kilometres in diameter, enclose a lagoon in their centre and are home to an exceptional diversity of marine life. It takes 30 million years for an atoll to form. Atolls are made of coral; if the latter disappear, these islands too will vanish. Furthermore, rising sea levels are likely to accelerate the deterioration of these islands. Atolls never rise more than 2 or 3 metres above sea level. They are therefore particularly vulnerable to both temporary and permanent changes in sea level. If the rise is gradual, healthy corals could continue to grow and possibly follow the water level, but degraded corals would be incapable of doing so.

4 IMPLICATIONS FOR SECURITY, TRADE & MIGRATION

After having assessed the main consequences of climate change impacts on key areas and sectors in the previous chapter, this chapter will draw together the most important implications for security, trade and migration.

4.1.1 Trade

The impacts of climate change on key economic sectors such as infrastructure, tourism, agriculture and biodiversity will ultimately affect trade between the islands and the EU mainland and other trading partners. Due to lack of statistical data it is not possible to provide insights on the trade of specific products and quantify trade implications.

The damage to infrastructure as a result of weather extremes, sea level rise or flooding will affect trade in several ways. A functioning transport infrastructure is the pre-condition for trade of products and services from and to an island. Since important nodes of the transport infrastructure including ports and airports are usually located in the coastal areas, climate change impacts pose a significant risk and require particular attention to prevent major disruption to the transport system. Damage costs of single events can be huge with important impacts on economic activities. **Madeira's flooding in February 2010 alone resulted in damage costs of €237.6 million for roads and €129.6 million for ports and coastal infrastructure.** At the same time the repair works may require significant imports of goods and materials.

Climate change will add up to the socio-economic factors that underpin agricultural trade, by determining food crop yield variations, price shifts and alteration of comparative advantage of products. For example, Reunion Island's domestic vegetable and fruit production, which is currently estimated to cover more than 70% of the island's demand, is particularly vulnerable to parasites and diseases which are expected to increase also due to climate change[cxxxiii]. The sugarcane cultivation, which occupies the largest portion of the total agricultural surface, is also a sensitive crop to climatic change impacts such as warmer temperatures and decreased precipitation. Under these conditions, sugarcane production is deemed to be particularly vulnerable, especially in the non-irrigated agricultural areas, and a reduction in yields would impact on domestic economy and trade, putting under risk the jobs of dozens of thousands of Reunionese employees[cxxxiv]. As such, the effects of climate change on agricultural production will result in a reduced contribution to the island's gross added value (currently around 2 per cent) and in turn require more imports of food produce (eg fresh fruit and vegetable) in order to respond to the needs to a growing population. At the same time, a lower agricultural production will result in substantially decreased rates of exports including exotic fruits and increased burden on foreign exchange revenues.

Agriculture is "highly sensitive" to long-term changes like mean rises in temperature as well as short-term variations from year to year.[cxxxv] The adverse effects of climate change on agriculture including changes to natural conditions for crop cultivation as well as the increased frequency of weather extremes, increase in pest outbreaks and frequency of diseases will impact the ability to trade agricultural products with the EU mainland. For instance, Greece is the world's third largest producer of olive oil (after Spain and Italy) and the world's leading exporter of extra virgin olive oil.[cxxxvi] The majority of olive oil production is centred in three regions: Peloponnese (37%), Crete (30%) and the Ionian Islands (12%)

where the chief olive growing areas are Messinia and Ilia (Peloponnese), Iraklion and Chania (Crete) and Corfu (Ionian Islands). Thus climate change impacts on these islands can be expected to affect the main areas of olive oil production in Greece. As a result of decreased agricultural output, less agricultural products will be exported to the EU mainland and more food will have to be imported.

Climate change is expected to have negative impacts on the fishing industry, as seen for the case of the Canary Islands and Madeira's biodiversity loss, decreasing trade in fishing products and worsening the trade balance. A temperature increase of coastal waters will shorten the reproduction period of temperate water fish species, decreasing the natural recruitment of young fish, resulting in a decrease of exploitable stock of several fish of temperate waters for commercial purposes. In **French Polynesia**, pearl farming, a very delicate process with a high value added, has become one of the main economic resources. **In 2008, pearl cultivation provided over three quarters of Polynesian export revenues (in 2012, this was equivalent to about 6,888 million FCFP (EUR 58 million))[13] and employed about 5000 people** (IEOM, 2008). Climate change could undermine the profitability of this industry through an increased mortality and more frequent damages to material (Quinquis, 2012).

The tourism industry is also expected to be significantly affected by climate change. Warmer summers in northern Europe may encourage northern Europeans to take domestic holidays and thus reduce travel to the Mediterranean, while increasingly frequent and intense heat waves and periods of drought are expected to discourage holidays in the Mediterranean during the summer months.[cxxxvii] The tourist season in the Mediterranean is expected to shift from the summer months to spring and autumn.[cxxxviii] The influence of climate change on local environmental conditions may also deter potential tourists. For example, **following the devastating fires** in the summer of 2000 **in Greece, more than 50 per cent of tourist bookings for 2001 were cancelled**.[cxxxix] **The Caribbean may lose between $715 million (€528 million) and $1,430 million (€1,055 million) annually in tourist expenditure due to rising sea levels**[cxl]. **The loss of Melanesian mangroves is estimated to cost between US$24 million – 470 million (€18 – 347 million) a year by 2100**, "with the upper estimate including ecological services".[cxli]

4.1.2 Security

Climate change will also have various security related impacts on islands, in particular with respect to the following security dimensions:

- **physical security** (e.g. higher exposure to natural hazards, health related impacts).
- **energy security** (e.g. higher demand for energy (for heating or cooling purposes) combined with higher risk exposure of existing infrastructure);
- **water security** (e.g. decreasing access to fresh water as well as increased coastal risks (e.g. flooding, coastline erosion)
- **food security** (e.g. extreme weather patterns reducing crop yields, ocean acidification and warming seas destroying coral reef systems which in turn affect fish stocks)[cxlii]:

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[13] ISPF, 2013

Addressing these security-related impacts will in many cases involve significant costs, in terms of damage/repair costs and adaptation costs. For example, coast lines are particularly prone to being affected by climate change through, for instance, beach erosion and increasingly prevalent tropical storms and cyclones. Residential housing will have to be adapted to accommodate climate change[cxliii]. Highways also tend to run along the shore, and are therefore in danger: bridges need to be elevated to allow for higher water levels, and roads maintenance carried out more often so as to adapt to less stable surfaces and frequent flooding and landslides)[cxliv]. **Damage and potential adaptation costs constitute significant challenges for most islands. The damage costs of the flooding in February 2010 in Madeira were around 20 per cent of Madeira's GDP**.

For example, as many other islands, Reunion's low-lying areas concentrate 82 per cent of the population and have a per capita density that is three to four times bigger as compared to the island average[cxlv]. This constitutes a major security risk in view of projected sea level rise and more frequent extreme weather events. Critical infrastructure, installations and facilities that support local communities will be at severe risk. The capacity to respond to such climatic challenges is limited due to the island's territorial confinement, as well as its limited economic, technical, and social resources[cxlvi]. In addition, the risk of degradation of coral reefs means also that large urban settlement will be exempt from shoreline protection and will get directly exposed to heavy ocean swells, which will cause severe damages to beaches. As such, altering coral communities has further ramifications to human health and well-being, as well as the tourism, fishing and trade industry.

A large majority of the population of **French Polynesia** lives in the narrow coastal strips and urbanisation is particularly concentrated on the limited number of flat areas located along the seashores. A rise in sea levels could therefore have disastrous consequences on these urban settlements and hence on the economy of the territory. A simulation of rising sea levels carried out on the site of Tahiti international airport illustrated their potential impacts. Tahiti airport, like many in French Polynesia, has been built on a coral reef. **A rise of 88 centimetres in the sea's level (the top end of IPCC projections) would result in the complete submersion of the airport** and of part of the **surrounding town of Faaa** where it is situated. In addition to sea level rise the intensification of cyclones could result in concrete risks for such infrastructures and related populations. Increased rainfall in specific periods in the year can increase the risks of landslides and floods, threatening housing that is at risk. Economic impacts could be very serious for the territory. Also in **New Caledonia** a large majority of the inhabitants lives along the coast, in low-lying urban areas that are highly vulnerable to rising sea levels but there is more scope for inland migration.

Although future climate scenarios on the evolution of cyclones on Reunion Island indicate roughly that their number will decrease, they also predict that the intensity of cyclone-associated phenomena will escalate, thus the risks posed on human and economic security would remain present. A series of cyclones with dramatic effects were recorded over the last decades on Reunion Island, such as the Hyacinthe cyclone in 1980, which resulted in the loss of 25 human lives. In the aftermath of the event, a total of 7,500 human displacements took place, and the damage costs reached €85 million, including settlements, roads and infrastructural networks. Nine years later, Firinga, a cyclone of a lower intensity, hit the island and caused the death of 4 people, entailing a damage bill of €25 million. The most recent cyclone, Dina, reported in 2002, destroyed 500 buildings and had an estimated cost of €95 million damages in installations, roads and infrastructural networks, as well as cultural amenities[cxlvii].

More frequent extreme weather events caused climate change may pose serious concerns for food security and the ability to feed the Reunion's rapidly growing population. The projected decrease in annual rainfalls and prolonged drought periods are likely to result in reduced crop yields and livestock production. As a large portion of the available agricultural lands are located in the lowlands and coastal plains, sea level rise entailing land loss, soil erosion and salinisation will put a high pressure on mainland fertile land. Accentuated droughts will increase the risk of forest fires, whereas extreme weather events will disrupt the availability of food crops and compromise agricultural yields, entailing a heavier reliance on imports. Prolonged periods of water scarcity will deteriorate soil fertility and its cover, with direct effects on food security. The migration pattern and the depth of fish stocks distribution and availability of fish stocks will also be impacted by changes in climatic conditions[cxlviii]. Increased sea temperatures and the degradation of coral reefs create conducive conditions for the proliferation of toxic micro-algae and poses a threat to marine ecosystems as well as to human health.

Public health concerns rise with environmental degradation, as extreme weather events, such as heat waves, droughts, and strong storms, cause damages in terms of loss of human lives, health and economic growth. There are also **vector-borne viruses such as malaria and dengue fever which proliferate when dramatic changes in temperature and precipitation patterns occur**[cxlix]. Warmer air temperatures could act as a vehicle for spreading tropical diseases, and an illustrative example in this case is the **chikungunya crisis reported in Reunion between 2005 and 2006. The mosquito-borne infection touched 35% of the population and lead to a dramatic drop in tourist numbers**[cl]. The consequences of the fall in influx of visitors was however not confined to the local economy but affected also global tour operators and international aviation companies[cli]. A warmer climate increases the likelihood of proliferation of such epidemics. In 2004 the dengue disease infected 119 inhabitants[clii].

The feeling of security of tourists is very important to ensure tourism revenues, economic development of these regions and employment of their population. In 2003, an exceptional heat wave increasing temperatures up to 46°C in Lanzarote (Canary Islands) led to the death of 13 people. A rise in temperatures, and other climate change effects, can also facilitate the spread of tropical diseases, especially insect-borne diseases.[cliii] In the case that more extreme weather events occur, and the feeling of security of tourists decreases as illustrated with the Canary Islands example, the tourism sector may be heavily damaged.

Greek islands have experienced increased water shortage in recent years requiring the use of water tankers for maintaining water supply. **Water resource loss is expected to lead to a 1.69 per cent decline in GDP for Greece in a high-impact climate change scenario**[cliv]. Water security is a major issue for the Macaronesia region too, especially concerning the irrigation of agricultural land. Less water availability and greater variability of supply will put current systems of water management at risk. Increase in water stress will impact all sectors of economic activity that are dependent on water as a raw resource, as well as drinkable water sources. **The Netherlands Antilles are already dependent on food and water imports**, only a single digit share of total food consumed on the islands is produced domestically. A key threat to food security is disruptions in the transport system that may hinder imports at certain times. A change in precipitation levels and temperature patterns will affect the availability of the already scarce water resources especially in the low-lying areas islands, ultimately leading to lower freshwater supply. Combined with saline intrusion and reduced groundwater recharge capacity during the summer period droughts and severe water stress are likely to become more frequent and put water security at risk. This would have important consequences for the local economy and constitute a serious concern for health and lead to the proliferation of water-borne diseases.

For the Canary Islands, food security may become an issue, especially in the supply of fish as marine ecosystems change drastically. In the whole region, as water becomes a scarcer resource, agricultural production may be challenged and food security will become an issue.

With climate change in most islands energy demand will increase, mainly due to increased use of air-conditioning, which will put the local energy system under increased stress. Moreover, the disruptions of distribution channels may compromise supply of oil imports. In Madeira, where part of the electricity is generated with hydroelectric power plants, variability of precipitation will affect electricity production, further affecting the energy security for the region.

4.1.3 Migration

A third implication and often the ultimate consequence of climate change impacts is migration[clv] Climate induced migration is strongly linked with environmental migration as a result of drought, soil erosion, desertification, deforestation and other environmental problems, in combination with associated problems of population pressures and profound poverty[clvi]. Myers estimates that as many as **200 million people worldwide could be forced to migrate for environmental reasons if the predicted effects of climate change take hold**.

The predominant reason for environmental migration is economic - land degradation and other factors that could limit agricultural productivity in rural areas will encourage many to seek employment elsewhere[clvii]. Natural disasters will be a key cause for migration. However this kind of migration, also called ‘distress migration’, is often only temporary, with even hard-hit areas having a population retention rate of around 90 per cent (Raleigh, 2008). In general, the return rates of disaster victims are rather high, although little research has been done on this to provide concrete numbers[clviii]. The characteristics of distress migration are quite different within and across countries as they are influenced by the severity and geography of a crisis, the ability of a household to respond, evacuation opportunities, existing and perpetuating vulnerabilities, available relief, and intervening government policies[clix].Due to the specificities of islands, as described above, such as high vulnerability and lower capacity to cope with climate impacts and irreversible damage the return rates can be expected to be lower than average.

Thus while extreme weather events, such as hurricanes and floods, will show patterns of more dramatic, direct migration, this will mostly be temporary and internal affecting island inhabitants who move to higher grounds until their coastal dwellings are rebuilt. Migration for economic reasons, which occurs far more gradually, similarly does not tend to have permanent effects. Many workers will choose to work elsewhere only seasonally, often close-by, but given the small size of islands, at times also necessarily overseas. Instead of migrating elsewhere, poor populations tend to adapt their livelihoods to the possible occurrences of environmental hardship instead[clx]. Only if an island becomes virtually uninhabitable, for example due to sea level rise, but also complete resource depletion, is permanent displacement likely to happen. However, concrete examples of this happening are not (yet) available.

The exact impacts of climate change on migration are hard to quantify: the important decision on whether or not to relocate is based on a complex interplay between many factors, in which environmental concerns may matter to varying degrees. However, there are many key factors of climate change that are predicted to affect human wellbeing on many European islands.

For example, Reunion Island is the only French department Outre Mer (DOM) that registers a positive migratory rate. This amounts to 0.6 inhabitants for 10,000 existent inhabitants. In 2009, a number of 15,000 people immigrated in Reunion Island, representing 1.8 per cent of the total population of the island. Three thirds of the immigrants come from the South-West of the Indian Ocean, mostly from Madagascar, followed by Mauritius and Comores Islands (INSEE, 2009)[14]. Similarly the Netherlands Antilles are attracting immigrants from the Caribbean region, which includes both economic and environmental refugees, the latter for example from Haiti which was badly hit by earthquakes and hurricanes in the past. The special relationship between the Netherlands and Netherlands Antilles still allows for a free exchange between the islanders and Dutch citizens to move overseas. There are currently around a 100,000 immigrants of Antilles origin in the Netherlands - the majority of which are originally from Curacao[clxi]. Because of the ease of migration and the absence of a language barrier, many of these migrants tend to move back and forth. Ultimately a key driver for migration remains the economic situation on the island. If key economic sectors such as agriculture and tourism are negatively affected by climate change and moreover water security cannot be maintained emigration to other islands or mainland Europe is very likely in the future.

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5 CONCLUSIONS

This report shows that **European islands face very concrete risks as a result of a changing climate**. The research to this report covered a wide range of islands, located in different climate zones in the Northern and Southern Hemisphere. It underlines that **climate related risks are not limited to specific regions or countries but that it is an issue for all islands**, at least in the long term. Already now many islands are faced with negative consequences from weather extremes, higher temperatures, flooding or sea level rise. These consequences and future risks are related to significant costs which are particularly challenging when put in relation to the islands' GDP.

The empirical evidence for all five case studies shows that **climate change is not an abstract threat that may occur in the future but it is a concrete risk with the consequences of which many islands are already faced with now.** Temperatures have increased for all five islands or island regions that have been analysed in more detail for this report over the last decades. Precipitation patterns have changed over the last decades in all these regions. While some islands such as the Azores, parts of La Reunion and French Polynesia and New Caledonia register higher annual average precipitation levels, the Canary Islands, the Greek Islands as well as the Netherlands Antilles have been faced with lower mean precipitation rates. It is expected that average rainfall will increase for the Azores and French Polynesia, whereas the other islands are expected to be faced with reduced rainfalls which may be even significant as in the case of the Greek islands. Higher temperatures will be most pertinent for the Mediterranean islands in the summer when temperatures are already at high levels. At the same time weather extremes are expected to become more frequent including heat waves, heavy rainfalls or storms.

An island's exposure to climate impacts depends on many factors including the island's topography, location, population density, economic structure. However, as this report shows there are features that are common to many islands. **Islands' infrastructure including its most critical components such as airports, sea ports and highways is often located near the coast and hence particularly vulnerable to sea level rise and flooding**. Besides the transport infrastructure the **water supply and energy system is faced with particular challenges.** Decreasing rainfall and the expected decline in the quality of aquifers through salinization, sewage and chemical spillage, in combination with continuously increasing demand is creating a situation where water shortages become most precarious. Already now, small islands **rely on imports of fresh water** to meet their water needs during periods of low rainfall – **at considerable** costs. Similarly, the energy supply infrastructure is under increased stress in the face of weather extremes and higher energy demand as a result of higher temperatures.

Many islands are strongly dependent on revenues from the tourism industry with a share in the island's GDP of 20 per cent or even higher. Tourists' motivation to visit an island will influence the extent to which climate change will affect an islands' tourism industry. If tourism is strongly or mainly motivated by the island's biodiversity as **in the case of French Polynesia for example climate induced biodiversity loss is likely to have direct impact on the tourism sector**. For the **Netherlands Antilles** the future costs of climate change for the tourism sector, mainly as a result of loss in marine biodiversity, have been estimated to be as high as **US$4 billion (€3 billion) in 2020** already. Weather extremes result in considerable damage costs and loss in tourist revenues. **The flooding and intensive rainfalls in February 2010 in Madeira resulted in a fall of 14 per cent in revenues from tourism and caused damage costs of more than € 1 billion.**

It is difficult to quantify the impact on biodiversity but the example of New Caledonia in particular shows the devastating consequences climate change may have on marine biodiversity. Coral reefs have already been seriously damaged due to unusually warm water temperatures and tropical storms. This does not only constitute a huge biodiversity loss but coral reefs are also important for physical barriers which shelters Atolls, among the most complex and fascinating geological structures of the planet, from heavy ocean swells.

Among the European islands located in Europe the Mediterranean islands are those that are expected to be hardest hit by climate change. The case study on the **Greek islands** has shown that key economic sectors such as **tourism but also the olive production are significantly affected by climate change**. This is of particular concern as Greece as other EU Member States in the Mediterranean region are facing economic difficulties which underline the importance of maintaining and further expand these sectors. Combining action on climate mitigation and adaptation can create important economic synergies. The **total discounted costs** as a result of **sea level rise** have been calculated to be equal to **2 per cent of the Greek GDP**.[clxii] By adopting appropriate adaptation measures land loss could be reduced from 3.5 per cent of the country's total land surface to 0.5 per cent, while the **expenditure on coastal protection would be equivalent to 0.02 per cent of Greek GDP**.

This report has brought together important evidence on empirical evidence on already occurring climate change and consequences thereof as well as projected climate change and likely implications, focusing on a subset of European islands and specific sectors and areas. **Much more information is warranted on the specific consequences which would allow the islands to better prepare for climate change and hence reduce the costs of inaction.** The research for this report showed that while the local interest and expertise is available, there is often a lack of funding to carry out such research projects. The existing evidence of this report should help underline the need for climate mitigation and adaptation measures. Which instruments, measures and funds could be used to contribute to these challenges is outside the scope of this current study. Similarly the identification of where adaptation measures would be most cost-effective, also beyond the scope of this study, would merit specific study and engagement with the islands. The challenge is one that is beyond most islands' capacities to address on their own, and the benefits of addressing them also accrue beyond their borders. This raises the question of governance and cooperation in light of both solidarity and cohesion as well as own interest.

ANNEX I

People contacted for further information:

Name	Organisation
Aurélie Ghysels	OCTA
Bengt-Olof Grahn	Swedish island of Gotland/ Isle Pact Partner
Carole Martinez	IUCN
Dr. Bran Quinquis	n.a.
Debora Kimitete	Elue aux Marquises
Fernando Herrera Hernández	Regional Government of Canary Islands
Frédérique Lehoux	SOPAC
Ghislaine Arlie	Elue en Nouvelle Caledonie, Mairie de Farino
Gonzalo Piernavieja Izquierdo	Canary Islands Institute of Technology (ITC) / Isle Pact partner
Ilias Efthymiopoulos	DAFNI - AEGEAN SUSTAINABLE ISLANDS NETWORK/ Isle Pact Partner
José Simas	AZORINA S.A.
Malcolm Burr	Outer Hebrides of Scotland/ Isle Pact Partner
Mathieu Fichtner	European Commission, DG REGIO
Nikos Zografakis	Regional Energy Agency of Crete
Soren Hermansen	Samso Energy Acadamy
Tomas Salazar-Brier	European Commission, DG REGIO

Interviews conducted

Name	Organisation
Macaronesia	
Filipe Oliveira	AREAM
Carla Melo	SIMBIENTE AÇORES
Greek islands	
Dr. Christos Giannakopoulos	Institute of Environmental Research and Sustainable Development, National Observatory of Athens
La Réunion	
Amélie Navaro	Service Déchets et Energie, Direction de l'Environnement, Depart. De la Reunion
Netherlands Antilles	
Lloyd Narain	Friends of the Earth Curacao

ANNEX II

Five case studies on the impacts of climate change on European islands.

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