

**Vulnerability and Adaptation to Climate Change
in the Mediterranean Region.
Climate Out of Balance in Aiguamolls de l'Empordà?**

Doctoral Dissertation

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Ph.D. Program in Geography

Dissertation Director
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Cover: View on Roses from Empuriabrava during the storm. Photo by Egidij Rodica

“Not only is climate change altering our physical world, but the idea of climate change is altering our social worlds...Rather than asking ‘How do we solve climate change?’ we need to turn the question around and ask ‘How does the idea of climate change alter the way we arrive at and achieve our personal aspirations and our collective social goals?’”.

(Hulme, 2009, xxviii)

SUMMARY

Aiguamolls de l'Empordà was the first natural protected area to be created in the Costa Brava and is the second most important wetland area in Catalonia, after the Ebro Delta. This thesis researched how key stakeholders experience, perceive and respond to changing climate, together with an analysis of the climate variability in the approximately last forty years in one of the most economically dynamic coastal areas in Spain. My approach supports a position that vulnerability and adaptation analyses should be participatory and should include social, cultural, environmental, economic and political dimensions.

This thesis firstly found that since the early 1970s, both average air and sea temperatures in Aiguamolls de l'Empordà have been on a warming trend. Furthermore, precipitation trend showed insignificant increasing trend. While the average annual wind velocity increased in the period 1990–2012, the frequency of storms decreased. Regarding Fluvià and Muga flows, a decrease in the annual average river flows was observed in the period 1971–2011. Recent marine data of the local sea level near Aiguamolls de l'Empordà showed an increase between 1990 and 2012. Furthermore, results of current available climate projections showed that increases in air temperatures will continue, while precipitation are likely to decrease by 2050.

This thesis also showed that large majorities of interviewed stakeholders already believe that climate change is a very serious problem and that concern about this issue is growing. Most of them said that human activities are a significant cause of climate change, especially over recent decades. Furthermore, stakeholders considered that the increase in air temperature over the past few decades, precipitation changes, the increase in the severity of droughts, and the decrease in biodiversity and ecosystem productivity and services are the most pressing climate change effects and serious risks to the study area. These perceptions appeared to be in line with present climate data and prior studies. In addition to this, the location of the coastal municipalities (e.g. exposure) also makes them directly vulnerable to coastal erosion, flooding, saltwater intrusion and rises in sea level what was also stressed by majority of stakeholders. This finding is also consistent with some prior studies, which demonstrated that the study area's natural and socio-economic systems are likely to be particularly vulnerable to four effects of climate change: alterations in the magnitude and frequency of coastal erosion; alterations in the

frequency and severity of saltwater intrusion; alterations in the magnitude of water scarcity; and major changes in sediment supply of Fluvià.

Finally, over half of the stakeholders found that climate change adaptation is needed, but only a few of them expressed a high level of familiarity with mitigation. This finding may suggest that even if costs of adaptation are high, further losses to the economy, ecosystems and properties in Aiguamolls de l'Empordà might be even higher. Furthermore, it was found that it was easier to gain support for natural adaptation measures than for the measures that are artificial. A half of stakeholders that were in favour for adaptation, reported that they would implement natural measures such as setting dunes and beach barriers. From the thesis, it was also noted that the option of abandoning the area (i.e. outmigration) was clearly believed to be acceptable by some stakeholders, especially men, older residents and foreigners.

Aiguamolls de l'Empordà fue la primera área natural protegida creada en la Costa Brava y es la segunda zona de humedales más importante de Cataluña, después del Delta del Ebro. En esta tesis se ha investigado cómo los actores principales perciben y responden al cambio climático. Además se ha realizado un análisis de la variabilidad climática en los últimos cuarenta años en una de las zonas costeras económicamente más dinámicas de España. El enfoque adoptado apoya la necesidad de que el análisis de vulnerabilidad y adaptación deben ser participativos y deben incluir dimensiones sociales, culturales, ambientales, económicas y políticas.

En la tesis se muestra, en primer lugar, que desde principios de 1970, las temperaturas medias del aire y del mar en los Aiguamolls de l'Empordà han seguido una tendencia de calentamiento o incremento. Por otra parte, la precipitación mostró una tendencia creciente no significativa. Mientras que la velocidad promedia anual del viento aumentó en el período de 1990–2012, la frecuencia de las tormentas disminuyó. En cuanto a los caudales de los ríos Fluvià y Muga, se observó una disminución en el período 1971–2011. Recientes datos marinos del nivel local del mar, cerca de los Aiguamolls de l'Empordà mostraron un aumento entre 1990 y 2012. Por otra parte, los resultados de las proyecciones actuales del clima disponibles mostraron que los aumentos en la temperatura del aire continuarán, mientras que la precipitación es probable que disminuya hasta 2050.

Además, en la tesis se ha observado, que la gran mayoría de los principales actores entrevistados creen que el cambio climático ya es un problema muy grave y que la preocupación por este tema es cada vez mayor. La mayoría de ellos dijo que las actividades humanas son una causa importante del cambio climático, especialmente en las últimas décadas. Por otra parte, los entrevistados consideran que el aumento de la temperatura del aire durante las últimas décadas, los cambios en las precipitaciones, el aumento de la severidad de las sequías y la disminución de la biodiversidad y la productividad, así como de los servicios de los ecosistemas, son los efectos más negativos del cambio climático y suponen graves riesgos para el área de estudio. Estas percepciones parecen estar en consonancia con los actuales datos climáticos y los estudios previos. Además, la ubicación de los municipios costeros (i.e. exposición) también los hace directamente vulnerables a la erosión costera, inundaciones, intrusión

de agua salada y a la elevación del nivel del mar; factores también destacados por la mayoría de los principales actores. Estos resultados también son coherentes con algunos estudios anteriores, lo que demuestra que los sistemas naturales y socioeconómicos del área de estudio probablemente sean particularmente vulnerables a cuatro efectos del cambio climático: las alteraciones en la magnitud y la frecuencia de la erosión costera; las alteración de la frecuencia y magnitud de la intrusión de agua salada; las alteraciones en la magnitud de la escasez de agua; y cambios en el transporte de los sedimentos del Fluvià.

Por último, más de la mitad de los actores entrevistados consideró que es necesaria la adaptación al cambio climático, pero sólo unos pocos de ellos expresaron un alto nivel de familiaridad con la mitigación. Este resultado puede sugerir que incluso si los costes de la adaptación son altos, más alta sería la pérdida en la economía, los ecosistemas y las propiedades de los Aiguamolls de l'Empordà. Además, se encontró que es más fácil obtener apoyo para la adaptación con medidas naturales que con el uso de medidas artificiales. De hecho, la mitad de los principales actores estaban a favor de las dunas y las barreras de playa. En la tesis también se ha observado que la opción de abandonar el área de estudio (i.e. la emigración a otros lugares) puede ser una opción claramente aceptable por parte de algunos grupos de actores, especialmente por los hombres, residentes de mayor edad y los extranjeros.

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MAIN ACRONYMS AND ABBREVIATIONS

- ACA – *Agència Catalana de l'Aigua* (Catalan Water Agency)
- CIIRC – *Centre Internacional d'Investigació dels Recursos Costaners* (Centre for Coastal Resources Research)
- CO₂ – Carbon dioxide
- CREAF – *Centre de Recerca Ecològica i Aplicacions Forestals* (Centre for Ecological Research and Forestry Applications)
- DTS – *Departament de Territori i Sostenibilitat* (Catalan Ministry of Territory and Sustainability)
- EEA – European Environment Agency
- EU – European Union
- GHG – Greenhouse gas
- ICHN – *Institució Catalana d'Història Natural* (Catalan Institute of Natural History)
- ICTA – *Institut de Ciència i Tecnologia Ambientals* (Institute for Environmental Science and Technology)
- IDESCAT – *Institut d'Estadística de Catalunya* (National Institute of Statistics of Catalonia)
- INE – *Instituto Nacional de Estadística* (National Statistics Institute)
- IPCC – Intergovernmental Panel on Climate Change
- MAGRAMA – *Ministerio de Agricultura, Alimentación y Medio Ambiente* (Spanish Ministry of Agriculture, Food and Environment)
- NASA – National Aeronautics and Space Administration
- PEIN – *Pla d'Espais d'Interès Natural* (Plan for Areas of Natural Interest)
- SMC – *Servei Meteorològic de Catalunya* (Meteorological Service of Catalonia)
- SPA – Special Protection Area
- UNDP – United Nations Development Programme
- UNISDR – United Nations Office for Disaster Risk Reduction
- WMO – World Meteorological Organization

CHAPTER 1
INTRODUCTION

The Mediterranean basin is located at the crossroad of three continents and is one of the richest ecoregions and one of the most vulnerable natural environments in the world (EEA, 2010: 136). Europe's natural protected areas generally play a key role in protecting biodiversity. The European Environment Agency (EEA) indicated that natural protected areas are also a critical component of the continent's economy, contributing over €15 billion a year in jobs, food and other services. The current rationale for designating a protected area in the European Union (EU) combines two main factors. Firstly, there has been a growing recognition of the role that protected areas play in safeguarding biodiversity. But in addition, there has been an acknowledgement that protected areas are vital parts of the European economy. The production of food and the creation of employment within their boundaries are the most easily measured economic benefits of protected areas, but there are also indirect services provided by protected areas that contribute to the economy (EEA, 2012a). These include so-called ecosystem services, i.e. direct benefits and life supporting processes emanating from the environment (Daily, 1997; Millennium Ecosystem Assessment, 2005), such as the provision of clean water as well as the regulation of the water cycle carried out by forests, wetlands and watersheds, all of which help to mitigate flooding. Well-managed protected areas also prevent soil erosion and desertification and help sequester carbon. In marine environments, protected areas can maintain fisheries stocks at sustainable levels by providing areas for fish to breed and grow without being caught (EEA, 2012a). Additionally, natural protected areas can also contribute to social welfare and environmental education, such as through outdoor nature-based recreational activities that may take place there involving a wide variety of communities (e.g. Lovelock et al., 2011).

Over the last five decades, the quality of the Mediterranean environment has been increasingly degraded by rapid urban sprawl, littoralisation and various human activities (Scoullou & Ferragina, 2010). In particular, many Mediterranean wetlands have been destroyed and degraded to prevent water-borne diseases and to expand agriculture, industry and tourism (Doukakis, 2003; Farantouris, 2009; Kalivas et al., 2003). Furthermore, the degradation of the Mediterranean wetlands has especially triggered a loss of the functions and values originally provided by wetlands, such as shoreline protection, flood protection, sediment trapping, erosion control, land building, carbon storage, water quality maintenance and pollution abatement, maintenance of surface and underground water supplies, support for fisheries, grazing and agriculture, outdoor

recreation and education for human society, and the provision of habitats for flora and fauna (Doukakis, 2003; Hobbs et al., 2006). The pressures from human activities in these environments have generated major environmental problems, which are likely to be exacerbated by climate change in future decades (Scoullou & Ferragina, 2010).

Climate change has been in recent two decades a subject of large topical interest (Brauch, 2010; IPCC, 2013) which has caught the attention especially of politicians and research funding bodies (Bardsley & Wiseman, 2012) and it is one of the key issues in environmental research and studies on sustainable development (Bormann et al., 2012). Specifically, the likelihood of adverse climate change impacts has created a growing urgency to improve the understanding of how communities and ecosystems in the Mediterranean region will be affected by changing climate, and how they may adapt to such changes (e.g. Aaheim et al., 2012; Fatorić & Chelleri, 2012; Lung et al., 2012).

Over the two last decades has been documented that humans have exerted an increasingly important influence on the climate system, especially with industrial revolution where human activities began to alter the composition of the atmosphere thereby changing the Earth's climate on a global scale (EEA, 2012a; Rosenzweig et al., 2008). In particular, the Intergovernmental Panel on Climate Change, IPCC (2007a) concluded with very high confidence that the total warming effect of human activities is at least ten times larger than that of natural factors, in particular changes in solar activity. The continued global rise in greenhouse gas (GHG) emissions projected for the latter part of this century (IPCC, 2013) is a strong indicator that climate change will be unavoidable. Here, it seems likely that it will greatly affect natural protected areas and other vulnerable areas, such as coastal areas that have been under climate change stress and risk. According to McGranahan et al. (2007), roughly 600 million people (or 10% of the Earth's population) live in areas that are within 100 km of the coast and at elevations less than 100 m above sea level.

In particular, the Mediterranean basin is predicted to be one of the most severely affected world regions. The increase in global temperature may have serious impacts on the Mediterranean region, including an increase in sea level, which may threaten coastal and low lying areas, disruption of precipitation patterns, an increase in the frequency of extreme weather events, an increase in the intensity and frequency of floods and droughts along with repercussions on the qualitative and quantitative state of water resources. These changes are expected to exacerbate the already existing serious water stress in most parts of the Mediterranean region resulting in severe, detrimental effects

on the natural systems (IPCC, 2013; Lenton, 2013; Scoullos & Ferragina, 2010; Sumner et al., 2003) and further increase the stress on communities, which may undermine many of the Mediterranean region's conservation efforts (Combest-Friedman et al., 2012) and the provision of ecosystem services and goods on which people's livelihoods depend (Scoullos & Ferragina, 2010).

In this thesis, I argue that although the physical evidence of changing climate is observed and well-documented, there is a surprising lack of studies at the local level that may provide ground level information for communities trying to reduce vulnerability to climate change and mitigate some of the effects of climate change. In particular, a coastal wetland such as Aiguamolls de l'Empordà area has been the target of much research (e.g. Bach, 1989; Mas-Pla et al., 1999; Morén-Alegret, 2008; Pavón et al., 2003; Ribas Palom, 2006; Romagosa Casals, 2008; Saurí et al., 1995; Serra et al., 2008), but climate change or variability have rarely featured in any of these efforts. Here, in terms of identifying vulnerability to climate change, my thesis follows the spirit of the IPCC Guidelines. There is vulnerability understood as the degree of exposure to climate variability or change (sensitivity) that both humans and the environment face and their adaptive capacity and ability to adjust to climate change (IPCC, 2007b). The interaction of environmental and social forces determines exposures and sensitivities, and various social, cultural, political and economic forces shape the adaptive capacity (Smit & Wandel, 2006).

Over recent decades, debates on climate change have focused on mitigation of GHG emissions because of the urgency of promoting international action to reduce the causes of human induced climate change (Füssel & Klein, 2006; Paavola & Adger, 2006). However, roughly at the same time, a growing perspective has emerged on the necessary role of climate change adaptation, in the context of society, economies and ecosystems. Globally, an amount of coastal infrastructure and development increased dramatically during the 20th century and settlements at all scales have been concentrated along the coastline (Small & Nicholls, 2003). It is estimated that future rising population and GDP will also increase significantly the amount of coastal infrastructure and settlements thus, the exposure to climate change effects in coastal areas will greatly increase the asset and may displace land uses and settlements from coastal areas (Nicholls et al., 2008). Hence, integrating adaptation in the future spatial planning process may become necessary if climate change exceeds present climate variability. Moreover, I acknowledge that adaptation should be based on the local communities'

perception and knowledge and should address all aspects of vulnerability, which can result in a success and further sustainable management initiative, so that lessons can be learned for other coastal areas. Similarly, Berkes (2007) claimed that climate change could be used as an example to illustrate the potential contributions of local and traditional knowledge and perception (see Chapter 2 for more insights on climate change and public perception).

Specifically, I focused in this thesis on the environment-driven aspects of the problem of climate change, under the assumption that vulnerability analysis must be participatory and must include social, cultural, environmental, economic and political dimensions. The fieldworks provided the possibility of engaging with stakeholders across the study area and I fostered a better understanding of vulnerability and adaptation to the changing climate with the aim of reducing vulnerability and maintaining or increasing the opportunities for sustainable development in the natural protected area of Aiguamolls de l'Empordà. The study area, however, may serve as an example for some similar regions along the Mediterranean coast.

1.1 Aims and objectives of the thesis

The overarching goal of this thesis is to identify, develop, and explain the vulnerability assessment for the communities¹ and livelihoods in Aiguamolls de l'Empordà in the face of climate change and to identify and explain principal measures for adaptation.

In line with this goal, there are four broad aims of this thesis:

- Analyse climate change variables for the study area;
- Assess the dimensions of communities' vulnerability to climate change in the study area that is characterised by a high rate of foreign immigration;
- Identify, analyse and evaluate the most appropriate technical, socio-economic and structural adaptation measures to respond to vulnerability according to key stakeholders;
- Identify and evaluate outmigration due to climate change.

¹ Although I use the term “community” throughout the thesis in an uncritical manner, I am aware of the fact that the people in my study case are not homogenous, having the same socio-economic, demographic, social, cultural characteristics and they are not mutually supportive collection of people with the same interests.

In order to achieve these aims, my thesis has four specific objectives outlined below:

- Aim 1. Analyse climate change variables of the study area:
Objective 1: Examine if the meteorological, hydrological and marine data have changed in the period 1971–2012 and 1990–2012 by using the longest available climate record in the Mediterranean coast of Aiguamolls de l’Empordà (Chapter 4).
- Aim 2. Assess the dimensions of communities’ vulnerability to climate change in the study area that is characterised by a high rate of foreign immigration:
Objective 2: Identify and characterise the vulnerability of the socio-economic system to the effects of climate change in Aiguamolls de l’Empordà.
Here I identify and document exposure and sensitivity that community has to deal with, and how they deal with these, including their adaptive capacity (Chapter 5).
- Aim 3. Identify, analyse and evaluate the most appropriate technical, socio-economic and structural adaptation measures to respond to vulnerability according to key stakeholders:
Objective 3: To carry out fieldwork and semi-structured interviews with the stakeholders in order to collect ideas, practices, knowledge and perceptions that may indicate some paths that could be followed in order to find practical solutions and to propose possible measures for climate change adaptation.
This can help to highlight which measures may reduce vulnerability most effectively and enable the local community to cope with climate variability (Chapter 6).
- Aim 4. Identify and evaluate outmigration due to climate change:
Objective 4: Identify and evaluate possible future human migration and accounting for outmigration as a consequence of climate change impacts (Chapter 7).

1.2 Hypotheses of the thesis

Last but not least, in this introductory chapter, the main points of departure for this thesis can be noted (see Chapter 3 for more details on methodological framework, methods and techniques). In this sense, the two following hypotheses based upon the research carried out by other authors in various areas and my previous research experience in the Ebro Delta² area can be underlined:

- Environmental stresses caused by climate change are already visible in Aiguamolls de l'Empordà and affect the environment and community living in this area.
- Local stakeholders in Aiguamolls de l'Empordà area are in favour of the mildest measure for adapting to climate change, i.e. the one that is most in harmony with nature. Furthermore, outmigration is perceived as not acceptable option for dealing with climate change impacts.

I assume that testing these two main hypotheses would provide the guidelines to reach the aforementioned aims and to understand the main problems in Aiguamolls de l'Empordà. In this sense, understanding problems in such geographical area would help to know, which vulnerability issues should be prioritised and which would be the most relevant adaptation measures to be implemented in the study area.

1.3 Thesis structure

This thesis consists of eight distinct, stand-alone, but hierarchically integrated data chapters (Figure 1). The thesis after this introductory chapter, which also sets out and clarifies the four main aims, four main objectives and two hypotheses, proceeds as follows. Chapter 2 discusses the literature on the principles of climate change vulnerability, adaptation, public perceptions that should be taken into account in efforts to understand climate change, its effects, adaptation, and stakeholders' participation in decision-making. This chapter forms a background theory for the later chapters on vulnerability and adaptation assessments that take a locally relevant, interviews-based

² Fatorić, S., 2010. Vulnerability to the effects of climate change and adaptation: the case of Ebro Delta. Master Thesis. ICTA, Autonomous University of Barcelona, Barcelona.

approach. Chapter 3 focuses on the chosen methodological framework and approach, research methods and main environmental, economic and population description of the study area, while Chapter 4 turns its attention into the analyses of meteorological, hydrological and marine data mainly for the period 1971–2012 and climate change projections for the study area. Chapter 5 explores the issue of communities' vulnerability using documental and statistical data and stakeholders' perceptions and knowledge. Then, Chapter 6 identifies and examines anticipatory adaptation based on technical measures, which policy-makers can take to reduce vulnerability and increase the communities' adaptive capacity. In particular, Chapter 7 addresses questions on how climate-related hazards may affect communities with an emphasis on outmigration from the study area. Finally, Chapter 8 concludes the thesis and highlights some future institutional, environmental and socio-economic challenges of taking forward a research of this kind.

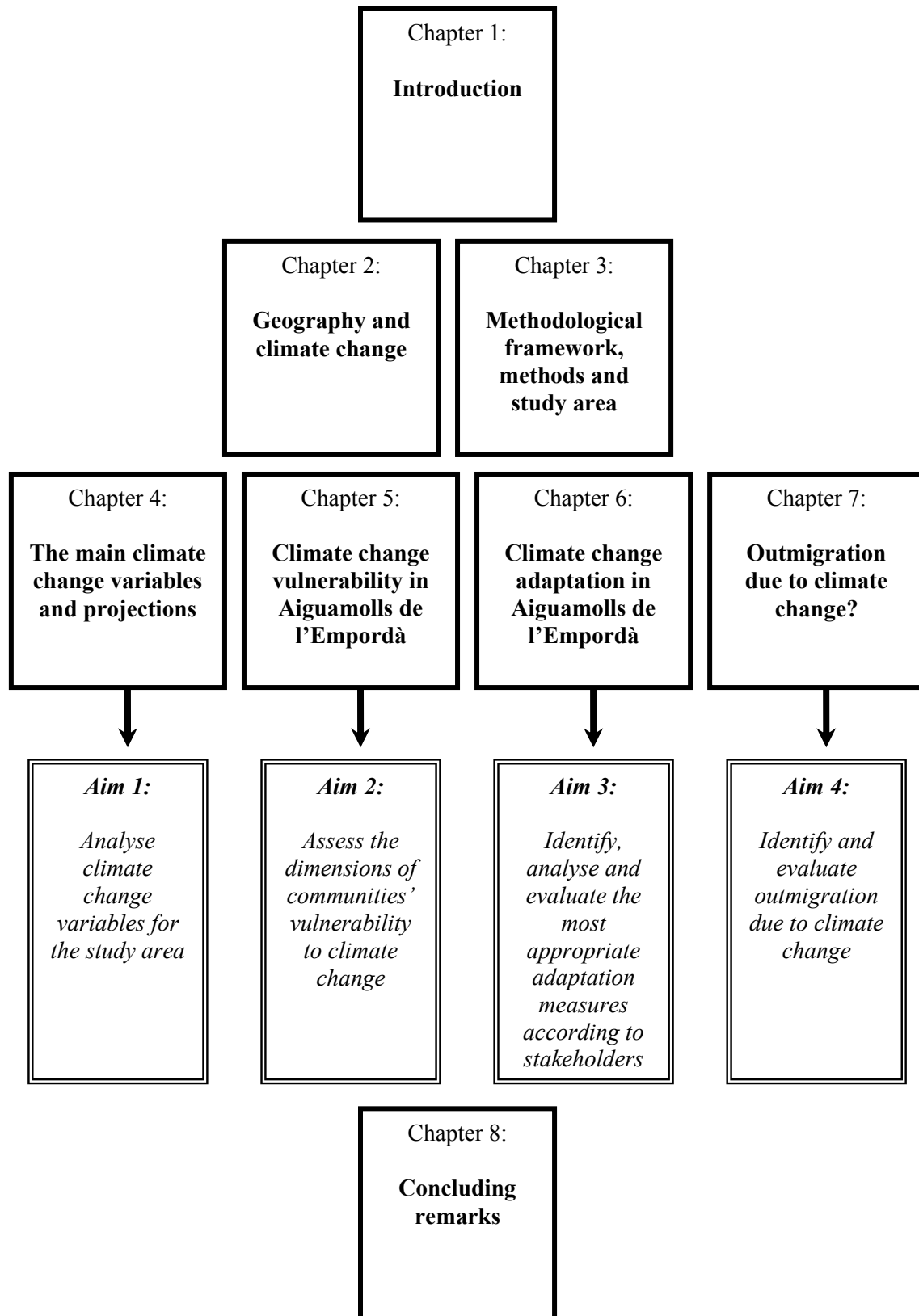


Figure 1. Thesis structure.

CHAPTER 2

GEOGRAPHY AND CLIMATE CHANGE

This chapter analyses the key theoretical concepts underpinning first, an overview of the main definitions of climate change applied in this thesis. Then, it highlights a keystone background theory about vulnerability and adaptation to climate change. Here, I outline the literature regarding the various ways in which vulnerability and adaptation have been defined within the climate change field with special reference to the IPCC. I then move to a specific overview of importance of stakeholders' participation who according to a number of authors should have a voice within the decision-making process in the environmental and climate change field by integrating their perceptions and knowledge.

Specifically, the focus of this thesis is on climate change as one of the essential aspects of environmental change. Over the last two decades, we have witnessed extensive research on observed climate change (IPCC, 2013). However, there are many ways, in which science sets out an understanding of climate change and it is not the purpose of this thesis to review them all. But rather, I focus in particular, on widely acknowledged scholar definitions in geography such as Oxford's Dictionary of Geography (Mayhew, 2009), the Dictionary of Human Geography (Gregory et al., 2009), and in general, on definition of the IPCC Fourth Assessment (2007a).

First, it is important to clarify a definition of the term climate, which according to Mayhew (2009) is "a summary of mean weather conditions over a time period, usually based on thirty years of records". She further stated that "climates are largely determined by location with respect to land- and sea-masses, to large scale patterns in the general circulation of the atmosphere, latitude, altitude and to local geographical features" (Mayhew, 2009). This definition is in tune with the principal definition of climate in the IPCC Fourth Assessment (IPCC, 2007a: 942), defined as "the average weather, or more rigorously, the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is thirty years, as defined by the World Meteorological Organization (WMO). The relevant quantities are most often surface variables such as temperature, precipitation and wind." Following this definition, Gregory et al. (2009) added a dimension of human geography's engagements with climate highlighting for instance, the importance of the incorporation of climatic conditions into studies of the perception of environmental hazard and risk; discussion about the role of human agents in inducing climate change and global warming; and debates about human capacities to adapt to different climatic regimes.

Moreover, they argued that climate is manifested as a cultural construct, for instance, among others, through societal politics of climatic determinists, the apocalyptic tincture of certain strands of climatic prophecy, the economic geography of weather-related insurance and the social constitution of climatological knowledge (Gregory et al., 2009).

In addition, the definition of climate change, which is at the root of this thesis is defined by the IPCC (2007a: 943) as “a change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It may be due to natural internal processes or external forcings or to anthropogenic changes in the composition of the atmosphere or in land use”. Sometimes, however, the term climate change is confused with climate variability, which refers to “variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events” (IPCC, 2007a: 944). An important issue of the research on climate change over the last few decades has been global warming, which is the increase in global temperature resulting from human activities (i.e. anthropogenic changes) that exacerbate the natural processes (Gregory et al., 2009: 308). Specifically, solar and volcanic forcings are the main natural contributors to climate change, while GHG emissions³ are the main anthropogenic contributors. Moreover, there is a high confidence that the 21st century solar forcing will be much smaller than the projected increased forcing due to GHG emissions (IPCC, 2013).

In particular, the Dictionary of Human Geography (Gregory et al., 2009) highlights a human dimension of climate change where it is argued that human-induced climate change is seen by many environmentalists as the most serious environmental problem, because it exacerbates other environmental issues. In this formulation, Hulme (2009) pointed out that climate change is a meeting of nature and culture, where humans are the central actors in both of those realms, and how humans are continually creating both nature and culture. Furthermore, Adger (2006) found that climate change represents a classic multi-scale global change problem, which it is characterised by

³ The most important GHG emissions are carbon dioxide (CO₂), water vapour (H₂O), methane (CH₄) and nitrous oxide (N₂O). These are also natural compounds that allow the Earth’s atmosphere to trap heat released as long-wave energy from the Earth’s surface. This process, called the greenhouse effect, means that the earth is 33 °C warmer than expected given its distance from the sun (Gregory et al., 2009).

infinitely diverse actors, multiple stressors and multiple time scales. Similarly, Naustdalslid (2011) pointed out that climate change is probably the hottest issue as an example of a modern environmental problem where the most serious effects lie in the future. Sterner (2009) determined that climate change is an intergenerational problem and “public bad” whose solution cannot be achieved through the efforts of any single country and it requires changes in the habits of communities together with political, social and economic interests, power and beliefs.

Evidence of climate change and its effects have been generally accepted by the international community where 97% of scientists have acknowledged that global warming over the past century has been very likely due to human activities (National Aeronautics and Space Administration, 2013), resulting in adverse impacts on both natural and socio-economic systems (EEA, 2012b; IPCC, 2013; Millennium Ecosystem Assessment, 2005). Over the last decade, information available to the general public about climate change has increased significantly, which is evident in the number of scientific studies, newspaper articles, television and radio news, and popular culture such as documentaries and movies. Indeed, the movie “Day After Tomorrow (2004)”, the documentary movie “An Inconvenient Truth (2006)”, the animated movie “Ice Age: The Meltdown (2006)” and the movie “The Age of Stupid (2009)” have received large consideration and directly and/or indirectly have risen awareness of climate change and global warming⁴. Consistent with this view, Naustdalslid (2011) argued that without climate research, without the concerted action of scientists and without systematic and convincing dissemination from this scientific activity to policy-makers and general public, climate change would not have been visible as a problem for society today.

⁴ “Day After Tomorrow (2004)”, director Roland Emmerich, studios Centropolis Entertainment & Lions Gate (see <http://www.imdb.com/title/tt0319262>); “An Inconvenient Truth (2006)”, director Davis Guggenheim, studios Lawrence Bender Productions & Participant Productions (see <http://www.imdb.com/title/tt0497116>); “Ice Age: The Meltdown (2006)”, director Carlos Saldanha, studio Blue Sky Studios (see <http://www.imdb.com/title/tt0438097>); “The Age of Stupid (2009)”, director Franny Armstrong, studio Spanner Films (see <http://www.imdb.com/title/tt1300563>)

2.1 Vulnerability to climate change

Vulnerability has many definitions. Given the large body of literature on vulnerability, I do not intend to present a review of the various schools of vulnerability research or their historical development. Rather, I define vulnerability in the context of climate change issue. Furthermore, vulnerability may be conceptualised in different ways by scholars from different knowledge domains, which may lead to confusion and misunderstanding among researchers, policy-makers and the public in general (Brooks, 2003; Füssel, 2007a; O'Brien et al., 2004).

The scientific use of vulnerability has its roots in geography and natural hazards research, but this term has been over the last two decades a central concept in a variety of research contexts such as natural hazards and disaster management, climate science, ecology, public health, poverty and development, secure livelihoods and famine, sustainability science, land change, climate impacts and adaptation (e.g. Adger, 1999, 2006; Cutter, 1996; Füssel, 2007a; Turner II et al., 2010). In these fields, researchers consider vulnerability a key component of risk where risk is a function of a hazard and the probability of that hazard occurs (Brooks et al., 2005).

The ordinary use of the term “vulnerability” refers to the capacity to be wounded, i.e. a degree to which a system is likely to experience harm due to exposure to a hazard (Turner II et al., 2003). The term “system” as it is presented in vulnerability studies is often understood in terms of an unit of analysis, such as an ecosystem, household, community, group, economic sector, region, country (Füssel, 2007a; Miller et al., 2010; Smit & Wandel, 2006). In this thesis, concretely, I follow the spirit of the IPCC terminology where the term “system” distinguishes between a natural and socio-economic system (IPCC, 2007b). Furthermore, the term “hazard” is used throughout the thesis to refer to a dangerous phenomenon, substance, human activity, or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage (UNISDR, 2009). Vulnerability is both hazard- and system-specific; we can only talk meaningfully about the vulnerability of a particular population group or system to a particular hazard (Brooks & Adger, 2003). Changes and shocks in systems will always cause vulnerability to some, making it necessary to identify acceptable levels of vulnerability and to maintain the ability to respond (Nelson et al., 2007).

The existence of competing conceptualisations and terminologies of vulnerability has become particularly problematic in the environmental and climate change research, which is characterised by intense collaboration between scholars from many different research traditions, such as climate science, risk assessment, development, economics, policy analysis (Adger, 2006; Fussel, 2007a). Definitions of vulnerability in the climate change related literature tend to fall into two categories (Adger, 2006; Brooks, 2003; Cutter, 1996; Moss et al., 2001):

- Natural (or biophysical) vulnerability, which is vulnerability in terms of the amount of potential damage caused to a system by a particular climate-related event or hazard;
- Socio-economic (or social) vulnerability, which is vulnerability as a state that exists within a system before it encounters a hazard event.

The former view of vulnerability has arisen from a risk-hazards approach based on assessments of hazards, in which the role of socio-economic systems in mediating the outcomes of hazard is downplayed or neglected (Brooks, 2003; Turner II et al., 2003). The hazards and impacts approach typically views the vulnerability of a socio-economic system as determined by the nature of the physical hazard to which it is exposed, the frequency of the occurrence of the hazard, the extent of system's exposure to a hazard, and the system's sensitivity to the impacts of the hazard (IPCC, 2007b). This vulnerability, a function of hazard, exposure and sensitivity, is used here as natural vulnerability (Brooks, 2003). Natural vulnerability is concerned with the ultimate impacts of a hazard event and is often viewed in terms of the amount of damage experienced by a system as a result of an encounter with a hazard (Brooks, 2003). Natural vulnerability is determined by factors such as topography, environmental conditions, land cover, sea level change (Füssel, 2007a) (see Table 1).

Similarly, other disciplines have pushed for the consideration of the underlying social conditions that make humans vulnerable (Adger, 2006). Specifically, political ecology and geography have focused on vulnerability by emphasising socio-economic, demographic, cultural and political characteristics, as well as the role of institutions and governance for shaping vulnerability (Allen, 2003; Cutter, 1996; Fussel, 2007a). This vulnerability that is inherent property of the socio-economic system arising from its internal characteristics, independently of external hazards may be termed socio-

economic vulnerability. The nature of socio-economic vulnerability will depend on the nature of the hazard to which the socio-economic system is exposed. Certain properties of a system will make it more vulnerable to certain hazards than to others, although socio-economic vulnerability is not a function of hazard severity and frequency (Adger, 1999; Brooks, 2003; O'Brien et al., 2004). Socio-economic vulnerability is determined by factors such as poverty, inequality, health, marginalisation, social status, exclusion, food entitlements, housing quality, access to insurance, knowledge, information, technology (Cutter et al., 2003; Füssel, 2007a; Heltberg et al., 2009) (see Table 1). Hence, socio-economic vulnerability may be viewed as one of the determinants of natural vulnerability (Brooks, 2003). In this formulation, it is the interaction of hazard with socio-economic vulnerability, which produces an outcome, generally measured in terms of physical or economic damage, household income, human mortality or health and morbidity (Brooks & Adger, 2003).

Table 1. Examples of factors that influence vulnerability

Vulnerability	
<i>Socio-economic (social)</i>	<i>Natural (biophysical)</i>
household income	topography
social network	environmental conditions
access to information	land cover
policy	weather events
international aid	natural disasters
economic globalisation	sea level change

Source: Füssel, 2007a.

In addition, a special focus is related to the IPCC definition of vulnerability. The IPCC is an authoritative source that sets agendas and acts as a legitimising device for research (Adger, 2006). It is therefore worth examining research on vulnerability to climate change and its interpretation within the reports of the IPCC.

The IPCC promoted a definition of vulnerability as natural or socio-economic system's exposure and degree (sensitivity) to which they are affected by climate variability or change and their adaptive capacity that relates to ability to adjust to climate change (IPCC, 2007b: 883). This means that vulnerability depends on context

and the factors that make a system vulnerable to a hazard will depend on the nature of the system and the type of hazard in question (Brooks et al., 2005). The interaction of environmental and social forces determines exposures and sensitivities, and various social, cultural, political and economic forces shape the adaptive capacity. The overlap recognises that the processes driving exposure, sensitivity and adaptive capacity are frequently interdependent (Smit & Wandel, 2006).

First, exposure is defined by the IPCC as a nature and degree to which a system is exposed to climate variability or change (IPCC, 2007b). Second, sensitivity is a degree to which a system is affected, either adversely or beneficially, by climate variability or change. Here, the effect may be direct (e.g. a change in crop yield in response to a change in the average temperature) or indirect (e.g. damages caused by an increase in the frequency of coastal flooding due to sea level rise) (IPCC, 2007b: 881). And third, like vulnerability, adaptive capacity has multiple interpretations in the climate change literature (O'Brien et al., 2004). In general terms, it is defined as the system's ability to adjust to climate variability or change, moderate potential damages, take advantage of opportunities, or cope with the consequences (IPCC, 2007b: 869). In the face of uncertainty, adaptive capacity is a critical system property, which describes the ability to mobilise scarce resources to anticipate or respond to perceived or current stresses (Engle, 2011). The determinants of adaptive capacity include, for instance, available technological options for adaptation, available resources and their distribution across the population, structure of critical institutions and decision-making, human capital (including education and security), social capital (including property rights), access to risk spreading processes, ability of decision-makers to manage information, communication and public perception (IPCC, 2007b; Nelson et al., 2007; Yohe & Tol, 2002). For instance, some determinants of adaptive capacity operate on macro-scales in which national or regional factors play a significant role, while other determinants function on micro-scales which are precisely location specific (Smit & Wandel, 2006; Yohe & Tol, 2002). Furthermore, Eakin & Luers (2006) found that because of its unique position as being shaped by human actions and as influencing both the natural and social elements of a system, adaptive capacity is considered critical for reducing vulnerability. Furthermore, it is rightly pointed out in a study by Yohe & Tol (2002) that vulnerability is likely to increase monotonically with higher rates of exposure and sensitivity, and exposure and sensitivity are likely to decrease with higher adaptive capacity.

An extensive use of vulnerability in the climate change literature hides at least two interpretations of the word, and two purposes for using it. On the one hand, vulnerability is viewed as an end point, i.e. as a residual of climate change impacts minus adaptation. Here, vulnerability represents the net impacts of climate change; it serves as a means of defining the extent of the climate problem and providing input into policy decisions regarding the cost of climate change versus costs related to mitigation of the GHG emissions (Kelly & Adger, 2000). On the other hand, it is viewed as a starting point, i.e. vulnerability is a characteristic generated by multiple environmental and social processes, but exacerbated by climate change (Kelly & Adger, 2000). In this case, vulnerability provides a means of understanding how the impacts of climate change will be distributed, primarily to identify how vulnerability can be reduced (O'Brien et al., 2004). Moreover, this approach, assumes that addressing current vulnerability will reduce vulnerability under future climate conditions (Burton et al., 2002). According to O'Brien et al. (2004), using this approach identifies policies or measures that reduce vulnerability, increase adaptive capacity, or illuminate adaptation options and constraints. The aim of this thesis is to shed a light on this approach regarding Aiguamolls de l'Empordà area.

For the purposes of this thesis, it is also important to distinguish between frameworks of vulnerability (Eakin & Luers, 2006) and resilience, or achieve desirable states in the face of change (Folke, 2006). Vulnerability and resilience constitute different, but overlapping characterisations and interpretations (Miller et al., 2010; Turner II, 2010). Resilience is rooted in ecology sciences and theoretical and mathematical modelling methodologies (Gallopín, 2006). The resilience perspective increasingly includes human contributions to system dynamics, as shown by the expanding scholarly focus on social-ecological systems (i.e. the human components such as institutions, infrastructure, culture; and the environmental components such as geological, climatological, biological) (Gallopín, 2006; Turner II et al., 2003). Here, it is important to note that the adaptive capacity in resilience studies, often described as adaptability, is the capacity of actors in the system to manage and influence resilience (Walker et al., 2004). Thus, the more adaptive capacity within a system, the greater the likelihood that the system will be resilient in the face of climate stress (i.e. humans can manage social-ecological interactions in a manner that maintains the system state, or the status quo). In the resilience literature, adaptive capacity is also a property that can facilitate transitions or transformations, with transformation meaning to move to a new

system state when the current state is untenable (oftentimes when the system is in a resilient, but undesirable situation) (Folke, 2006). This thesis does not attempt to focus on resilience perspectives, rather on vulnerability. As such, it provides basic information and analysis on vulnerability to climate change in Aiguamolls de l'Empordà.

2.2 Adaptation to climate change

While scientists forecast climate variability and change over decades at broad spatial scales, hazards are expressed at local scales thus, it is at this level where responses and adaptations are most important (Füssel, 2007b; Moser, 2009; Paavola & Adger, 2006; Riedlinger & Berkes, 2001).

Regarding this thesis' study area, although there are highly developed economic activities within and around natural protected areas along the Spanish coastline, very little work has been conducted on assessing the climate change vulnerability and adaptation to climate change in general. This is a shortage that needs to be covered because, for instance, along the Catalan coastal region, climate change effects such as accelerated coastal erosion, changes in the frequency of storms, flooding have been significantly analysed (e.g. Barnolas & Llasat, 2007; Fatorić & Morén-Alegret, 2013; Jiménez & Sánchez-Arcilla, 2004; Jiménez et al., 2011; Llasat et al., 2010). To date, in Catalonia, a study on climate change adaptation on a regional level has been conducted (see DTS, 2012) which does not include comprehensive proposals for climate change adaptation based on technical measures. However, a few studies have been conducted at the local level, for instance in the Ebro Delta (e.g. DTS, 2008; Fatorić & Chelleri, 2012; Roca & Villasar, 2012) and in some river basins (e.g. CREAM, 2012). My thesis contributes to this issue.

The term adaptation, as it is presently used in the global change field, has its origins in natural sciences, particularly evolutionary biology (Smit & Wandel 2006). For instance, Darwin (1998) used the term adaptation by commenting that it is not the strongest of the species that survives, nor the most intelligent, but the one that is the most adaptable to change. Likewise, this is the idea that later was used, reformulated and complemented by some historical geographers (e.g. Reclus, Kropotkin). Here, Kropotkin's major theoretical contribution was in the field of evolutionary theory, suggesting that cooperation within a group explains natural selection of species more

satisfactorily than competition (Paleo, 2012). Similarly, Reclus suggested that society adapts its environment to its needs (Olwig, 1980). Furthermore, in recent decades the concept of adaptation has been used specially in the social sciences such as psychology, anthropology, geography, political ecology, resource management, community development, risk management, planning, food and livelihood security and sustainable development (Smit & Wandel 2006). In fact, in each discipline, the environment is strongly linked to the concept of adaptation (Simonet, 2010).

Although the definition of adaptation in the natural sciences is disputed, it is generally seen as a complex product of immediate behavioural flexibility, changing social traditions and genetic change which allow the organism (or system) to minimise its chance of extinction when responding appropriately to a stress (Winterhalder, 1980). Hence, adaptation is a continuous stream of activities, actions, decisions and attitudes that inform decisions about all aspects of life and that reflect existing social norms and processes (Nelson et al., 2007). Indeed, O'Brien (2009) found that climate change adaptation is starting to be considered as an integral dimension of human values formation. Furthermore, Füssel (2007b) highlighted that in a wider sense, research and data collection are also adaptation, because they facilitate implementation of effective actions for reducing climate risks.

In climate change adaptation field, natural or socio-economic system is dynamic and is likely to adapt to climate change. In this thesis, adaptation is acknowledged as “adjustment in natural or human systems in response to actual or expected climatic stimuli, their effects, which moderates harm or exploits beneficial opportunities” (IPCC, 2007b: 869). Importantly, adaptation usually acts to reduce the magnitude of the potential impacts that would occur in its absence (Nicholls & Klein, 2005). I agree with Smit & Wandel (2006) who showed that adaptation is an outcome of the interaction of environmental, social, cultural, political and economic forces. Similarly, Brooks (2003) demonstrated that adaptation is determined by factors such as health and education, access to information, financial and natural resources, the existence of social networks, and the presence or absence of conflict.

Furthermore, adaptation is also influenced by one's ability to have learned from experiences; particularly what worked (and/or did not) in similar circumstances (Engle, 2011). Additionally, Ford et al. (2006) reported that climate change might increase the consequences of a lack of knowledge and more risk-taking behaviour.

The IPCC defines various types of adaptation, including anticipatory, autonomous and planned adaptation. First, anticipatory adaptation considers adaptation taken in anticipation of the expected climate change impacts (also referred to as proactive adaptation). Second, autonomous adaptation is adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems (also referred to as spontaneous adaptation). Third, planned adaptation is adaptation that is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state (IPCC, 2007b: 869). In this thesis, however, I focus on anticipatory adaptation. Nonetheless, adaptation does not always moderate the damage or harm, but instead it can exacerbate it, i.e. maladaptation (Nicholls & Klein, 2005).

Hence, actual climate change impacts are normally much less than the potential impacts that are estimated in the absence of adaptation (Nicholls & Klein, 2005). In addition, I agree with Klein & Nicholls (1999) that a successful environmental management in climate change era requires that the planning, design and implementation of adaptation measures are based on the best available information and awareness is being risen as well as on the regular monitoring and evaluation of their performance. Similarly, Wilbanks & Kates (2010) found that climate change adaptation is not just a narrow infrastructure or emergency preparedness assignment of disaster planning rather an opportunity for broad-based participation by a wide range of stakeholders. Moreover, while discussions of sustainability in relation to climate change frequently pertain to mitigation, there are similarly important sustainability implications regarding the ways that natural and socio-economic systems may adapt to climate change (Engle, 2011). In this thesis, I further argue that policy-makers should have an essential need to start preparing for climate change adaptation in coastal areas, even if we continue with reducing current and future GHG emissions. The need for climate change adaptation may be even more essential in natural protected areas with significant ecosystem services and dynamic economies such as the Spanish Aiguamolls de l'Empordà. Mainstreaming the present study case into climate change adaptation planning allows also other natural protected areas to learn some lessons that may be useful in the future.

According to Nicholls & Cazenave (2010), while there is a confidence that Europe can afford significant levels and measures of adaptation, it is much less clear

which would be the most appropriate ones. Barnett & Adger (2007) highlighted that existing social, political, environmental and economic factors largely determine which adaptation measure become available, desirable, affordable and sustainable in the short or medium-term. For instance, the study of Fatorić & Chelleri (2012) about vulnerability and adaptation to climate change in the Ebro Delta demonstrated that choosing the most suitable adaptation measure does not mean the same for each stakeholder, but it differs in level of vulnerability among stakeholders. Further, Yohe & Tol (2002) argued that the set of available, applicable and appropriate measure should be defined on a micro-scale even though the complete set of possible remedies might have macro roots.

2.3 Stakeholders participation and integrating local perception in climate change disciplines

This subchapter outlines the need to incorporate stakeholders' perception and knowledge into decision-making which initially shaped my vulnerability and adaptation assessment.

2.3.1 *Public perception regarding climate change*

An understanding of public perceptions about climate change can contribute to policy discussions on climate change (Bord et al., 1998) and complement global science (Berkes, 2007). Over the past few decades there has been considerable research on climate change perception, finding a greater number of the studies focusing on so-called developing countries (e.g. Adger, 1999; Adeniji-Oloukoi et al., 2013; Bhave et al., 2013; Bryan et al., 2009; Byg & Salick, 2009; Grothmann & Patt., 2005; Kakota et al., 2011; Kpadonou et al., 2012; Kuruppu & Liverman, 2011; Mubaya et al., 2012; Mustelin et al., 2010), but less on countries considered as developed, i.e. OECD countries.⁵

⁵ OECD countries: Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States
(see <http://www.oecd.org/general/listofocdmembercountries-ratificationoftheconventionontheoecd.htm>)

Public perception is critical because it is a key component of the socio-political context, within which policy-makers operate. It can fundamentally compel or constrain political, economic and social action to address particular risks (Leiserowitz, 2007). Moreover, it was shown that risk perception studies have contributed to improve risk communication activities and to understand better public responses to certain hazards (Slovic, 1992). Policy-makers need to know what the public wants, thinks, or believes with the aim to design policies that will be supported or at least tolerated. For example, Leiserowitz (2006) claimed that public perceptions of climate change risks might be influential regarding national and international support or opposition to policies, such as legislation, regulations and treaties designed to lessen the harms of global change. On the other hand, scientists need to know how the public is likely to respond to climate change impacts or initiatives, because those responses can attenuate or amplify the impacts. Both groups need to understand the extent to which people's responses will differ across regions (Bord et al., 1998), especially those of vulnerable groups whose voices can be heard by including them in the science and by generating local interest (Eriksen et al., 2011).

The vast majority of climate change surveys have focused on concerns of the general public. These surveys usually reflect public opinions and have limitations for guiding policies because of the public's lack of knowledge, experience and interest in complex issues like climate change (Cameron, 2005; Ruddell et al., 2012). Similar surveys have not adequately investigated the perceptions of local experts, stakeholders or decision-makers regarding risk exposure in their jurisdictions, and work is particularly sparse on the potential for reducing risk associated with climate change in general (Mozumder et al., 2011).

Therefore, it is essential to understand local stakeholder's perceptions of climate change because the processes at the local level are crucial since local perceptions reflect local concerns (Byg & Salick, 2009; Combest-Friedman et al., 2012; Danielsen et al., 2005; Fatorić & Morén-Alegret 2013; Mubaya et al., 2012), they can influence global-level processes (Wilbanks & Kates, 1999) and complement global science (Haque & Etkin, 2012). Local knowledge and perceptions influence people's decisions regarding whether to act or not (Alessa et al., 2008). They can provide information about local conditions and redirect the foci of empirical studies to issues that have been overlooked by mainstream science (Kloprogge & van der Sluijs, 2006; van Aalst et al., 2008). Local perception may influence the organisation and implementation of effective strategies for

mitigation and adaptation that can reduce vulnerability to global and local climate change effects (Bryan et al., 2009; Grothmann & Patt; 2005; Kellens et al., 2013; Kittipongvises et al., 2011; Moser, 2009; Ruddell et al., 2012; Terpstra et al., 2009).

For instance, there is currently little information on experts, stakeholders, or decision-makers' perception about climate change issues in Mediterranean coastal areas. In particular, among the contributions made so far on these issues, one can highlight, for instance, the following: a few studies have analysed the perception of the hazards stemming from climate change in the coastal areas of Asia and Oceania (e.g. Combest-Friedman et al., 2012; Kuruppu & Liverman, 2011), the perception of flooding stemming from climate change in the coastal areas of Central and North America (e.g. Linnekamp et al., 2011; Mozumder et al., 2011) and the perception of adaptation to climate change in some coastal areas of Europe (e.g. Bormann et al., 2012; Tompkins et al., 2008). Hence, local perception and knowledge can make valuable contributions towards a better understanding of the climate change's impact on people's lives (Laidler, 2006; Kloprogge & van der Sluijs, 2006). Moreover, local stakeholders may have the knowledge and representative interest in developing effective environmental management or policies due to their strong local input (Hegarty, 1997; Kasemir et al., 2003; Mulcrone, 1993). Their perceptions also create a narrative that can be built upon or critiqued to develop an understanding of the relationship between climate change, place and people (Bardsley & Wiseman, 2012; Ogalleh et al., 2012). Nevertheless, some studies (e.g. Berkes et al., 2007; Byg & Salick, 2009) highlighted that local observations cannot replace scientific measurements, but stakeholder participation brings a wider range of knowledge to integrated management.

2.3.2 Stakeholder consultation and participation in decision-making processes regarding climate change

Public participation is becoming increasingly rooted in national and international environmental sector (e.g. Bormann et al., 2012; Edwards et al., 1997; Hagerman et al., 2010; Kasemir et al., 2003; Renn, 2006; Stojanovic & Barker 2008; Young et al., 2013), as decision-makers recognise the need to understand who is affected by the decisions and actions they take, and who has the power to influence their outcome, i.e. the stakeholders (Freeman, 1984). Particularly, since the 1980s, Brundtland report and Agenda 21 have resulted in a trend towards greater levels of public involvement and

multi-level planning and management of natural resources (Edwards et al., 1997; Young et al., 2013). The main arguments for stakeholders' importance in natural resource management and planning have been strengthening democratic cultures and processes (Webler & Renn, 1995), bringing additional knowledge and values into decision-making in order to make better decisions, providing greater legitimacy (Renn, 2006) and reducing the intensity of conflicts (Young et al., 2013).

Traditionally, environmental planning and management have often used top-down approach, which is primarily a domain of government agencies (van Aalst et al, 2008). It assumes that once a policy is formulated it automatically has a beneficial outcome on the ground. This neglects the necessary integration of perceptions, knowledge, decision-making and responses to policies by stakeholders and communities (Lemon et al., 1999). However, this approach can create problems, which undermine effective implementation of policies (Edwards et al., 1997). According to Edwards et al. (1997), lack of stakeholder consultation in the planning and management process creates suspicion and hostility amongst stakeholders. This fosters conflict rather than cooperation. Similarly, Hegarty (1997) found that top-down approaches might result in confusion, conflict and a lack of understanding between the parties involved.

The opposite of the top-down approach is a bottom-up approach for environmental planning and management. This approach is based on a participatory process, i.e. including provision for the formulation and implementation of plans with the full and active participation of communities (Bhave et al., 2013; Edwards et al., 1997, van Aalst et al., 2008) which can develop social capital and community cohesion, improve service delivery and meet local needs (Taylor, 2007). In this sense, Hegarty (1997) claimed that there it should be crucial to start with what people know and work from there in a coordinated and integrated manner. It is only then that sustainable development can be developed. Further, it is reported that effective management comes about when the context of the local environment is clearly understood (Stojanovic et al., 2004). Studies on the value of participation in management processes suggest that communities that participate in the formation of planning and management are more likely to support their implementation (Stojanovic et al., 2004). Similarly, some other studies (e.g. Barnett & Adger, 2007; Dolan & Walker, 2006; Moser, 2009; Munang et al., 2013; Paavola & Adger, 2006) showed that both scientific views and institutional governance of climate change should be framed in a local context. In this way, research is grounded at the community-level and involves local knowledge as well as cultural

interpretations of the environment. This allows for better examination of how global changes may be expressed and interpreted locally (Riedlinger & Berkes, 2001).

This thesis adds to this body of research. I also assume that adaptation to climate change is a local process where it is crucial to consider the integration of scientific knowledge with stakeholders' perception and knowledge for the implementation of adaptation policy. Furthermore, local studies require a major analysis of climate variability and change and socio-economic analysis than global predictions about these issues.

CHAPTER 3
METHODOLOGICAL FRAMEWORK, METHODS AND STUDY
AREA

In the previous chapter, the theoretical background was presented by describing, explaining and justifying the approaches of vulnerability and adaptation to climate change and stakeholders' perception and participation in decision-making. This chapter moves on to explain the methodological framework and approach and research methods and procedure followed to enable me to address four research aims. It begins with informing how my professional profile fits into this research and present an outline of the methodological framework and approach. The chapter then discusses the method of data collection utilised within the thesis and provides an overview of the data analysis method. It concludes with an essential description of the study area, focusing on the reason for choosing this area and some of its main environmental, economic and population characteristics.

Before proceeding with the presentation of the applied methodological framework, it would seem appropriate to offer some information about my personal and professional background. Here, I recognise that is particularly important to consider a researcher's positionality in the research process, i.e. how his demographic factors (e.g. age, race, gender, ethnicity) and biography can affect, for instance, the choice of research topic and study area (location), methods of research data (e.g. fieldwork) and providing research results (England, 1994; Hastrup, 1992).

Moving on with my personal and professional background, my fascination with the Earth appeared in the early childhood years with the first geographic atlas that my parents bought me in order to show me a diversity of our family roots. Definitely, beside the location and typical characteristics such as climate of the few countries from where my family comes from, my passion for geography was born too. However, my formative intellectual years have started on the coast of the Adriatic Sea during the early- to mid-2000s, where my interest in climate change phenomenon was born. My first research experience was as an undergraduate student at the University of Primorska, examining the rise of the sea level in North Adriatic Sea as an indicator of climate change (see Fatorić, 2009). Initially trained in quantitative approaches with a strong emphasis on oceanography and climatology, my master's degree at the Institute for Environmental Science and Technology (ICTA) was just opposite (mainly qualitative analyses and fieldwork with the stakeholders). My master's thesis examined climate change vulnerability and adaptation in the case of a natural protected area – the Ebro Delta (see Fatorić & Chelleri, 2012) which is documented as one of the most vulnerable areas in Mediterranean basin in general, and in Spain in particular. After my

master's degree, I have reached a Ph.D. studies programme at the Department of Geography at the UAB and I have maintained my interest and knowledge in crossing both natural and social science disciplines and qualitative and quantitative approaches, so I have been working during my Ph.D. project combining environmental and social disciplines mainstreaming the climate change issue. This time I have focused on another natural protected area along the Mediterranean Sea – Aiguamolls de l'Empordà which is also likely to be vulnerable to climate change effects. Furthermore, it is worth mentioning that during my Ph.D. project, in the framework of R+D project titled “Immigrants’ Integration and the Role of a Diversity of Organizations in Achieving Sustainable Small Town and Rural Areas”⁶ funded by the Spanish Ministry for Research and Innovation, I also conducted fieldworks in Greece – Kotychi-Strofyliia wetland (Western Peloponnese) and South Australia – Lower Murray River, Alexandrina Lake and Encounter Bay area (south-east of South Australia). The aim of these fieldworks was to explore key stakeholders’ perceptions and knowledge regarding climate change, sustainability and migration issues and to provide an international comparison (in the Mediterranean climatic zone) of these two areas with Aiguamolls de l'Empordà. Moreover, together with my thesis director Dr. Ricard Morén-Alegreat and other colleagues several scientific articles have been done and sent to peer-review. All in all, during my Ph.D. research, I have been able to foster my intellectual curiosity in many aspects of environmental science by working in interdisciplinary contexts and combining the understanding of the relationships between physical and social systems, methodological diversity and approaches.

Moving on, this thesis combined the methodological framework and approach plus two methods that are tackled in the following pages:

- Methodological framework and approach,
- Method of data collection,
- Method of data analysis.

⁶ For more information about the project, see http://geografia.uab.es/migracions/eng/Project_Immigrants-Integration.htm

3.1 Methodological framework and approach

This thesis builds on the definitions of climate change vulnerability and adaptation as specified by the IPCC (2007b) and the concept of Smit & Wandel (2006), who provided an assessment framework to contribute to practical applications of the IPCC definitions.

The aim of this conceptual framework by Smit & Wandel (2006) was not to score adaptation or measure relative vulnerability and its specific determinants (i.e. exposure, sensitivity, adaptive capacity), but rather, the focus was to identify these empirically from the communities and document the ways in which they experienced changing climate⁷. Furthermore, this thesis focused on conditions that were important to the communities rather than those assumed by the researcher or for which data were readily available. It employed the perception and knowledge of communities to characterise vulnerability and to identify and document adaptation measures, which can be integrated. Specifically, this thesis looked closest at applications to socio-economic system. Even though I acknowledge that this system depends on natural system, I did not review applications relating to the vulnerability and adaptation of natural system directly. In this context, framework included broader changes (e.g. demographic, socio-economic, environmental processes) as well as climate effects and risks.

For this thesis I implemented a participatory vulnerability assessment approach (Figure 2), based on such work as Adger, 1999; Ford et al., 2006; Kelly & Adger, 2000; Ogalleh et al., 2012. Hence, my role as the principal researcher was to integrate involvement of stakeholders with assessment of current and possible future vulnerability and further respond to these conditions by adapting processes.

Furthermore, this thesis is also an interdisciplinary-based research but carried out from geography. By interdisciplinary I mean “a mode of research by teams or individuals that integrate information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialised knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice” (National Academy of Sciences, 2004: 26). In particular, I integrated documental and statistical data (e.g. climatology,

⁷ Moreover, while analysing vulnerability, I took into account also the study of Yohe & Tol (2002) who demonstrated that many of the variables cannot be quantified and many of the component functions can only be qualitatively described.

ecology, human geography and sociology), methodology and methods from across the social and natural sciences. I also collaborated with colleagues in the other fields in which I am less well-skilled (hydrology, oceanography, coastal engineering, etc.) to raise the level of analyses and expertise beyond what I could do on my own.

This thesis while challenging, evolved in various phases over the three years of Ph.D. research, with each phase occurring over the span of approximately one year.

I began the research in 2010/2011 with two broad questions about the natural and socio-economic systems' characteristics and climate variability in the study area. This phase therefore, identified patterns of local climate variability and/or change and systems' characteristics in order to create the appropriate context to discuss later the broader issues of vulnerability and adaptation to climate change on the local level. These questions were:

- Did meteorological, hydrological and marine variables change over the past 42-years in Aiguamolls de l'Empordà?
- What are environmental, economic and population characteristics that could increase vulnerability and which ones are most important for reducing the vulnerability to climate change?

Through the evolution of the research, in the next 2011/2012 I tackled the other two questions that form the baseline for the vulnerability assessment:

- Are stakeholders aware of the climate change? Do they perceive any effects of climate change?
- Do documental and statistical data show natural and socio-economic systems' vulnerability to climate change?

Here, it is worth mentioning that during my fieldworks I gained great acceptance among the interviewed stakeholders (comments on my Ph.D. research such as “much needed”, “very useful”, “privileged to be funded for doing it” and “brave”) despite the frequent curiosity of where I am from and how come I am tackling this kind of research.

Finally, in the last year 2012/2013 I examined the adaptation to climate change from a perspective that included the stakeholders' perception and knowledge in an effort to analyse the most suitable measures. The research questions were:

- What measures can be implemented to support climate change adaptation and reduce vulnerability?
- How is outmigration perceived by the key stakeholders? Can it be an acceptable option for adaptation?

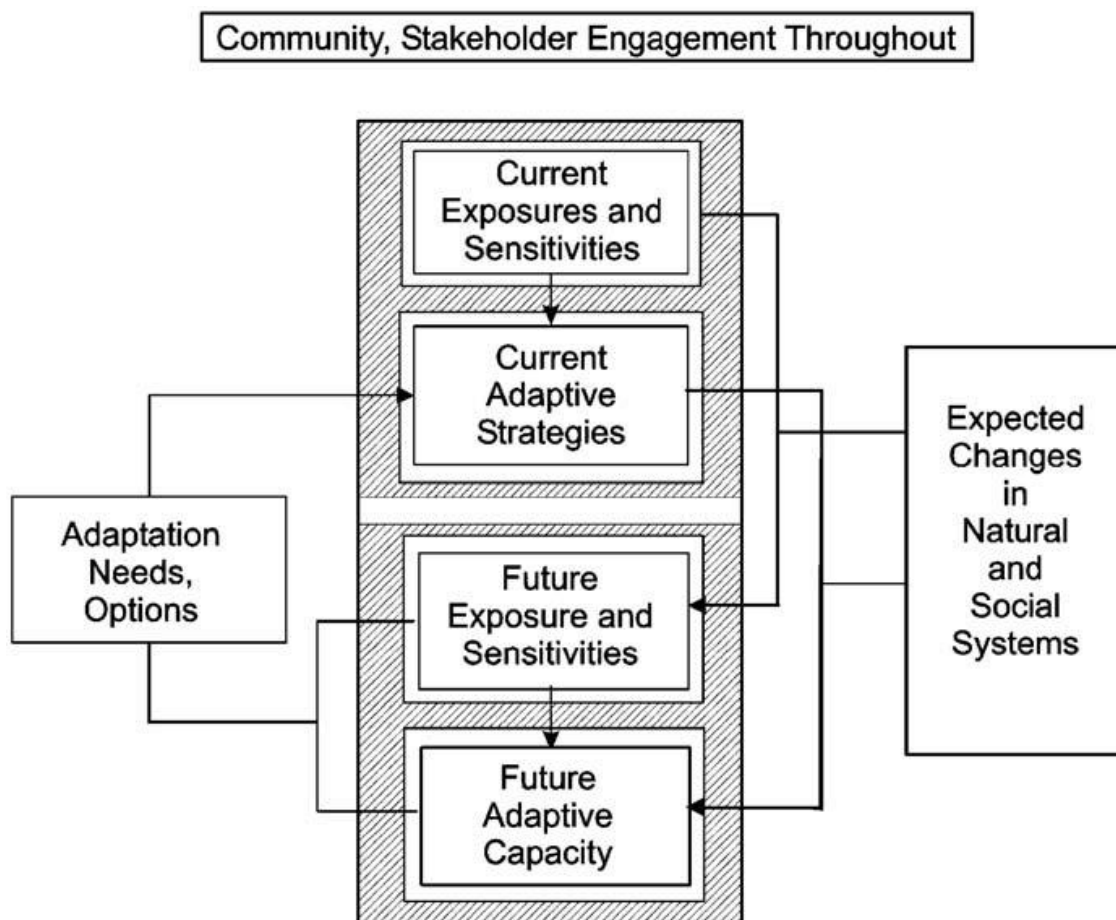


Figure 2. Framework for vulnerability assessment. Source: Smit & Wandel, 2006.

3.2 Method of data collection

The following subchapter provides an explanation of the quantitative and qualitative data collection methods utilised within the thesis: statistical data collection, documental data collection and semi-structured interviews.

3.2.1 Statistical data collection

To investigate climate variability or change in the study area, different variables (meteorological, hydrological and marine) were selected assuming that they may affect vulnerability of socio-economic and natural system in Aiguamolls de l'Empordà. Furthermore, the selection of these three types of variables corresponds to the analyses in the IPCC Forth Assessment Report (IPCC, 2007a).

The analysis of the meteorological and marine variables is based on data for the measuring station of Estartit, which is located approximately 17 km from Escala (the most southern municipality of Aiguamolls de l'Empordà area). Estartit has the longest (since 1971) and most continuous meteorological and marine records, including air temperature, precipitation, evaporation, sea temperatures, sea storms, wind velocity and sea level (these last two variables only since 1990). The classical period used to measure climate variability is thirty years (WMO, 2012). However, the other useful measuring stations in the study area, Sant Pere Pescador and Roses, are likely to be unsuitable for long-term comparisons and analyses due to their short period of records (1990 and 1997, respectively). The sources of meteorological and marine data are Meteorological Service of Catalonia (SMC) and Meteo Estartit.

Furthermore, the hydrological record (including flows of Muga and Fluvià rivers) is used for the period 1971–2011. Muga has a hydro-meteorological monitoring network consisting of four river gauging stations, and Fluvià of two river gauging stations, which are effectively managed by the Catalan Water Agency (ACA)⁸.

All these data were obtained after submitting a written request to the SMC, ACA and Meteo Estartit and further analysed by me (see Chapter 4).

⁸ Flow data for the gauging stations in the inland basins of Catalonia, see http://aca-web.gencat.cat/aca/appmanager/aca/aca?_nfpb=true&_pageLabel=P1222154461208201295903

Furthermore, future climate change projections for the study area (Barrera-Escoda & Cunillera, 2011) are provided using data from numerical model ECHAM5/MPI-OM⁹ (atmosphere-ocean global coupled model) for the medium-term period 2011–2050. These variables were calculated by the MM5+EH5OM simulation at 15 km for the control period 1971–2000 and considering two different GHG emission scenarios (A2 and B1)¹⁰ (Barrera-Escoda & Cunillera, 2011). This set of scenarios spans two of the IPCC scenario ranges, with the B1 being close to the low end of the range (CO₂ concentration of about 550 ppm by 2100) and the A2 to the high end of the range (CO₂ concentration of about 850 ppm by 2100) (Giorgi & Lionello, 2008). However, it must be understood that these projections give us approximate values: it would be wrong to assume that the numerical model can provide perfect results (Sumner et al., 2003).

Likewise, the population and socio-economic analyses (i.e. total number of population by municipality, age group, nationality, GDP, economic activities, water consumption, labour) were based on statistical data, which were obtained from the National Institute of Statistics of Catalonia (IDESCAT) and National Statistics Institute (INE).

3.2.2 Documental data collection

In order to facilitate the collection of data and analysis of results, an area that is a part of the Natural Park Aiguamolls de l'Empordà was selected for the period spanning back to the late 1960s, which marks the construction of the Boadella dam along the Muga. Significant work was involved in checking and validating all the data sources in order to have an accurate database.

An extensive literature search was conducted on the electronic online database ScienceDirect (www.sciencedirect.com) and Scopus (www.scopus.com). These two

⁹ ECHAM is an atmospheric general circulation model, developed at the Max Planck Institute for Meteorology (see: <http://www.mpimet.mpg.de/en/science/models/echam.html>).

¹⁰ The A2 scenario 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 global population. Economic development is primarily regionally oriented and per capita economic growth and technological change are more fragmented and slower than in other scenarios. The B1 scenario describes a convergent world with the global population that peaks in the mid-century and declines thereafter, with rapid changes 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 (Nakicenovic et al., 2000).

were the main information sources of qualitative (and other quantitative) published scientific studies. ScienceDirect and Scopus are well-regarded and some of the most powerful, current and widely used scientific databases which provide access to multidisciplinary coverage of more than millions of journal articles and book chapters. A keyword search was performed by using the English key topic terms: “Aiguamolls”, “climate change”, “climate variability”, “vulnerability”, “adaptation”, “stakeholder”, “environmental migration”. This data selection included empirical studies and theoretical studies to get a complete assessment of the existing knowledge on climate change vulnerability, adaptation, stakeholders’ perceptions, climate change and variability, environmental migration and characteristics of the study area.

Furthermore, data available from technical reports, local available material (pamphlets and maps) and national and Catalan media sources were collected and studied. Vulnerability and adaptive assessment were identified also by an exhaustive study of the leading regional (Alt Empordà countywide) weekly newspapers *Hora Nova*¹¹ and *Empordà*¹² from 2008 onwards, when a digital version of two newspapers has been available. Thus, the keyword searched in both newspapers was the key topic term “Aiguamolls”.

Documental data selection was limited on English, Spanish and Catalan written materials.

3.2.3 *Semi-structured interviews*

Semi-structured interviews were chosen as the main method of data collection as they were considered one of the most effective methods of collecting local perception and knowledge from respondents on climate change issues (e.g. Baker et al., 2012; Biesbroek et al., 2011; Byg & Salick, 2009; Fatorić & Morén-Alegret, 2013; Mortreux & Barnett, 2009; Mustelin et al., 2010).

The process of semi-structured interviews included:

- ***Identifying stakeholders:***

The key data used in this thesis consists of answers to interviews provided by stakeholders involved in (or responsible for) social, political, economic and

¹¹ See <http://www.horanova.cat>

¹² See <http://www.emporda.info>

environmental processes in nine municipalities with some surface within the Natural Park Aiguamolls de l'Empordà: Armentera, Castelló d'Empúries, Escala, Palau-Saverdera, Pau, Pedret i Marzà, Peralada, Roses and Sant Pere Pescador.

By “stakeholder”, following Grimble & Wellard (1997), I mean individuals who affect (determine) a decision or action or those who are affected by this decision or action.

Stakeholders in this thesis were selected to include a broad spectrum of local interests and knowledge regarding climate change vulnerability of Aiguamolls de l'Empordà and the main socio-environmental conflicts. The selection process of stakeholders considered this variety and was informed by previous knowledge of the area. As it has been suggested by Renn (2006), it is crucial that all relevant value groups are represented and that the value clusters are comprehensive and include economic, political, social, cultural and religious values. Moreover, the stakeholder selection process is based on both those who may be affected by climate change effects and those who could influence policies in the study area. In this sense, the selection done when researching in Aiguamolls de l'Empordà area provided valuable insights into the overall functioning of the study area.

Concretely, forty-five semi-structured interviews with stakeholders were conducted from July 2011 to January 2013, divided into eight groups: six environmental actors (referred to as ENA in later quotes), six public administration actors (PAA), six touristic actors (TA), six economic actors (ECA), five agricultural-farming actors (AFA), six industrial actors (IA), four research actors (RA) and six cultural actors (CA). These groups comprised stakeholders such as employees of local tourist information centres, touristic companies, consulting companies, employees of provincial and municipal institutes, employees of Catalan and local public administration, farmers and peasants, engineers, members of environmental groups and NGOs, members of trade unions, immigrants' organisations and researchers specialising in the area and its conflicts.

In this thesis, I do not claim that the number of stakeholders is fully representative of the wider community, rather the focus is given to ensure that a wide range of stakeholders from the local, regional and national level were identified and engaged into the research project upon which this thesis is based. Moreover, a number of forty-five interviewees was sufficient to achieve saturation of information. By saturation, I mean

that additional interviews did not yield new information, perspectives, perceptions and knowledge within the context of the issues being discussed (Charmaz, 2006).

Among the interviewed stakeholders, there was a larger proportion of relatively older stakeholders (69% aged between 41 and 69 years old) in order to capture information related to historical trends in climate. It was considered that they would be able to remember as far back as they could and provide vivid perceptions on climate change. In the same context, younger stakeholders (31% aged between 20 and 40 years old) were included into the sample in order to verify or put into contrast some of the recent climate trends suggested by older stakeholders and to learn about their opinions about the future.

Among the interviewed stakeholders, there were 12 (27%) female and 33 (73%) male stakeholders (see Table 2) although I initially aimed to include approximately equal gender distribution. This distribution is consistent with some other studies noting that female participation in the public realm is less frequent than male participation, (e.g. Bhave et al., 2013; Bradford et al., 2012; Fatorić et al., forthcoming; Kuruppu & Liverman, 2011;).

Moreover, stakeholders were chosen also by their nationality, differentiating Spanish (76%) and foreigners (24%) (Table 2). This proportion roughly corresponds to the average percentage of Spanish residents and foreigners for the observed period 1991–2012 (73% and 27%, respectively) in the study area.

Table 2. Number of interviewed stakeholders by gender and age and by gender and nationality

	Male	Female	<i>Total</i>		Male	Female	<i>Total</i>
Age 0-40	8	6	<i>14</i>	Spanish	26	8	<i>34</i>
Age 41-69	25	6	<i>31</i>	Foreigners	7	4	<i>11</i>
<i>Total</i>	<i>33</i>	<i>12</i>	<i>45</i>	<i>Total</i>	<i>33</i>	<i>12</i>	<i>45</i>

Source: Author 2013.

- ***Conducting a dialogue process:***

Interviews with the stakeholders, which were conducted as qualitative conversations (e.g. Nichols, 1991; Yin, 2003), allowed me to gather structured data and efficiently compare the answers. The stakeholders were asked open-ended questions or

comments were expressed about their opinion on climate change and sustainability. Moreover, this technique allows the research of various themes and ideas rather than only relying on concepts and questions defined prior to the interview.

The interviews were roughly organised around various thematic areas and categories (Table 3), reflecting the rationale of the thesis.

Firstly, they were asked what in their opinion climate change was, and whether it has been occurring due to natural or anthropogenic causes over the last two decades. Secondly, they were asked to express if they observed any climate change effects in the study area and if so, what the nature of the impacts was. They were then asked about the importance and effects of the future sea level rise, and about current and possible future impacts of climate change on their economic and/or social activity(s).

The stakeholders were then asked about their awareness of sustainable development in the study area and had to express if the municipalities of study area are sustainable. Furthermore, they were asked about their level of understanding of measures of climate change adaptation and to identify some of the main constraints on implementing technical solutions. Finally, they were explicitly required to express their perceptions attitudes on a possible outmigration or abandonment of the study area.

Some interviews were conducted indoors (in offices or other premises) while others took place outdoors with the stakeholders showing some spots to the researcher and commenting in situ on lands that may be affected by environmental and/or climate change (i.e. so-called walking interviews).

Additionally, independent direct observation was made and photographs were taken, which are considered as helpful complementary documents for checking stakeholders' points of view and statistical data on some spots.

The interviews were conducted in Catalan, Spanish and English, and they varied in length from roughly 20 to 90 minutes.

Moreover, all these interviews were digitally audio-recorded and transcribed for the analyses.

Table 3. Thematic areas and categories used in the interviews

Thematic area	Category
<i>Climate change</i>	Climate change awareness Perception about the cause of climate change Perceived past and present climate change effects in the study area Sea level rise in the study area during the 21 st century Climate change impacts on stakeholders' work activity
<i>Sustainability</i>	Sustainable development awareness Perception about the study area's past and present sustainability
<i>Adaptation and mitigation</i>	Adaptation and mitigation awareness Measures for adaptation Perception of outmigration

Source: Author 2011.

3.3 Method of data analysis

This subchapter gives an overview of the method used for the analyses of statistical and documental data and data from semi-structured interviews.

3.3.1 Statistical data analysis

Meteorological, hydrological and marine monthly and annual parameters were determined from daily or monthly records and were used to produce graphs to explain observed patterns and variability in meteorological, hydrological and marine variables that were observed during the 1971–2012 and 1990–2012 period in the study area. Coefficient of Determination (r^2) of the linear regression was also calculated and shown in the graphs.

Simple descriptive statistics were applied to the analyses of population and socio-economic data in the study area for the period of 1981–2012. The results were represented in the form of tables and graphs. These analyses provided sufficient information to establish an overall picture of the past and current state and

environmental and socio-economic characteristics of the study area, especially those that may increase vulnerability to climate change effects.

3.3.2 Documental data analysis

Since the mid-1980s, studies that focus on social, physical, economic and environmental characteristics of Aiguamolls de l'Empordà has been emerged. The majority of the analysed studies (about three-quarters) were from the period 2001–2012, much fewer studies (about one-fourth) were from the period 1991–2000 and only a few studies were from the period 1981–1990.

Furthermore, roughly half of the available studies were based on physical characteristics of Aiguamolls de l'Empordà and the other half on social characteristics. The greater part of the studies that was used in this thesis is focused on issues of land use change as the causal factor in socio-environmental changes and conflicts. Much of the studies were also focused on the debate on the environmental management (flooding, water supply and demand, wetland and ecosystems conservation), on the impacts of tourism, agriculture, urban sprawl, and on the seismology. Only few studies addressed the meteorological or hydrological variables. Therefore, I argue that given the lack of studies addressing climate change vulnerability in Aiguamolls de l'Empordà area, it is useful to learn from the studies on these issues from other territories.

In addition, studies on climate change and its effects, climate change vulnerability, adaptation to climate change and environmental migration have increased rapidly after 2001 where more than three-quarter of analysed studies were published in the period 2001–2013. This is in line with the observed scientific progress on climate change issues (IPCC, 2007a, 2007b, 2013). Likewise, less than one-quarter of the studies were published in the period 1991–2000 and 1981–1990.

These analysed studies showed a variety of analytical scales, but most of them were focused on regional and (supra) national level. Here, both the southern hemisphere and developing countries were overrepresented in the literature.

Furthermore, the majority (about two-thirds) of the analysed studies were empirical and less were theoretical studies with conceptual frameworks¹³. The majority of the empirical studies used semi-structured interviews, questionnaires and workshops as

¹³ Conceptual frameworks are analytical instruments used by researchers to connect the conceptual ideas and guide scientific inquiry (Biesbroek et al., 2013).

primary data sources. Here, regarding the target group, roughly half of the studies aimed at analysing authorities and decision-makers, while about one-third analysed specific target group such as stakeholders. Other studies (about one-quarter) simply addressed the general public.

This analysis together with statistical and semi-structured interview analyses provided sufficient information to write up a background report with an overall picture of the following issues:

- The past and current state of the physical, natural and socio-economic systems in the study area;
- Vulnerability assessment;
- Adaptation to climate change in the study area.

3.3.3 *Analysis of semi-structured interviews*

The information gathered in the interviews is qualitatively analysed, informed by the three qualitative analysis objectives set out by Ragin (1994):

- Give voice to key actors;
- Interpret significant phenomena;
- Propose a theory.

In my thesis, I focus on achieving the first two objectives. However, in the future research it would be interesting to widen up this analysis and fully achieve the third objective by proposing a new theoretical perspective.

Interview data were analysed using counting techniques and a process of categorising, linking and comparing to explore patterns and trends among different issues and groups of stakeholders (e.g. Nichols, 1991; Yin, 2003). Furthermore, direct quotes were also used to explain, support and clarify important issues observed by the stakeholders and to illustrate common themes and differences between groups of stakeholders. Participation in the interviews was anonymous and care was taken to remove identifying information in the presentation of results. Therefore, in each quote, details on the main sector of activity, gender (female/male) and age (years old) of the

interviewees are provided. Direct quotes were translated into English from the original language. Thus, an effort was made to shed light on the contents of current perceptions and knowledge about climate change issues.

It is important to note that this analysis highlights issues that deserve special consideration and difficulties, which stakeholders are facing, identify good practices, frame and facilitate the implementation of future projects and decisions, and assess the feasibility of future policy development. Moreover, the stakeholders may represent a dialogue among affected communities and may contribute significantly to understand the current vulnerability and define possible measures for climate change adaptation in order to contribute to practical adaptation initiatives in the study area.

3.4 Description of the study area

The case study of this thesis is natural protected area Aiguamolls de l'Empordà. Before proceeding with a detailed discussion on the characteristics of Aiguamolls de l'Empordà, it would be appropriate to introduce some reasons for the selection of this study area:

- The commonalities with the Ebro Delta that was the case study of my prior master's thesis (see Chapter 3): (1) both areas are natural protected areas by Ramsar Convention on Wetlands; (2) both areas lie along the Mediterranean Sea and comprise coastal wetlands with an important hydrographic network; (3) both areas are placed in Catalonia; (4) in both areas a significant part of the economy is tourism, irrigated agriculture and fishing; (5) both areas are far away from the large cities.
- Aiguamolls de l'Empordà area has rarely been a focus of climate variability and even rarer of climate change research. In contrast, the Ebro Delta has been a subject of large topical interest and has been one of the key case studies in environmental and engineering research in Spain.
- Aiguamolls de l'Empordà population is very diverse, including a significant immigrant population that has increased in recent decades what makes it demographically different from other Spanish areas with similar geomorphologic characteristics. This immigration is both international and internal and it includes people from many geographical and cultural

backgrounds. The foreign immigration rate in Aiguamolls de l'Empordà area is clearly above the Catalan, Spanish and European averages¹⁴.

- I maintained and continue with my interest of researching climate change vulnerability and adaptation in natural protected areas also due to Dr. Ricard Morén-Alegret's R+D project "Immigrants' Integration and the Role of a Diversity of Organizations in Achieving Sustainable Small Town and Rural Areas" funded by the Spanish Ministry for Research and Innovation. My Ph.D. research project was part of the umbrella R+D project, together with three other Ph.D. research projects carried out by other GRM doctoral students in Alt Empordà.

3.4.1 The main environmental characteristics of Aiguamolls de l'Empordà

Alt Empordà is a county located in the north-eastern part of the Iberian Peninsula, which covers 1358 km² and, in 2012, had a population of 141,517 registered residents (IDESCAT, 2013a). It is surrounded to the east by the Mediterranean Sea, to the north by France, to the west by Garrotxa county and to the south by Gironès and Baix Empordà counties (Badia et al., 2011). This county is an example of settlement in an agro-forestry mosaic associated with tourism development. It has contrasting physiography ranging from the low, sandy coastline to Pyrenean peaks of over 1000 m high which landscape is a mosaic of dry and irrigated agriculture mixed with forested areas, tourist and residential developments and small towns (Badia et al., 2011; Pavón et al., 2003). The climate is Mediterranean, with high temperatures in summer and mild winters (Badia et al., 2011). One particularity is the relatively usual presence of the north wind or *tramuntana* (Gósalbez et al., 1994; Saura-Mas & Lloret, 2005).

Alt Empordà coastal plain is mainly composed by the so-called Aiguamolls de l'Empordà and embodies a mosaic of very different environments characterised by distinct natural and historical trends. Most of the physical setting is the product of the interaction between structural features (Empordà is a tectonic plain linked to the Pyrenees and dating back to the Tertiary period), the sediment load carried mainly by Fluvià and Muga rivers and coastal processes (Bach, 1989).

¹⁴ In 2012 foreign population: Aiguamolls de l'Empordà 37%, Catalonia 16%, Spain 12%, EU-27 4,1% (Eurostat, 2013; IDESCAT, 2013a, 2013f; INE, 2013a)

Aiguamolls de l'Empordà is situated between municipalities of Roses and Escala (Figure 3) and is the second most important wetland area in Catalonia, after the Ebro Delta (Saurí et al., 2000). In 1983, the Government of Catalonia proclaimed this area a Natural Park Aiguamolls de l'Empordà and created a first protected area on Costa Brava (Ribas Palom, 2006; Romagosa Casals, 2008). Here, after seven years long and intense defence campaign and social protest successfully prevented a construction of a large marina and urbanised centre called *Port Llevant* between the river mouths of Fluvià and Muga¹⁵. The implementation of the planned project would have meant the destruction of the littoral marshland and the spread of urban development along almost the entire coastline of Aiguamolls de l'Empordà (Pavón et al., 2003; Romagosa Casals, 2001).

With the establishment of the Natural Park in 1983, the protected area first occupied 4824 ha and in 2006 with the approval of the new demarcation passed by the Catalan government within the Plan for Areas of Natural Interest (PEIN), the area was enlarged to 4973 ha of land with 5857 ha corresponding to the marine area adjacent to the park. The presence of the residential marina and urban centre of Empuriabrava divides the Natural Park in two parts, the north and south of this tourist urbanisation (Romagosa Casals, 2008) (Figure 3). In 2010, the Catalan Ministry of Territory and Sustainability (DTS)¹⁶ proposed a new plan to enlarge the Natural Park. This new plan was designed by the previous centre-left wing government and aimed to protect a total area of 7277 ha of land, 46% more than is currently protected. In doing so, it would protect peripheral zone of the park, which acts as biological corridor, regulate the park conservation and public use, and establish new recreation activities (Empordà, 2010a; Hora Nova, 2010b). Here, especially farmers showed disagreement with the park enlargement opining that the area has been already sufficiently protected by other environmental laws like Natura 2000 (Empordà, 2010c). Since then, the new plan has not yet been approved¹⁷.

¹⁵ The late 1970s and early 1980s was a period of political change from dictatorship to liberal democracy in Catalonia and Spain as a whole and it had several implications at the local level.

¹⁶ Previously named as the Catalan Ministry of Environment and Housing (DMAH) (see www.gencat.cat/territori)

¹⁷ There were Catalan Parliament elections in late 2010 and posterior centre-right wing government with other priorities has been in power.

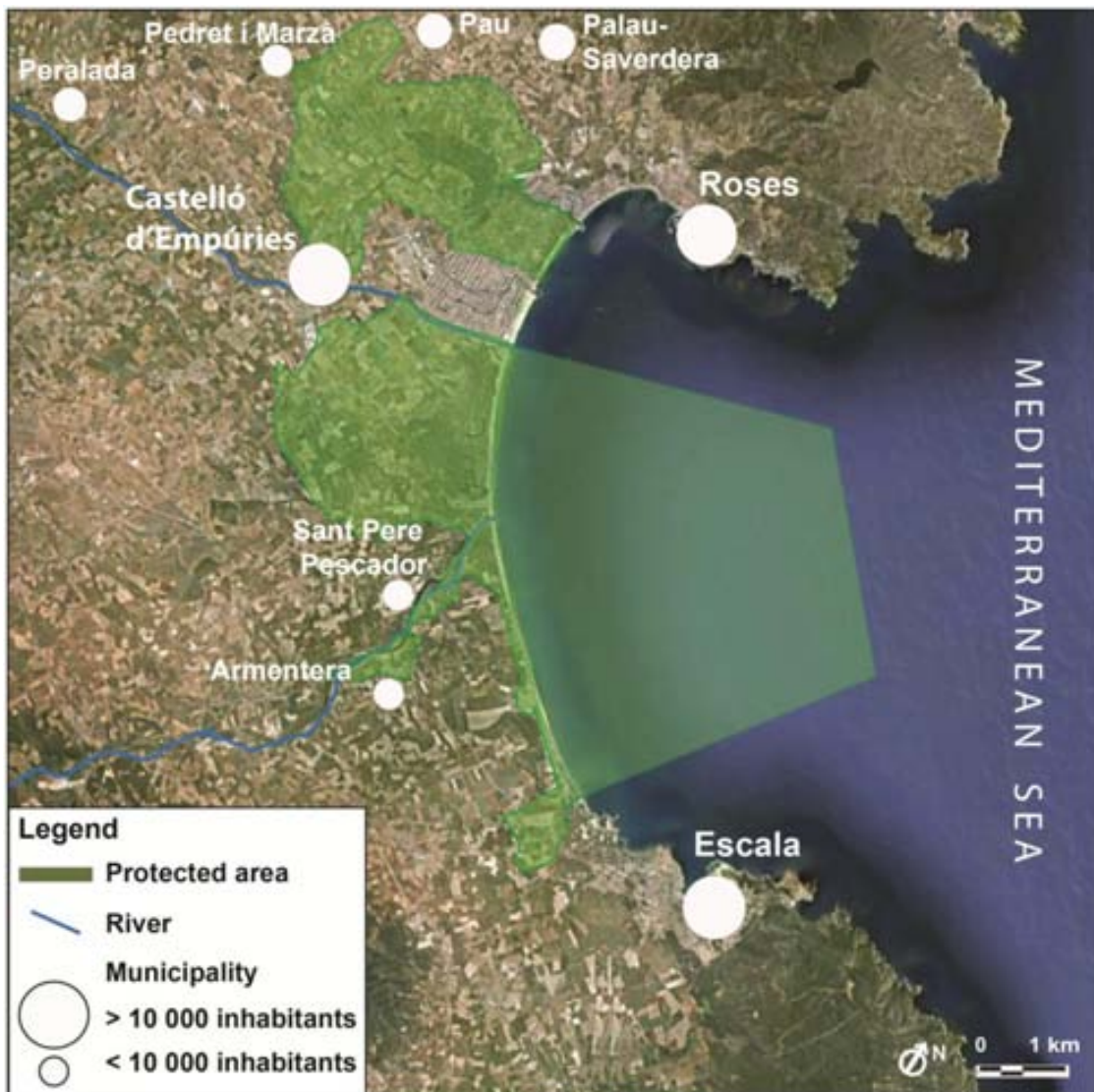


Figure 3. The map of the locations of the nine municipalities of Aiguamolls de l'Empordà and the natural protected area. Source from author, 2011.

Aiguamolls de l'Empordà's territory is composed of:

- Natural areas and water bodies: forests, grassfields, marshlands, coastal lagoons, beaches, dunes, inland freshwater ponds, rivers;
- Cultivated and agricultural areas: pasturelands and cropfields;
- Urbanised areas: touristic centres and small towns (Figure 4).

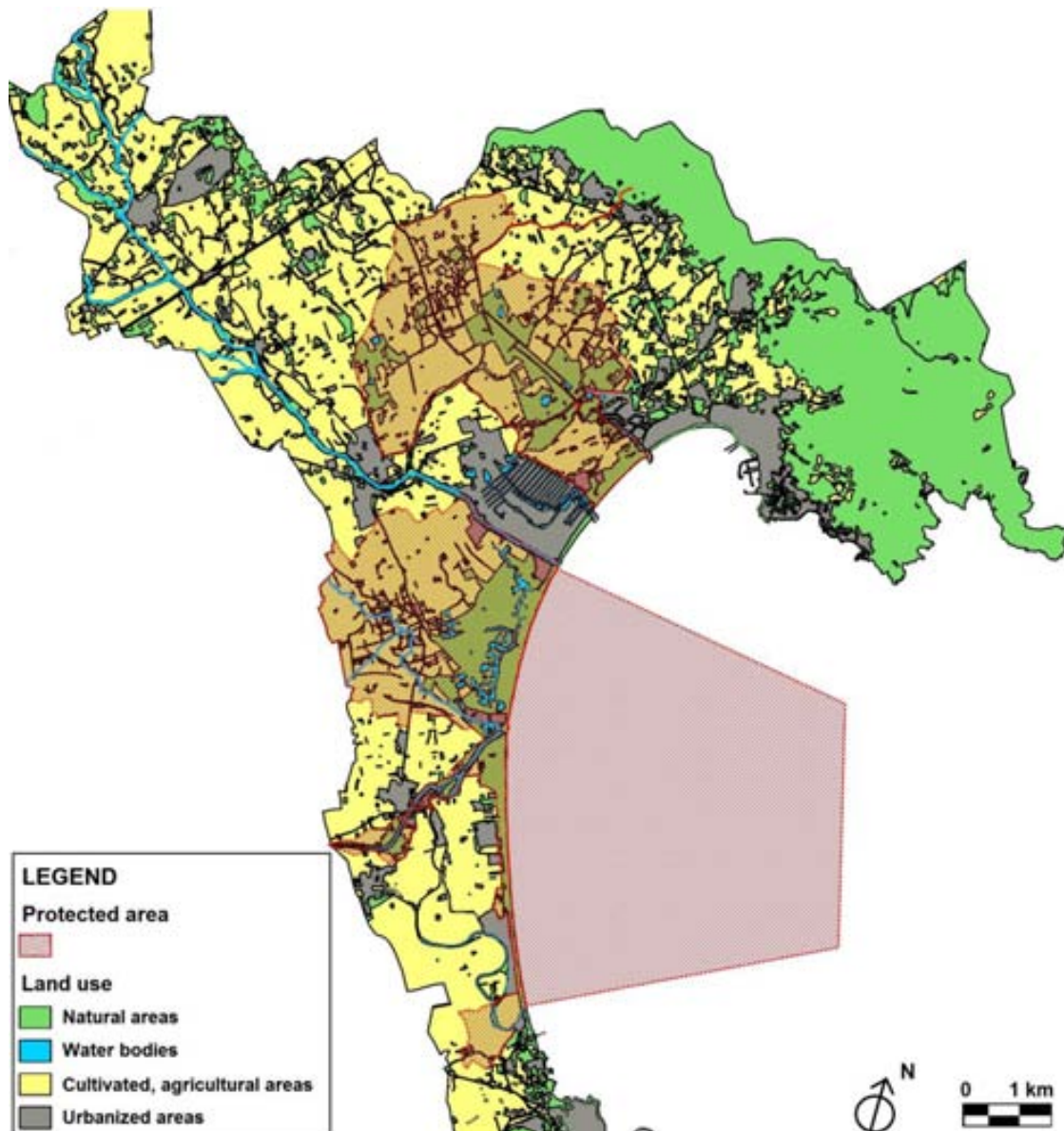


Figure 4. The map of a land use in nine municipalities of Aiguamolls de l'Empordà and the natural protected area. Source: Author from Centre for Ecological Research and Forestry Applications, CREAM (2013).

Furthermore, regarding geological characteristics, three sedimentary environments can be differentiated in this area:

- Fluvial environment: located inland on higher ground providing soils of high agricultural value;
- Lacustrine environment: formed by lagoons with waters of variable salinity and seasonally flooded soils of high organic content;

- Coastal environment: along the coastline with dunes and sandy coastal bars (Saurí et al., 1995; Serra Ruiz, 2006).

The hydrographic network of Aiguamolls de l'Empordà comprises two relatively large rivers with headwaters in the Pyrenees: Muga on the north and Fluvià on the south.

Muga drains the north part of the Alt Empordà, it originates in the Muga plain (Garrotxa county) and empties into the Gulf of Roses. The drainage area of the 65 km long Muga is 854 km² and its average annual water discharge at the river gauging stations Castelló d'Empúries and Boadella was 5.2 m³/s in 2011 (ACA, 2012). It is regulated by the Boadella dam, which has a capacity of 62 hm³ and was built in 1968 (Plana Castellví, 2004) for various purposes, such as the controlling of frequent river floods, the supply of drinking water mainly for the towns of Figueres, Roses and Castelló d'Empúries, crop irrigation and electricity production (Ribas Palom, 2006; Serra Ruiz, 2006).

Fluvià river originates in Garrotxa county, passes through Alt Empordà county almost in its final stretch and flows into the south part of Aiguamolls de l'Empordà (Montaner et al., 1995; Ribas Palom, 2006; Serra Ruiz, 2006). The drainage area of the 97 km long Fluvià is 1125 km² and its annual average water discharge at the river gauging station Esponellà was 6.6 m³/s in 2011 (ACA, 2012). Fluvià's final stretch has undergone various changes and interventions such as aggregate extraction, river channelisation, breakwater constructions (Ribas Palom, 2006). These activities resulted in a meander cut-off and in riverbed deepening (Mas-Pla et al., 1999b; Martín-Vide et al., 2012).

Tributaries of these two rivers, with marked seasonal variability, have developed a 120 km² delta plain, located in the Gulf of Rosas limited by the Creus Cape on the north and the Montgri Massif to the south (Díaz & Ercilla, 1993; Flos, 1985). It is a wave-dominated coast, which has progressed offshore through beach ridge development (Bach, 1986–87).

The alluvial plain of Aiguamolls de l'Empordà is rich in groundwater. A leaky aquifer system, with the main sandy aquifer of 10 m thick is located at 35–40 m below surface. Since 1987, groundwater has been replaced mainly by surface water brought through channels from the Boadella dam (Mas-Pla et al., 1999a).

Aiguamolls de l'Empordà's important natural value and charm come above all from its avifauna, since more than 320 nesting and migratory species have been identified. Different levels of protection and the fact that the birds can be easily

observed have been the key elements for creating the destination for birdwatchers and lovers of nature (Romagosa Casals, 2008; Saurí et al., 1995). The study area is included in the Natura 2000 network and was also declared as a Special Protection Area for Birds (SPA) in 1986 and since 1992 is designated as a Wetland of International Importance by Ramsar Convention on Wetlands (Romagosa Casals, 2008).

3.4.2 The main economic characteristics of Aiguamolls de l'Empordà

The economy of Aiguamolls de l'Empordà is mainly based on agriculture and tourism (IDESCAT, 2013a). Therefore, its environment is under significant pressure due to agriculture, urban and tourist development. It is also one of the most touristic and urban areas on Costa Brava and Catalonia in general (Romagosa Casals, 2008).

As in many other European areas, social interest in agricultural development of the Alt Empordà coastal plain appeared early in history (Saurí et al., 2000). In the Middle Ages, current agricultural land near the coast featured sand dunes, lagoons and marshlands (Serra et al., 2008), which were periodically flooded land and left to a variety of uses including hunting, fishing, plant collecting and cattle grazing (Saurí et al., 2000), whereas human settlement occupied the higher grounds of this landscape (Serra et al., 2008).

In the 18th century, new agricultural techniques, imported from the south France, and the introduction of new crops (maize, fodder), transformed the traditional agriculture based on cereals and fallowland. This change coincided with population growth and further encouraged new lagoon desiccations, the construction of drainage channels and the diversions of Fluvià and Muga near the sea (Serra Ruiz, 2006; Serra et al., 2008).

Another significant landscape transformation occurred in the 19th century by means of new gains in agricultural land through the drainage of other lagoons, using new techniques such as water pumps, as well as by the increase of agricultural mechanisation (Serra Ruiz, 2006; Serra et al., 2008). One of the most peculiar features of early human adaptation to this humid lowland environment was the system known as *closes* (Saurí et al., 1995). These were a sort of meadow polders occupied by humid pastures mainly with a function of protecting the land against the *tramuntana* wind and controlling physical, chemical and biological fluxes, such as water for drainage or irrigation and soil particles to reduce erosion (Llausàs et al., 2009; Saurí et al., 1995). Many *closes* were originally transformed into paddy fields as they already had the infrastructure to

control the water input and output. However, for sanitation reasons, rice was prohibited in 1838. Many former paddy fields were then converted again into *closes*.

The 20th century was marked by irrigation that appeared in the late 1930s and expanded in the 1940s and 1950s benefiting from very accessible groundwater sources (Serra Ruiz, 2006; Serra et al., 2008). The irrigation boom, however, did not take place until the late 1960s when the Boadella dam and the Muga Irrigation Project provided the irrigation infrastructure for more than 12,200 ha (Ribas Palom, 2006; Serra et al., 2008). In the first decades of the 20th century rice returned to the area, it occupied soils still uncultivated whereas *closes* retreated after the progression of permanent agriculture (Ribas Palom, 2006; Saurí et al., 2000). Rice pioneered the agricultural colonisation of these lands around the 1950, but not without periods of social protest and prohibition due to the malign images of paddy fields as foci of all sorts of diseases (Saurí et al., 2000). Crop farming between the mid-1950s and mid-1990s experienced a slight decline mainly because of the decrease in dryland farming (olives and vines), which in the mid-1990s occupied about half of the land it had in the mid-1950s (Pavón et al., 2003). Moreover, various fruit trees have expanded until the early 1980s due to the presence of abundant groundwater, and for example, came to occupy 80% of cultivated land in Sant Pere Pescador (Serra Ruiz, 2006; Serra et al., 2008). The creation of the Natural Park has encouraged the reintroduction of rice. Land had to be rented to rice growers coming from the Ebro Delta since farming knowledge about this crop in the study area disappeared. The first results were positive and rice expanded again from 1985 to 1989. In the 1990s, however, the Natural Park's authorities stopped further expansion because rice cultivation without using herbicides and pesticides proved to be very difficult (Saurí et al., 2000; Serra Ruiz, 2006). Over the last decade, the most important agriculture products have been cereals, fruit trees, vines and olives (IDESCAT, 2013b).

Another significant agricultural activity was a seasonal migration of cattle from the mountain pastures of the Pyrenees in summer to the coastal meadows in winter that virtually disappeared in the 1960s. Milk production, the main activity in most farms, was threatened by the limitations imposed by the reform of the Common Agricultural Policy of the European Union. In some cases, farms were responding by turning to meat, including pigs, that is, to an even more intensive form of production with severe pollution problems (Saurí et al., 2000). With the creation of Natural Park was reintroduced the traditional cattle such as the Vaca marinera (*Bos taurus domestica*) and

some other animals adapted to the humid environment, especially the Camargue horse and the domesticated donkey (Ribas Palom, 2006). In recent years, the farmers who have land in the Natural Park have considered a possibility of introducing the traditional cattle from the Natural Park of Arbera aiming to promote the Natural Park's agriculture and to enhance economic growth (Hora Nova, 2011).

Moreover, the creation of the Natural Park has also triggered several disputes relating to the regulation of hunting and fishing practices, or the mandatory flooding of some private agricultural fields for waterfowl management (Pavón et al, 2003; Saurí et al., 1995). In particular, the Port of Roses is the most important fishing port in the study area, where fish catches in 2012 totalled about 1880 tonnes and Escala came in second with about 1420 tonnes. Together provided about 11% of Catalonia's annual fish production (IDESCAT, 2013b).

The coastal region of Costa Brava in general, and coastal plain of Alt Empordà in particular, are one of the clearest examples of intense urbanisation dynamics related to tourism in the developed countries. In the second part of 20th century, territorial changes were accelerated and these areas entered into an intense process of redefinition, which was taking them towards a greater complexity in the land uses, related to the processes of economic globalisation and to the increase of mobility flows. These processes entailed a change in the urbanisation pattern of the territory, with the transformation of settlements and the appearance of new urban forms (Cuadrado Ciuraneta et al., 2007). In particular, the Alt Empordà's built environment is reflected in the traditional settlement and tourist settlement (Saurí et al., 1995). Alt Empordà is characterised for having an urbanised land that mostly has tourism in its origin, appears concentrated closely to the coast, and was developed in low density patterns, whereas the rest is formed by settlements of traditional type, distributed in a more regular way throughout the territory (Cuadrado Ciuraneta et al., 2007). More recently, and due to physical constraints and saturation, new developments have been built on the mountain ranges and have expanded into the rural hinterlands. In total, it is estimated that about 55% of the coastline has been urbanised, the proportion increasing from the north (40%) to the south (86%) (Saurí-Pujol et al., 2001). Interestingly, increases in campsites and new homes (particularly second homes) were the mainstay of tourism development (Emmi & Santigosa, 1989).

The most important tourist developments are Santa Margarida (Roses) and Empuriabrava (Castelló d'Empúries) which were built partially on former marshland

areas (Romagosa Casals, 2009). Empuriabrava was built in the late 1960s and covers about 600 ha of former marshlands, cropfields and pasturelands located north of Muga and took the model of marinas in Florida where canals act as streets and people may have their boats parked in front of their homes. There are about 2500 mooring points for boats, and this figure makes Empuriabrava the most important marina in Spain and one of the biggest in the Mediterranean region. To this original, residential project were additions in the form of multistorey apartment and hotel blocks designed for tourists with lower incomes (Ribas Palom, 2006; Saurí et al., 2000; Serra et al., 2008). Another tourist development, Santa Margarida was constructed on the rocky coast of Roses and it is located where vines and olive trees were traditionally grown, but later abandoned (Pavón et al., 2003). In Aiguamolls de l'Empordà can be found also another type of tourist and recreational developments situated further inland in the alluvial plain, such as golf course in Peralada (Pavón et al., 2003) and several campsites along the coast (Castelló d'Empúries, Escala, Roses, Sant Pere Pescador). It is worth noting that these coastal municipalities have noted a 109% increase in hotel and camping places in the period 1975–2012 (IDESCAT, 2013a).

In addition, in recent decades there has been a growing role of environmental conservation, which is also reflected through ecotourism. This type of tourism is linked with activities such as cycling, horse riding and birdwatching that differ enormously from the traditional “sand, sun and sea tourism”. In theory, these tendencies can lead to the restructuring of economic activities in the area towards a more sustainable use of resources (Saurí et al., 2000).

Table 4. Socio-economic indicators for nine municipalities of Aiguamolls de l'Empordà

	Roses	Castelló d'Empúries	Escala
% of increase in resident population 1981-2012	149	344	158
% of disabled population 2011	3.3	2.5	2.9
% of literacy (population of +10 years)	97.9	97.7	97.6
GDP total 2010	410.4 mil	241.6 mil	227.8 mil
GDP/capita 2010	21,300	20,900	22,700
% of registered unemployment in relation to Catalonia 2012	0.2	0.1	0.1
% of increase in house construction 1981-2012	-72	-96	-92
% of increase in accommodation beds 1975-2012	42	128	27
% of increase in motorisation 1991-2012	10	-9	10
	Sant Pere Pescador	Peralada	Pau
% of increase in resident population 1981-2012	104	52	91
% of disabled population 2011	2.9	2.3	2.5
% of literacy (aged 10+)	95.3	99.4	99
GDP total 2010	/	/	/
GDP/capita 2010	/	/	/
% of registered unemployment in relation to Catalonia 2012	0.03	0.01	0.01
% of increase in house construction 1981-2012	/	/	/
% of increase in accommodation beds 1975-2012	377	/	0
% of increase in motorisation 1991-2012	33	47	81
	Palau- Saverdera	Armentera	Pedret i Marzà
% of increase in resident population 1981-2012	121	13	30
% of disabled population 2011	2.6	3.1	2.9
% of literacy (aged 10+)	99.6	99.3	99.2
GDP total 2010	/	/	/
GDP/capita 2010	/	/	/
% of registered unemployment in relation to Catalonia 2012	0.01	0.01	0.002
% of increase in house construction 1981-2012	/	/	/
% of increase in accommodation beds 1975-2012	/	0	0
% of increase in motorisation 1991-2012	27	61	59

Source: IDESCAT, 2013a.

3.4.3 *The main characteristics of population and migration in Aiguamolls de l'Empordà*

According to distribution of population and territorial structure are distinguished two units quite distinct in the nine municipalities of Aiguamolls de l'Empordà:

- Coastal municipalities marked by tourism: Castelló d'Empúries, Roses and Escala;
- Municipalities marked by agriculture: Armentera, Sant Pere Pescador, Perelada, Pau, Palau-Saverdera, Pau, Pedret i Marzà and Peralada.

The population in nine municipalities of Aiguamolls de l'Empordà in 2012 was 49,396 registered residents (Figure 5). The most remarkable aspect lies not with its absolute size but, rather, in its 161% increase between 1981 and 2012 (IDESCAT, 2013a; INE, 2013a).

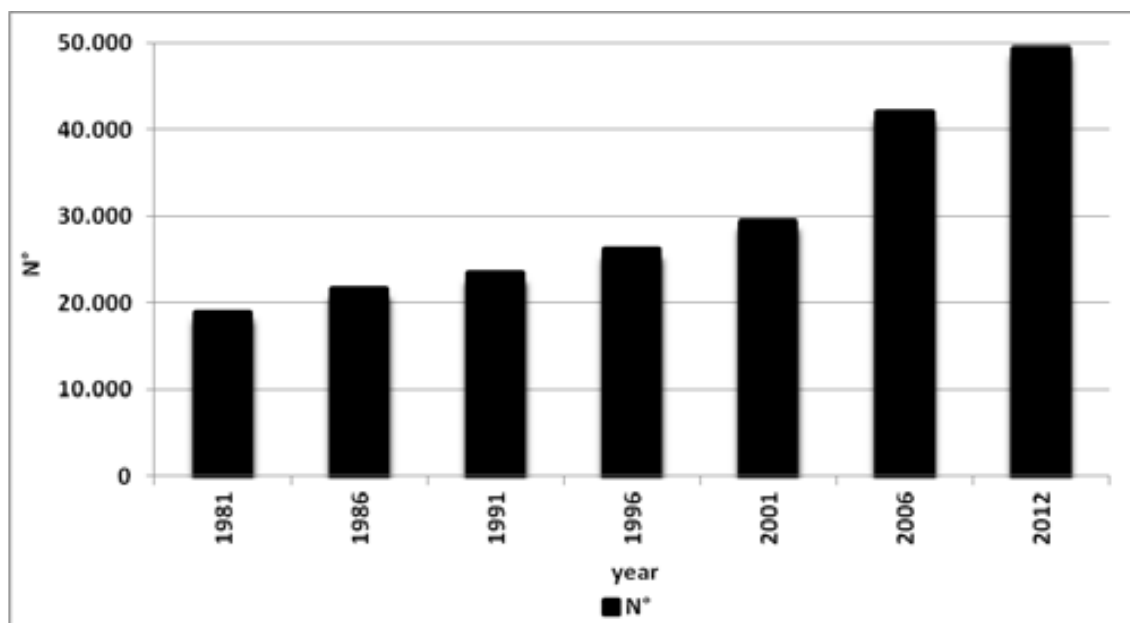


Figure 5. Total number of population in Aiguamolls de l'Empordà in the period 1981–2012. Source: IDESCAT, 2013a; INE, 2013a.

Furthermore, it can be observed that in the period 1981–2012 the highest number of population was in Roses and the lowest in Pedret i Marzà in all period in question (Figure 6). In particular, Alt Empordà has increased its number of population during the summer season since the 1970s because of tourism (Mas-Pla et al., 1999a; Ribas Palom, 2006). In July and August, the total population of coastal municipalities of Aiguamolls de l’Empordà raises more than five times the number of permanent residents (Saurí-Pujol et al., 2001).

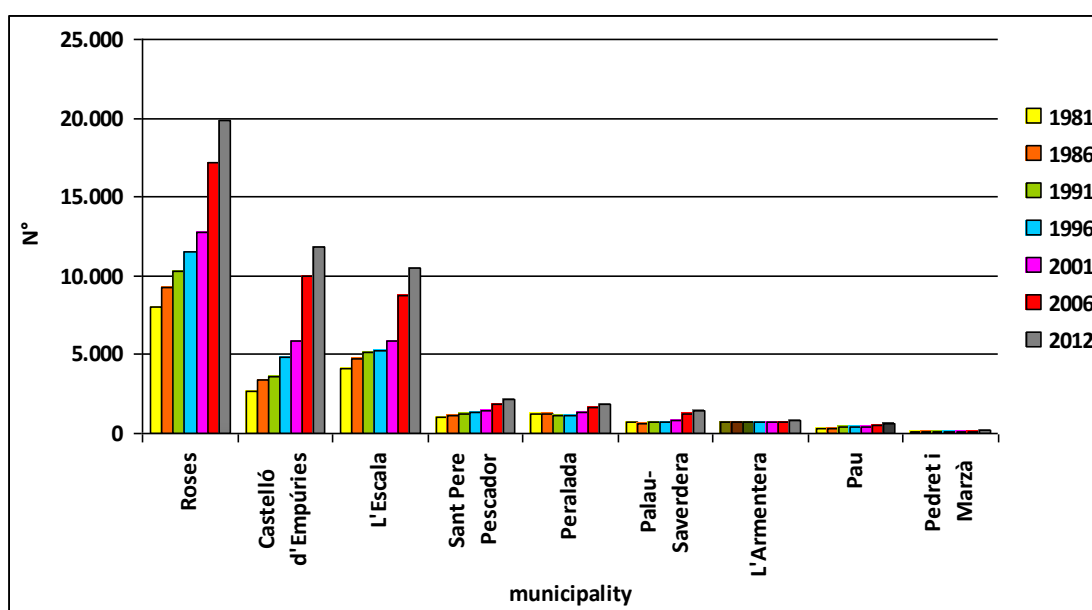


Figure 6. Total number of population by municipality in Aiguamolls de l’Empordà in the period 1981–2012. Source: IDESCAT, 2013a; INE, 2013a.

The largest age group of population in nine municipalities of Aiguamolls de l’Empordà was the group of 16–64 years, which was representing the 67% of all population in the period 1981–2001 (Figure 7). The second largest age group was the age group of 0–15 years (18%) and the smallest one, the age group of 65 years and more (15%). It can be observed that in 2012 the number of people in all three age groups increased by 78%, 178% and 238% since 1981 for age groups of 0–15, 16–64, and 65 years and more, respectively.

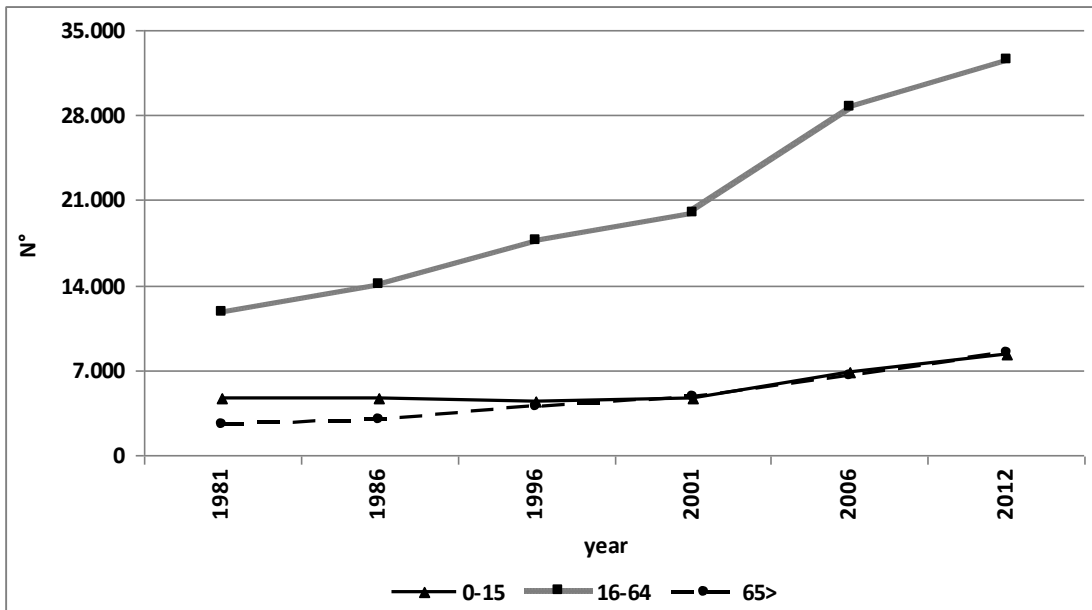


Figure 7. Total number of population by age group in nine municipalities of Aiguamolls de l'Empordà in the period 1981–2012. Source: IDESCAT, 2013a; INE, 2013a.

In nine municipalities of Aiguamolls de l'Empordà during the period 1991–2012, Spanish people represented between 93% (1991) and 63% (2012) of total number of population, while foreigners between 7% (1991) and 37% (2012) (Figure 8). Thus, the number of both groups increased in the period 1991–2012. The highest number of both groups was in 2012. The number of population with Spanish nationality increased by 43% while the number of foreigners increased by 1037% in the observed period.

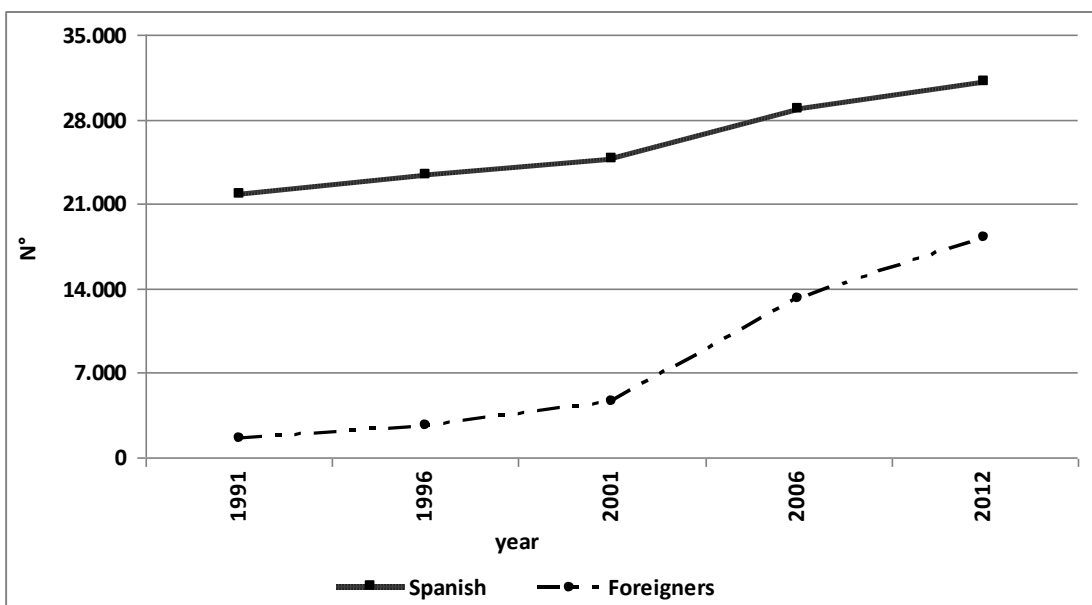


Figure 8. Total number of population by nationality in nine municipalities of Aiguamolls de l'Empordà in the period 1991–2012. Source: IDESCAT, 2013a; INE, 2013a.

In this sense, it is worth mentioning that analysing and managing vulnerability and adaptation to climate change in a highly diverse area like Aiguamolls de l'Empordà (with people speaking many languages and coming from a wide variety of cultures) (see Table 5) is potentially different than in areas inhabited by a culturally homogenous population.

Table 5. Total number of population by nationality in nine municipalities of Aiguamolls de l'Empordà in the period 1991–2012

Castelló d'Empuries	Spanish	EU	Non-EU	Africa	North & Central America	South America	Asia & Oceania
2012	5884	3360	503	1481	91	374	101
2001	4404	1488	198	643	23	114	13
1996	3928	509	21	317	9	45	1
1991	3329	189	0	80	11	26	2
Escala	Spanish	EU	Non-EU	Africa	North & Central America	South America	Asia & Oceania
2012	7002	1880	221	891	98	353	63
2001	5218	336	45	177	4	36	7
1996	4952	224	20	53	1	15	1
1991	4906	205	21	25	5	14	2
Roses	Spanish	EU	Non-EU	Africa	North & Central America	South America	Asia & Oceania
2012	13,035	2927	368	2595	88	681	202
2001	10,848	646	113	939	21	132	27
1996	10,385	492	21	529	15	26	15
1991	9425	283	3	521	16	35	20

Source: IDESCAT, 2013a.

CHAPTER 4
THE MAIN CLIMATE CHANGE VARIABLES AND
PROJECTIONS

In this chapter first, some results of the analysis of three variables types are presented:

- Meteorological variables,
- Hydrological variables,
- Marine variables.

Assuming that natural events may occur in the future in similar circumstances as those that led to past events, a valuable aid to the study of climate change lies in knowledge of historical evolution of variables (Barnolas & Llasat, 2007; IPCC, 2007a). Following authors such as Adeniji-Oloukoi et al., 2013; Bryan et al., 2009; Combest-Friedman et al., 2012; Fatorić & Chelleri, 2012; Ogalleh et al., 2012; Ruddell et al., 2012 in this thesis, I assume that observed changes in variables are crucial for the study of vulnerability and adaptation.

Moreover, regional projections for the study area are done and based on the high-resolution numerical model ECHAM5/MPI-OM (atmosphere-ocean global coupled model) for the medium-term period 2011–2050. Projections show the expected changes and variations on the meteorological variables such as annual and seasonal temperature and precipitation considering two different GHG emission scenarios, A2 and B1 (Barrera-Escoda & Cunillera, 2011).

4.1 Analysis of meteorological variables

Regular monitoring of the trends in air temperatures, precipitation, evaporation, wind velocity and frequency of storms, which is based mainly on the long time-series 1971–2012 can determine climate variability and/or change in the study area. This provides an opportunity to prepare for newly arising conditions and to adapt to possible adverse effects.

4.1.1 Air temperature

The period from 1971 to 2012 was characterised by an average air temperature of 15.5 °C (Figure 9). A chart showed a peak of 2.7 °C amplitude. The period 1971–2012 recorded 1980 as the coldest year (14.1 °C) and 2006 and 2011 as the warmest ones

(16.8 °C). There has been a large variation of air temperature, occurred from a short period to another with warmest years being more frequently recorded in recent times than was the case in the past decades.

A review of a decadal average air temperatures demonstrated that the air temperature was in the 1970s and 1980s (14.5 °C and 15.4 °C, respectively) under the average value for the period 1971–2012, while in the 1990s and in the period 2001–2010 was 0.4 °C and 0.7 °C, respectively higher than the average value for the 42-year studied period.

Regarding seasons, spring and summer were the time of year in which the fastest temperature increase took place (0.7 °C per decade), while autumn and winter showed an increase of 0.6 °C and 0.3 °C per decade, respectively.

The annual average air temperature rose by approximately 0.56 °C per decade from 1971 to 2012, which means that it increased by 2.3 °C over the 42-year period.

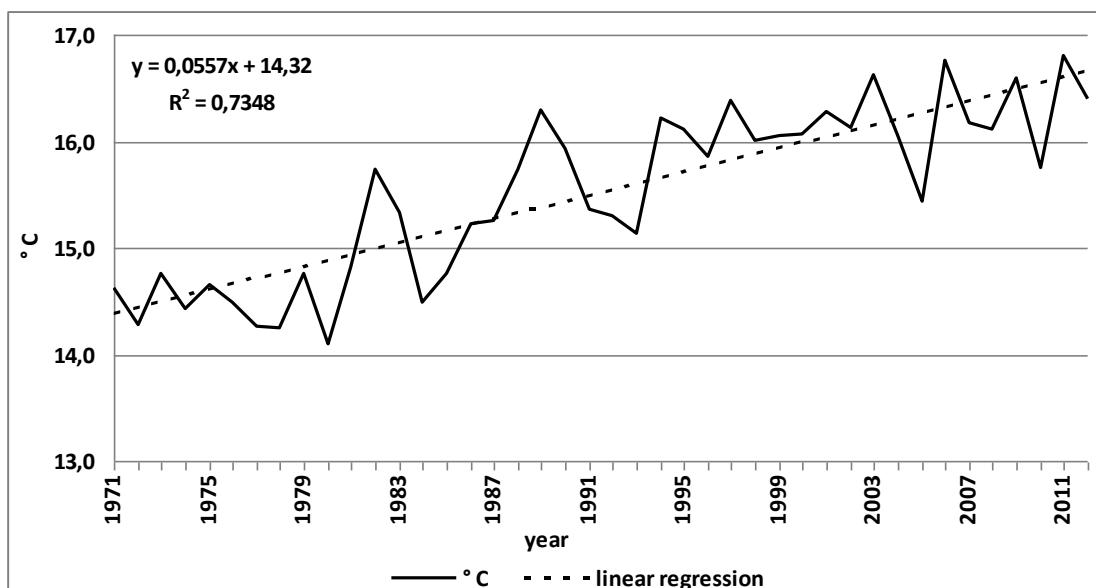


Figure 9. Annual average air temperature and linear regression for the period 1971–2012 at Estartit station. Source: Meteo Estartit, 2013.

In the period 1971–2012, a trend of growing absolute maximum and minimum air temperature was observed (Figure 10). Year 2003 stood out for the highest absolute temperature (36.9 °C) and 1985 for the lowest absolute temperature (−7.1 °C).

The absolute maximum temperature increased at a faster rate than the absolute minimum temperature, by approximately thirteen times more: 0.63 °C per decade and 0.05 °C per decade, respectively from 1971 to 2012.

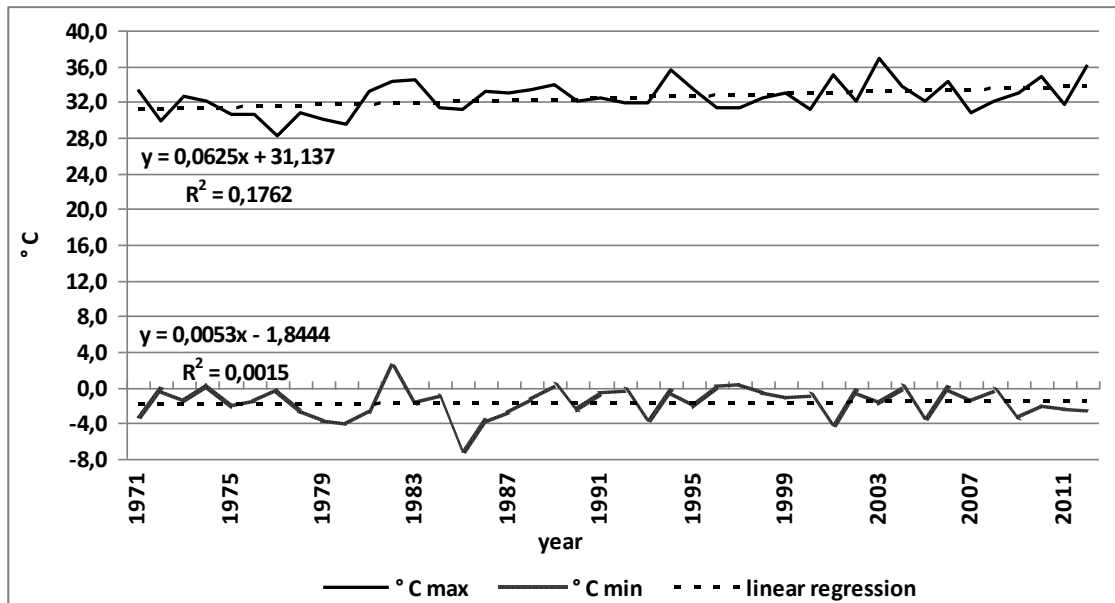


Figure 10. Annual absolute maximum and absolute minimum air temperature and linear regressions for the period 1971–2012 at Estartit station. Source: Meteo Estartit, 2013.

4.1.2 Precipitation

Annual accumulated precipitation ranged from 267 to 986 mm in the period 1971–2012 (Figure 11). The average value for precipitation was 597 mm. The highest annual accumulated precipitation was 986 mm in 1994 while the lowest was 267 mm in 1973. The chart shows the typical fluctuating trend of annual accumulated precipitation in which the trend was decreasing and increasing, though not constantly.

Comparison of the decadal values of precipitation showed that in the 1970s (590 mm) and 1980s (524 mm), there were precipitations under the average value for the period 1971–2012 while in the 1990s (655 mm) and in the period 2001–2010 (611 mm) were above the average value for the 42-year period.

By seasons, precipitation increased in autumn and winter and decreased in spring and summer since 1971.

Linear regression indicates that the annual accumulated precipitation slightly increased in Estartit from 1971 to 2012.

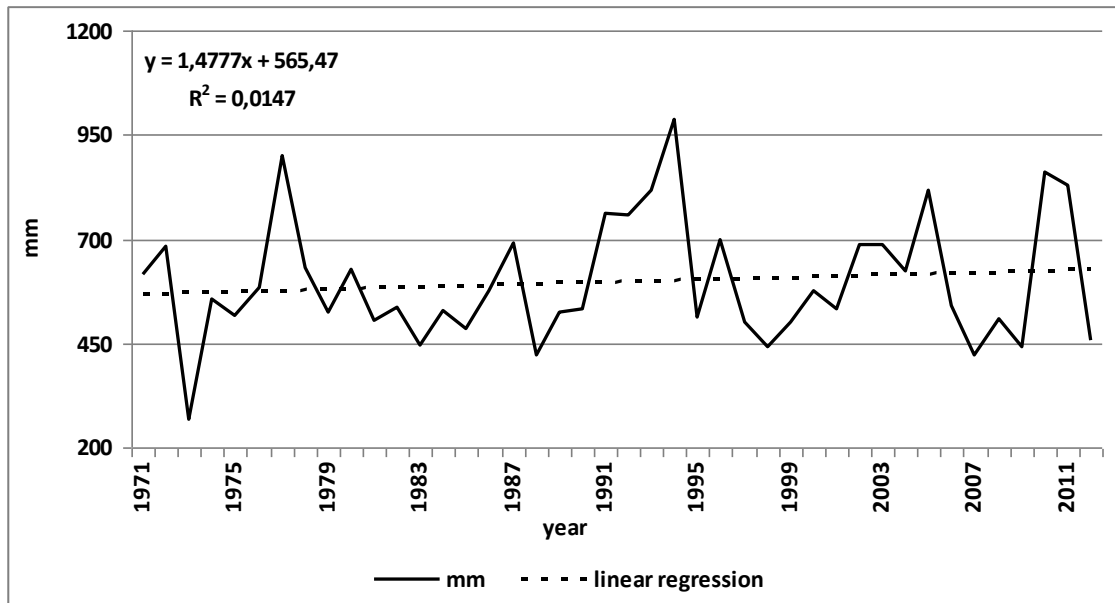


Figure 11. Total annual precipitation and linear regression for the period 1971–2012 at Estartit station. Source: Meteo Estartit, 2013.

4.1.3 Evaporation

Annual average evaporation ranged from 889 to 1245 mm in the period 1976–2012¹⁸ (Figure 12). The average value for evaporation was 1098 mm. The highest annual evaporation was 1245 mm in 2012.

Linear regression indicates that the annual average evaporation in Estartit increased over the period 1976–2012. Furthermore, it exceeded the annual accumulated precipitation for all the period observed.

¹⁸ Evaporation data are available since 1976.

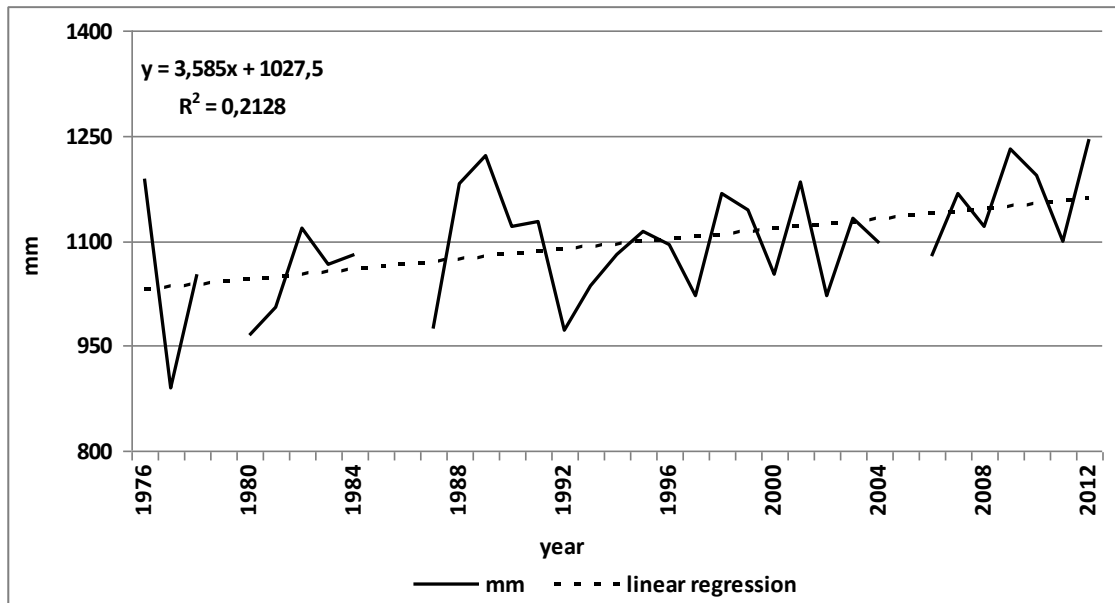


Figure 12. Annual average evaporation and linear regression for the period 1976–2012 at Estartit station. Source: Meteo Estartit, 2013.

4.1.4 Wind

It is difficult to obtain clear trends of changing wind velocity, as the longest data series available covers only 23 years (Figure 13).

Nevertheless, the highest wind velocity recorded at Estartit station was 19.9 km/h in 1999 while the average velocity of the 23-year period was 18.1 km/h.

Furthermore, the annual average wind velocity increased in the period 1990–2012, at the decadal rate of 1.1 km/h, which is evident from the increasing linear regression.

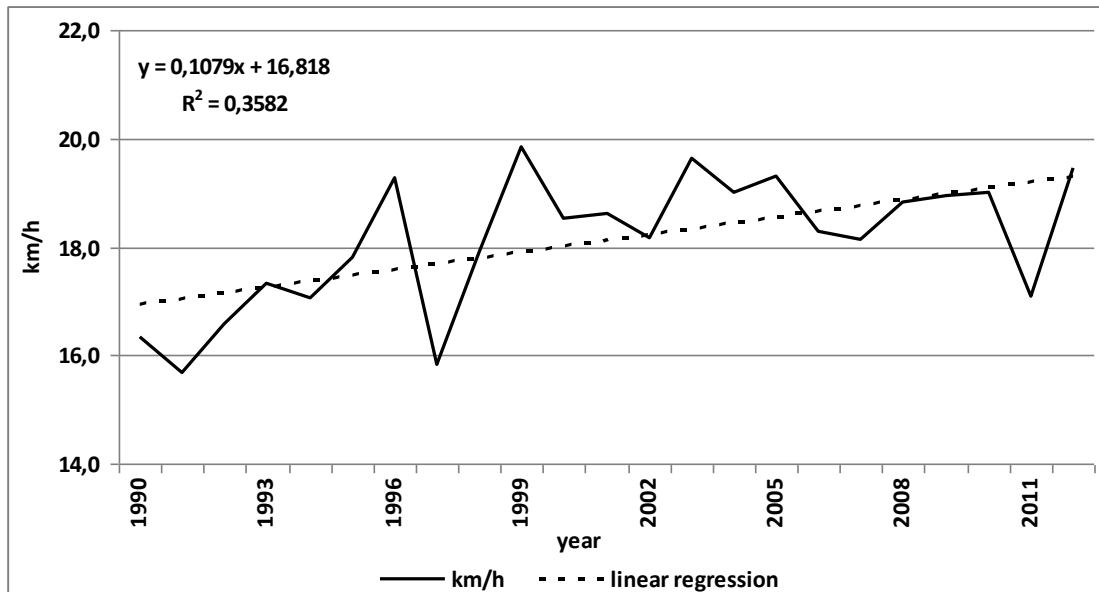


Figure 13. Annual average wind velocity and linear regression for the period 1990–2012 at Estartit station. Source: Meteo Estartit, 2013.

4.1.5 Storms

The period from 1971 to 2012 was in Estartit characterised by an average frequency of 22 storms (Figure 14). From the chart is evident that the most frequent storms were in 1976 and 1990 occurring on 34 days in those years. After 1990, there was no explicit rise or drop in the frequency of storms.

A long time-series, covering the past 42-years, showed that the frequency of storms decreased at the rate of almost one day per decade.

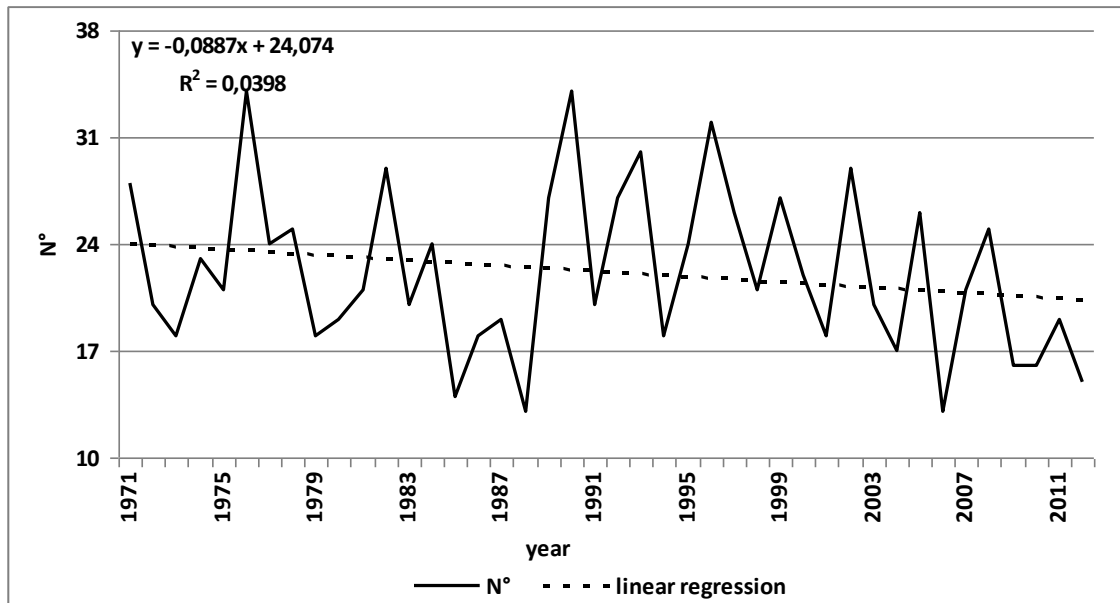


Figure 14. Total number of storms and linear regression for the period 1971–2012 at Estartit station. Source: Meteo Estartit, 2013.

4.2 Analysis of hydrological variables

Muga and Fluvià are the representative rivers in the study area, which have a long-term records spanning back to 1912. In this analysis, I focus on the river gauging station of Boadella on Muga and the river gauging station of Esponellà on Fluvià for the period 1971–2011.

4.2.1 River flow of Muga

Annual average river flow of Muga at the gauging station Boadella indicated high variability and temporal fluctuations from 1971 to 2011 (Figure 15). The highest river flow was recorded in 1972 with 4.6 m³/s and the lowest 0.4 m³/s in 2009, while the average flow was 1.9 m³/s.

It gradually decreased (0.2 m³/s per decade) in the period 1971–2011, which is evident from the decreasing linear regression.

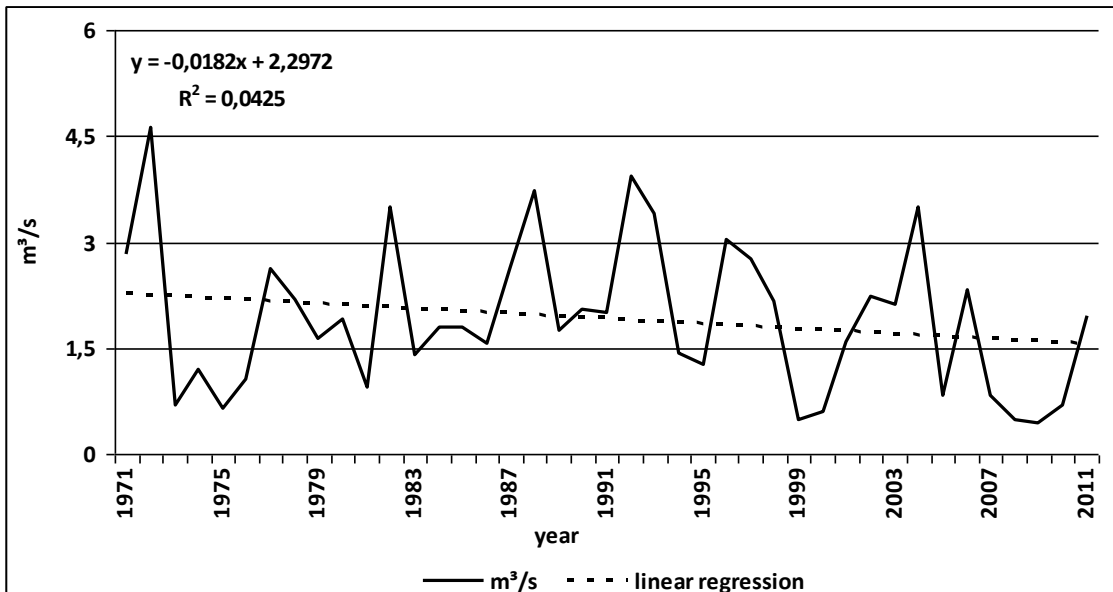


Figure 15. Annual average river flow of Muga (river gauging station Boadella) and linear regression for the period 1971–2011. Source: ACA, 2012.

4.2.2 River flow of Fluvià

The highest Fluvià flow of 17.7 m³/s was measured in 1992 and the lowest of 1.7 m³/s in 2007, while the average river flow of the period observed was 6.9 m³/s (Figure 16).

A significant decrease in the annual average river flow is observed in the period 1971–2011 where the average river flow progressively decreased at a rate of 0.7 m³/s per decade since 1971.

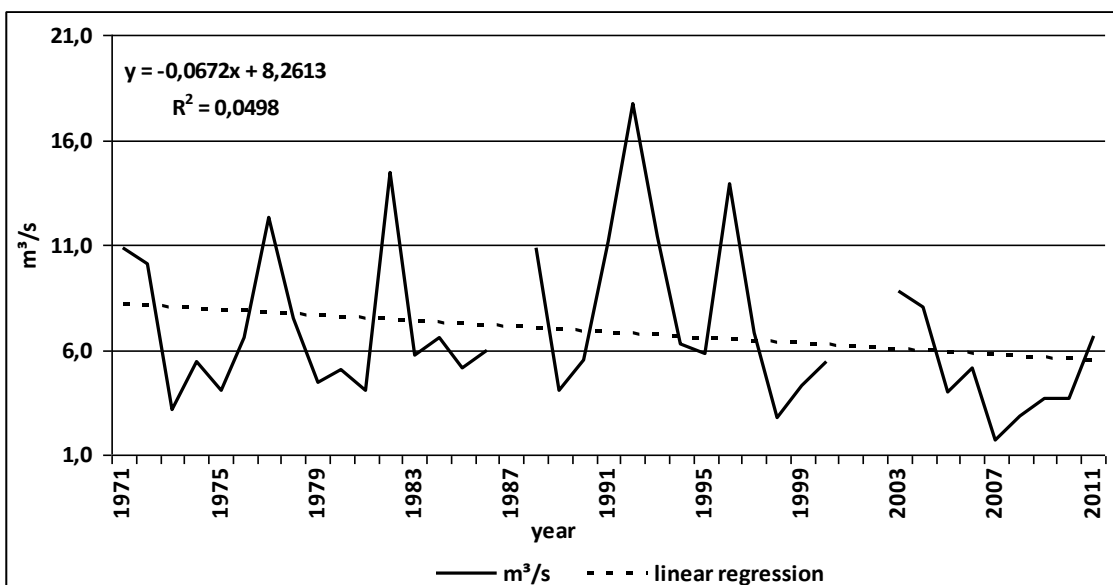


Figure 16. Annual average river flow of Fluvià (river gauging station Esponellà) and linear regression for the period 1971–2011. Source: ACA, 2012.

4.3 Analysis of marine variables

The analysis of marine variables such as sea temperatures and sea level are very meaningful, being based on the long time-series 1971–2012 and shorter time-series 1990–2012 for the tide gauge station in Estartit. In particular, there may be insufficient data to establish trends in sea level over the Mediterranean Sea near Aiguamolls de l'Empordà, because the sea level data are available in Estartit only since 1990. However, these analyses may help in understanding one of the most pronounced effects of climate change.

4.3.1 *Sea level*

Annual average sea level in Estartit ranged from –0.8 to 11.8 cm during the 23-year period in question (Figure 17). The period from 1990 to 2012 was characterised by an average value of 3.7 cm. The highest annual average sea level in Estartit was 11.8 cm in 2010. It is worth pointing out that the annual average sea level indicated a large oscillation, and a new strong rising phase seems to have started in 2006.

Comparison of the decadal average sea levels showed that in the 1990s was under the average value (1.9 cm), while in the period 2001–2010 was above the average value (5.5 cm) for the period 1990–2010.

With regards seasons, winter and spring were the time of year in which the fastest sea level increase occurred (4.3 and 3.9 cm per decade, respectively), while summer and autumn showed an increase of 3.4 cm and 2.8 cm per decade, respectively.

In particular, the trend line for the period 1991–2000 showed a positive inclination indicating a remarkable sea level rise of 4.25 cm and 5.6 cm in the period 2001–2010. Moreover, the sea level rose by 3.6 cm per decade in the period 1990–2012, which means that the sea level rose for 8.2 cm in the observed period.

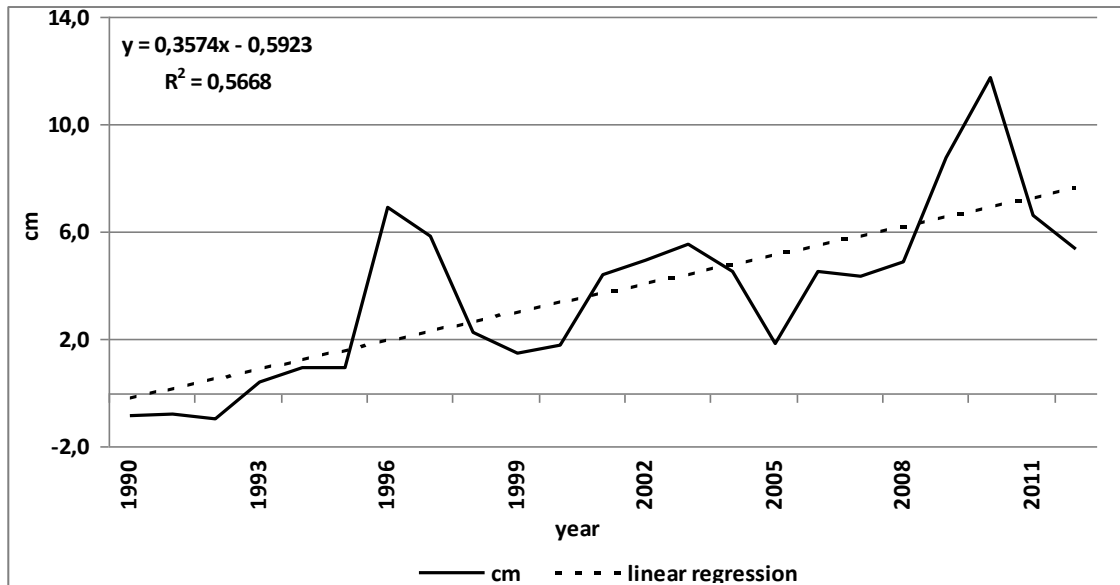


Figure 17. Annual average sea level and linear regression for the period 1990–2012 at Estartit station. Source: ACA, 2013.

4.3.2 Sea temperatures

The sea surface temperature was characterised by an average value of 16.8 °C in the period from 1971 to 2012 (Figure 18). From the chart is evident that the highest average annual sea surface temperature was 17.6 °C in 1990. The average sea surface temperature is dominated by a signal of 1.7 °C in amplitude. It should be noted that until the end of the 1980s there was no explicit increase or decrease in the sea surface temperature. Furthermore, particularly low temperatures in the mid-1970s (1974) and mid-1980s (1984) were noted. A strong rising phase appears to have started in 1990.

Changes in decadal sea surface temperature showed that in the 1970s were the temperatures under the average value (16.2 °C) while in the 1980s were the same as the average value. In contrast, in the 1990s and in the period 2001–2010 were above the average value (16.9 °C and 17.1 °C, respectively) for the 42-year period.

By seasons, the highest increase in sea surface temperatures was in spring (0.27 °C) and summer (0.25 °C) while in autumn and winter it was smaller (0.23 °C).

Over the past 42-years, the sea surface temperature increased at the rate of 0.26 °C per decade thus, it increased for 1.1 °C since 1971.

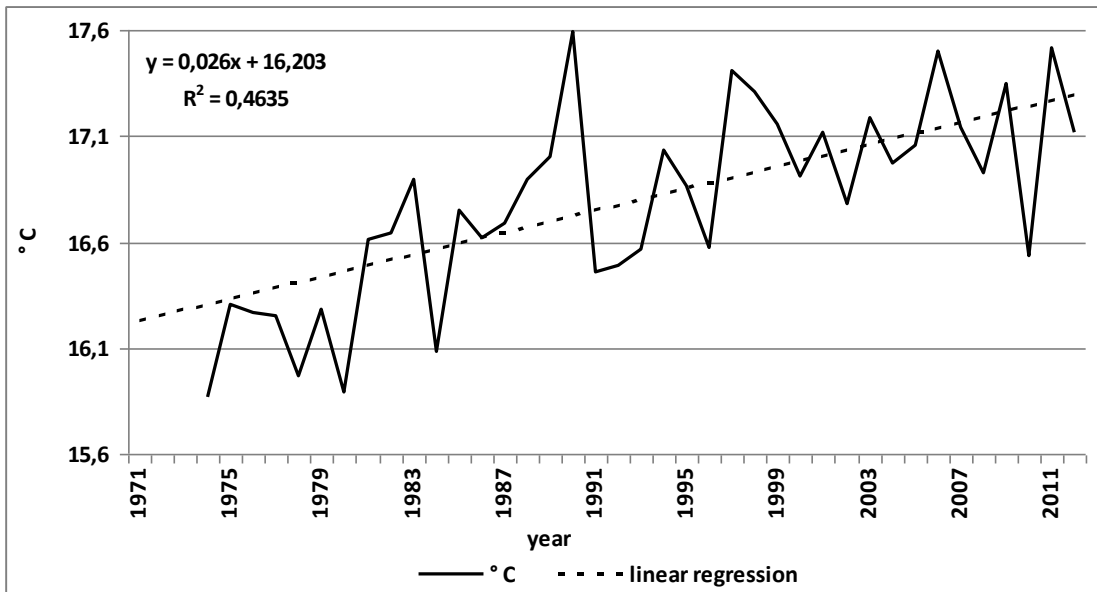


Figure 18. Annual average sea surface temperature and linear regression for the period 1971–2012 at Estartit station. Source: SMC, 2013.

Furthermore, it was observed a significant increase in the seawater temperature up to a depth of 80 m (Figure 19). These increases varied throughout the years and were particularly pronounced after 1997.

The Meteo Estartit quantifies the increase in temperatures for the period 1971–2012 as 0.33 °C, 0.29 °C and 0.18 °C per decade at different depths: 20 m, 50 m and 80 m, respectively.

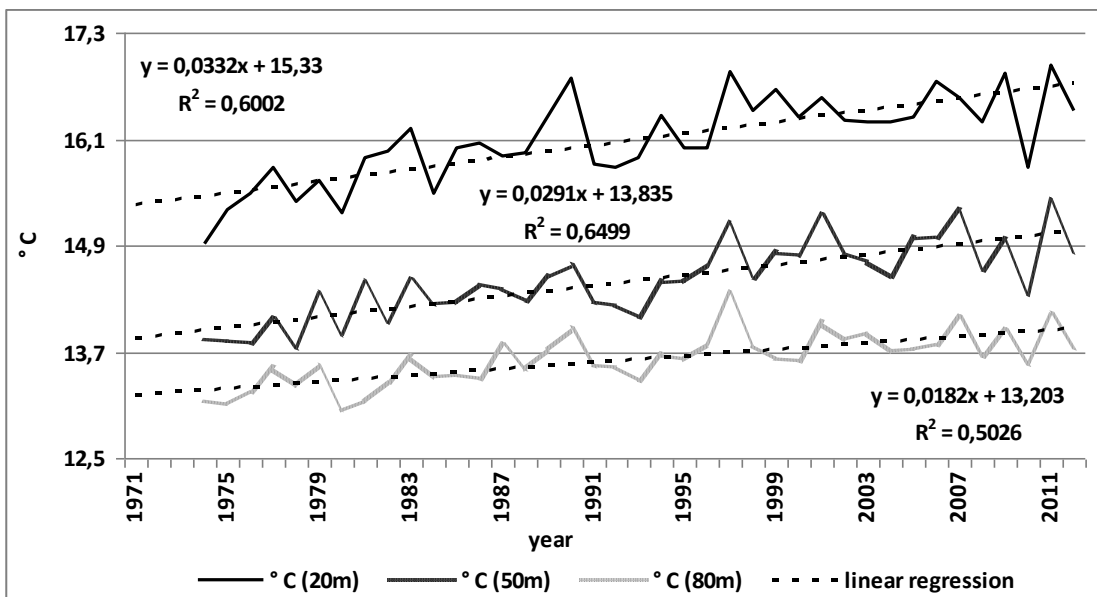


Figure 19. Annual average sea temperature and linear regressions at different depth for the period 1971–2012 at Estartit station. Source: Meteo Estartit, 2013.

4.4 Climate change projections for the study area

Using the scenario A2, average temperature in the study area may increase between 0.6 and 1 °C by 2050, yet higher increase (0.8–1 °C) will be more noticeable in the inland and central part of coastline than along the north and south part of the study area's coastline (0.6–0.8 °C) (Figure 20). Regarding seasons, increase in temperatures will be the most pronounced in summer (0.8–1.2 °C) (Figure 21). The range of precipitation variations is likely to be larger than is the case of temperature. Average precipitation may decrease between 6 and 9%, with the highest decrease in spring (9–15%) (Figure 22, Figure 23).

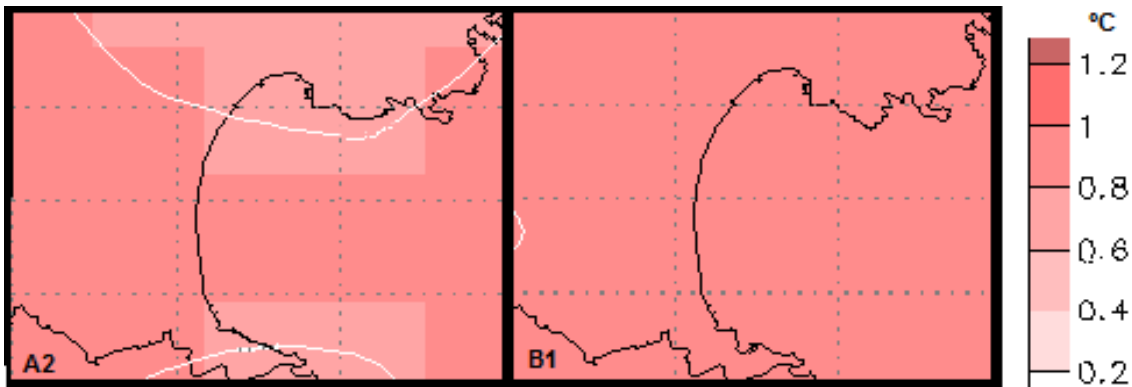


Figure 20. Annual average temperature variation (for the emissions scenarios A2 and B1) for the period 2011–2050 in the study area. Source: SMC, 2012; Barrera-Escoda & Cunillera, 2011.

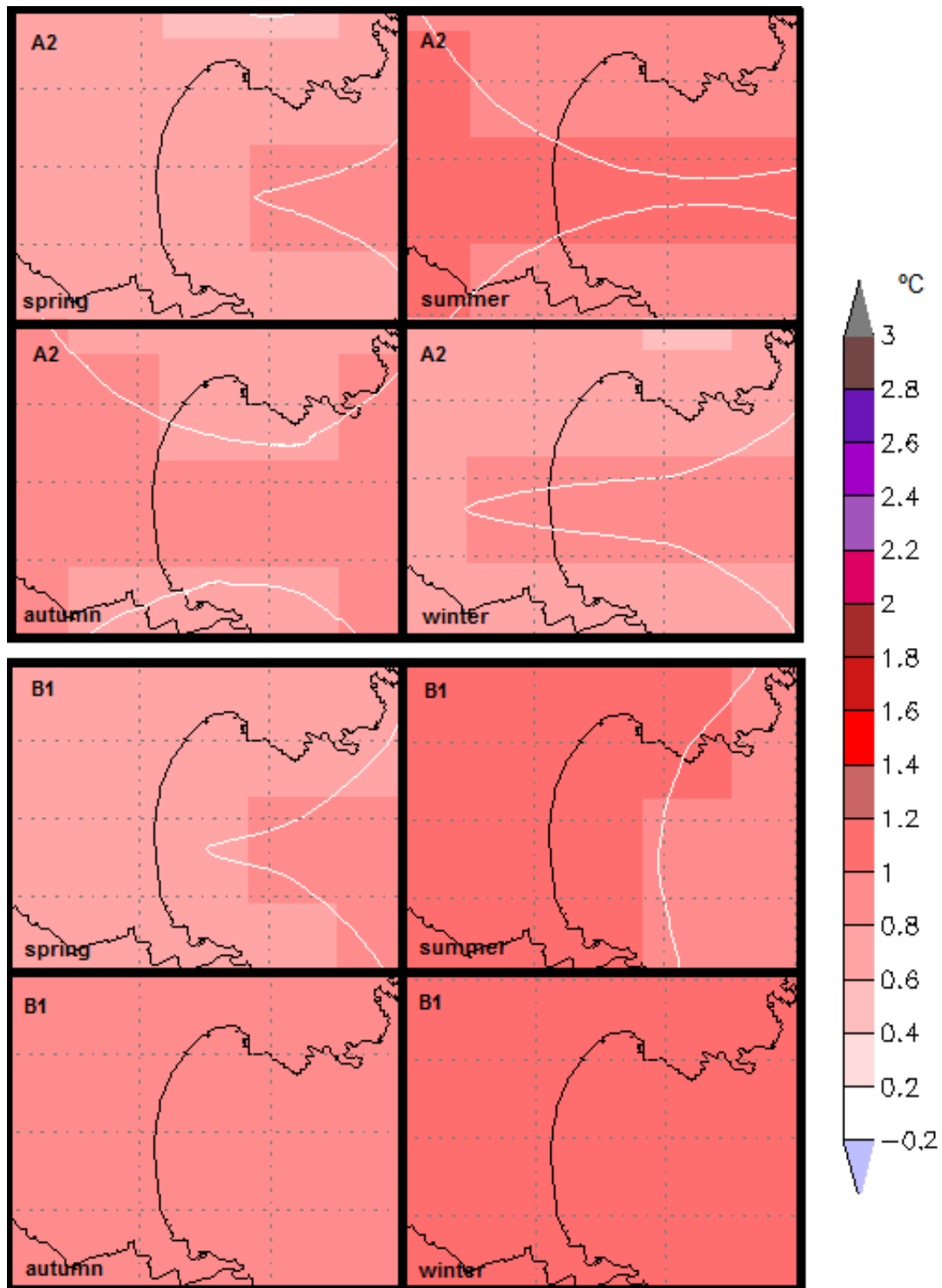


Figure 21. Seasonal average temperature variation (for the emissions scenarios A2 and B1) for the period 2011–2050 in the study area. Source: SMC, 2012; Barrera-Escoda & Cunillera, 2011.

Moreover, current projections indicate that also in the scenario B1 increases in air temperatures will continue in the period 2011–2050 (0.8–1 °C) with the highest increase in winter (1–1.2 °C) (Figure 20, Figure 21). Regarding precipitation, an average reduction of precipitation between 3 and 6% by 2050 is projected, with the highest reduction in spring (6–15%) (Figure 22, Figure 23). However, future projections for summer and autumn precipitation considering B1 scenario are uncertain as opposite trends are projected for both seasons (Figure 23).

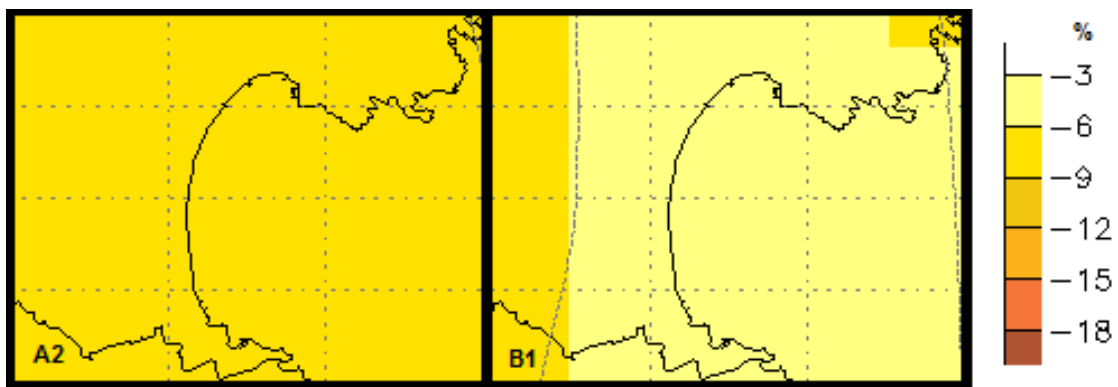


Figure 22. Annual average precipitation variation (for the emissions scenarios A2 and B1) for the period 2011–2050 in the study area. Source: SMC, 2012; Barrera-Escoda & Cunillera, 2011.

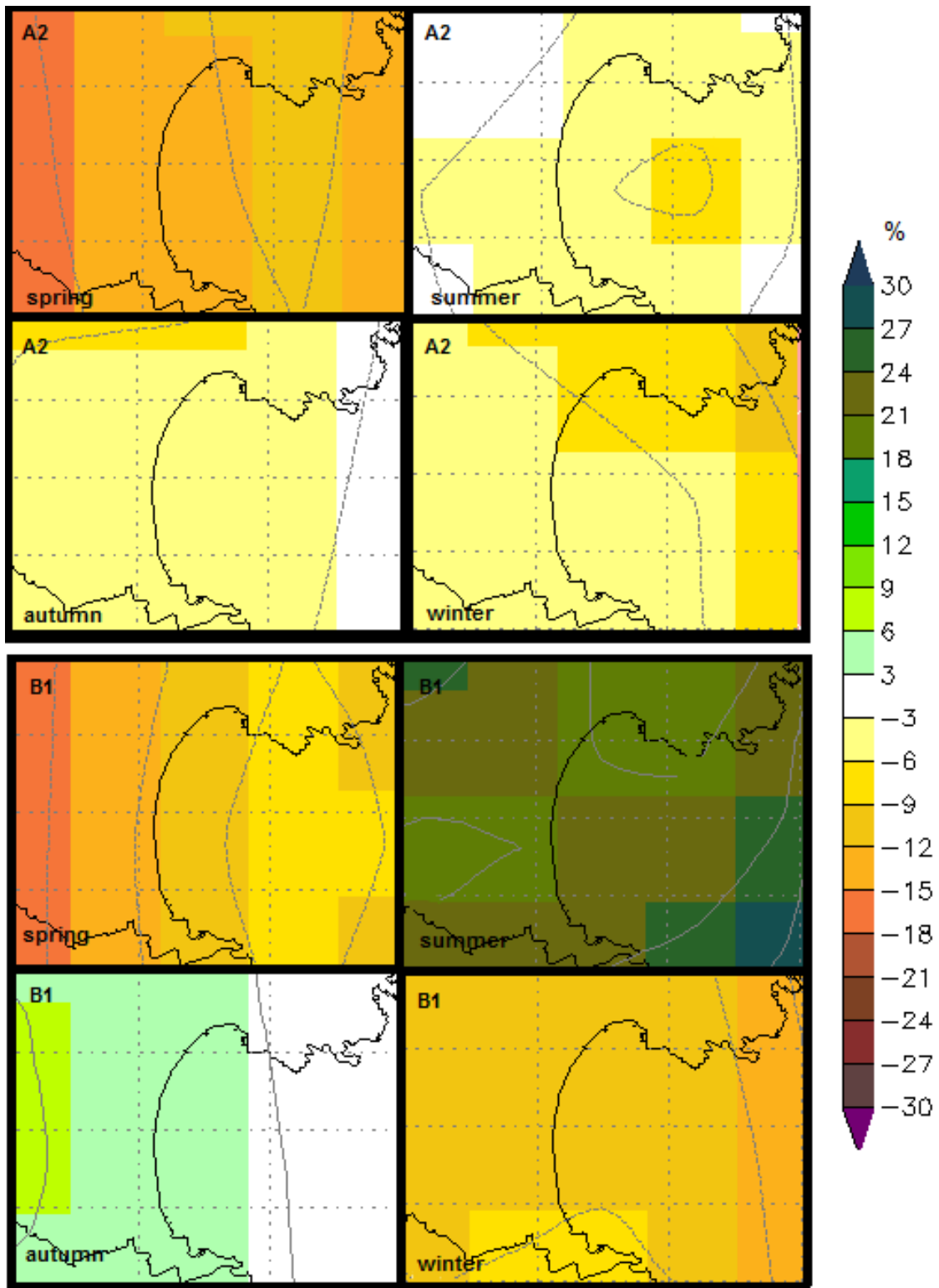


Figure 23. Seasonal average precipitation variation (for the emissions scenarios A2 and B1) for the period 2011–2050 in the study area. Source: SMC, 2012; Barrera-Escoda & Cunillera, 2011.

CHAPTER 5
CLIMATE CHANGE VULNERABILITY IN AIGUAMOLLS DE
L'EMPORDÀ

In this chapter (and following two, Chapter 6 & Chapter 7) the main findings of the thesis are presented. However, in this chapter I first, explore some of the main existing vulnerabilities to climate change effects in Aiguamolls de l'Empordà and then I turn attention into presenting and analysing stakeholders' knowledge and perceptions on two thematic areas: climate change and sustainability (see Table 3), which I argue, are essential part of vulnerability assessment together with scientific knowledge.

5.1 Climate change effects in Aiguamolls de l'Empordà. Reporting a documental analysis

This subchapter deals with identifying and analysing some of the main vulnerabilities to climate change effects in the study area. The analysis is based on the documental and statistical data and on photographs, which are helpful complementary documents.

5.1.1 Floods

Mediterranean climate, coupled with a diverse topography, makes Aiguamolls de l'Empordà very susceptible to flooding, a tendency that was aggravated by the transformation of the coastal environments for tourism (Saurí-Pujol et al., 2001).

Floods are a complex hydro-meteorological hazard (Llasat et al., 2010). According to Barnolas & Llasat (2007), floods are the major cause of loss of human lives and property damage in Catalonia. The geographical characteristics of Catalonia (the proximity to the Mediterranean Sea, complex orography), its precipitation regime and the population distribution (concentrated in coastal and plain areas) contribute to make floods the most important natural hazard in this region. Although floods are a complex hydro-meteorological hazard, they are usually a direct effect of precipitation, river overflow and sea surges (Barnolas & Llasat, 2007; Quintana, 2002; Saurí et al., 1995). The maximum in the occurrence of floods in period 1901–2000 was in autumn, what coincided with the months with largest precipitation amounts (Barnolas & Llasat, 2007; Llasat et al., 2010) up to 300 mm in 24 hours (Saurí et al., 1995). These kind of convective events are frequent in autumn mainly because the Mediterranean Sea, after the high solar radiation received during the summer season, is warm enough to ensure

considerable moisture and instability at low atmospheric levels (Barnolas & Llasat, 2007).

Using data from the Meteorological Hazards Analysis Team, 31 flooding events were identified in Alt Empordà in the period 1971–2010 (Figure 24). It was shown that flood events had a decreasing trend over the period observed. Furthermore, from Figure 11, a significant increase in precipitation in Aiguamolls de l’Empordà has not been noticed over recent years. Hence, in this way it can be estimated that the negative linear regression for the flooding may be due to increased urbanisation, new roads and motorways, increased population density over the last two decades and changes in hydrological river conditions (Barnolas & Llasat, 2007). Moreover, this is also supported by the findings of Saurí-Pujol et al. (2001), who underlined that flooding can be attributed, at least in part, to land degradation linked to brush and forest fires in the upstream portions of coastal catchments, changes in land use patterns from woodland or agriculture to urban uses (especially on the periphery of Roses) and torrential precipitation. However, Gallart & Llorens (2003) reported that forest cover could reduce flooding. Indeed, the decrease in water yield from forested catchments is actually linked to lower peak flows during the flood events. Likewise, Quintana (2002) considered that water levels in basins have become less dependent on weather and more dependent on flows in the permanent supply channel, and on the level of the water retained at the sluice gate. Flow regulation destroyed the pattern of flash flooding and gradual emptying typical during and after storms (Quintana, 2002).

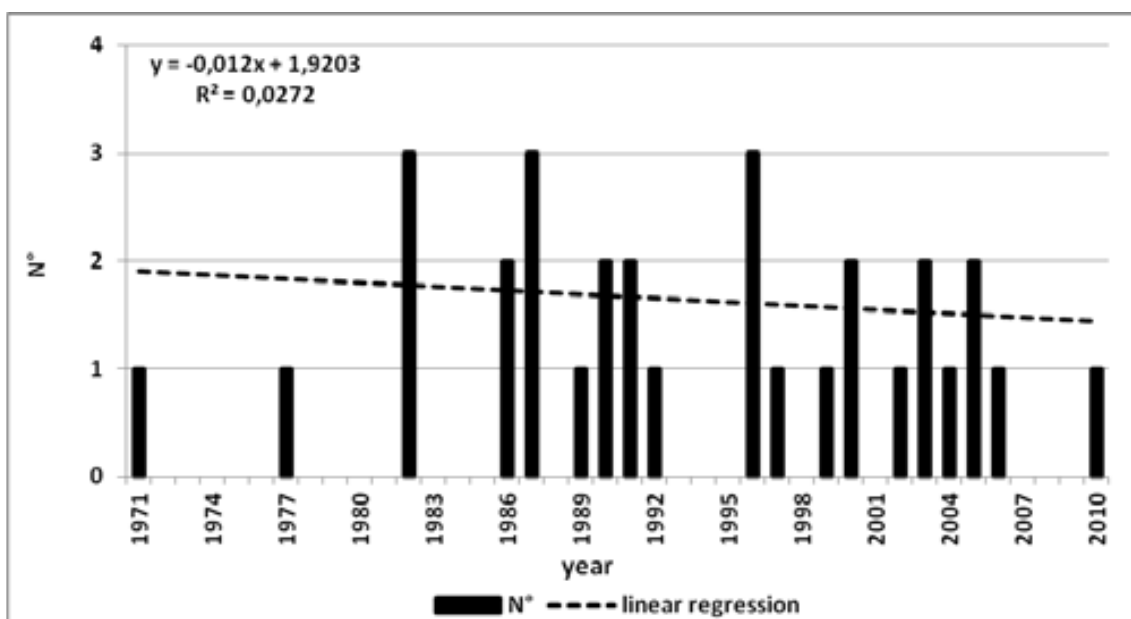


Figure 24. Number of total floods and linear regression for the period 1971–2010 in Alt Empordà.
Source: Llasat et al., 2009.

It is important to note that most of the municipalities of Aiguamolls de l'Empordà affected by floods have modified or plan to modify the watercourses that flow through their urban area (Pavón et al., 2003). Especially, the tourist developments of Santa Margarida and Empuriabrava, which were built on flood-prone land had periodically problems with flooding (Romagosa Casals, 2001). Castelló d'Empúries municipality area, at the mouth of Muga, has experienced recurrent flooding, aggravated by the construction of Empuriabrava since 1968 (Saurí-Pujol et al., 2001). However, after Muga river regulation storms have caused less flooding and wind and sea level have had negligible effects on water levels in the saltmarsh basins (Quintana, 2002).

In the study area, there have been the different views among park managers, farmers and tourist interests on artificial flooding in some parts of the Natural Park. Park managers want *closets* to be seasonally flooded to protect and enhance their ecological functions (Saurí et al., 1995; Ventura Pujolar et al., 2000), sometimes for periods of up to two months, during which farming is impossible (Llausàs et al., 2009). This is done by controlling water levels in existing irrigation ditches and installing or repairing gates able to regulate water inflows and outflows in the *closets* (Quintana, 2002; Saurí et al., 2000) (see Figure 25). In this sense, surface of lakes and floodplains increased from 37 to 350 ha after 1985 (Ventura Pujolar et al., 2000). These flood episodes are recognised by park managers to provide abundant freshwater and nutrient supplies to the wetland ecosystem and contribute to restore salinity balances (Saurí et al., 1995). In contrast, farmers reacted negatively to this policy although the reform of the Common Agricultural Policy of the EU (introduced in 1962) may benefit the traditional *closets* system, in the sense that their conservation and even expansion may be possible with a return to traditional grazing practice (Saurí et al., 1995). In sum, this issue of artificial flooding and different views among different stakeholders in Aiguamolls de l'Empordà has been moving toward new directions over the recent decade. My results suggest, however, that agriculture sector has moved toward more sustainable agriculture practices, contributing to environmental sustainability and conservation of the flooded areas and Natural Park have started to be perceived as a beneficial for the local economy. Here, mainly believed that at one hand, it can promote local and regional ecotourism industry and combat the problem of seasonality in

tourism, and at the other hand, it can further improve the mid- and long-term security of food.

Finally, one of the immediate effects of sea level rise is flooding of coastal land (Saurí et al., 1995). For instance, in autumn 2011, it was documented a coastal flooding on Escala beach, which was overtopped by waves during the strong storm event (Empordà, 2011b). Hence, it may be suggested that the Natural Park may face more frequent climate change effects since it is a natural buffer zone between the sea and some urbanised areas. The additional effects of catchment management and water use also need to be considered, as this may have a larger effect than climate change (Nicholls et al., 2008). It was also shown that some kinds of economic development may increase vulnerability to coastal hazards (e.g. flooding) due to destruction of natural protections (e.g. wetlands), increased exposure of populations and assets, and more subtle social processes such as a possible decline in the effectiveness of collective behaviour, which can lead to a decline in flood-defence maintenance and hence increased risk of their failure (Adger et al., 2001). Saurí et al. (1995) reported that flood-control through structural works has been already forming the first response in the several adaptive responses in order to minimise losses in the study area.



Figure 25. Flooded closes (left) and gate for water inflow and outflow regulation (right). Source: Author, 2012.

5.1.2 Coastal erosion

Coastal erosion is a permanent loss of sand from the beach-dune system and strongly depends on the type of coast: exposure, wave climate, surge levels, sediment composition and beach slope (van Rijn, 2011). Coastal erosion, whether due to natural or anthropogenic reasons can cause significant ecological damages, economic losses and social problems. In the Mediterranean region it is particularly acute due to mounting pressure arising from human activities, such as farming, shipping, industry, urbanisation, but in particular due to mass tourism (Council of Europe, 2003).

The situation has become truly alarming for numerous stretches along the Mediterranean coastline that have been subject to unprecedented erosion and excessive tidal flooding. It is estimated that three-quarters of the sand dunes on the coastline between Spain and Sicily have disappeared since 1960 (Council of Europe, 2003). The loss of wetlands as a result of coastal erosion, flooding and human activities constitute a major problem. It is estimated that the Mediterranean region has lost about 1 million ha of wetlands in the last sixty years (Council of Europe, 2003). Furthermore, the phenomenon of coastal subsidence (i.e. relative sea level rise or the natural lowering of land) is expected to exacerbate the adverse coastal erosion effects of a sea level rise caused by climate change. Coastal erosion might also be exacerbated by the upstream construction of dams and the development of other forms of river or coastal infrastructures as such constructions hinder the natural sediment flow that rivers bring to the sea and the coasts. One conspicuous example is the coastal erosion in Egypt in the wake of the construction of the High Dam at Aswan (Council of Europe, 2003).

According to the International Centre for Coastal Resources Research, CIIRC (2010), is estimated that about 72% of the Catalan coastline is affected by erosion at an average retreat rate of 1.9 m per year. The average annual erosion rate in the study area has been of about 1.4 m. The highest erosion in Aiguamolls de l'Empordà area has been documented on Sant Pere Pescador beach, near Fluvià river mouth, at annual rate about 3.5 m and in Roses (Punta beach) at annual rate about 3.4 m (CIIRC, 2010).

In particular, the sandy coastlines and wetlands of Aiguamolls de l'Empordà are at high risk of erosion and flooding (Ulled & Xalabarder, 2007). Prior studies reported that there are various factors affecting erosion along the Catalan coastline, however, the most significant are storms, the reduction in river sediments due to the upstream construction of dams, the dredging operations on the riverbed, the decrease in river

liquid discharge, the proliferation of ports and the installation of hard structures for coastal protection (ICHN, 2010; Jiménez et al., 2002).

The Catalan Institute of Natural History, ICHN (2010) found that is likely that coastal erosion will increase as a result of sea level rise associated with climate change over coming decades. Over recent years, it has been reported that storms have provoked damage to infrastructures (e.g. promenades) and water and sediment floods during massive overwash events, when storm waves overtop promenades (Ariza et al., 2008). It was recorded that storms waves reached height between 12 m and 18 m (Díaz & Ercilla, 1993). However, from the storm data available (Figure 14), it can be noted that in the period 1971–2012 the frequency of storms decreased in the study area.



Figure 26. Signs of overwashed beach due to storm event in Roses. Source: Author, 2012

5.1.3 *Water scarcity*

Water is the most vulnerable natural resource to climate change. Global warming is expected to make water resources scarcer in the Mediterranean countries because of a decrease in average annual precipitation, increased variability in the frequency and intensity of precipitation events, increased average temperatures that result in higher evaporation from dams and reservoirs, and increased urban and irrigation water

demands (Scoullos & Ferragina, 2010). According to the Spanish Ministry of Agriculture, Food and Environment, MAGRAMA¹⁹ (2005), water resources over the Iberian Peninsula are likely to decline between 5 and 14% until 2030 and by 17% until 2060. These trends can exceed between 20 and 22% until the end of the 21st century. It was documented that potential changes in the volume, timing and quality of surface and groundwater may jeopardise water supply and industrial, agricultural and touristic demand, increase risk of flood events and water-related diseases, and adversely affect the ecosystems and services they provide (Kundzewicz et al., 2008; Mas-Pla et al., 2012).

I recognise that climate change poses challenges and concerns for the agriculture, tourism and domestic water supply in Aiguamolls de l'Empordà. This might be observed through the Drought Decree 2007–2008, which was approved in April 2007 with the aim to enhance water preservation and its efficient use. This decree operated until January 2009 (ACA, 2008; Hora Nova, 2009a). Moreover, in the study area factors that have caused increased water demand (i.e. population growth, tourism, agriculture, ecological conservation) led to a growing process of economic diversification and a further increase in water demand that generated social and environmental conflicts caused by lack of water (Ventura, 2005). In response to the drought, the DTS proposed a plan of building a desalinisation plant (Empordà, 2010b), which at the moment of writing up this chapter has not yet been implemented. The interview data, along with observation, point to a picture that the main reason for this has been the current economic recession in Spain.

5.1.4 *Saltwater intrusion*

Saltwater intrusion is another immediate effect of sea level rise. One-quarter of the global population live in coastal regions that have less than 10% of the global renewable water supply and are undergoing rapid population growth. Saltwater intrusion due to excessive water withdrawals from aquifers is expected to be exacerbated by the effect of sea level rise, leading to reduction of freshwater availability (Kundzewicz et al., 2008).

¹⁹ Previously named as the Ministry of Agriculture and Fishing (1981-2008) and the Ministry of the Environment, Rural and Marine Affairs (2008-2011) (see <http://www.magrama.gob.es>)

The saltwater intrusion is one of the major problems facing Aiguamolls de l'Empordà (Empordà, 2010b). It has been observed that some of the wells and aquifers have been already affected by saltwater intrusion, but they still constitute an important resource for agriculture and coastal tourism of the study area (Candela et al., 2007; Emmi & Santigosa, 1989).

Coastal aquifers highlight the human alteration of the hydrological cycle through the reduced river discharge in the final stretch of Muga, the construction of the Boadella dam and wells overexploitation, which has changed the water composition and has led to the horizontal saltwater entry (Ribas Palom, 2006). Furthermore, hydro-geological data shows a decline of the alluvial watertable and an increase of the Fluvià river water salinity, which enters the aquifer through well-induced intrusion. In addition, deepening of the riverbed of Fluvià in coastal areas facilitates seawater penetration into the aquifer (Mas-Pla et al., 1999b).

The park authority has been also very critical of the salinisation process, which affects the area and its ecosystems (Empordà, 2010b). Moreover, excessive water use during the summer by agriculture and tourism and the flood control policy have stimulated the saltwater intrusion to the extent that most municipalities have been provided with surface waters (Saurí et al., 2000). Furthermore, the saltwater intrusion also adversely affects the ecosystem, especially around 20,000 birds, which stop every year in the Natural Park (Empordà, 2010b).

Hence, the DTS has proposed to install various facilities for preventing the saltwater intrusion, to maintain adequate amounts of water in streams, to inundate the lagoons (which have gradually lost the ability of temporarily flooding) and to preserve the soil fertility of the *closes* (Empordà, 2010b). The interview data suggests that the main reason for not implementing the proposed plan has been the current economic recession in Spain.

5.1.5 Deficit in sediment supply from Fluvià

It was found in prior studies (e.g. Gallart & Llorens, 2003; Gallart & Llorens, 2001; Gallart et al., 2011) that average annual flow in several of the main rivers in Spain has decreased between 37 and 59% in the last sixty years. It has been also claimed that decrease in river flows was not only due to water abstractions for irrigation and climate

variability or change rather it has been attributed to the increase in forest land cover (i.e. afforestation) as a consequence of land abandonment.

However, observed decrease in the Fluvià flow (Figure 16) can lead to the decrease in river sediment transport and supply (Martín-Vide et al., 2012). This process can lead to erosive behavior of the river mouth of Fluvià (Jiménez et al., 2011). Therefore, it can be suggested that a balance between river sediment supply and removal due to littoral dynamics determines the Fluvià river mouth to be reshaped and eroded. For instance, this erosion has affected the beach stability north (Can Comes beach) and south (Sant Pere Pescador beach) from the river mouth with erosion rates of 2.7 and 3.5 m per year, respectively (CIIRC, 2010).



Figure 27. Fluvià river mouth (up) and Fluvià in Sant Pere Pescador (down). Source: Author 2012.

This subchapter identified some of the main vulnerabilities to climate change effects. In the following subchapter, I present the results of the fieldworks, which provided the possibility of engaging with stakeholders across the study area and fostering a better understanding of vulnerability to the changing climate.

5.2 Integrating local knowledge and perception for assessing climate change vulnerability. Listening to voices from the field

Chapter 2 established and argued that vulnerability assessment should be an essentially participatory process, fully engaging stakeholders, their perceptions and knowledge in all stages of setting out environmental policies or strategies. In line with these fundamental principles, I move on to present and discuss my research results. Furthermore, a variety of documental data (i.e. scientific studies, regional newspaper articles), statistical data and photographs as complementary documents are used for enriching the analysis.

5.2.1 *Climate change awareness*

The stakeholders who were interviewed during fieldwork in Catalonia had a high level of awareness about global and regional climate change, most of them having noticed changes in recent decades, while only two stakeholders believed that climate change is not occurring at all. Similar, was found in the study of Marino's (2012) who documented that respondents in Alaska had high awareness about climate change and stating that it is the greatest threat to their future. Also, Gurran et al. (2012) documented that in the case of Australia's coastal cities respondents indicated a high level of awareness about potential climate risks to their communities. Here, can be suggested that stakeholders' high level of awareness, may be a result of interaction between place attachment and emotional connection with the study area. According to Akerlof et al. (2013), the place attachment can more strongly motivate both perceptions of local, regional global warming risks and higher levels of beliefs in having experienced climate change. However, some prior studies (e.g. Leiserowitz, 2005; Rabe & Borick, 2012) reported that public opinion about the existence and importance of global warming and climate change depends strongly on perceptions of recent local climate variations, and on the content and format of these information provided (Whithmarsh, 2011).

Furthermore, as is described by Neuwirth et al. (2000) higher levels of perceived risk increase protection motivation. Risk perception has long been theorised and empirically identified as an important predictor of people's decisions to adjust to various kinds of natural hazards (Terpstra et al., 2009). Similarly, Burton et al. (1993) pointed out that risk perception and awareness are crucial as individuals and institutions must perceive and understand climate change as a present and future threat before making steps for adaptation. However, awareness is dependent on the effectiveness of social networks and infrastructure to support and facilitate information flow and skills (Buckland & Rahman, 1999). Biesbroek et al. (2011) found that lack of communication between science, policy and society on climate change adaptation can result in a low level of awareness, skepticism, overconfidence, or denial. I acknowledge that social and information network and services in the present study case are likely to be highly effective and easily accessible.

Climate change awareness did not importantly differ in terms of the interviewed stakeholders' nationality or sector of work activity. In terms of gender, even if there are not many differences, it could be noted that women were more aware of climate change since both stakeholders that were not aware of climate change were men. These findings are largely consistent with some other studies (e.g. Akerlof et al., 2013; Bord et al., 1998; McCright, 2010; Semenza et al., 2008) where was documented that women are more likely than men to be aware of changing climate. In addition, the stakeholders that were not aware of climate change in general were older than the ones who were aware of it. Similar to some previous studies (e.g. Kellstedt et al., 2008; McCright, 2010), older respondents expressed less concern and awareness for climate change than younger respondents. The following interview quotes are illustrative of opinions gathered in Aiguamolls de l'Empordà:

"Climate change is a hoax where people just want to make money of this issue" (CA-male-53).

"Nobody knows what is actually happening with the climate; we have one year cycle of warmer weather and another cycle of colder weather" (ENA-male-64).

"Sure, there is definitely climate change due to human stupidity. It represents a serious problem to our present and future society and environment" (PAA-female-40).

"I believe climate change is real and is occurring, at least in part due to man-made carbon emissions" (IA-female-31).

In perceiving the causes of climate change (Figure 28), the interviewed stakeholders most commonly agreed that the climate is changing due to a range of human activities:

“Changing climate is occurring due to human activities what is well-proven” (RA-female-33).

These results contrast with the findings of Whitmarsh (2011), who claimed that the notion of anthropogenic climate change was not widespread amongst the UK public. It is important to note that an acceptance of anthropogenic climate change is likely to be a critical determinant of supporting mitigation policies and a willingness to engage in individual emissions reduction (Leiserowitz, 2007).

However, about a quarter of the stakeholders were more likely to state that climate change is the result of a combination of natural fluctuations in the Earth’s temperature and human activity, while only a few stakeholders believed that climate change is occurring due to natural climate variation:

“It is a combination of natural phenomenon and man’s activities, which emit greenhouse gases to the atmosphere” (AFA-male-39).

“Man overvalues himself. I do not think we can change the climate with our activities” (IA-male-46).

Interestingly, the majority of stakeholders who stated the opinion that humans are not at fault for climate change, it being rather part of Earth’s natural cycle, were from the industrial sector. The study of Buzinde et al. (2010) found that such views are common within the tourism sector and may offer an escape for stakeholders who are apprehensive about recognising their role in the degradation of the local environment. Thus, similar views can also be attributed to stakeholders from industry due to their role in affecting the environment.

In particular, roughly two thirds of foreign stakeholders, as with Spanish ones, perceived climate change as a result of human activity. The anthropogenic cause of climate change was more likely to be perceived by younger stakeholders rather than older ones. This finding contrast somewhat with the study by Chowdhury & Haque (2008) who found that older respondents in Winnipeg (Canada) were more likely to perceive that climate change effects were correlated with an increase in a concentration of GHG. Moreover, a clear majority of women perceived climate change as a result of human intervention. This finding appears to be consistent with McCright (2010) in the USA, who reported that a greater percentage of women than men believe that climate

change is primarily caused by human activities. Further, the opinion about the combination of natural and anthropogenic causes of climate change was much stronger among men in Aiguamolls de l'Empordà.

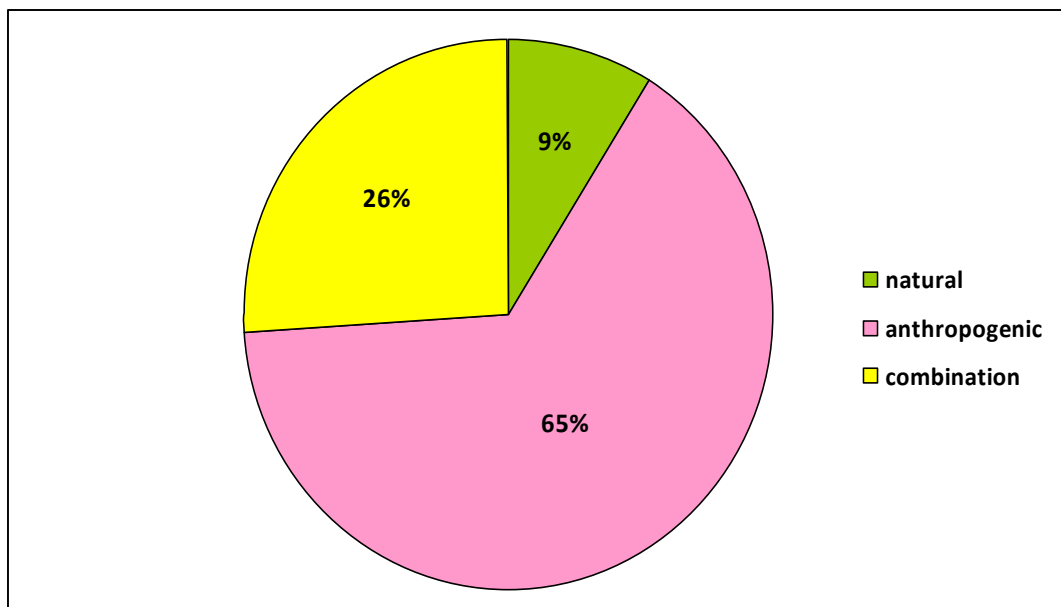


Figure 28. Percentage of stakeholders citing causes of climate change (n=45). Source: Author, 2013.

5.2.2 Perceived climate change effects

General awareness about climate change was primarily framed by the effects and changes or variability that have affected the study area. Bier (2001) underlined the importance of assessing what the stakeholders already know or believe about a particular issue in order to design effective risk communication messages and further strategies for climate change adaptation and mitigation.

In the Catalan wetlands of Aiguamolls de l'Empordà, most local stakeholders were aware of climate change and its effects (Figure 34). Trends such as an increase in air temperature, changes in water supply, change to patterns of precipitation, more severe droughts, loss of biodiversity and a decrease in ecosystem productivity, more frequent coastal flooding and erosion and a rise in sea level have all had effects on the communities and the environment of Aiguamolls de l'Empordà.

Furthermore, they considered that air temperature increases over the past few decades, decrease in water supply, decrease in precipitation, but with an occasional increase in intensity, the worsening droughts, and the decrease in biodiversity and

ecosystem productivity to be the most significant climate change effects and serious threats to this area.

For the most part, stakeholders' perception of an increase in **air temperature** appeared to be in line with current meteorological data (Figure 9). Specifically, interested actors from the environmental and industrial sectors indicated that the increase in air temperature and droughts over the past few decades were the most serious climate change effects. Thus, air temperature data at the meteorological station in Estartit shows that temperature increased over the period from 1971 to 2012. According to data from this station, air temperature increased by 2.3 °C over 42-year period.

Consequently, the observed increase in average sea temperatures at all depths (Figure 18, 19) is likely to affect the geographical distribution of fish species (EEA, 2012b). According to some leading national and regional newspapers (e.g. El País, 2012a; Empordà, 2012a; Hora Nova, 2009d), it has been observed that some fish species are already migrating northward to colder waters (e.g. *Sprattus sprattus*) while the frequency of other species from warmer waters is increasing (e.g. *Vieja*). Moreover, some invasive marine and terrestrial species (e.g. *Carpobrotus sp.* along the dunes in Escala) have been detected and later eradicated and it is likely that these are correlated to the warming trends (Hora Nova, 2010a; Empordà, 2011a). It is worth mentioning that invasive species are one of the most important threats to biodiversity, which affects economy, human health and ecosystems services (Millennium Ecosystem Assessment, 2005).

In addition, Fischer & Schär (2010) suggested that for the Iberian Peninsula the frequency of heatwaves days is projected to increase from 2 days per year (1961–1990) to 13 days per year in 2021–2050 and 40 days per year in 2071–2100. The increase in heatwaves days, along with increase in air temperature can make the study area less attractive destination both for tourism and second home residence. Heatwaves can also increase risks of heat-related illnesses and mortality, however, it was documented that heatwaves have caused about 10,000 of premature deaths in Europe in recent decade (EEA, 2012b). As one of the stakeholders pointed out:

“The weather is less predictable, temperatures have notably increased and over the last decade we have had just two seasons, summer and winter. The occurrence of heatwaves has increased” (CA-female-48).

In contrast, it is worth mentioning that some prior studies (Kalkstein & Greene, 1997; Langford & Bentham, 1995) showed that it is estimated that increase in temperatures may lead to a future reduction in winter mortality.

Regarding **precipitation**, in contrast to stakeholders' perception, there was no statistically clear significant decrease in precipitation over the period 1971–2012 (Figure 11). The stakeholders' perception of the decrease in precipitation might be explained by the fact that after 1994, there was a drop in the volume of precipitation, so the stakeholders' perception may be based more on short-term rather than long-term trends.

Furthermore, **drought**, which was highlighted by over a third of stakeholders, could be more difficult to perceive, but because it plays a crucial role in various economic sectors, many stakeholders had a strong perception of its magnitude and frequency:

“The climate has become hotter and drier. Rainfall is also shorter, but more intense. So the drought is much more frequent and intense” (ENA-male-44).

Interestingly, earlier study dealing with the perception of droughts (e.g. Taylor, 1988) found that stakeholders who believed droughts were occurring at higher frequency and severity were more likely to attribute the cause to human activities and to a lesser degree to natural variability. On the contrary, in the study by Diggs (1991) a majority of farmers in the USA's Great Plains reported that drought was probably not due to human activities.

In this respect, Sheffield & Wood (2008) showed that the Mediterranean region is likely to be one of the regions with the largest and most consistent projected increase in drought. A year of detecting the projected increase in short-term (4–6 month duration) drought is estimated to be 2049, with estimates of 2038 for long-term (more than 12 month duration) drought and 2018 for increased area of drought. Hence, I acknowledge that this can importantly affect agricultural yields of existing crops, increase the use of irrigation and reduce the water supply so for domestic use as industrial and services use.

Stakeholders who reported the loss of **biodiversity** and the ecosystem tended to be younger and work in public administration. Their perception is in accordance with some prior studies where it was examined that about 60–70% of all Spanish wetlands and their ecosystems were lost compared to those existing in the 1940s (MAGRAMA, 2010), including about 50% of all Catalan wetlands (Seguí et al., 2009). Furthermore, according to an Alt Empordà county newspaper (Hora Nova, 2009e) dune ecosystem is

likely to be degraded in some parts of the study area due to tourism and recreation such as kitesurfing, which is not compatible with the purposes and conservation of the Natural Park. Similarly, there has been documented the loss of endemic species such as seagrass *Poseidonia oceanica* due to tourism activities and extreme weather events such as storms (Hora Nova, 2009d).

During the 20th century most Mediterranean wetlands were drained and dried out to reduce the dissemination of infectious diseases and to convert these areas for agricultural, urban and tourism uses (Pearce & Crivelli, 1994; Romagosa Casals, 2009; Seguí et al., 2009). Beside the land use change, climate change has accelerated the ecosystem and biodiversity losses and it is likely that it will result in the extinction of many species and a further reduction in ecosystems' diversity (IPCC, 2007b). It is important to note that biodiversity loss could cause the breakdown of food chains and eventually the collapse of the ecosystem, leading to the total loss of its buffering ability and other services to human well-being (Millennium Ecosystem Assessment, 2005; Munang et al., 2013). The buffering ability and services provided by ecosystems (e.g. climate and water regulation, protection from natural hazards such as floods, water and air purification, carbon sequestration) are critical for climate change adaptation since it is argued that ecosystems can reduce physical exposure to natural hazards by serving as natural protective barriers or buffers and thus, mitigating hazard impacts (Munang et al., 2013).

Hence, ecosystems as buffers can also increase the adaptive capacity of natural and socio-economic systems to climate change. In addition, the latest available average ecological footprint estimated for Catalonia in 2003 was 3.92 ha per capita, a value 1.5 times higher than that calculated on a global scale which was 2.36 ha per capita. This means that each Catalan citizen consumed 1.24 ha more ecosystem products and services than an average citizen globally (Mayor et al., 2005). Based on the data presented by Brenner et al. (2010), Alt Empordà has been the second county on the Catalan coast that accounts for the largest value of ecosystem services. They furthermore indicated that an economic value of about \$3.2 million USD was delivered to citizens in 2004 by ecosystem services on the Catalan coast (e.g. beach and dunes provided the largest economic value on a per hectare basis). This implies that ecosystem services have provided a substantial and quantifiable contribution to the well-being of coastal communities in Catalonia in general and in Alt Empordà in particular. Here, it is worth mentioning that if we had to pay for ecosystem services in Catalonia, or replace

them, then an annual increment in GDP of at least 2.7% would be necessary (since the evaluated services are not currently captured in GDP) (Brenner et al., 2010). Hence, it can be assumed that change or loss of biodiversity and ecosystems may be a significant factor in increasing vulnerability and the consequent adaptive capacity for the people and their economies in Aiguamolls de l'Empordà to adapt over coming decades. For instance in agreement with this finding one of the stakeholders stressed:

“Ecosystem and biodiversity decline undermine drinking water supply and food production and because of that human health and livelihoods in municipalities of Aiguamolls de l'Empordà may be in the future threatened” (PAA-male-36).



Figure 29. Ramsar Convention on Wetlands warning (left), White stork (*Ciconia ciconia*) (right-up) and Vaca marinera (*Bos taurus domestica*) (right-down). Source: Author, 2012.

Furthermore, more frequent flooding, a rise in sea level and coastal erosion were considered by stakeholders as having a significant effect on Aiguamolls de l'Empordà's community, economies and its ecosystem.

Regarding perception of sea level rise, stakeholders appeared to reflect present **sea level** data provided by Estartit station (Figure 17), which showed an increase of 8.2 cm in sea level between 1990 and 2012. It is important to note that the increase in average sea level in Estartit (3.6 mm/year) was higher than the global average sea level (3.2 mm/year in the period 1993-2010) (IPCC, 2013). However, Nicholls & Klein (2005) argued that it is not the global average sea level that matters, but the locally observed, relative sea level, which takes into account regional sea level variations and vertical movements of the land (e.g. subsidence). In particular, the north-east part of Spain, where the area of Aiguamolls de l'Empordà is located, is a region where present tectonic deformation and seismicity are moderate to low. The recent vertical movements with significant uplift rates along the Empordà basin have been about 0.8 mm per year (Giménez et al., 1996). Therefore, it can be suggested that subsidence, which influences the sea level is not significant in this study area.

Interestingly, stakeholders from the public administration and tourism were more likely to identify changes in sea level than other sectors. Moreover, these stakeholders were likely to attribute the cause of rising sea levels to human activities.

Furthermore, an increase in **coastal erosion** matched stakeholders' perception, where it is estimated that about 72% of the Catalan coastline is affected by erosion at an average retreat rate of 1.9 m per year. The annual erosion rate in the study area has been of about 1.4 m (CIIRC, 2010):

“Tourism, agriculture and ecosystems along the coast are prone to being damaged as erosion and wave intensity increase” (AFA-male-51).

During fieldwork, it was observed that there were signs of erosion along the beaches in municipalities of Roses (Figure 26), Escala (Figure 30) and Sant Pere Pescador. In terms of the tourism sector, coastal erosion is likely to affect the potential exploitation of the area because of a change in surface area of beaches (Valdemoro & Jiménez, 2006) what can lead to a reduced income and loss of employment in the study area. This finding most likely implies that Catalan coastal tourism is particularly susceptible as the coastline is a focal point for an important part of tourism in Catalonia. Therefore, it can be adversely affected to a significant extent (e.g. effects on income by damage to tourism infrastructure) when it is considered that most tourists (95% in 2010) chose to stay in the coastal areas (Catalan Ministry for Business and Labour, 2011).



Figure 30. Signs of coastal erosion in Escala. Author, 2012.

Another significant climate change effect, an increase in **flooding**, which was reported by roughly a quarter of stakeholders, did not match the available flooding data for Alt Empordà (Figure 24). It can be observed that over the period 1971–2010 flood events steadily decreased from 2005 onwards and increase in precipitation was not noticed in recent years (Figure 11). Hence, in this way it can be estimated that the negative linear regression for the flooding may be due to increased urbanisation, new roads and motorways, increased population density over recent years and changes in hydrological river conditions (Barnolas & Llasat, 2007). Regarding gender, men perceived higher levels of flood events than women. However, Kellens et al. (2013) discovered the opposite relation.

Furthermore, I argue that although socio-economic vulnerability is not a function of flood severity, certain properties of socio-economic system in Aiguamolls de l'Empordà's may make it more vulnerable to flooding. For instance, quality of housing (stakeholders especially mentioned marinas like Empuriabrava) may be an important determinant of a community's vulnerability to possible future flooding and storm occurrence, but is less likely to influence its vulnerability to drought:

“Property sales in Empuriabrava and Santa Margarida could be restricted under the recurring climate hazards such as flooding” (ECA-male-42).

Consequently, flooding can also affect tourism by discouraging tourists from visiting the study area because impacts of climate change can reduce its appeal.

However, all groups of stakeholders reported having observed flooding events, though those in the public administration were significantly more likely to indicate widespread concern about these issues than were other groups:

“More intense precipitation that usually results in flash flooding and in increases of stormwater runoffs cause damage to public and private properties and lands...And on the other hand we must cope with the prolonged droughts” (PAA-male-41).

An important finding of this research is a presence of good risk communication by the Catalan General Directorate of Civil Protection (DGPC)²⁰, which is the responsible body both for the safety of residents and their properties, and for managing and coordinating rapid emergency situations in Catalonia. It is acknowledged that it can successfully warn and inform the residents about the risks of extreme weather events and the measures they could take (Hora Nova, 2009g). Indeed, one of the interviewed stakeholders highlighted the role of good risk warning and communication:

“We are adjusting our well-managed risk communication to the needs of the Catalan residents. Over the last decade our work has increased due to people’s concern and awareness about the increased frequency and severity of extreme weather events” (PAA-male-53).

Nevertheless, it is important to highlight the demographic differences regarding the issue of warning and communication in municipalities of Aiguamolls de l’Empordà. For instance, the large percentage of foreign residents (see Figure 8, Table 5) may have language difficulties of understanding warning or emergency communication, for instance in the time of extreme weather event. Although, it is worth noting that in the study area there is a proper and regular risk communication by DGPC (both directly by DGPC’s authorities and agents and social media such as Internet, Twitter, Gencat Mobil), the language variety used to inform the residents is limited on Spanish, Catalan, English and French. Therefore, I argue that special attention should be addressed at considering larger language variety (i.e. Arabic and German in my study case) in order to create effective risk communication both in normal situations and during warning or emergency situations. In doing so, the adaptive capacity to cope with the climate change effects increase with good risk communication (IPCC, 2007b; Nelson et al., 2007).

²⁰ See http://www10.gencat.cat/sac/AppJava/organisme_fitxa.jsp?codi=15681



Figure 31. Flooding warning in Castelló d'Empúries. Source: Author, 2012.

Many water-related effects were mentioned by the stakeholders. **Water supply** in the study area was, in the stakeholders' opinion, influenced on one hand by precipitation and temperature patterns, and on the other by river management of Muga and Fluvià and decreased water levels in aquifers. Therefore, over a third of stakeholders claimed that decreased water supply has affected the whole of the study area:

“Short periods of intense precipitation are threatening already scarce water resources...Water levels in aquifers and Fluvià flow have had decreasing trends” (PAA-male-48).

In particular, perception of decreased Fluvià **river flow** was consistent with the existing hydrological data provided by the ACA (Figure 16). According to the CREAM (2012), is projected that water supply from Fluvià will decrease by about 20% and precipitation in Fluvià catchment area by 7% until 2030 due to climate change. Nevertheless, some years ago it was suggested that in extremely dry years Fluvià

discharge would be able to provide an 85% of the required volume of water (Mas-Pla et al., 1999a).

Part of the reason why water scarcity is important for Alt Empordà is due to its significant water use: domestic use accounts for about 80%, while industrial and services use for about 20% (IDESCAT, 2013d). In the study area the factors that have caused increased water demand (e.g. population growth, tourism, agriculture, wetland conservation) have led to a growing process of diversification and an increase in water demand that has generated social and environmental conflicts caused by lack of water over recent decades (Ventura, 2005). Therefore it is possible to expect that these conflicts may intensify and jeopardise the agricultural and tourism sectors as well as ecological preservation if the availability and supply of water changes. These results are also in line with those of Barnett & Adger (2007) who found that the more people are dependent on climate sensitive forms of natural capital (e.g. natural resources, ecosystem services) and the less they rely on economic or social forms of capital, the more at risk they are from climate change.

Agriculture and **tourism** were mentioned as being vulnerable to climate change effects by one fifth of stakeholders. Some stakeholders stated that agriculture has been affected mainly by changed weather patterns, forest fires, saltwater invading rivers and aquifers whose freshwater is used for irrigation and changing agricultural growth conditions, while tourism has been affected by climate variability and change and beach management, mainly via shifting seasons, heatwaves and beach quality:

“The tourism is likely to be severely affected by intense heatwaves and higher temperatures, losing the ecosystem and additional economic activity” (IA-male-38).

In addition, these stakeholders' perception can be supported by the IPCC reports, citing that Mediterranean tourism and agriculture are already vulnerable to climate variability due to increasing temperature and decreasing water availability caused by climate change (IPCC, 2007b). Furthermore, Aaheim et al. (2012) highlighted that crops and forests in Europe have been impacted by climate change through growth conditions and the length of growth season. Quality of fruit and vegetables may be affected also, which is particularly important for wine producers. The location and size of fish stocks in the Mediterranean Sea may be affected by increasing sea temperatures and it is expected that fish stocks will move northwards and bring benefits to the northern European regions. All in all, climate conditions in the Mediterranean region may explain to a great extent why agriculture and services in this region are so vulnerable to

water scarcity. Part of the reason why water scarcity is important for Alt Empordà is due to the importance of the agriculture and services (especially tourism and construction) sectors in its economy. Services have traditionally a high share in GDP in Alt Empordà (about 88%). Moreover, the agricultural sector (4%) has lower share of GDP than industrial 8% (IDESCAT, 2013e). Most likely, this implies that although the study area has a low dependence on agriculture for livelihoods, finding alternative economic source at the time of economic recession and when food production and security are an important issue globally, may result as precarious and costly. It may be the case therefore, that these two economic sectors could be characterised as being climate dependent.



Figure 32. Vineyards in Armentera. Source: Author, 2012.

However, IPCC (2007b) highlighted that economic diversification and thereby broader range of income source can increase adaptive capacity. Here, is worth mentioning that in the study area some adaptive responses have been noted, for instance, through fishery diversification, where Roses has introduced an aquaculture activity. The aim was to introduce new economic activities, which may enable economic recovery and sustainability of the fishing industry in Roses (Empordà, 2013a). Another example is also promoting ecotourism: in recent years many plans for

reconstruction of the tourism industry have been suggested, for instance, the plan for constructing a tourist accommodation named *Ecovila* in the Natural Park's area with sustainable prices and practices (Empordà, 2013b) and creation of a network of natural roads aiming to improve the tourism offer and seasonality patterns (Hora Nova, 2009f).



Figure 33. Empuriabrava. Source: Author, 2012.

The perception of **forest fires** matched with the general trend in the Mediterranean region (Badia et al., 2011). However, forest fires have become a serious hazard in the area of Aiguamolls de l'Empordà in recent decades (Pavón et al, 2003):

“A present drier environment may lead to more frequent and severe forest fires and desertification. These fires would also release far more carbon dioxide into the atmosphere than before” (IA-male-46).

Forest fires have increased in Mediterranean regions, primarily because of the low economic viability of forestry, due to the use of other fuels such as gas or diesel, and the combined effects of fields and pastures abandoned to afforestation and greatly increased recreational use of the natural environment. The increasing wildfire intensity and size due to the changing fuel density is only one consequence of land use change, but it has become the focus of many fire prevention and extinction efforts (Badia et al., 2011) especially in recent decades with changing climate (IPCC, 2007b). Furthermore, it is projected that fire risk in Europe will increase the most in Spain, Portugal, southern Italy and Greece (Lung et al., 2012).

Here, it is important to note that in July 2012 Alt Empordà county suffered a three-day long wildfires, which spread rapidly due to the strong *tramuntana* wind and destroyed about 13,000 ha (14 municipalities were affected), killed four people (over twenty people were injured) and caused losses of about €143.6 million (BBC News, 2012; El País, 2012b; Empordà, 2013c; La Vanguardia, 2012). This was the largest fire in Alt Empordà since 1986 (La Vanguardia, 2012), but none of the nine municipalities of this thesis' study area were affected by fires indirectly. However, some of the solutions for mitigating forest fires have been the proposed idea of implementing a mosaic of vineyards, orchards and crops, which can act as natural firewalls (Empordà, 2013d).

Moving on, another serious perceived climate change effect by stakeholders was **saltwater intrusion**. Despite some of the wells and low-lying aquifers being affected by saltwater intrusion, they still constitute an important resource for agriculture and the coastal tourism resorts of the study area (Candela et al., 2007; Emmi & Santigosa, 1989). Moreover, excessive water use during the summer by agriculture and tourism, and the flood control policy have stimulated saltwater intrusion to the extent that most municipalities have been provided with surface waters (Saurí et al., 2000):

“When the aquifers record low recharge level then saltwater starts to enter in the underground freshwater reserves” (ECA-male-36).

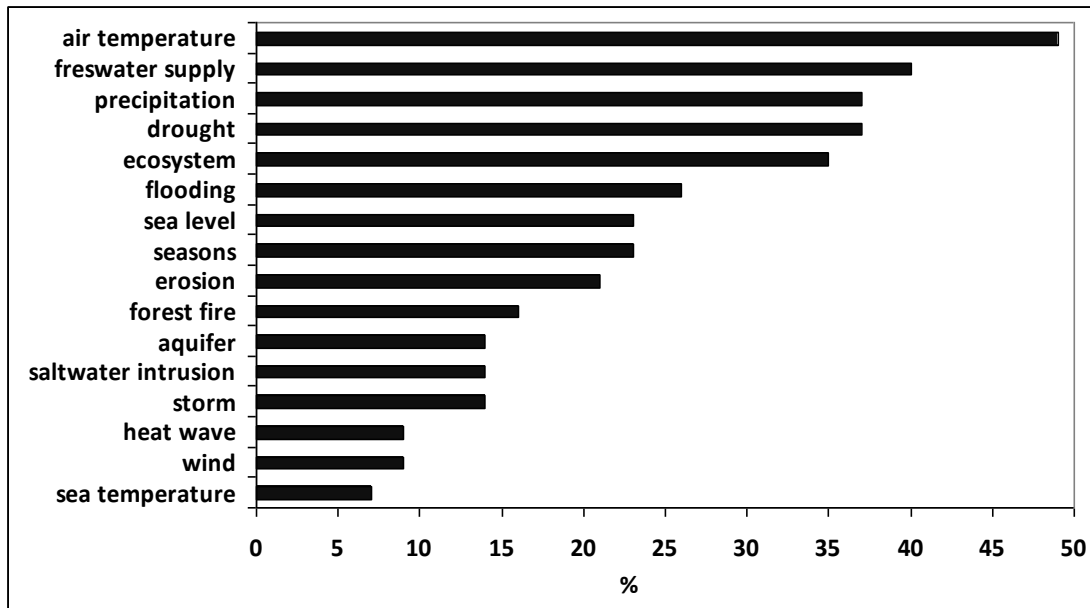


Figure 34. Percentage of stakeholders citing specific changes in climate and its effects in Aiguamolls de l'Empordà (n=45). Note that stakeholders mentioned often several changes and effects thus, the percentage represents the number of times the change or effect was mentioned. Source: Author, 2013.

5.2.3 Future sea level rise

Considering the issue of sea level rise of 50 cm during the 21st century in this part of the Mediterranean Sea, a clear majority of the interviewed stakeholders strongly felt that a 50 cm rise in sea level might happen and trigger further flooding, coastal erosion, and saltwater intrusion. The foregoing perception of sea level rise is consistent with the IPCC projections for Mediterranean Sea in general (IPCC, 2007a) and for Catalan Sea near Aiguamolls de l'Empordà in particular (ACA, 2009).

There was a high level of agreement on a future rise in sea level across the majority of research, tourism, industry, economic and cultural sectors. In this context, it is interesting to note that most of the women interviewed perceived the possibility of a 50 cm rise in sea level, which would negatively affect their lives. This data can be linked to other studies, which demonstrated that women are more vulnerable to environmental and climate hazards than men (e.g. Adger, 2006; Arora-Jonsson, 2011; Cutter et al., 2003; Fordham, 2003). According to the stakeholders' nationality, ten of eleven foreign stakeholders expressed a strong belief in sea level rise of 50 cm by 2050. This perception was stronger among younger stakeholders when compared to older ones:

“Sure, sea level will rise as a result of anthropogenic climate change and overexploitation of natural resources over last century” (CA-female-20).

“The sea level will rise and it is going to prompt more frequent and more severe flooding and coastal erosion than are already present in this area” (IA-female-31).

It can be assumed that if this projection of sea level turns out to be accurate, Aiguamolls de l’Empordà’s community and ecosystem services are likely to be greatly affected by losing properties, infrastructures, habitats, natural resources and economies what may push the limits of potentials for adaptation in situ, and therefore raise the questions about the planning for the possible relocation of some coastal land uses and outmigration.

In contrast, only a small proportion of stakeholders claimed that sea level would not rise 50 cm during the 21st century and thought that this is an exaggerated projection (and only few stakeholders stated that they had no idea what might happen with sea level within the next few decades):

“This projection about sea level rise here is overexaggerated and I do not see it probable to happen” (ENA-male-64).

5.2.4 Climate change impacts on work activity

When asked about the influence of climate change impacts on stakeholders’ work activity, large proportions of them indicated that climate change is already or may further continue to affect their work activity. Stakeholders from the tourism, industry, economic and research sectors were the most aware of climate change impacts on their current and future work.

Specifically, here it can be estimated that climate change seems no longer to be simply a global and distant issue, but rather one that has become a visible and current problem, whose impacts are felt in stakeholders’ work activities in Aiguamolls de l’Empordà area. Furthermore, contrary to what one might imagine, the current economic recession has not overshadowed the possible impacts of climate change on work activity. This result might be explained by the fact that in 2012 Alt Empordà had a relatively low unemployment rate, accounting just for 1.7% of the total unemployed people in Catalonia²¹ (IDESCAT, 2013c; INE, 2013b). It is rightly pointed out in the

²¹ Spain’s unemployment rate in 2012 was 25% and Catalonia’s was 22.7% (INE, 2013b).

study by Adger et al. (2004) that unemployment may increase vulnerability to climate change as communities lack the financial capacity to meet the cost of responding to it. This may be an important issue for future research on the regional and national capacity to respond to climate change.

The stakeholders who indicated an awareness of climate change's impacts on work activity were then asked if they believed that they could benefit from changing climate. Almost half of them stated that climate change would positively affect their work activity in the next few decades. These were mainly stating that climate change would create new areas of work or expand the tasks of their existing jobs due to the growing demand and interest in climate change issues. This was also expressed in interviews as the following:

“We can benefit from climate change because today there is always more research on this important issue” (RA-female-33).

“I think that climate change could in fact benefit my work activity because our company is specialised in coastal and port engineering, so with sea level rise our work would increase too due to the new coastal management” (IA-male-38).

However, there were also stakeholders who perceived that climate change might affect their work activity only in a negative way. Here, especially the stakeholders from tourism felt themselves to be negatively affected by climate change:

“Climate change is already impacting our tourism industry and further development could be restricted under the recurring climate hazards” (TA-male-41).

On the other hand, almost one third of interviewed stakeholders considered that climate change is not and may not affect their work activity. Interestingly, the public administration, cultural and environmental sectors claimed that their work activity would not be affected by climate change:

“Coupled with the changing climate and sea level rise, our coastal community may lose one economic activity, but may gain another one” (PAA-male-48).

Regarding gender, women were significantly more likely than men to perceive that their work activity is affected by changing climate. These results are in line with those of Bord et al. (1998) who found that with regard to gender, women are more fearful of the risks of climate change and they are also more concerned generally about environmental risks (Kellstedt et al., 2008). Furthermore, older stakeholders tended to express stronger perception of the impacts of a changing climate on their work activity than did younger ones.

5.2.5 Sustainable development awareness

There was generally a high awareness of the meaning of sustainable principles among the stakeholders, with about three-quarter of them knowing the concept of sustainability, which influences the economy, society and the environment in the study area.

Regarding the sector of work activity especially the stakeholders from industry, agriculture, tourism and public administration were greatly aware of this issue:

“It is about balancing community, environment and economy while focusing on the long-term period” (TA-female-46).

Women were again significantly more aware of sustainability issues than men (two-thirds of women, one-third of men). This may be consistent with the existing findings that women express more concern than do men about local environmental issues and problems (Arora-Jonsson, 2011; Davidson & Freudenberg, 1996). Similarly, Johnsson-Latham (2007) found that women globally live in a more sustainable way than men, leave a smaller ecological footprint and cause less climate change.

However, interestingly, the majority of foreigner stakeholders were not aware with the principles of sustainability. As argued elsewhere (e.g. Wagner, 2007) local conditions may have major effects on people’s knowledge, therefore it can be assumed that people with no awareness of sustainability may not perceive strong place or cultural attachment for the area in which they live.

It is worth mentioning that sustainable development can reduce vulnerability and enhance the capacity of countries to adapt to climate change (Sullivan, 2008) especially over coming decades where is projected further increase in global urbanisation trend, which may be swelled by additional migrants pushed from rural areas to urban areas by resource scarcity (Black et al., 2011)

Furthermore, an important finding of this research is the positive value of community participation in sustainability issues in Alt Empordà. It has been shown that community has been active participating in environmental education issues such as marine conservation and the Natural Park management (El Punt Avui, 2011b), in preserving and maintaining environment, e.g. cleaning up the Natural Park and surrounding area (Hora Nova, 2009b), and community’s successful involvement also resulted in withdrawing of new industrial complex along the area that acts as a biological corridor (Empordà, 2012b). Stojanovic et al. (2004) claimed that a wide

range of community participation is likely to affect positively sustainable environmental implementation of strategies and policies.

In addition, among those stakeholders who were aware of sustainability issues, more than half of them perceived their municipalities as unsustainable. The main reasons for the unsustainability have been the past economic growth and activities (i.e. rapid mass tourism growth) along the coastline and unsustainable exploitation of natural resources (i.e. wetlands, water supply). Here, especially economic, environmental and public administration sectors perceived their municipalities as unsustainable:

“This area cannot be sustainable while focusing on mass tourism... In April, Spain in general has exhausted the nature’s budget for year 2012 and we are already operating in overdraft and it means we are in debt towards the Earth” (ECA-male-68).

“No, with the pressure from rapid urban sprawl over the last few decades it cannot be a sustainable area. That is why they create a Natural Park... To maintain some of natural areas that would not be further degraded by littoralisation” (ENA-female-45).

This subchapter analysed climate change and sustainability awareness in general among the interviewed stakeholders. However, I assume that the perceived climate change effects and sustainability awareness of the study area should be considered both the extent and nature in order to understand better the concerns and levels of awareness in order to design the appropriate policy and/or strategy for climate change adaptation.

CHAPTER 6
CLIMATE CHANGE ADAPTATION IN AIGUAMOLLS DE
L'EMPORDÀ

In the following chapter I examine the adaptation to climate change in Aiguamolls de l'Empordà from a perspective that include stakeholders' perception and knowledge in an effort to analyse the most suitable measure for adaptation together with documental and statistical data, which support the analysis.

Recently, assessments of adaptation have often took place within the assessments of vulnerability, since the two are often seen as inextricably linked (e.g. El Raey et al., 1999; Fatorić & Chelleri, 2012; Mustelin et al., 2010). Planning the adaptation to climate change requires the use of information on present conditions and future climate projections (Bormann et al., 2012). Therefore, projections of the study case climate models (see Figure 20, 21, 22, 23) were used to quantify possible future climate variability or change in the study area, which may need an adaptation to climate change. Additionally, understanding how to reduce vulnerability to climate change becomes an exercise in adaptation planning (Dolan & Walker, 2004).

The interviewed stakeholders had a very homogeneous opinion and knowledge about adaptation to and mitigation of climate change. When asked about their awareness and understanding of adaptation to and mitigation of climate change effects on both the coastline and inland areas, the stakeholders expressed a very high level of familiarity with adaptation measures, but much less with mitigation measures (Figure 35). Regardless of mitigation, stakeholders mainly opined that promotion and implementation of renewable energy, increasing energy efficiency and reduction of GHG emissions are the key issues:

“To fight climate change we should implement appropriate renewable energy technologies and promote better energy efficiency” (ENA-female-45).

So far, it has been highlighted by the IPCC (2007b) that coastal areas are very likely to be at greater risk than at present due to sea level rise and more intense coastal storms, unless significant adaptation measures are carried out. Nevertheless, mitigation is particularly important, as continued global warming can overwhelm the local adaptive capacity (Eriksen et al., 2011). Here, one of the important, but neglected dimensions of mitigation is that supply of renewable energy is closely related to the climate (Aaheim et al., 2012). For instance, in Spain solar energy may benefit from the expected increase in sun exposure and the increase in strong wind episodes would derive in the increase of wind energy too, while a decrease in the generation capacity of hydraulic energy, may affect the functioning of thermal power plants and nuclear power plants with open-circuit cooling systems (MAGRAMA, 2008).

Regarding stakeholders' age, the older stakeholders showed a greater awareness of mitigation measures than younger stakeholders, as did women more than men. In addition, adaptation measures were more highly represented among men than women.

Stakeholders most commonly perceived that they have some idea of how to adapt to climate change:

"The ability to make adjustments to changing climate is an essential need because human security is threatened. It would be less expensive to start acting now instead of waiting until something really catastrophic happens" (RA-male-48).

This finding is consistent with study by Biesbroek et al. (2011) who found that most of Dutch stakeholders considered adaptation necessary in order to prepare society for the impacts of climate change.

In particular, the Catalan stakeholders who strongly agreed in the need for short/medium-term adaptation were likely to be from the research, tourism, cultural, public administration and environmental sectors, while the stakeholders from industry and agriculture were less willing to implement any adaptation measure. However, these differences are in contrast to what one would expect, because generally the local level stakeholders are closer to adaptation action (i.e. where directly and most of the climate change adaptation happen) than regional or national level stakeholders.

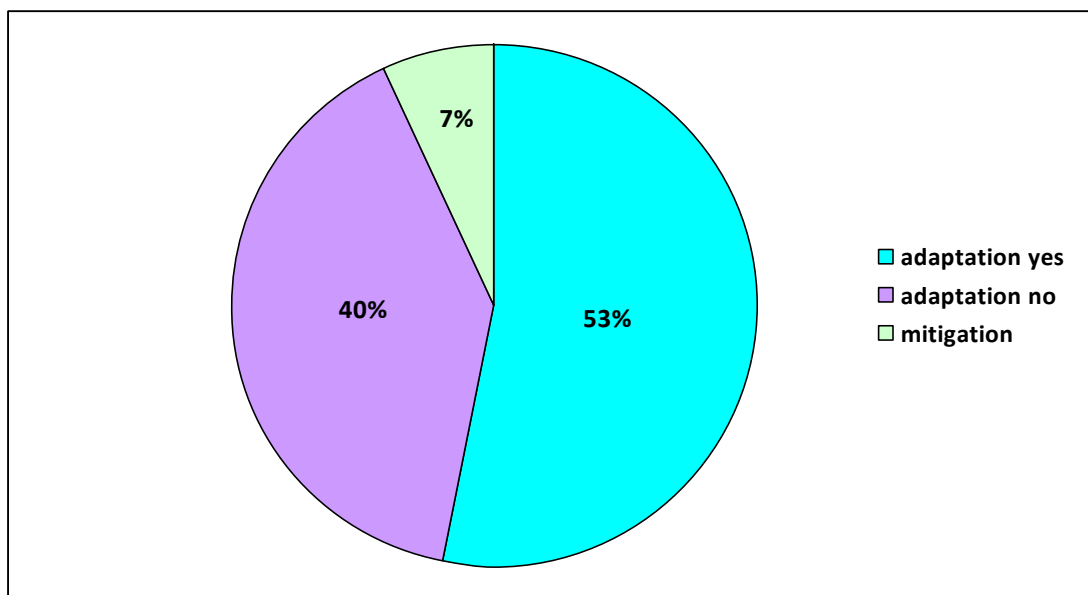


Figure 35. Percentage of stakeholders in favour or not for adaptation and mitigation (n=45). Source: Author, 2013.

However, stakeholders were asked to point out what was the main constraint for not implementing adaptation measures. Most of them expressed opinions like “you cannot beat Mother Nature”, a lack of funding and the current economic recession:

“We cannot win the battle with Mother Nature, so implementing adaptation measures will not be effective” (IA-male-47).

“The financial cost for protecting the area in such economic crisis would be higher than to abandon a high risk area” (AFA-male-51).

This last perception tends to be consistent with Whitmarsh (2011) who demonstrated that economic recessions and financial worries might displace concerns about climate change issues. Additionally, a justification for individuals’ reduced interest and action in relation to climate change may be expressed through doubt about the reality or severity of the issue. Also, as argued elsewhere (e.g. Leiserowitz, 2007; Spence et al., 2011; Weber, 2010) the perception that climate change is a distant issue as well as having no direct personal experience with the impacts of climate change can also be some of the reasons for not taking any adaptation measure.

Other constraints mentioned by stakeholders were a lack of conviction that adapting to climate change is important as well as a lack of access to information about climate change adaptation measures. Similarly, Gurrán et al. (2012) found that local governments in coastal Australia faced barriers to adaptation associated with limited financial and human resources and climate change scepticism, which were likely to weaken local political support for adaptation. Moreover, it was felt that weak political support for adaptation was driven by concern that identifying areas of climate risk, development restrictions that may limit economic uses of these areas and imposing development controls to reduce future exposure, could lower property values. Here, my results offer some support for similar view where one stakeholder summarised the anxiety about climate change effects on private property values:

“Due to poor quality of the buildings in Empuriabrava and Santa Margarida and flooding that is projected to be even more frequent over the following decades people have already difficulties in selling their properties” (ENA-female-45).

However, prior studies have documented that the most commonly reported adaptation barriers are lack of technical and scientific data, local expertise, staffing and financial resources and political support (Allman et al., 2004; Baker et al., 2012; Tribbia & Moser, 2008).

It is important to note that high level of adaptive capacity does not automatically translate into efficient and successful adaptation (Moser, 2009). For instance, Table 6 indicates that Spain has in general, a high per capita income, high technological development, high adult literacy, high life expectancy and low percentage of degraded land (i.e. biomass, soil health, water quantity, biodiversity degradation). Thus, it could be acknowledged that Spain can quite easily adapt to climate change due to its potential high technological, institutional and infrastructural capacity. Using these indicators, Spain is likely to have a high adaptive capacity and thus, a low vulnerability to climate variability or change. However, O'Brien et al. (2006) argued that high level of adaptive capacity at the national level is not necessarily reflected as high level of capacity at the lower levels of governance (e.g. regional, local level). For example, Moser & Luers (2008) found that in California, coastal resource managers had limited awareness and analytical capacity for dealing with climate change impacts and important constraints for undertaking adaptation were documented. Similarly, Baker et al. (2012) found that in the context of Southeast Queensland (Australia) despite high awareness of expected climate change impacts, local governments had limited capacity to use this information to develop a specific adaptation plans.

Table 6: Indicators of adaptive capacity for Spain

Determinants	Indicators	Spain 2010
Economic wealth	GDP/capita (2005)	27,063
Technology	Sum of telephone lines and mobile subscribers per 100 people	155.9
Information and skills	Adult literacy rate both sexes (% aged +15)	97.7
Sustainability	Population living on degraded land (%)	1.4
Health	Life expectancy at birth (years)	81

Source: United Nations Development Programme (UNDP), 2013.

During fieldwork, I found that vulnerability of the study area is likely to be higher due to its dependence on climate-sensitive economic activities and ecosystem services. Barnett (2001) argued that the insurance industry, transport and communications infrastructure, democratic participation, and (a base level of) personal affluence are likely to help facing the environmental stress and increase adaptive capacity of a socio-

economic system (IPCC, 2007b; Nelson et al., 2007). Likewise, Yohe et al. (2011) pointed out that efficient insurance should be part of the efficient adaptation to climate hazards. For instance, in Spain, insurances against extreme weather events are available, but according to fieldwork observation is suggested that often other adaptation measures should be taken before. Generally, insurances are also likely to be limited, for instance, some insurance companies accept the damage only when the storm winds exceed some determinate speed (El País, 2009).

Furthermore, my findings suggests that it is likely that continued population growth combined with an increasing importance of tourism sector, especially in the coastal municipalities of Aiguamolls de l'Empordà, may increase adaptation costs due to the increased sensitivity and exposure to current and further climate change effects (e.g. increased drought, coastal erosion, storms, and decreased river flow). A growing number of population in the study area may also increase demand for land, housing, goods and services such as transport, energy, infrastructure and ecosystem services. Furthermore, it was suggested in the study by Donner & Rodríguez (2008) that population growth, migration and urbanisation were the most important factors that have increased the United States' exposure to natural hazards and have contributed to the devastating impacts of these events, as seen in the case of Hurricane Katrina. Similarly, Misomali & McEntire (2008) documented that new families that move to a new community are often not familiar with hazards that threaten the community and they do not know how to respond to them appropriately. My interview data, along with observation, point to a similar picture of unfamiliarity²² with potential environmental hazards in the study area where one of the interviewed stakeholders expressed:

“Even if today there is a lot of debate around sea level rise and flooding in this part of Catalonia, do you think that people here will stop buying properties and abandon the area? Of course this will not happen” (ECA-male-68).

Nevertheless, it is worth mentioning that the absence of strong policies to restrict development in vulnerable coastal areas and costs associated with adaptation are likely to increase and hence, this may reduce adaptive capacity. For instance, one of the issues that also emerged from the fieldwork is the new Spanish Shore Act (*Ley de Costas*

²² My findings do not distinguish between foreign and Spanish residents' unfamiliarity with potential environmental hazards. Nevertheless, it is important to note that international immigration to municipalities of the study area has grown significantly over the last two decades, where the number of registered foreign residents increased by 1037% in the period 1991–2012 (Figure 8). Most of these residents reside in the three coastal municipalities – Roses, Castelló d'Empúries and Escala (Table 5).

22/1988) passed by the Spanish Central Government in 2012. This new law seeks to provide more legal security for situations that previous legislations were not able to regulate properly and provide for a more sustainable improvement of the Spanish coastline. It aims to better protect the coast from the excesses of urban planning, generate more economic activity and to be an effective tool against the coastal erosion. The law established two zones separated by a demarcation line: the public domain, made up of the surf zone and the beach, in which there can be no private ownership; and the second zone, running inland to about 500 m, including areas with restrictions on private ownership, with even more stringent restrictions nearer the shoreline. Moreover, the new legislation provides a special regime for eleven specific areas in Spain, one of these is Empuriabrava (Castelló d'Empúries) which will be taken out of the public domain and built properties will be able to be sold (MAGRAMA, 2013). Further study of this issue is needed in order to address how it may affect adaptive capacity on a community level. For instance, there is ongoing debate between a variety of social, political and environmental actors²³, including at the local-regional level the NGO *Salvem l'Empordà*²⁴ and the local political party *Unitat i Defensa d'Empuriabrava*²⁵.

6.1 Stakeholders' support for adaptation measures

Analytically adaptation is most often narrowly conceptualised as a set of technological or technical options to respond to specific risks (Nelson et al., 2007) where the need for local stakeholder involvement has been increasingly acknowledged (Eriksen et al., 2011; Mustelin et al., 2010; Roiko et al., 2012). This is applied in the present thesis where adaptation is defined as the decision-making process and the set of actions undertaken to maintain the capacity to deal with future change to the socio-economic system without undergoing significant changes in function, structural identity, or feedbacks of that system while maintaining the option to develop. It is important to note that these measures may not necessarily be suitably subjected to represent the most important components for climate change adaptation in the study area – this may only be revealed through more in deep field-level studies.

²³ Reuters, 2013. Spain coastal law revamp sparks fears of new construction wave. Available at <http://www.reuters.com/article/2013/05/09/spain-property-idUSL6N0DQ3NR20130509> (accessed 20/10/2013)

²⁴ See <http://www.iaeden.cat>

²⁵ See <http://udem-empuriabrava.blogspot.com.es>

However, two types of technical measures were indicated: natural (based on natural components such as vegetation, sand, rocks) and artificial measures (based on solid human-made structures). Further, some stakeholders suggested as solution a combination of both types of measures (Figure 36).

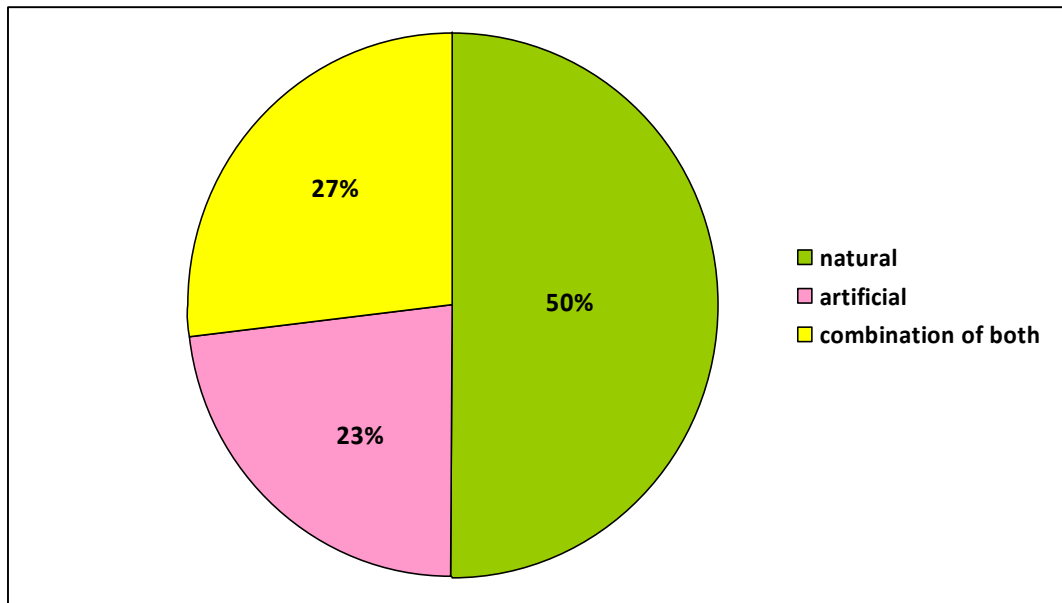


Figure 36. Percentage of stakeholders in favour of adaptation with natural and artificial technical measures (n=45). Source: Author, 2013.

Half of the interviewed stakeholders reported that they were in favour of natural adaptation measures, such as setting dunes, beach barriers, coastal vegetations, rising ground level and find alternative agricultural practices, while approximately one-quarter of stakeholders were in favour of artificial adaptation measures, such as seawalls, breakwaters; flood and saltwater intrusion-gates; beach nourishment and rainwater harvesting (Figure 37).

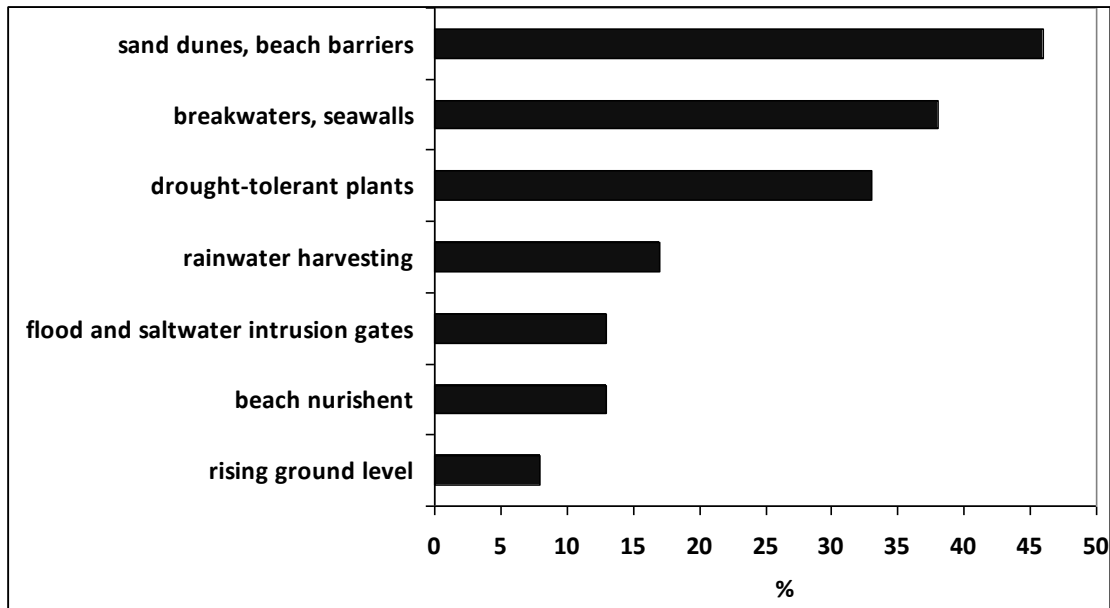


Figure 37. Proposed technical solutions for climate change adaptation as mentioned by the stakeholders in Aiguamolls de l’Empordà (n=45). Note that stakeholders mentioned often several technical solutions thus, the percentage represents the number of times an option was mentioned. Source: Author, 2013.

Following on from the possible implementation of climate change adaptation, stakeholders provided and discussed on seven technical measures, which are presented more in detail in the following subchapter.

6.2 Natural measures for adaptation

Phillips & Jones (2006) argued that there should be a need to adopt techniques that work with natural processes rather than simply implement hard engineering (or artificial) measures. Similarly, Council of Europe (2003) suggested that modern approach of coastal management recognises the dynamic nature of coastal regions by emphasising natural measures over an exclusive reliance on artificial ones trying to force nature to comply (Council of Europe, 2003).

In particular, the stakeholders from the research, environmental and industry sectors who were interviewed in Aiguamolls de l’Empordà were likely to be in favour of natural measures too:

“We should avoid artificial solutions on the already vulnerable coastline, so dykes and seawalls are not seen as the right solutions for adaptation” (ENA-female-41).

The rest of the stakeholders, specifically those from the tourism and cultural sectors were much more in favour of the artificial measures (see Subchapter 6.3), while interviewed stakeholder from the economic sector were more likely to perceive that in the study area should be implemented a combination of natural and artificial measures for adaptation.

6.2.1 Sand dunes, beach barriers and coastal vegetations

Prior studies (e.g. Gómez-Pina et al., 2002; Grafals-Soto, 2012; Fatorić & Chelleri, 2012; Jiménez & Sánchez-Arcilla, 2004) suggested the importance of natural adaptation measures, for instance, where coastlines can be protected by natural beach barriers, sand dunes and coastal vegetations. Nicholls & Klein (2005) claimed that natural coastal buffers such as dunes and wetlands should be preserved and enhanced as climate change indicates the value of these buffering capacities.

The sand dunes act as a resilient barrier to the destructive forces of waves and winds. Dunes absorb the impact of high-energy storms preventing or delaying intrusion of waters into inland areas. During high-energy storms, waves flatten the beach and erode sand, undermining and collapsing the seaward dune. On the other hand, the calmer waves carry sand from offshore bars and the surf zone to the beach, causing the beach to accrete gradually. Thus, it can be said that dune systems are likely to be the most efficient and least expensive defence against coastline erosion (Gómez-Pina et al., 2002). They are potentially able to attain a dynamic equilibrium configuration with respect to marine drivers, if their capacity response is not altered by human activities and if there is sufficient sediments supply (Jiménez & Sánchez-Arcilla, 2004). Human activities contribute to the acceleration of dune degradation with tourist urbanisation, construction of roads, harbours and marinas, human trampling, recreation, cropping and grazing animals (Gómez-Pina et al., 2002). Especially human trampling was observed during fieldwork in the study area (Figure 38). In addition, sea level rise due to climate change is likely to provoke further dune degradation with projected increase in frequency and severity of the storm waves along the Catalan coast (ICHN, 2010).



Figure 38. Human trampling on dunes in Escala. Source: Author, 2012.

Nevertheless, in Aiguamolls de l'Empordà area many actions have been carried out to prevent dune degradation, such as construction of walkways on the dunes to prevent deterioration and preserve the natural defence they provide against erosion on beaches; regeneration of dunes, fencing dunes and fixing them with stakes and dune vegetations; preventing the dunes being used for car parks and limiting traffic in the dunes; creating new alternative beach accesses (fieldwork observation) (Figure 39).



Figure 39. Fencing dunes in Roses (up) and Escala (down). Source: Author, 2012.

Moreover, coastal and marine vegetation cover can have a function of a barrier, for example, against storm waves, by absorbing and reducing wave energy, which otherwise erodes the beach and causes a decrease in offshore sedimentation (Türker et al., 2006) and waste processing (Brenner et al., 2010). During fieldwork, seagrass *Poseidonia oceanica* was observed in the study area (Figure 40), together with signs of coastal erosion, especially in Roses and Escala (Figure 26, 30).

Regarding stakeholders' perception of the most suitable adaptation measure, almost half of them proposed natural adaptation measure by setting sand dunes parallel to the shoreline where none exist, preserving the stabilisation of existing ones, repairing the damaged dunes and planting coastal vegetations. It was also often opined that this is the cheapest measure at this moment of economic recession and it is compatible with environmental sustainability principles. Furthermore, stakeholders from environmental and research sector expressed the highest confidence in dunes setup:

“Dune building and preservation of existing ones provide an effective measure of land protection” (ENA-male-63).

“The solution is to keep installing soft adaptation structures such as dunes with native vegetation (seagrass) to protect the area against coastal storms, saltwater intrusion and coastal erosion...And also to replenish the sand” (RA-male-33).



Figure 40. Seagrass *Poseidonia oceanica*. Source: Author, 2012.

6.2.2 *Rising ground level*

It is rightly pointed out in a study published by Holden (2008) that a response of wetlands to sea level rise is dependent upon the availability of an adequate and appropriate sediment supply, and the subsequent rate of accretion of sediment upon the wetland surface. Also Sánchez-Arcilla et al. (1996) found that river mouths (such as deltas) can continue to exist in the face of climate change effects if there is sufficient vertical accretion of inorganic sediments and/or organic matter and sufficient supply of sediments to the shoreline. To help achieve this, deltas need to be managed to withstand climate change effects by enhancing the natural functioning of coastal fringes (e.g. promoting natural dune formation, uniformity of alongshore transport) and ecosystems (e.g. primary productivity, material processing and interaction among subsystems). Furthermore, Nyman et al. (1990) argued that vertical accretion must counter not only climate change effects, but also subsidence. Similar ideas can be suggested also for the case of Fluvià and Muga river mouths.

Only a few stakeholders suggested an incentive of rising ground level for a few centimetres:

“If you want to continue living here you need to rise structures and properties at higher elevation, what means leaving the natural sediment flow so that can lead to a rising of ground level” (IA-male-37).

6.2.3 *Adaptation in agriculture*

The inland climate change adaptation measures are mainly focused on agriculture due to the relative importance of this sector in Aiguamolls de l’Empordà. According to Lereboullet et al. (2013), the perception of future climate risk is important in agriculture sector because is argued that this sector may not invest in major change unless they understand that their systems are highly vulnerable.

Roughly, one-third of the stakeholders expressed the highest confidence in the drought-resistant crop growing, such as olive tree, vineyards and some other crops that can easily adapt to drought. Moreover, they perceived that a longer growing season would allow new fruit varieties to be grown:

“Changing the variety of crops, more drought-tolerant products will need to be introduced...Such as olive trees and vineyards” (ECA-male-34).

However, others more ironical about the future situations:

“We do not plan to grow cactus instead of fruits” (PAA-female-40).

Lereboullet et al. (2013) highlighted that the choice to plant new varieties is linked with climatic conditions and market demand in unequal proportions. For instance, it was shown that in the case of two Mediterranean wine industries in France and Australia diversification is necessary to tolerate variability in climatic and economic conditions, and it is a valuable basis to long-term adaptation to climate change. Furthermore, Gilbert & McLeman (2010) showed that in the case of Alberta (Canada) the financial capital of households was very important in building adaptation capacity to drought in agriculture.

6.3 Artificial measures for adaptation

The stakeholders from cultural and tourism sectors were more likely to be in favour of artificialisation. Consistent with this view, Roca & Villares (2012) found that artificial measures for coastal protection are especially in the interest of mass tourism because of its vision of beaches as stable recreational spaces:

“Here are thousands of people who depend on ecosystems for their livelihoods, so we need to use artificial measures for protection” (TA-male-41).

In contrast, building the artificial measures in natural protected areas was also often perceived as an inadequate solution from the ecological viewpoint. Many stakeholders declared that they have suffered enough artificialisation over the past few decades and they prefer not to become like the Netherlands. Furthermore, this solution was perceived as too costly to build and maintain and it requires too much space. Here, most stakeholders from industry, environment and research sector underlined this perception. It is likely that these stakeholders had this opinion due to their experience in living with, working in natural areas such as wetlands, lagoons and knowing that these areas provide wide range of services and benefits for the communities (e.g. coastal protection, flood regulation, freshwater supply, food production, recreation):

“We need to avoid artificialisation because this area has been already degraded through the process of littoralisation. Therefore, artificial solutions such as seawalls are not appropriate solutions for the vulnerable coastline” (RA-female-33).

“It is not worth trying to wall off the Mediterranean Sea like the Netherlands did” (IA-male-37).

Furthermore, (Dolan & Walker, 2004) claimed that artificial measures do not necessarily discourage people from living in high-risk areas (e.g. floodplains), but may encourage development and consequently, increase vulnerability.

6.3.1 *Breakwaters and seawalls*

Breakwaters are hard structures used to reduce the wave energy reaching the shoreline and are considered as one of the tools for protection of lowland areas (El Raey et al., 1999). During fieldwork were observed breakwaters along a coastal section of about 20 km from Roses to Escala (Figure 41). Although they look massive, they have been done nicely using natural rocks and the view from the promenade is not unattractive. According to Jiménez et al. (2011), these were built in the 1970s during the touristic boom. At that period, beaches were wide and promenades were generally built without considering the probability of suffering the expected wave action. Consequently, they were not designed as coastal structures, but as architectural elements. As coastal erosion has become dominant, beaches protecting these infrastructures got progressively narrower and storm waves started to directly impact on them. Moreover, these beaches offer opportunities to all types of beach recreation. Disadvantage of breakwaters is a relatively high construction and maintenance costs, inconvenience or danger to swimmers and small boats and aesthetic problems such as visual blocking of horizon (Phillips & Jones, 2006; van Rijn, 2011).



Figure 41. Breakwaters in Roses. Source: Author, 2012.

Seawalls are usually built to stop dune and cliff erosion completely in zones (along boulevards of beach resorts) where natural dunes are absent or have been removed for recreational purposes (van Rijn, 2011). Pittock (2000) demonstrated that seawalls could increase vulnerability in the long-term period because they can lead to

increased investments and population concentration in locations subject to climate hazards.

When asked about the artificial measures, more than one-third of stakeholders agreed that coastline should be protected against climate change effects by hard structure such as seawalls, breakwaters. This option was particularly preferred by tourism sector. A possible explanation for this may be that this measure is preserving the aesthetical aspect of the beaches hence, increasing the economic value for tourism purpose:

“Especially seawalls are essential to the whole coastal area’s ability to withstand more severe storms” (TA-male-41).

“First, Empuriabrava and Santa Margarida are built on a system of channels and second, poor quality of buildings makes them vulnerable to severe storm surges. Therefore, additional breakwaters are needed to prevent an overwash of these areas” (TA-male-56).

6.3.2 Beach nourishment

Beaches along the Spanish Mediterranean coastline play two important functions: protection and recreation. Protection relates to the function played by the beach to protect the hinterland (usually occupied by a promenade, waterfront) from wave action during storms. On the other hand, recreation relates to the function played by the beach to offer properly an environment for leisure, such as beach surface to accommodate users (Jiménez et al., 2011).

Hence, beach maintenance is important as continued coastal erosion can overwhelm local adaptive capacity. Nevertheless, coastal erosion can be prevented (compensated) by beach nourishment (van Rijn, 2011). Beach nourishment acts as a wave filter (larger waves are reduced by breaking), resulting in a decrease of the alongshore transport landward of the nourishment location; updrift sedimentation and down-drift erosion. According to Jiménez et al. (2011), beach resilience depends on wave climate and beach characteristics (width and volume) that control the resulting configuration after the impact of a storm. Beach resilience increase with increasing width, which can be done by beach nourishment or/and by retreating the landward. This finding has important implications for developing beach management and coastal protection. Jiménez et al. (2011) demonstrated that the coastal management

implemented in Catalan beaches to cope with erosion-induced problems has been purely reactive, i.e. any time when a problem appeared a practical solution to deal with the specific problem has been executed.

The nourishment can be relatively cheap (compared with implementation of other hard structures) as the sand can be dumped during sailing in shallow water (5–10 m) (van Rijn, 2011). Yet, it can be a costly method if life spans are short at very exposed beaches or if the long-term availability of adequate volumes of compatible sand at nearby (economic) locations is problematic. For example, sand material suitable for beach nourishment cannot easily be found at most Spanish sites along the Mediterranean coast (van Rijn, 2011). Hence, in Spain, where the significant portion of income is based on tourism industry, hard structures such as breakwaters are often used with beach nourishment to deal with erosion and to maintain a minimum beach width for recreation (El Raey et al., 1999; Hanson et al., 2002; van Rijn, 2011) rather than for the concerns about flooding (Hanson et al., 2002). Beach nourishment has many benefits such as creating new beaches for tourism and recreation, increasing fishing catches because sand material can constitute a new source of nutrients for fish, and protecting the land from flooding and saltwater intrusion (El Raey et al., 1999). Symes & Byrd (2003) argued that there is a natural symmetry to combat coastal erosion with ballast won from the sea, therefore beach nourishment is increasingly used as a soft engineering solution for the sustainable coastal management (Phillips & Jones, 2006).

In this context, it is interesting to note that overall response to this measure was positive, often reported as suitable, effective and aesthetically pleasing measure for climate change adaptation under the current climate variability and expected increase in frequency and intensity of storms, flooding and coastal erosion. Moreover, it is interesting to note that the stakeholders from agricultural sector who were initially not in favour of adaptation, were occasionally opined about the need for this measure, where a possible explanation for this may be that it helps preserving the beaches which function as a protective barrier for instance, against storm waves that can reach agricultural and cultivated areas behind. Thus, this option can increase the economic value for agriculture purpose in the study area:

“Natural process such as beach replenishment is an adequate adaptation measure where sand that is lost through the storm is replaced with sand outside of the eroded beach. More the beach is wider more can protect or reduce storm damages to

infrastructure along the coast. Also it can importantly increase the economic and recreational value of the beaches along Gulf of Roses” (AFA-male-39).

In contrast, small number of stakeholders expressed that they are not in favour of sand replenishment through beach nourishment because of its high cost and often expressing that beaches are likely to be constantly overwashed due to increase in frequency and intensity of storms:

“Supplying sand to eroded beaches is not an effective long-term solution mainly because of its cost” (TA-female-46).

Consistent with this view, regional newspaper Hora Nova (2009c) reported that only the municipality of Roses spends annually about €40–50,000 for beach nourishment.

6.3.3 Rainwater harvesting

During fieldwork, it was observed that Aiguamolls de l’Empordà has often undergone significant conflicts during the summer time, when residents have to be supplied with drinking water and water consumption peaks are additionally under the pressure. That is a season when tourist demand overlaps with high water demand by irrigated agriculture. This is also in tune with earlier findings of Pavón et al. (2003) who showed that in Aiguamolls de l’Empordà over the last two decades due to water demand from agriculture, tourism and wetland conservation were observed severe conflicts so called “the water battle” or “the war of the wells”.

Therefore, rainwater harvesting can be one of the adaptation measures for addressing the water stress resulting from climate variability and change. It is one of the favourable ways of supplementing the surface and underground scarce water resources (Aladenola & Adeboye, 2010; Mwenge Kahinda et al., 2010; Pandey et al., 2003; Tzilivakis et al., 2013), and it has the potential to enhance ecosystem and livelihood resilience (Muller, 2007). It is a technology used for collecting and storing rainwater from rooftops and land surfaces using simple techniques such as furrow dikes, ponds, tanks and reservoirs (Krishna, 2005). Some of the most important benefits are: (1) providing a source of free water with only storage and it is cheaper than well drilling or water supply from the public taps; and (2) expanded use of rainwater harvesting has the potential of reducing GHG emissions from water storage reservoirs and water treatment processes which contribute to climate change (Flower et al., 2007; Krishna, 2005).

However, I can suppose that such a measure may not be entirely viable in the long-term period if projected precipitation on the Iberian Peninsula decrease for 25% (Aaheim et al., 2012) and evapotranspiration increases due to higher temperatures, but it can be implemented at individual household level (e.g. rainfall harvesting from roads, car parks, rooftops).

Rainwater harvesting was an adaptation measure suggested only by a minority of stakeholders who expressed the opinion of responding to the challenges of climate change by building reservoirs to store precipitation runoff and provide additional water supply. The choice of rainwater harvesting was quite uncommon, I suppose due to weak awareness although it does not require hard technical implementation, but mainly communities' behavioural changes to cope with water scarcity:

“Building reservoirs can increase the water supply for irrigation and other uses because the precipitations we have here are adequate mainly for filling artificial reservoirs and rivers, but to recharge aquifers are needed more regular precipitations during the winter” (RA-male-53).

6.3.4 Flood and saltwater intrusion-gates

Flood and saltwater intrusion-gates are in general terms designed to: (1) increase surface and subsurface drainage by maintaining water flooding by blocking flow from rivers; and (2) restrict saline intrusion into the drains for agriculture, tourism and public purposes such as irrigation, drinking water (Glamore & Indraratna, 2001). However, these structures can also retain sediments and nutrients, which in turn can increase erosion of coastal headlands and impair the ability of deltaic wetlands to keep pace with climate change effects and maintain the fertility of agricultural lands (IPCC, 1990).

In particular, in the coastal municipalities of the study area a few flood control works were implemented, for instance, building up earthen dykes for protecting Empuriabrava and agricultural land along the river Muga. In Roses, protection against flooding was implemented by installing pumping stations, stormwater network and emergency planning; in Sant Pere Pescador hydraulic works were carried out; in Escala channelisation was done; and in Castelló d'Empúries a storm-water network was extended and a periodic clean up of the riverbed and margins was carried out (Saurí-Pujol et al., 2001). Furthermore, in agricultural land a network of small drainage channels was created, which allow the water to be carried away more quickly. The

channels are also used for combating the soil salinisation. As the land was formerly flooded salts abound on the soil surface and cause problems for the crop development. The drainage network is therefore, also used as a water distribution network, to wash the soil and irrigate the pastures (Llausàs et al., 2009). Moreover, several infrastructures have been implemented in order to prevent the saltwater intrusion and recover the biodiversity of the Natural Park such as floating gates, which can prevent the entry of saltwater and at the same time retain a freshwater what increases the ponds and lagoons' flooded period (Empordà, 2009).

However, a small number of stakeholders commented on the implementation of these measures as suitable ones from a technical and urban design point of view:

“Floodgate structures and new wastewater treatment plant would be essential installations in this area... But now is not the right time for such high income investments” (PAA-male-41).

“Here are thousands of people who depend on ecosystems and freshwater for their livelihoods, so we need to implement gates against saltwater intrusion” (TA-male-56).

This chapter brought together the local issue of adaptation in Aiguamolls de l'Empordà by identifying and analysing several possible technical measures with issue prevalent in the mainstream international adaptation discourse.

CHAPTER 7
OUTMIGRATION DUE TO CLIMATE CHANGE?

In this chapter, first, I provide a documental analysis on environmental migration and then I expand this discussion on identifying and evaluating possible future outmigration²⁶ from Aiguamolls de l'Empordà. Moreover, I present a model of outmigration as a part of adaptive response to climate and/or environmental change.

Historically, climate change and human migration have been linked where climate variability has been a driving force behind migration for many thousands of years (Smith, 2007; Walsham, 2010; Warner, 2010). Moreover, in recent decades, while social, economic, political and environmental factors are dominant drivers of migration²⁷, climate change is also having detectable effects (Hugo 2011; McLeman & Smit, 2006; Smith, 2007; Warner, 2010). Here, Ravenstein (1889) was the first to suggest that various factors, including an unattractive climate, tend to push persons from one area to another area. Notably, it has long been recognised that environmental factors have an impact on migration, but until recently, the issue received comparatively little attention within mainstream debates on the movements of people, both within and between states (e.g. Black et al., 2011; Findlay, 2011; McLeman & Smith, 2006; Perch-Nielson et al., 2008; Walsham, 2010). These recent debates on climate change and migration have focused mainly on displacement and have perceived migration as a problem (Hartmann, 2010; Tacoli, 2009). Moreover, majority of studies linking environmental change and migration are focused on developing countries (e.g. Adger et al., 2002; Arnall et al., 2013; Meze-Hausken, 2000; Mortreux & Barnett, 2009; Penning-Rowsell et al., 2013), while there have been less studies on the impacts of climate change on migration in developed countries (e.g. Fielding, 2011; Hurlimann & Dolnicar, 2011).

The International Organization for Migration (IOM) defines environmental migrants as “persons or groups of persons who, for compelling reasons of sudden or progressive change in the environment that adversely affects their lives or living conditions, are obliged to leave their habitual homes, or choose to do so, either temporarily or permanently, and who move either within their country or abroad” (IOM, 2009: 19). This definition attempts to facilitate the identification of environmental migrants and to discourage the use of the term environmental refugees (Warner, 2010). According to United Nations High Commissioner for Refugees, UNHCR (2010), a

²⁶ Throughout the thesis, I use the term “outmigration” for abandoning the study area.

²⁷ However, it is important to note that the climate can also act as a pull factor in migration, for instance, people migrate in search of a more favourable climate, so called tourism-related migration, retirement-related migration (Gustafson, 2002; Rodriguez et al., 1998).

refugee is someone who is unable or unwilling to return to his country of origin owing to a well-founded fear of being persecuted for reasons of race, religion, nationality, membership of a particular social group, or political opinion. Yet this term, does not clearly offer protection for refugees who are affected by environmental factors, although it is often difficult to differentiate between refugees/migrants driven by environmental factors and those driven by economical or political problems (Döös, 1997). The acceptance of the term of environmental refugee would mean that each state of United Nations, which adopted Convention and Protocol relating to status of refugees, should guarantee rights such as access to the courts, primary education, work and the provision for documentation. In contrast, affected people may not want to be identified as refugees because of the implicit hopelessness and defencelessness of this term (Mortreux & Barnett, 2009).

It is rightly pointed out in the study by the geographer Black et al. (2011) that five drivers can influence migration:

- Economic drivers: employment opportunities and income differentials between places;
- Political drivers: conflict, security, discrimination, persecution and enforced relocation;
- Demographic drivers: the size and structure of populations in source areas, together with the prevalence of diseases that affect morbidity and mortality;
- Social drivers: familial or cultural expectations, the search for educational opportunities and cultural practices;
- Environmental drivers: exposure to environmental or climate hazard, land degradation and availability of ecosystem services.

The five drivers rarely act in isolation and the interaction of the five drivers determines the details of movement (Black et al., 2011). The focus of the present thesis is on environmental drivers, particularly on climatic drivers linked to current and future climate change.

A range of future environmental changes have the potential to influence the drivers of migration, with the most significant being climate change, land degradation and coastal and marine ecosystem degradation, which are likely to impact migration

both directly, as well as indirectly, through impacts on other drivers (Barnett 2003; Birkmann et al., 2013; Black et al., 2011; McLeman, 2011b; Penning-Rowsell et al., 2013; Poston Jr. et al., 2009; Reuveny, 2007; Warner, 2010). However, Barnett (2003) highlighted that people rarely migrate for environmental reasons alone. One of the important dimensions of environmental events is the frequency either long-term or rapid-onset. First one refers to cumulative environmental or climate changes that can lead to the destruction or degradation of livelihoods over a relatively long period of time, while the second one refers to sudden meteorological, hydrological, biological and geophysical hazards which can destroy lives and livelihoods and force people to migrate (Johnson & Krishnamurthy, 2010; Meze-Hausken, 2000).

In particular, climate change is not simply manifested in changes in long-term average conditions, but may include changes in extremes or variability and it is very likely that will be experienced via changes in the frequency, severity, timing and spatial extent of climatic conditions and events (IPCC, 2007a).

Climate change driven by increases in GHG emissions primarily manifests itself in:

- Changes to weather patterns at a place: change in tropical storm and cyclone frequency or intensity, changes in rainfall regimes, increases in temperature, changes in atmospheric chemistry;
- An increase in sea level due to the thermal expansion of seawater and inputs from melting land ice (Black et al., 2011; McLeman & Smit, 2006; Tacoli, 2009).

The issue of sea level is especially important in light of the future projections where is estimated that during the 21st century it may rise between 3 and 61 cm over the Mediterranean basin (Marcos & Tsimpilis, 2008). Therefore, it is of great concern for present study case because it also clashes with one of the prevailing demographic trends, where human settlements and highly dynamic economies occupy the coastal area. Islands of Chesapeake Bay (USA) serves as a good example of areas struggling with socio-economic repercussions, while at the same time being positioned directly to coastal erosion, sea level rise and storms in the beginning of 20th century (Arenstam Gibbons & Nicholls, 2006). Similarly, the Gulf Coast of the United States and Central America were severely affected by Hurricanes Katrina and Mitch in 2005, which

slammed into both areas and displaced from 10,000 until 3 million of people (Smith, 2007). In addition, in line with projected precipitation reduction in the study area (see Figure 22, 23) I acknowledge that migration may hypothetically represent a response to this climate change effect and affected touristic and agricultural sectors in the study area. For example, in the study by Meze-Hausken (2000) was shown that affected Ethiopian's community would emigrate due to drought and insecure livelihoods prospects.

In addition to climate change, land degradation has also the potential to drive directly migration. Land degradation is the deterioration in the quality of land used for agriculture and the provision of ecosystem services, for example by loss of nutrients, pollution by salinisation or exposure of toxic materials and loss of soil through erosion. This degradation is a result of a combination of agricultural practices, extreme weather events and climate change (Black et al., 2011). For example, Crighton et al. (2003) documented that south Aral Sea region in the 1960s experienced high levels of outmigration and the abandonment of smaller seafront communities due to highly saline and less productive land and rivers, and high levels of agrochemicals pollutants in groundwater.

Similarly, the degradation of coastal and marine ecosystems includes the loss of species and habitats and the removal of their function of protection against coastal storms, triggered not only by agricultural and fisheries practices, but also by encroachment or urban and mineral developments into the coastal area and land use changes in river catchments. Both land and coastal degradation alter exposure to hazards and the provision of ecosystem services. The primary effects of future degradation of coastal and marine ecosystems will be on regulating and provisioning ecosystem services (Black et al., 2011). Ecosystem services are those parts of the environment and ecosystems that are utilised to produce human well-being, through the functions of provisioning (e.g. providing food and water), regulating (e.g. erosion protection) and providing cultural services (e.g. having emotional or spiritual value), among others (Millennium Ecosystem Assessment, 2005). An example that influenced high outmigration in the Tigris-Euphrates Delta was fire of marsh settlements, livestock destruction, drain up of the marshlands and water diversions during the first Persian Gulf War between Iraq and Iran in the 1980s (Coast, 2002).

Environmental or climate change has a clear impact upon the environmental drivers of migration, but also has the potential to affect migration indirectly through its

influence on the other drivers (Black et al., 2011; Lenton, 2013; McLeman & Smit, 2006).

Changing environmental risks affect economic drivers, for example through effects on agricultural productivity and rural livelihoods, the locations of industry, employment and settlement. Adam (2013) demonstrated that when natural disasters hit developed countries, taxes are cut and public expenditure increases, with the budget deficit taking the slack, as the authorities use fiscal measures to mitigate the adverse effects of disaster on the private sector. From a macroeconomic perspective, a natural disaster can be thought of as an adverse supply shock to the economy, one that reduces potential and actual output and employment. Therefore, it may influence the cost of moving and limit people's ability to move, which are related to levels of wealth and income. At the other hand, a reduction in income may become an economic driver for migration (Adam, 2013; Black et al., 2011, Tacoli, 2009). As has been described by De Haas (2011), while economic factors such as income and employment seem to be dominant migration drivers in the Mediterranean region, political factors also have a major impact on economic growth, inequality and labour market structure. Taken together, such factors may determine the extent to which people can fulfil their life aspirations locally and, hence, their aspirations and intentions to migrate as a perceived way to achieve their life objectives. Within this context, it is suggested that high levels of human and economic development mean higher ability to cope with environmental stress. For example, until the mid-20th century livelihoods in large part of the Mediterranean region were largely dependent on subsistence agriculture. This also meant that climate variability and long-term environmental change had more direct repercussions for people's livelihoods and could therefore, be more directly linked to migration. In contrast, it was occasionally argued that by imparting a major shock to economic and social structures, environmental or climate change might be opportunity for change or renovation in a community (Adam, 2013; Adger et al., 2002). The idea here is that the forces that are holding the economy in the grip of an inefficient configuration are somehow broken down by the crisis and the resulting reconfiguration is somehow more efficient. Nevertheless, it is important to note that such opportunities have been rarely realised (Adam, 2013).

Moreover, environmental change can affect also political drivers through influencing conflict and public policy (Black et al., 2011), through legitimacy of governments, it may undermine individual and collective economic livelihood; affect

human health through reduced availability of freshwater and food and by exposing people to new disease vectors; undermine state wealth and military capability; and exacerbate inequalities between people (Barnett, 2003).

In addition, Hugo (2011) captured that demographic changes may influence the environment, which in turn causes migration. Population increase can lead to the carrying capacity of an area being exceeded so that outmigration results. For example, Hugo (1978) showed that in Indonesia continued population growth in rural areas placed considerable pressure on the ability of the environment to absorb all of the increase in agriculture, which led to outmigration. In some especially fragile areas (steep hill slopes, coastal plains), clearing and overuse led to deterioration of the environment through erosion and leaching of soils, which further reduced the capacity to provide a sustainable living to people in the area. Also, Birkmann et al. (2013) argued that displaced people might lack the important local knowledge that is needed for adaptive management of resources where, for example, distressed migrants can add further stresses to ecosystems thus, creating other environmental crises.

Bearing all that in mind, one may wonder what is occurring in Aiguamolls de l'Empordà area regarding these issues and potential challenges.

7.1 Outmigration from the study area

Interviewed stakeholders were asked to provide an opinion on the option of outmigration or abandoning the area (i.e. to move elsewhere). The majority of stakeholders strongly agreed that this option would be an acceptable one (Figure 42):

“This area may become a coastal high hazard zone where the residents may be restricted to retreat and allow nature to take its course” (ECA-male-59).

“Santa Margarida and Empuriabrava’s communities will be forced to move inland if the sea level continues to rise. And future generations may move back to this area if climate change stop to affect us” (AFA-male-62).

“The financial cost for protecting the area in such economic crisis would be higher than to abandon a high risk area” (AFA-male-51).

These results are also consistent with those of Mozumder et al. (2011), who reported that a majority of experts and decision-makers from Florida Keys (USA) thought that outmigration from the area due to sea level rise would be acceptable. Consistent with this view, Granja & Carvalho (2000) argued that is unrealistic to

believe that coastlines can be conserved from impending sea level rise and subsequent coastal erosion. They suggested retreat and selective conservation of parts of the coast that are important to society and to use technological developments, where possible, to halt inland beach migration. Furthermore, it was also shown that in case of more severe hurricane events in New Orleans (USA) retreat is likely to be the primary consideration for decision-makers. Moreover, Hurlimann & Dolnicar (2011) found that the majority of the respondents in eight cities around Australia indicated they would abandon their settlements because of the unavailability of water due to the changing climate. Similarly, Marino (2012) documented that in the case of Iñupiat community in Alaska, abandonment and relocation were the only sustainable option in terms of changing climate.

In contrast, a quarter of stakeholders had a higher awareness of the desire not to abandon their area due to its high economical and ecological importance and personal attachment to the study area, as well as financial investments in the area:

“They will protect the area against climate-related hazards because it will not be acceptable to lose even one cm of land” (RA-male-33).

“We should defeat nature and win, like the Netherlands has done...We cannot let nature win” (ECA-male-34).

This finding of not abandoning the study area is also in line with those of Fatorić & Chelleri (2012) and El Raey et al. (1999) who concluded in prior studies that strong majority of respondents in the Ebro Delta and Nile Delta, respectively were not willing to move away from the area neither. Interestingly, Roca & Villares (2012) pointed out that in the context of the Ebro Delta, personal attachment to the place is particularly heightened in a culture such as that of Spain where property is highly valued. Phillips & Jones (2006) suggested that stakeholders would be unwilling to allow areas of high value real estate to be abandoned to the will of the sea unless political power would prove otherwise. For instance, in Somerset (UK) public bodies in the late 1990s removed seawall defences what led to a consequent flooding of low-lying areas beyond the beach. Flooding resulted in the loss of valuable grazing farmland, but also in the creation of a wetland, which has provided a new recreational resource (e.g. birdwatching) and has become an asset for the local tourism industry. Also as has been described by Walsh et al. (2004), the abandonment of urban areas is generally not a viable option, as the cost of the infrastructure to be abandoned is often too high. For instance, in the case of Japanese tsunami of 2011 was demonstrated that even in the face

of exposure to such extreme environmental event, the great proportion of the population usually preferred to stay and rebuild the affected area (Black et al., 2011). Also, Collins (2013) for example, emphasised that not migrating away from an environmental hazard area can be for want of hanging on to the potential of rebuilding a livelihood within the impact zone and to protect ongoing assets held there despite ongoing risks.

Option of outmigration due to climate change impacts did not importantly differ in terms of the interviewed stakeholders' work activity. In terms of gender, even if there are not many differences, it could be noted that men were more willing to abandon the area than women, and older stakeholders more so than younger ones:

“Here we have significant economic sectors that cannot be abandoned” (CA-female-20).

“No one will be willing to move. Economic interests will be always defended here” (IA-female-31).

For instance, these two findings are in contrast with another study from the south Pacific where it was shown that older people had a tendency not to abandon their homes (Mortreux & Barnett, 2009). Similarly, also Ravenstein (1889) showed that women are greater migrants than men.

It is interesting to note that regarding stakeholders' nationality, almost two thirds of foreigners stated that they would abandon the area in case of rising seas, coastal erosion, and more frequent and intense storms:

“I think that nature here would win because these places (Santa Margarida and Empuriabrava) are so artificial and you would need to put too much effort to maintain them” (CA-male-43).

“You cannot do a lot, nature will always win. It would be easier to outmigrate than to protect the area” (ECA-male-59).

This last finding may relate to people's place attachment where I can suppose that foreigners may not have such a strong personal attachment to the area that would prevent them from abandoning it. I also assume that they already have a previous migratory experience that may facilitate a new migration movement. This is a relevant issue, which is attracting more attention in geography and other social sciences (e.g. Mendoza & Morén-Alegret, 2013).

Finally, one of the possible concerns for the study area is where these people may emigrate? I argue that particularly coastal erosion, saltwater intrusion, flooding may imply major risks for socio-economic system and consequently may direct migration

patterns towards inland and higher grounds, especially if the well-being and livelihoods depend on ecosystem services and if there is no alternative source of income or adaptation measure. Furthermore, some studies (e.g. Cernea, 1997; Cernea & Schmidt-Soltau, 2006) showed that policies aimed at relocating communities can work when communities are well-informed about social, economic and environmental conditions, when all stakeholders have the ability to inform and affect the process and when adequate compensation (e.g. assets, incomes, economic opportunities) are provided for affected communities. In sum, further research is required before any predictions of migrant possible new location can be made. However, it is important to note that future plans should identify alternative sites, apply compensation formulas that allow migrants to relocate and develop new sources of livelihoods and build public and social infrastructure for community life (World Bank, 2010).

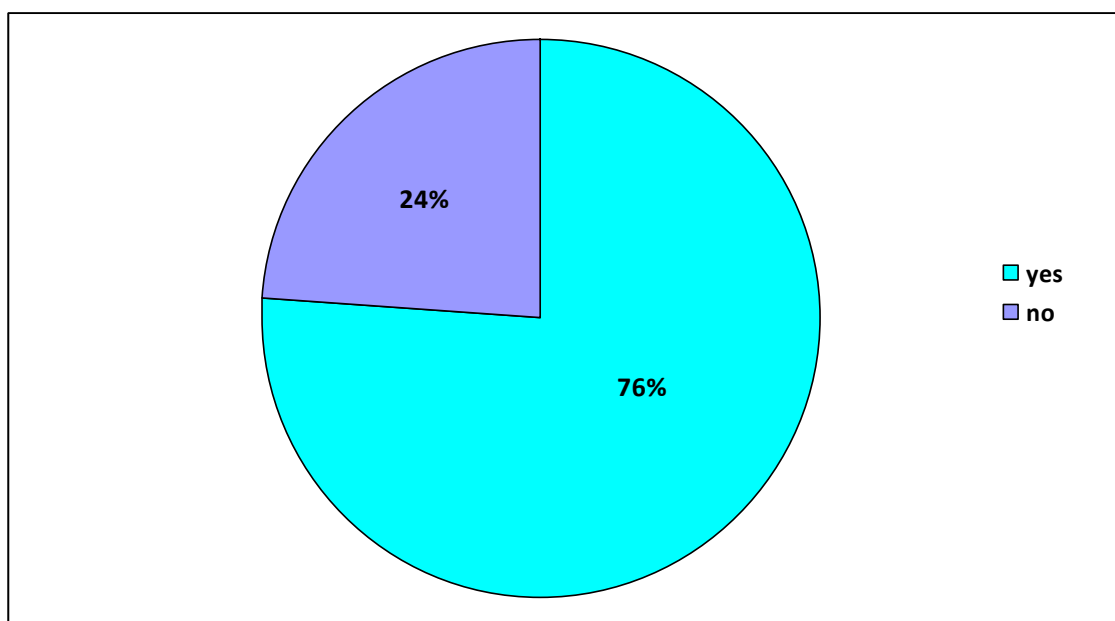


Figure 42. Percentage of stakeholders citing the outmigration as acceptable and not acceptable option (n=45). Source: Author, 2013.

7.2 Adaptive response to climate change?

In this subchapter, I present a model of outmigration as an adaptive capacity response suggested by McLeman & Smit (2006). Population responses to environmental or climate change are often described in the context of natural or socio-economic system's vulnerability (IPCC, 2007b). Here, the principal question is whether the socio-economic system's institutions are able to make the necessary adjustments so that the well-being of communities is not altered (McLeman & Smit, 2006). Additionally, Collins (2013) pointed out that politically it is difficult to invest in unseen risks in comparison to more obvious and well-reported scenes that follow an environmental shock involving migration. The unpredictability of migration decisions complicates prediction capacity further (Collins, 2013) therefore, information availability and warnings are clearly important in migration decisions (Penning-Rowsell et al., 2013). Warning systems have the potential to reduce the impact of environmental shock or change, but only if they provoke action that reduces the vulnerability of those due to be impacted. This can also help reduce the influence of environmental change on migration (Lenton, 2013).

According to McLeman & Smit (2006), if system' institutions are unable to cope with environmental or climate change, community may become vulnerable and be obliged to take other adaptive responses. Migration out of exposed area is seen as one of the possible adaptation outcomes (Arnall et al., 2013; Birkmann et al., 2013; Collins, 2013; McLeman & Smit, 2006; McLeman, 2011b, Perch-Nielsen et al., 2008). In some places, migration may be the main response to sea level rise yet, it depends on the capacity of communities, and governments to respond firstly through a range of options such as increased protection infrastructure and land use change (Tacoli, 2009).

In addition, Perch-Nielsen et al. (2008) indicated that it is generally agreed that people migrate if the costs for protection are higher than the benefits (avoided losses) although the emotional attachment to place may lead into the decision towards protection and prevent outmigration (Johnson & Krishnamurthy, 2010). Consistent with this view, Coplin & Galloway (1999) found that in the case of Brownwood (USA), a small peninsula, about 500 families preferred to keep on living on the exposed flooding area and to evacuate their homes several times a year than to relocate. Furthermore, the cost of protection against flooding was estimated to be about three times higher than

that of relocation. Finally, hurricane Alicia hit the peninsula and caused its complete abandonment.

Migration patterns, urbanisation and population growth are important factors that modify and in most cases increase exposure and in some cases increase vulnerability (Birkmann et al., 2013). Especially, migration usually changes the socio-economic characteristics and hence adaptive capacity of both sending and receiving communities (McLeman & Smit, 2006). Those who migrate are likely to be more mobile, for instance, due to extended social networks or transferable human capital (Johnson & Krishnamurthy, 2010; McLeman, 2011b). Some of the beneficial effects of outmigration for the sending community are reduced pressure on household resources, while loss of labour and local social capital, together with accelerated population decline are negative effects (Adger et al., 2002; McLeman & Smit, 2006; McLeman, 2011b), which further increase vulnerability.

Furthermore, as suggested elsewhere (e.g. McLeman, 2011b; Collins, 2013), there will be those who for social, political, economic and cultural reasons may be unwilling or unable to leave and their demands on remaining institutional resources for support and services will grow, further complicating already difficult situations (McLeman, 2011b, Warner, 2010). Key social and cultural characteristics that influence decisions to migrate are likely to be age, sex, educational level, wealth, marital status, place attachment and attitudes and preferences (such as degree of risk aversion). It is argued that these characteristics are independent of environmental conditions – with the possible significant exception of the extent to which place attachment is influenced also by local environmental characteristics (Black et al., 2011).

Demographic and environmental drivers influence whether displaced people return and are likely to be constrained by political stability (Black et al., 2011; McLeman, 2011b). Some processes of migration may be seen as a planned response to a succession of events rather than a single event. Usually migration tends to involve relocation close to the original site, limited to the social or cultural territory within which a community is based (Findlay, 2011). Thus, when possible, it occurs over short distances, and when it does span longer distances tends to follow well-established routes where social and cultural networks provide opportunities (Collins, 2013; Findlay, 2011; McLeman, 2011a). Furthermore, rapid-onset displacements are usually short-lived and people commonly return to the source location once the event has receded, often after only a short time has elapsed (Black et al., 2011; Perch-Nielsen et al., 2008). The

efficacy of governance plays a critical role in whether migrants will return, or whether they will become environmentally motivated or environmentally forced migrants. People may not have a choice to return to their former place of residence due to the physical loss of their land (e.g. due to coastal erosion or sea level rise). However, in cases where the physical land is still available, people may have the opportunity to return to their original place of living, particularly if they can implement alternative livelihoods or other coping capacities (Renaud et al., 2011; Warner, 2010). De Haas' (2011) study in the Mediterranean region documented possible future extreme forms of environmental stress (e.g. declining rainfall, drought), which may have a certain impact on internal and relatively short distance migration, but are unlikely to result in massive international migration because of the lack of people's social, economic and human resources.

In addition, environmentally related migration occurs not only in response to adverse conditions or events, but people may also migrate to access environmental amenities, such as the movement of homesteaders onto the North American Great Plains to take up agricultural land or migration of retirees to the United States Sunbelt states (Hudson, 1973; Happel & Hogan, 2002), but even if along Alt Empordà coast many immigrants are retired people from north-western European countries attracted by a warm Mediterranean climate, this attraction is not the focus of this thesis. The focus here is on the potential outmigration linked to climate change of all the residents in Aiguamolls de l'Empordà area, both natives and immigrants (and among immigrants both economically active and retired ones).

However, the analysis showed that there is possible future outmigration movement in the study area due to climate change impacts, but it does not automatically imply that migration will occur in Aiguamolls de l'Empordà. It is also important to point out that this thesis only identified some general principles of outmigration as an adaptive response to climate change and further study on this model is needed in order to address outmigration as a part of the solution rather than the problem.

CHAPTER 8
CONCLUDING REMARKS

From the above results and discussions, different general conclusions are made and values of the findings for the future research are presented.

8.1 General conclusions

Climate change is now a reality that is evident in many places around the world and it is very likely that its effects may intensify in the coming decades. While most environmental perception studies on climate change focus on a global or national scale, this thesis examines stakeholders' perceptions on a local level and finds out that is essential to gather and integrate local understanding, perception and knowledge with scientific knowledge in order to develop successful response to climate change, empower local decision-making and preserve current ecosystems, livelihoods and communities. As described by Leiserowitz (2007), risk perception is a critical component of the public and social response to environmental and climate hazards. Furthermore, it is important to outline that scientific knowledge is crucial for interpreting climate variability since cold winters or intense precipitation, for example, can be misinterpreted as counterevidence for global warming and long-term drought (Ruddell et al., 2012).

While most studies have examined environmental change, climate variability, or social perceptions, this thesis integrates all these issues. It has also gone some way towards providing a unique research perspective on climate change in natural protected area in the Mediterranean climatic zone. This thesis aims to support the position that any vulnerability and adaptation analysis must be participatory and must include social, cultural, environmental, economic and political dimensions, thereby allowing for building up a better understanding of vulnerability and adaptation in the changing climate with the aim of reducing vulnerability and maintaining or increasing the opportunities for sustainable development in the study area. Furthermore, this thesis suggests that meteorological, hydrological and marine variables together with climate projections are essential for forming the basis for decision-making in vulnerable areas, such as Aiguamolls de l'Empordà. Five important findings emerged from the thesis.

Firstly, the thesis found that since the early 1970s, both average annual and absolute minimum and maximum temperatures in Aiguamolls de l'Empordà have been on a warming trend. The average annual temperature rose by 2.3 °C since 1971. Also, the seawaters of the Mediterranean west basin near Aiguamolls de l'Empordà became

warmer (between 0.76 and 1.1 °C) up to a depth of 80 m over the period 1971–2012. Furthermore, precipitation trend showed insignificant increasing trend. In particular, precipitation have increased in autumn and winter and decreased in spring and summer since 1971. While the average annual wind velocity increased in the period 1990–2012, the frequency of storms decreased. Regarding Fluvià and Muga flows, a decrease in the annual average river flows was observed in the period 1971–2011. Recent marine data of the local sea level near Aiguamolls de l'Empordà showed an increase by 3.6 mm per year between 1990 and 2012.

The results of the thesis offer some support for the view that local climate change and/or variability and its effects have been observed over the last few decades together with high socio-economic pressure as a result of urbanisation and human activities, especially tourism and agriculture. It is likely that the communities and ecosystems in Aiguamolls de l'Empordà have been facing several pressures that make them vulnerable and this may affect their current and future capacity to cope with the effects of climate change.

Secondly, results of current available climate projections showed that increases in air temperatures will continue. The increase in annual average temperature for the study area is estimated to be between 0.6 and 1 °C by 2050 (scenario A2) and 0.8–1 °C (scenario B1) in relation to the average values for the period 1971–2000. Regarding precipitation, an average annual reduction of precipitation between 6 and 9% (scenario A2) and 3 and 6% (scenario B1) by 2050 is projected. This finding emphasises the need for more detailed projections on future meteorological, hydrological and marine variables. Additionally, it implies that climate conditions for communities, ecosystems and livelihoods may only worsen in the future if the local, regional, national, European and global policy-makers do not implement measures that result in deeper cuts in the anthropogenic GHG emissions responsible for climate change. All in all, it is important to note that from these two significant findings, the Aim 1: Analyse climate change variables of the study area, was reached.

Thirdly, the results of the thesis emphasised the importance of stakeholders' perceptions, knowledge and observations. Further, I acknowledge that stakeholder participation at all scales may play a key role in determining the nature of climate change vulnerability over time.

This thesis has demonstrated that scientific research and public awareness of climate change have grown during the past two decades. The interview data, along with

documental and statistical data and observation, point to a picture that Aiguamolls de l'Empordà's community showed themselves capable of generating social learning and they have a high level of risk awareness and knowledge about their physical environment and potential vulnerability. Large majorities of stakeholders believed that climate change is a very serious problem and that concern about this issue is growing. Most of them said that human activities are a significant cause of climate change especially over recent decades. Furthermore, stakeholders considered that the air temperature increases over the past few decades, decrease in water supply, decrease in precipitation, but with an occasional increase in intensity, the worsening droughts, and the decrease in biodiversity and ecosystem productivity are the most pressing effects of climate change and serious risks to the study area. For the most part, stakeholders' perception of the increase in air temperature, decrease in water supply, drought and biodiversity and ecosystem loss appears to be in line with present climate data and prior studies. In addition to this, the location of the coastal municipalities (e.g. exposure) also makes them directly vulnerable to coastal erosion, flooding, saltwater intrusion, and rises in sea level what was also stressed by majority of stakeholders. This is also consistent with some prior studies, which demonstrated that the study area's natural and socio-economic systems are likely to be particularly vulnerable to four effects of climate change:

- Alterations in the magnitude and frequency of coastal erosion;
- Altered frequency and severity of saltwater intrusion;
- Alterations in the magnitude of water scarcity;
- Major changes in sediment supply of Fluvià.

Moreover, I assume that natural systems' vulnerability over the last four decades has been related mainly to the impacts caused by economic activities and urbanisation rather than to climate change effects.

In turn, socio-economic vulnerability is likely to be more related to climate variability or change. Here, especially the tourism industry can be adversely affected to a significant extent, as Aiguamolls de l'Empordà's economic dependence on tourism and the sensitivity of tourist resources to climate form a situation of socio-economic vulnerability to climate change. Stakeholders claimed that this sector has already been

affected by climate variability and change and beach management, mainly via shifting seasons, heatwaves and beach quality. However, over coming decades the study area may become less attractive destination both for tourism and second home residence due to climate change effects (e.g. increased temperatures, heatwaves, coastal erosion) and particularly vulnerable as the coastline has been a focal point for an important part of tourism in Catalonia. Moreover, the agricultural sector was also perceived to have been affected mainly by changed weather patterns, forest fires, saltwater intrusion and changing growth conditions. This may go some way to explain how this sector can importantly be affected, for instance, by reduction in agricultural yields of existing crops, increased use of irrigation, presence of invasive species, reduction in fish catches.

Considering the issue of a sea level rise of 50 cm by 2050, a clear majority of the stakeholders strongly believed that a 50 cm rise in sea level might occur in this part of the Mediterranean Sea and trigger further flooding, coastal erosion and saltwater intrusion. This perception is consistent with both IPCC projections for the Mediterranean Sea in general (IPCC, 2007a) and the Catalan coastline in particular (ACA, 2009).

When asked about the influence of climate change impacts on stakeholders' work activity, significant proportions of them indicated that climate change is already or may further continue to affect their work activity. Interestingly, almost half of them stated that climate change might positively affect their work activity over coming decades, stating that climate change may create new areas of work or expand the tasks of their existing jobs. Particularly, stakeholders from research and industry sectors expressed that they have been facing growing demand and interest in climate change issues and it is likely that their future work activity and productivity will increase.

Despite the high level of familiarity with the meaning of sustainable principles and awareness, the municipalities of Aiguamolls de l'Empordà were mostly perceived to be unsustainable due to the rapid mass tourism growth along the coastline and unsustainable exploitation of natural resources.

The third finding furthermore suggests that the Aim 2: Assess the dimensions of communities' vulnerability to climate change in the study area that is characterised by a high rate of foreign immigration, was fulfilled.

In sum, according to these three main findings, I can verify the first hypothesis: "Environmental stresses caused by climate change are already visible and are affecting the environment and communities living in this area".

Fourthly, this thesis highlights also the local dimension of climate change adaptation in order to maintain a wide range of livelihoods while facing current and future climate variability and change. I recognise that adaptation depend on the social, cultural and economic characteristics within communities. One of the main lessons is that we should not wait until climate change additionally affects communities, livelihoods and ecosystems because then could be more difficult to manage the socio-economic and ecological consequences, and to take advantage of any potential opportunities and benefits. Therefore, encouraging communities and policy-makers of short/medium-term thinking and developing adaptation planning with more desirable sustainable outcomes should be a priority in the study area. Nevertheless, it is worth mentioning that these adaptation measures can represent only a part of climate change adaptation processes. A much more comprehensive adaptation evaluation approach will need to be taken into account in further research.

The semi-structured interviews carried out showed that roughly half of the stakeholders perceived, that climate change adaptation is needed and only a few of them expressed a high level of familiarity with mitigation. This finding may suggest that even if cost of adaptation is high, further losses to the economy, ecosystems and properties in Aiguamolls de l'Empordà might be even higher. Furthermore, it was found that was easier to gain support for natural adaptation measures than for the measures that are artificial. A half of stakeholders that were in favour for adaptation reported that they would implement natural measures such as setting dunes and beach barriers, rising ground level and find alternative agricultural practices, while approximately one-quarter of them were in favour of artificial adaptation measures, such as seawalls and breakwaters, flood and saltwater intrusion-gates, beach nourishment and rainwater harvesting. One of the important findings is that adaptation appears to be already taking place in the study area during the last few decades mainly through unsustainable adaptation measures such as artificial or hard structures.

One of the issues that emerge from these findings is that the most suitable adaptation measure according to half of stakeholders, coastal dune building can decrease vulnerability and produce benefits even in the absence of climate change effects. It can be assumed also that this measure would involve minor modifications to existing coastal management. The other measures did not have such unified support. For instance, seawalls and breakwaters carried different opinions. On the one hand, some stakeholders were against the artificialisation mainly due to the ecological value of the

study area, and on the other hand, others were willing to maintain an enough attractive landscape for economic activities (mainly tourism) by artificial measures. Moreover, seawalls and breakwaters were perceived as being too costly to build and maintain, especially during the current economic recession. Flood and saltwater intrusion gates were also suggested and discussed, but they may be not suitable measures because they entail significant investments. Beach nourishment was perceived as a suitable and aesthetically pleasing measure only by a minority of stakeholders, although it can be implemented within a relatively reasonable budget. On the contrary, rising ground level towards few centimetres did not gain too much support. Here, it can be supposed that due to weak awareness from a technical and urban design point of view. This research also revealed that the support for rainfall capture and storage in the Spanish Mediterranean, where water scarcity is likely to become more profound problem is becoming prioritised. Regarding, the inland adaptation measures, stakeholders were mainly focused on agriculture due to its economic importance in the study area. They expressed the highest confidence in the drought-resistant crop growing and they often perceived that a longer growing season would allow new fruit varieties to be grown.

This research furthermore suggests that any climate policy and implementation may be influenced by the available technical measures with due consideration being given to their sustainability and cost. I also argue that suggested adaptation measures should aim to secure benefits for all or at least for majority of stakeholders in the study area, moreover, should strengthen the ability of stakeholders, communities and policy-makers to respond to climate hazards and secure their livelihoods and ecosystems for the future. Furthermore, here I consider characterising an attempt to assess sustainable adaptation because I believe that there can be much more to gain from in the short/medium-term period. This thesis contributes to the literature on climate change adaptation in developed countries in terms of presenting research from a context where no prior local climate change scenarios, comprehensive vulnerability, or adaptation assessments have been done. However, I assume that there should be an emerging concern for these discussions to begin.

This significant forth finding furthermore indicate that Aim 3: Identify, analyse and evaluate the most appropriate technical, socio-economic and structural adaptation measures to respond to vulnerability according to key stakeholders, was achieved.

Finally, my results demonstrated that climate change is likely to have greater importance in influencing outmigration in the study area. From the research, it was

noted that the option of abandoning the area (i.e. emigration elsewhere) was clearly believed to be more acceptable by some kind of stakeholders, especially men, older residents (between 41 and 69 years old) and foreign immigrants. I recognise that vulnerability to climate change may affect migration drivers, but does not automatically imply that migration will occur in Aiguamolls de l'Empordà. It is important to point out that this thesis only identified some general principles of outmigration in response to climate change and it does not draw out specific policy recommendations. For this reason, I argue that is needed a better understanding of the role that local, regional and national institutions and policy need to play in making migration to be seen as part of the solution rather than the problem. Moreover, it remains challenging to make reliable forecasts of population movements that are likely to result from climate change effects. Accomplishing this task remains for other authors.

Additionally, the last of aims, Aim 4: Identify and evaluate outmigration due to climate change, was fulfilled.

Stemming from the latter, I can partly verify the second hypothesis, which suggested, "Local stakeholders in Aiguamolls de l'Empordà area are in favour of the mildest measure for adapting to climate change, i.e. the one that is most in harmony with nature. Furthermore, outmigration is perceived as not acceptable option for dealing with climate change impacts". Results of perceived outmigration are in contrast with the hypothesis regarding some groups of stakeholders (i.e. male, older and foreign residents), while the mildest measure for climate change adaptation (i.e. coastal dune building) can be verified.

8.2 Outlook for future research

It is important to point out that such research as presented in my thesis can contribute to the regional and national dialogue on climate change vulnerability and adaptation. Furthermore, I argue that these issues call for a multidisciplinary approach, in which climatologists, sociologists, economists, geographers and wide range of engineers are invited to interact. Considering the five findings of this thesis, it is of significant importance for local, regional and national policy-makers to start acting now and not leave this challenge to future generations.

The framework, approach, methods and analyses presented herein are flexible and have scope to be improved and updated in the future. For instance, I assume that incorporating improvements in scientific understanding of climate variables over a longer time scale is crucial for vulnerability and adaptation assessments. I acknowledge that longer time-series of meteorological, hydrological and marine data in combination with climate projections can form supportive basis for decision-making in the vulnerable areas such as Aiguamolls de l'Empordà. Furthermore, measuring vulnerability index and mapping possibly affected areas by climate change effects could be applied in order to understand better climate change effects that community and ecosystem have been facing and support the formulation of solutions to address optimally these effects. It may also need researching whether stakeholders' perceptions and knowledge are strong enough to influence short- and long-term planning and adaptation, or whether they are only non-operational perceptions on which stakeholders barely act. These recommended issues may generate greater sense of urgency to take action and could have outstanding importance for future policy aimed at reducing vulnerability to climate change in natural protected areas on a local, regional and national scale. Moreover, this is a fruitful issue for further research and development of the study area.

Second, future research should employ improved understanding of environmental migration, thus, it should prioritise this issue by researching institutional and policy frameworks needed to prepare for, prevent or respond effectively to possible future outmigration accounting for outmigration not only as a consequence of climate change impacts, but as a part of adaptive response to change within current regional and national governance systems. Future research could also identify areas where the affected community may emigrate by analysing limitations of possible inland and

higher grounds in the territory of Aiguamolls de l'Empordà. My understanding of this issue remains limited and ripe for further research.

Finally, future research could conduct similar studies in other natural protected areas representing a range of stakeholders' perception and knowledge and facing a variety of climatic challenges. Here, it would be interesting to widen up the international comparison (Fatorić et al., forthcoming) and to contrast or compare findings in this thesis with data gathered with the same methodological framework in other areas within Mediterranean climatic zone, such as Northern Africa, South Australia, California, Chile and South Africa.

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ANNEX 1: LIST AND DETAILS OF THE STAKEHOLDERS

Code for a stakeholder	Municipality	Gender	Age	Nationality
<i>Environmental actor</i>				
ENA-male-63	Castelló d'Empúries	M	63	Spanish
ENA-female-41	Figueres	F	41	German
ENA-female-45	Barcelona	F	45	Spanish
ENA-male-44	Figueres	M	44	Spanish
ENA-male-64	Palau-Saverdera	M	64	Spanish
ENA-female-37	Girona	F	37	Spanish
<i>Public administration actor</i>				
PAA-male-49	Castelló d'Empúries	M	49	Spanish
PAA-female-40	Pau	F	40	Spanish
PAA-male-36	Roses	M	36	Spanish
PAA-male-41	Barcelona	M	41	Spanish
PAA-male-48	Barcelona	M	48	Spanish
PAA-male-53	Barcelona	M	53	Spanish
<i>Touristic actor</i>				
TA-female-45	Castelló d'Empúries	F	45	Spanish
TA-female-38	Castelló d'Empúries	F	38	Spanish
TA-female-46	Roses	F	46	Spanish
TA-male-56	Castelló d'Empúries	M	56	Spanish
TA-female-44	Roses	F	44	French
TA-male-41	Escala	M	41	Spanish
<i>Economic actor</i>				
ECA-male-43	Girona	M	43	Spanish
ECA-male-34	Peralada	M	34	Spanish
ECA-male-68	Castelló d'Empúries	M	68	Spanish
ECA-male-36	Castelló d'Empúries	M	36	Spanish
ECA-male-59	Palau-Saverdera	M	59	Austrian
ECA-male-42	Roses	M	42	German
<i>Agricultural-farming actor</i>				
AFA-male-51	Roses	M	51	Argentinean
AFA-male-62	Figueres	M	62	Spanish
AFA-male-54	Pau	M	54	Spanish
AFA-male-39	Roses	M	39	Spanish
AFA-male-46	Figueres	M	46	Spanish
<i>Industrial actor</i>				
IA-male-38	Roses	M	38	Spanish
IA-female-31	Girona	F	31	Spanish
IA-male-37	Escala	M	37	Spanish
IA-male-46	Roses	M	46	Spanish
IA-male-47	Roses	M	47	Spanish
IA-male-44	Roses	M	44	Spanish

Research actor

RA-male-53	Barcelona	M	53	Spanish
RA-female-33	Castelló d'Empúries	M	33	Spanish
RA-male-33	Escala	F	33	Spanish
RA-male-48	Barcelona	M	48	Spanish

Cultural actor

CA-male-53	Castelló d'Empúries	M	53	German
CA-male-39	Castelló d'Empúries	M	39	Moroccan
CA-male-44	Roses	M	44	Dutch
CA-female-20	Roses	F	20	Moroccan
CA-female-48	Castelló d'Empúries	F	48	German
CA-male-43	Roses	M	43	British

ANNEX 2: A SELECTION OF TRANSCRIBED INTERVIEWS WITH THE STAKEHOLDERS

The summary of the interview with ENA-female-45

- Área temática: Cambio climático

El cambio climático es la consecuencia del calentamiento de la atmósfera debido a las concentraciones de gases de efecto invernadero. Es un fenómeno de gran complejidad que ya ha conducido a un aumento de temperatura de la tierra de más de 0.7 °C y que nos lleva a un peligro muy cierto si no limitamos los gases. Nos provoca asimismo el peligro de entrar en un aumento de 1.5–2 °C que provocaría un cambio climático catastrófico, que es la mayor amenaza para la sociedad humana y biodiversidad. El consenso científico dice que 90% del cambio climático está inducido por el hombre. Los modelos climáticos indican que el aumento de temperatura es debido a los gases de efecto invernadero, aunque también por la deforestación, ganadería, agricultura intensiva o el cambio del uso de suelo.

Los efectos de cambio climático más observados en la zona de estudio son de mayor intensidad en fenómenos extremos, sequías y temperaturas altas; de menor predictibilidad, menos regularidad. Había un gran aumento de la temperatura del aire y del mar, y presencia de especies invasoras. También la erosión costera está visible, dónde por cada cm de subida de mar representa 10m de regresión de costa.

La subida del nivel de mar tiene dos causas. Una, el aumento de la densidad del mar debido al aumento de la temperatura de agua, y otra, la aportación de agua dulce de glaciares. Es realmente preocupante, porque el CO₂ que liberamos ahora se activará dentro de unos cuantos años. La entrevistada ve la subida del nivel del mar muy probable hasta 70 cm y esta predicción no le parece nada catastrofista.

La actividad de trabajo podrá ser afectada mayormente porque está enfocada en la mitigación al cambio climático, pero no lo tiene claro si positivamente o negativamente.

- Área temática: Sostenibilidad

Sostenibilidad significa preservar lo que tenemos hoy para las futuras generaciones. Por ejemplo, hay que incorporar energías renovables en industria, transporte y en los hogares. Conseguir un servicio energético que tenga un impacto menor en el medio ambiente así como la energía tendría que ser renovable.

Las personas de zona de estudio no son, por norma general, sostenibles. Este hecho viene fundado por la culpa de pensar que hay que sacrificar algo, o que sus acciones aportarían muy poco a la sociedad. Las urbanizaciones y toda la zona con su rápido crecimiento en las últimas décadas no pueden ser sostenibles. Crearon el parque natural para mantener las zonas naturales y ser un poco más sostenibles. La entrevistada menciona que han denunciado proyectos de urbanización, como en Castelló d'Empúries, porque las autoridades plantearon construir un nuevo puerto deportivo y marina. Hacer obras precisamente al lado de la costa no es sostenible, además que el cambio climático a medio plazo puede provocar desertificación con un aumento de la temperatura en verano, y afectar al sector turístico.

- Área temática: Adaptación y mitigación al Cambio Climático

Cuanto más natural sea la costa mejor se pondrá adaptar a los efectos del cambio climático. Un ejemplo de ello pueden ser los humedales, un tipo de protección. Las medidas tienen que crear sinergias con la naturaleza y no artificializar la zona. Además, la gente que tiene casas al lado del mar no es consciente de que podrían inundarse. En cambio, se quejaron contra la ley de costas, que les dificulta la venta de propiedades. Además, la entrevistada cree que es un resultado de la ignorancia vivir en primera línea de mar y habrá que dejarlo de hacer. Proteger toda la costa sería difícil, así que la mejor opción es irse más al interior y dejar la primera línea para la defensa.

The summary of the interview with PAA-male-48

- Área temática: Cambio climático

El cambio climático es el incremento de la variabilidad climática tanto por causas naturales como antropogénicas que son debidas a la actividad humana y la emisión de gases de efecto invernadero. El cambio climático tiene efectos sobre las variables climáticas como temperatura, precipitaciones. El IPCC cree que el 99% del cambio climático en los últimos 20 años es por causas antropogénicas. El entrevistado cree lo mismo.

Algunos de los efectos del cambio climático son un incremento de la temperatura, del nivel del mar, los cuales han sido analizados. Además periodos de lluvias cortos y muy intensos que afectan a los recursos de agua. Esta área se alimenta con aguas del Muga y el Fluvià en los cuales se noto una reducción de los caudales y además su interacción con las aguas marinas les hacen vulnerables por la intrusión de agua salina. El acuífero de Sant Pere Pescador con una subida del nivel del mar estaría seriamente afectado. Las especies invasoras ya están presentes y se han convertido en un problema. Además otros efectos de cambio climático son cambios en fenología, maduración de frutos y el ciclo de alimentación de los animales.

Una subida del nivel del mar de 50 cm hasta el 2050, escenario probable, si tenemos en cuenta la tendencia histórica y presente, se han de extremar las máximas precaución.

La actividad de trabajo del entrevistado se ve afectada positivamente por el cambio climático. Si bien a nivel general hay una preocupación sobre este tema, su trabajo por ahora, se centra en diseñar las políticas de mitigación.

- Área temática: Sostenibilidad

Ser sostenible es dejar algo en las mismas condiciones en las que lo has encontrado. Eso implica cuidar los aspectos ambientales, económicos, financieros, sociales, culturales y preservarlos para futuras generaciones.

Sostenible es un concepto que actualmente se “prostituye” ya que se utiliza en muchos ámbitos sin una referencia real de esta palabra. Un mal ejemplo de este uso es el que ofrecen algunas empresas eléctricas o bancos importantes cuando hablan de

sostenibilidad. Además este concepto se asocia mucho con la economía verde o “sostenible” pese a su relevancia la sociedad aún no lo ha asimilado.

Ocho de los nueve municipios son urbanizados, especialmente Roses y Empuriabrava. Estos dos son referentes urbanísticos pero hay municipios que no quieren seguir su modelo como por ejemplo Sant Pere Pescador. La idea general es que la zona de estudio no es sostenible.

- Área temática: Adaptación y Mitigación del Cambio Climático

Somos de la opinión que hay medidas buenas y malas. No urbanizar las aéreas inundables es una adaptación, porque esto reduce la vulnerabilidad. Además la ley de urbanismo prohíbe urbanizar las zonas inundables. No ejecutar medidas que no se sustenten en principios de adaptación puede comportar grandes pérdidas económicas como regenerar las playas y gastar millones de euros. Adaptación con medidas artificiales como diques son crean una sensación de falsa seguridad.

La opinión del entrevistado es favorable a promover las medidas de mitigación de cambio climático, como la generación de energía renovable y autosuficiencia energética. Añade que las medidas de adaptación dependen del coste económico de su implementación. Ofrece el ejemplo de Holanda el cual se está adaptando porque no tiene otra alternativa.

El entrevistado cree que es posible una emigración de la población de la zona de estudio debido a los efectos de cambio climático. Es mejor pensar en actividades compatibles con la nueva situación de la zona en vez de fomentar medidas artificiales. Esta posible nueva situación le sugiere al entrevistado nuevas perspectivas económicas. Por ejemplo si se pierde turismo como sector de referencia, se pueden crear nuevas actividades económicas como piscifactoría. El entrevistado dice que hay que empezar a prepararse ya.

The summary of the interview with AFA-male-39

- Área temática: Cambio Climático

El cambio climático es un cambio en las características del clima. Puede ser que el efecto invernadero tiene la culpa, que la actividad humana ha favorecido que se haya adelantado el proceso. Pero también hay épocas glaciales y ahora estamos saliendo de una, por eso hay también un calentamiento global natural. Entrevistado piensa que es cambio climático es combinación del natural con el antropógeno.

Está cambiando el clima, aquí lo noto. Cuando tuve 15 años la tramuntana soplaba 15 días en Noviembre, pero ahora sopla todo el año con una intensidad brutal, tanto en invierno como en verano. También frío no hace más que 1 mes y medio, es siempre más corto, hay como una translación de estaciones. El clima Mediterráneo no es más como lo era antes, lo de que llueve en otoño y en invierno ya no es más así. Quizás lo que se nota más son las reservas de los acuíferos, ya que como no hay lluvias las reservas de agua subterránea han bajado mucho. Los incendios son el problema más grande en Cap de Creus, dónde hay una masa forestal inflamable, no hay árboles, pero hay mucho matorral que prende rápido el fuego. No existe ningún programa de prevención de incendios local, aunque sí que existe la Asociación de Defensa Forestal, que cubre varios municipios aunque con pocos medios.

La subida de nivel del mar aquí no sería una catástrofe y no la veo tan probable.

La actividad de trabajo del entrevistado es investigar el subsuelo para el sector agrario y procesos de agua subterránea. Quizás en los últimos años se ha notado más demanda particular de gente que busca los recursos de aguas privadas (pozos).

- Área temática: Sostenibilidad

Es llevar una buena gestión del agua (potable, residuales, subterránea), residuos, y paisaje. Trabajamos en el área de medio ambiente, en proyectos de ordenación del territorio para urbanizaciones. Cuando tu programas una urbanización buscas que haya una integración de esta urbanización en el medio ambiente y esto se logra con una gestión sostenible, como ahorrar en agua potable, energía, y hacer una buena gestión de residuos y agua.

Sí, se han hecho grandes avances, sobretodo dentro de la Agenda 21, dónde había una serie de planes de actuaciones. Nosotros hemos participado en el plan de residuos de Roses hace 8 años, dónde los apoyábamos por unos contenedores subterráneos. Tenemos una depuradora que se ha ampliado, la gestión de agua potable también, e hicimos un estudio hidrológico de todo el municipio para saber cuánta agua subterránea tenemos, si hay suficiente. A parte, el agua viene gestionada con el embalse de Boadella. Así que ahora no tenemos problemas.

- Área temática: Adaptación y Mitigación del Cambio Climático

Tenemos que evitar la artificialización de la línea de costera que ya está muy degradada, suerte que tenemos el parque natural. Tendríamos que crear una zona de dunas para evitar la salinización, erosión y la intrusión de agua salina. Regeneración de playas es una medida adecuada. Cuando la playa es más ancha más puede reducir los daños a la infraestructura por las tormentas. Aquí hicimos un proyecto de montaje de una especie de dunas artificiales para evitar la huída de arena durante la tramuntana y tormentas. Además económicamente sale muy caro cada año sacar la arena del mar y volverla a reponer en la costa.

Abandonar el terreno no lo veo aceptable, más que nada porque aquí se basan muchas actividades en la primera línea del mar.

The summary of the interview with RA-male-48

- Área temática: Cambio climático

El cambio de clima se debe principalmente a actividades del ser humano. Siempre ha habido un cambio natural pero ahora está pasando más rápido e intenso por la influencia humana en los últimos 20 años. Hay gente que no cree en el cambio climático porque no es invisible a escala humana o porque no está impactada.

Los cambios que sufre la costa catalana a efectos humanos son muy rápidos si los comparamos con los del cambio climático, que soy muy lentos. El estado de la costa está en mal estado por la erosión y la estabilidad, mayormente por actividades humanas como puertos, protecciones, y en cuencas de drenajes como presas en los ríos. Muchas

veces pensamos que hay más tormentas pero no es cierto, las tormentas son las mismas pero hay más daño porque la costa es más estrecha y es menos capaz de resistirlas. Cada vez más, vamos urbanizando la costa de lado a lado y ponemos valores como paseos marítimos, y hay más daños. Inundaciones siempre ha habido, son muy localizadas en zonas planas pero no hay ni más ni menos, no han aumentado. Es bueno estar preparado y ver qué pasa con varias proyecciones, y planificar. En la últimas dos décadas hay un número alto de investigaciones sobre el cambio climático, mayormente para valorar el impacto, planificación territorial y proyecciones.

- Área temática: Sostenibilidad

La sostenibilidad tiene elemento social, económico y ambiental y tiene que estar más o menos en un balance. Permite un desarrollo económico que no produce degradación ambiental o social. Significa preservar estos valores para nuestras futuras generaciones. Lo que estamos haciendo en la costa no es sostenible ni en el presente. Antes de su uso turístico la zona era sostenible, pero con la artificialización del turismo estamos degradando el medio ambiente y no creo que se tenga para nada en cuenta la parte ambiental.

- Área temática: Adaptación y mitigación al Cambio Climático

Adaptarnos al cambio climático sería reformular nuestra forma del uso del territorio, nuestra forma de vida en el sentido que si no podemos evitar el cambio climático podemos soportarlo, podemos vivir con él. Adaptarnos es nuestra necesidad esencial, porque la seguridad humana podría ser amenazada.

Si sube la temperatura en el Mediterráneo, tendríamos que reformular nuestro mercado turístico, buscar otro tipo de desarrollo turístico, quizás empezar la temporada turística antes. Desde el punto de vista de desarrollo urbanístico sería quizás abandonar algunas zonas costeras e irnos más hacia atrás para poder vivir con inundaciones; desde el punto de vista de infraestructuras sería buscar otro tipo de infraestructura que podrían aguantar las inundaciones periódicas. Además entrevistado cree que sería menos costoso empezar a actuar ahora en lugar de esperar hasta que suceda algo realmente catastrófico. Cualquier cambio grande es un problema y al mismo tiempo una oportunidad. Un problema para las zonas que están influenciadas por el cambio climático, por ejemplo si

sube nivel de mar dónde muchas serán difíciles de adaptarse por lo que tendrán que abandonarse. Una oportunidad para nuevas zonas de nuevas infraestructuras, como empezar de nuevo.

Medidas naturales habrán pocas, porque un 70% de la costa catalana ya está artificializada y no tiene sentido pensar en lo natural, pero como el Golfo de Roses y el Delta del Ebro, tendría que adaptarse de forma natural. Tendrían que hacerse políticas de planificación para mejorar la respuesta de la costa. No tendría sentido rodear un delta con un muro, sería un pólder con demasiado coste. Aquí en la ciencia todo es muy fácil: cualquier costa necesita sedimentos suficientes para responder y adaptarse a nuevas situaciones. Si no los tiene hay que pensar que no son naturales y que tenemos la capacidad técnica para hacerlo pero también es muy caro, así que dudo que sea suficiente desde el punto de vista económico.

ANNEX 3: PUBLISHED PEER-REVIEWED ARTICLES DURING THE PH.D. RESEARCH

This Ph.D. thesis was funded by a three years research grant [FI-DGR 2011] from the Research Agency of the Catalan Autonomous Government, Spain (AGAUR) and the Spanish Ministry for Research and Innovation [grant number CSO2009-13909], thanks to which I was assigned a position as researcher at the Department of Geography, UAB.

Over the three years, I published following peer-reviewed articles, which also motivated and helped me elaborating this thesis:

1. During the second year of Ph.D., I published my master's thesis, written at the ICTA, UAB together with a colleague Dr. Lorenzo Chelleri from the Department of Geography:
Fatorić, S., Chelleri, L., 2012. **Vulnerability to the effects of climate change and adaptation: The case of Spanish Ebro Delta.** *Ocean and Coastal Management* 60, 1–10.
2. During the third year of Ph.D., I published together with my thesis director Dr. Ricard Morén-Alegret an article:
Fatorić, S., Morén-Alegret, R., 2013. **Integrating local knowledge and perception for assessing vulnerability to climate change in economically dynamic coastal areas: The case of natural protected area Aiguamolls de l'Empordà, Spain.** *Ocean and Coastal Management* 85(A), 90–102.
3. Furthermore, during the third year of Ph.D., I got preliminary accepted an article done with my thesis director Dr. Ricard Morén-Alegret and professor Charalambos Kasimis from the Agricultural University of Athens:
Fatorić, S., Morén-Alegret, R., Kasimis, C., forthcoming. **Exploring climate change effects in Euro-Mediterranean protected coastal wetlands: the cases of Aiguamolls de l'Empordà, Spain, and Kotychi-Strofylia, Greece.** *International Journal for Sustainable Development & World Ecology*.

The focus of doctoral dissertation is on climate change as one of the essential aspects of environmental change.

The overarching goal of the dissertation is to identify, develop and explain the vulnerability assessment for the communities and livelihoods in Aiguamolls de l'Empordà in the face of climate change and to identify and explain principal measures for adaptation.

First, the dissertation aims to analyse climate change variables and future climate projections for the study area. Then, it turns its attention to assess the dimensions of communities' vulnerability to climate change in the study area in order to identify ways in which the adaptive capacity can be increased and exposure and sensitivity decreased. Thirdly, it focuses on identifying and evaluating the most appropriate technical, economic and structural adaptation measures to respond to vulnerability. This can help to highlight which measures may reduce vulnerability most effectively. Lastly, the aim is to provide an understanding of possible future human outmigration from the study area due to climate change impacts.

The study area, however, may serve as an example for some similar regions along the Mediterranean coast.

