ID 1510 | CLIMATE CHANGE ADAPTATION MEASURES FOR ITALIAN COASTAL CITIES

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1 CLIMATE CHANGE AND COASTAL AREAS: AN OVERVIEW OF THE MAIN IMPACTS

Coastal areas are commonly the geographical space of transition between land and sea, comprising of the land near the coast and the adjacent territorial waters. These areas include diverse systems such as delta environments, humid areas, lagoons, small islands, low-lying coastal plains, sandy beaches and sedimentary coasts. The borders of a coastal area are often defined arbitrarily and can be divided up among nations. Due to their own nature, these areas are intrinsically dynamic systems characterised by interacting morphological, ecological and socio-economical processes. Some of the characteristics that set them apart from all other systems (IPCC, 2007d, 2013, 2014) can be summed up as:

- high rate of dynamic change in the natural environment;
- high diversity and biological productivity;
- high rate of human population growth and economic development;
- high rate of degradation of natural resources;
- high exposure to extreme events
- strong need of management systems that consider both terrestrial and marine problems.

Thanks to these characteristics, coastal areas provide resources and suitable space for economic activities and human settlements, leading to a high rate of population concentration. It is estimated that, on a global level, 50-70% of the human population currently lives in coastal areas. The international scientific world appears to agree on the fact that coastal areas will be particularly affected by rising sea levels and by temperature and precipitation changes as well as by possible variations in the frequency, distribution and intensity of extreme events such as tornadoes and storms. Climate change will however have different characteristics depending on the region and the impact on the different coastal areas will vary from region to region according to environmental, social, cultural and economic characteristics.

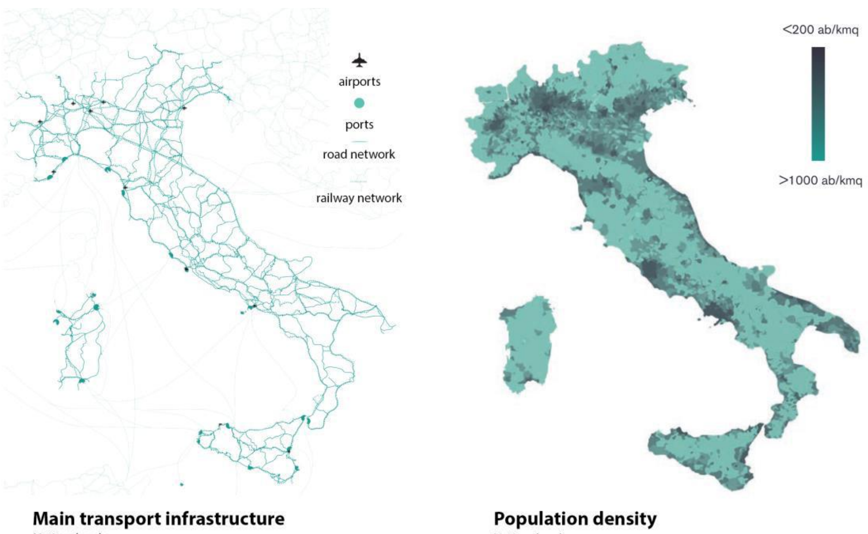
The Mediterranean basin is widely recognised as particularly vulnerable to climate change (Hoozemans et al., 1993; Nicholls et al., 1996, Klein and Nicholls, 1998). Most of the current stressful elements linked to the effect of human pressures will be inevitably exacerbated by climate change. As a general rule, the most serious effects will be felt by the coastal systems already under stress and where human activity diminished the natural capabilities of adaptation. Only a relatively limited number of studies analysed the vulnerability of the Mediterranean basin in light of climate and sea level change. As a consequence, these problems have been rarely considered by coastal planning and management processes. In these contexts, there are in fact no universally applicable methods to assess the impact of future climate change and the relative identification of vulnerabilities (Gorgas, 1999).

Italy has always been at the centre of the Mediterranean, not only on a geographical level - it has developed a unique coastal complexity that forces those in charge of territorial management and planning to make profound and thorough considerations. Of the 6,477 kilometres of coastline between Ventimiglia and Trieste and of the two largest islands (without therefore considering the numerous smaller islands): 3,291 kilometres have been transformed in an irreversible manner. More specifically, 719.4 kilometres are now occupied by industries, ports and infrastructures and 918,3 have been colonised by urban areas. Another worrying data is the diffusion of low-density settlements, which cover 1,653.3 kilometres, i.e. 25% of the entire coastline. One third of beaches is affected by increasing erosion, the marine habitat is constantly put to the test by pollution, as 25% of city sewage is still unsanitized (40% in some areas) (Zanchini et al. 2016). The Rapporto Ambiente Italia (Italy Environmental Report) paints a picture of these impacts with alarming data and studies that show how to address this situation through a change in policy. The challenge climate change is posing on Mediterranean coastal areas, with significant impact on the ecosystems, coastline and urban areas, must lead to a new and more incisive vision of the interventions to perform.

2 COAST VULNERABILITY: METHODOLOGY FOR SELECTION OF PILOT AREAS IN THE ITALIAN CONTEXT

The scientific consensus is that even if greenhouse gases were to be eliminated completely today, the air and sea temperatures would continue to rise due to past emissions (greenhouse gases have a lifespan of between 10 and thousands of years). The warming of the air and sea would lead to changes in precipitation, higher sea levels and more extreme weather events. According to Klein and Nicholls (1998) the six more important biogeophysical impacts induced by climate changes on coastal zones are: erosion and sediment deficit, increased flood frequency, inundation of low-lying areas, rising of water tables, saltwater intrusion and consequent biological effects. Due to their significant socio-economic implications, inundation and increased flood frequency will be treated in the socio-economic impacts section, rather than in the biogeophysical impacts one. The enhancement of the desertification process and the related soil degradation is another relevant impact which is already an environmental stress of concern for various Mediterranean regions. These effects, which are already affecting the Italian coastal areas and ecosystems, and the protections to take over the next decades paint a picture of the coastal impact on a national level and enable the identification of intervention areas on which to focus.

For the purposes of this research, we initially collected public data concerning geomorphology, settlements and infrastructures, economy, environment and the climate. Geomorphological data were taken from the Sistemi Informativi Ambientali (ISPRA) database, in particular, a national digital terrain model was used (DEM - 20 metre cells - National Geoportal) to reconstruct the orographic configuration of the Italian national territory. As regards the geological part, we used the geology map for Italy supplied by the Servizio Geologico d'Italia (ISPRA), which reports all geological and lithological characteristics of the Italian soil. This was done to distinguish the areas with alluvial/detrital soil from those with rocky/solid soil. Demographical, infrastructural and economic information was collected from multiple sources to reconstruct a reliable framework. For urban areas (settlements of various kinds, distribution of production macro-areas and population density), we used the database supplied by the IFEL-ANCI organisations. In particular, we took data concerning the localisation of urbanised areas, with specific attention to their population density. Secondly, to identify the economic weight of the settlements, we focused on mapping the economic-productive activities classifying them according to the primary, secondary and tertiary sectors. Transport infrastructures were mapped using two different databases, an open source one and a Ministerial one. The motorway network was taken from the OpenStreetMap database, while the railway network, airports and ports were identified thanks to the database supplied by the National Geoportal.



Main transport infrastructure
National scale
sources: *Geoportale Nazionale - OpenStreetMap*

Population density
National scale
source : *IFEL - ANCI*

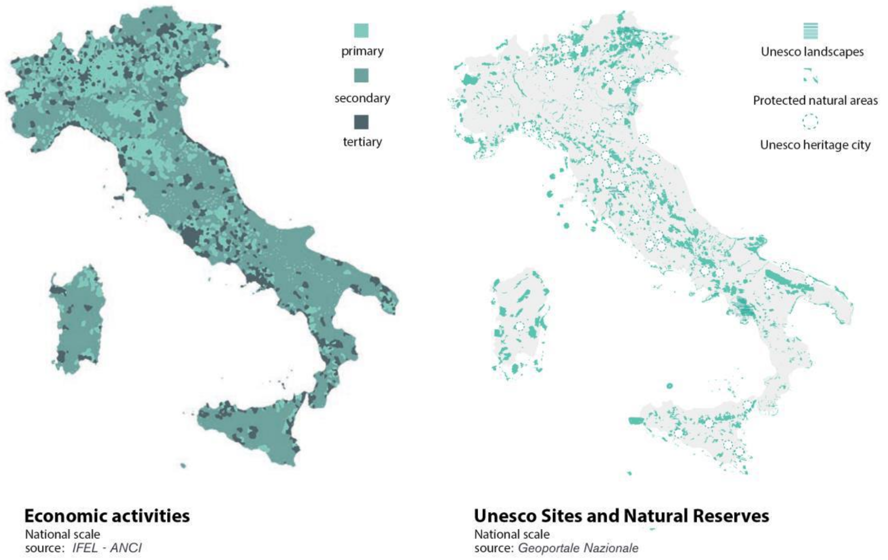


Figure 1 | National map of the main elements exposed to the impacts of climate change.
Processing by Magnabosco G. 2016

The climate question was tackled using multiple data and databases. The first macro-mapping of Italian climate areas was based on the Köppen climate classification scheme, then the factors specific to the Italian climate were analysed in depth: average sunlight (European Commission Joint Research Centre); annual average wind speed (European Commission Joint Research Centre); rainfall (Pluviometria Media Annua - SISEF) and sea currents (Carta delle Correnti Marine - Istituto Idrografico della Marina).

For the topics relating to the variables characterising existing and future problems on a national level, we used various databases and, in some cases, a re-processing of the data presented in said databases. As regards hydrogeological instability, we mapped the data supplied by the National Geoportal. Specifically, for what concerns inundations and flooding, we took into consideration the national data on these phenomena with return periods of 200 years. To these areas, we added the territories subjected to mechanical drainage (considering ENEA projections on the increase of extreme phenomena). As regards landslides, we consulted the Catalogo Frane IFFI (Landslide catalogue - Inventario Fenomeni Franosi Italia supplied by ISPRA) while, for droughts, we referred to the Atlante nazionale delle aree a rischio di desertificazione (National atlas of areas at risk of desertification) supplied by ISPRA and interpolated it with climate shift dynamics, which see the shifting of the interested areas towards higher latitudes.

The data on average sea rise and saltwater intrusion were taken from the Digital Terrain Model. The reports supplied by the IPCC and ENEA, suggesting an average value of +1 metre a.s.l., enabled the identification of the areas which will be affected by rising sea levels. Saltwater intrusion, which is a local dynamic not yet supported by an exhaustive national detection and mapping method, required approximation, calculated using a method similar to the one used for sea level rise. Only the land between 0 and 2 metres above sea level was considered. Finally, coastal erosion was identified using the data supplied by the EUROSION dataset.

2.1 METHOD TO IDENTIFY TARGET AREAS

The identification of target areas on which to focus analyses and governance actions was carried out by recognising and overlapping the drivers mentioned above according to a procedure divided into three steps:

STEP_1

A first selection was carried out by delimiting all the assets and forcings as far as 20 km from the coastline. Then we calculated the quantity of allocated assets (anthropogenic, productive, urban and infrastructural settlements) exposed to weather elements and assigned a number where the allocated asset is exposed to one of the elements. We then moved on to a recapping of the previous results to identify which areas/networks/soils are affected by most forcings and classified various degrees of exposure.

Starting from this consideration, we proceeded with cataloguing a series of factors to identify the areas with characteristics in common in addition to the exposure factor. The different areas were classified according to their particular geological (soil composition), morphological (sea level and ground roughness), climate (climate classification) and settlement (average population density, forma urbis, transport network distribution) parameters.

Figure 2 | Mapping of the coastal risk in Italy. Processing by Magnabosco G. 2016

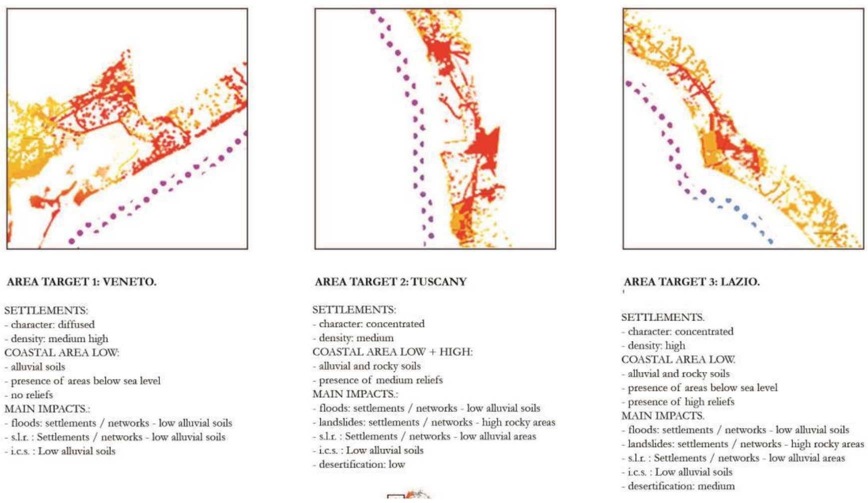
STEP_2

Starting from this consideration, we proceeded with cataloguing a series of factors to identify the areas with characteristics in common in addition to the exposure factor. The different areas were classified according to their particular geological (soil composition), morphological (sea level and ground roughness),

climate (climate classification) and settlement (average population density, forma urbis, transport network distribution) parameters.

STEP_3

We then proceeded to identify the areas that shared the conditions which emerged in step_1 and step_2, which enabled their classification according to exposure, anthropization, climate and geo-morphological conditions. 6 TARGET AREAS representative of the entire national coastal territory were categorised.



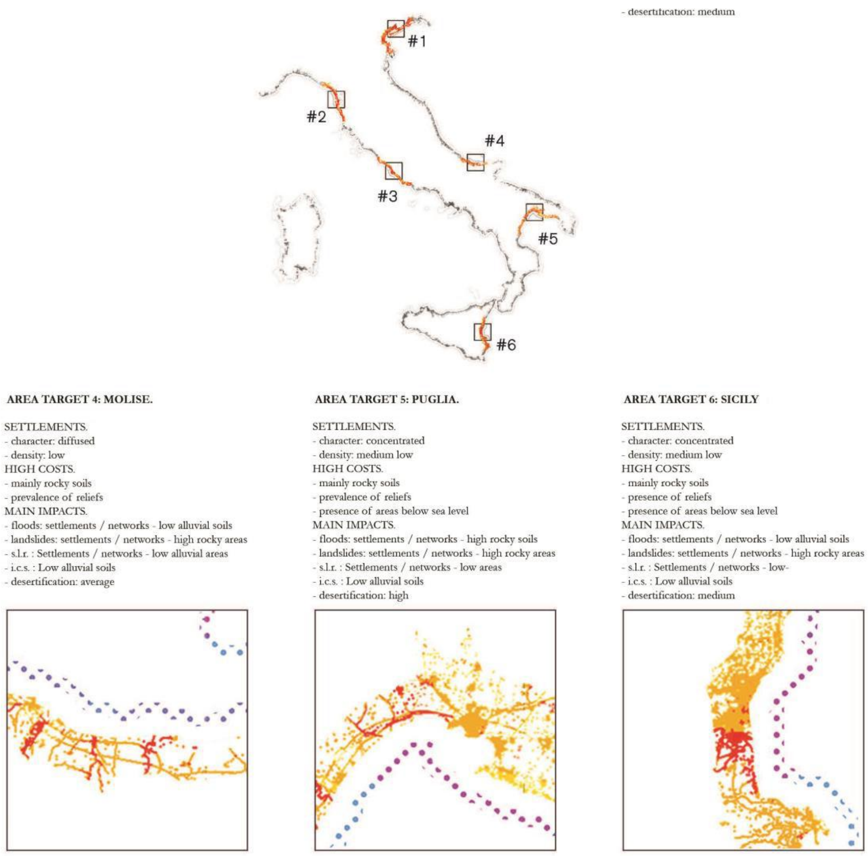


Figure 3 - Selection of target areas. Processing by Magnabosco G. 2016

2.2 2.1 IDENTIFICATION OF SOCIO-ECONOMIC IMPACTS ON TARGET AREAS

Socio-economic implications of sea level rise and climate change on coastal zones are mainly linked to the increase in the risks of flooding of human settlements, goods, infrastructure and services and to the loss of coastal land and habitats due to inundation of low-lying areas (Klein and Nicholls, 1998; Sterr and Klein, 1999). Other socio-economic impacts are those directly affecting important economic activities, such as coastal agriculture, fishery and tourism or those concerning water availability and human health (table 1)

Sector	Biogeophysical Effect					
	Flood Frequency	Erosion	Inundation	Rising Water Tables	Salt Intrusion	Desertification
Water Resources				■	■	■
Agricolture	■		■	■	■	
Human Health	■		■			■
Fisheries	■	■	■		■	■
Tourism	■	■	■			■
Human Settlements	■	■	■	■		

Table 1: Qualitative synthesis of direct socio-economic impacts of climate change and sea-level rise on a number of sectors in coastal zones (source: Sterr and Klein 1999).

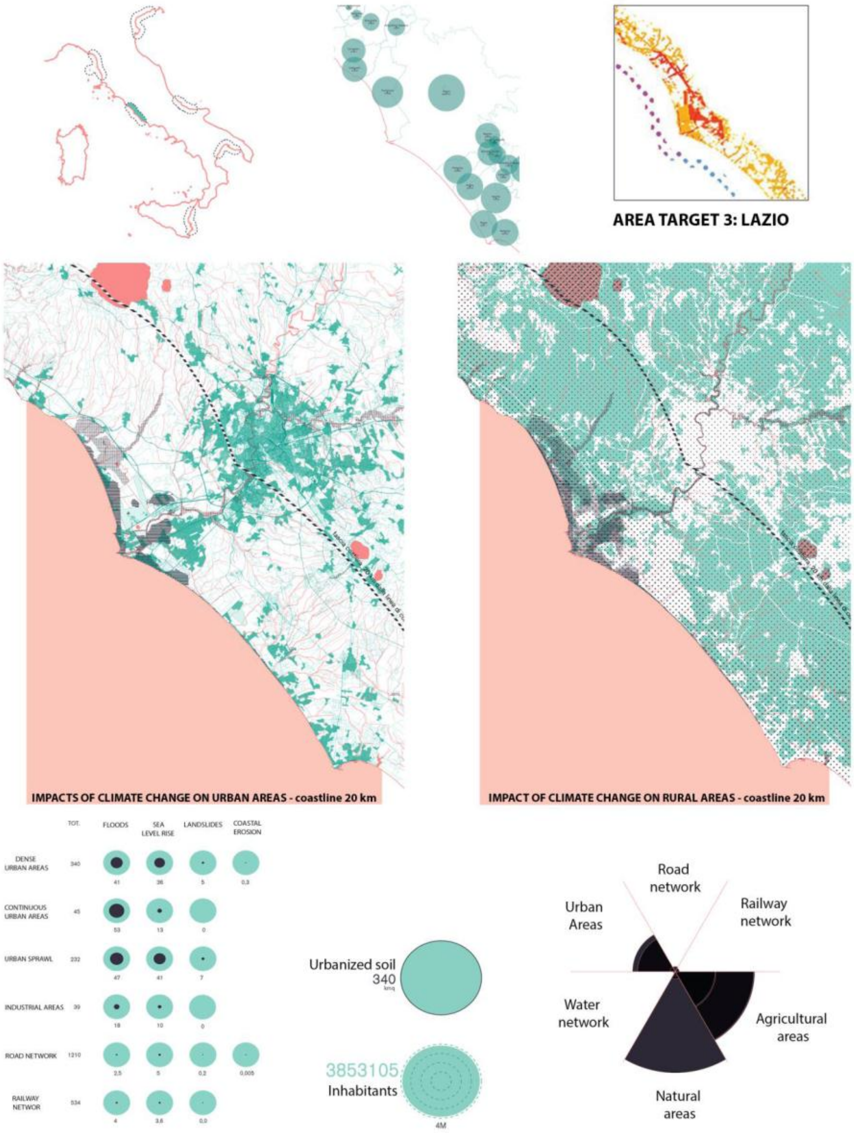


Figure 4 - Example of Climate change impacts on target area 3: Lazio. Processing by Magnabosco G. 2016

3 ADAPTATION AND COASTAL MANAGEMENT

Vulnerability (and related concepts) is specific to a given location, sector or group and depends on its ecological and socio-economic characteristics (Hinkel and Klein, 2007). Moreover, it is dynamic because sensitivity, exposure and adaptation capacity vary over time, stimulate and depend on various political, social, economic, ecological and technological aspects (ETC-ACC, 2010b). In this perspective, vulnerability assessments require different tools for different Space and Time, in different regions and for different purposes (ETC-ACC, 2010b). Considering the complexity of coastal zone dynamics and the long-term implications of climate change, coastal policy and management requires new large-scale integrated assessment and management tools in a wide range of scales: local, national (or regional), National and European. Assessments in each of these scales provide useful information for coastal zone management and if studies are consistent across all scales, they can result in nested results, maximizing their use for policy purposes. A more detailed approach at local and regional level is essential to understanding and managing the complexities of a specific area of study and to identifying more specific vulnerable areas and sectors that could support decision-making in designing appropriate adaptation strategies (Torresan Et al., 2008). Another important aspect to consider is the time scale involved in the processes and dynamics of coastal areas, which may, for example, vary from day to day for stormy waves, from days to years for tide ranges and for decades to decades Millennia in the case of vertical regions regional movements.

Sustainable management of coastal areas in Europe is strongly dependent on the success of an integrated climate adjustment and other changes that take account of and promote the capacity for adaptation of the system. The realistic assessment of adaptation options requires detailed analysis to capture the potential variation of responses within a region for a certain period of time rather than assume a uniform adaptation response (Nicholls and Klein, 2005). The need to adapt to climate change is evident and in coastal areas this need is greater and will continue for centuries considering long-term coastal challenges such as rising sea levels.

Integrated Coastal Zone Management is recognized as the most appropriate process for addressing climate change, sea level rise and other current and long-term coastal challenges (Nicholls et al., 2007; Nicholls and Klein, 2005). Proactive adaptation to climate change aims to reduce the vulnerability of a system by minimizing the risk and / or increasing the resilience of the system. Nicholls and Klein (2005) identified five proactive adaptation objectives for coastal areas: increasing the robustness of infrastructure designs and long-term investments; Increase the flexibility of vulnerable managed systems; Improve adaptability of vulnerable natural systems; Reverse Maladaptive Trends; And improve the company's awareness and preparation. Coastal adaptation is a complex and iterative process and for coastal areas there is another classification of three key adaptation strategies that are often used:

- Protect - to reduce the risk of the event by decreasing the likelihood of its occurrence;
- Accomodate - to increase the company's ability to cope with the effects of the events;
- Retreat - to reduce the risk of the event by limiting its potential effects (Smit et al., 2001; Nicholls and Klein, 2005).

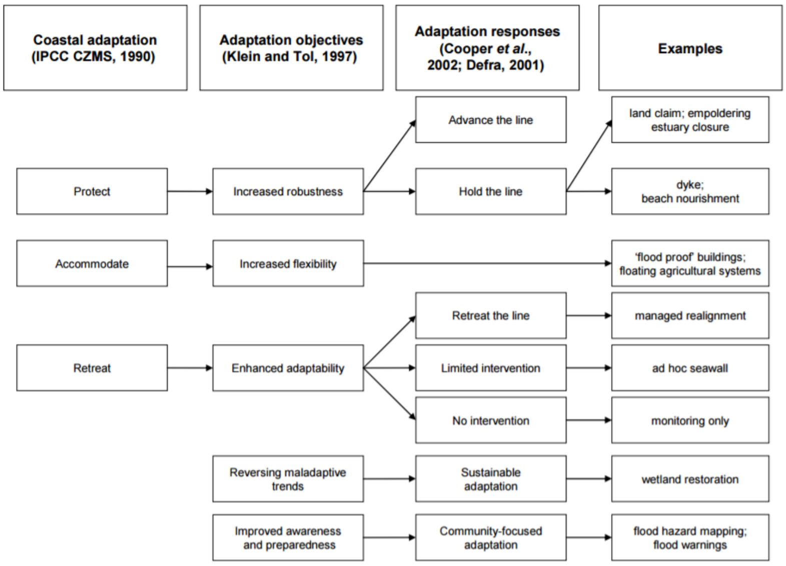


Figure 5 – Evolution of planned adaptation practices in coastal zones. Source: Nicholls et al., 2007

Nicholls et al. (2007) presented a diagram illustrating the links between these approaches and the evolution of thought with respect to adaptation practices in the coastal zone (Figure 5).

The EC White Paper on Adaptation to Climate Change (COM (2009) 147 final) It focuses on four pillars of action; One of these pillars is to integrate adaptation into key EU policies. The EU has a number of relevant instruments and policies for coastal areas that can facilitate sea and coastal adaptation to climate change, including: the Marine Strategy Framework Directive, the Water Framework Directive, the Floods Directive , The Integrated Coastal Zone Management Policy for the European Union, the Birds and Habitats Directives, the Integrated Maritime Policy for the European Union, maritime spatial planning and marine knowledge policy. In addition, EU Member States are developing and implementing national adaptation strategies. The implementation of these strategies has generated hard and soft measures and actions such as the improvement or installation of coastal defenses / floods / drainage, adaptation of ecosystem conservation management and their services, adaptation of agriculture and forestry, Water, climate integration Change in spatial and urban planning, implementation of beach nourishment schemes and institutional and legal measures (ETC-ACC, 2010a).

4 MEASUREMENTS AND TOOLS TO IMPROVE LOCAL PLANNING SYSTEM

It is possible to state that, instead of generating new impacts, climate change will affect Italian and Mediterranean coasts through the growth and intensification of existing problems such as speedy urbanisation, tourist and industrial development, excessive exploitation of marine resources, etc. with a high degree of certainty. These areas of high territorial complexity, where excessive exploitation and a mismanagement of coastal resources has already created vulnerable environments at risk (heat waves, storms, inundations, drought, etc), are precisely where human activity and ecosystems might be worsened by climate change. As it is now widely recognised that a sudden reduction of greenhouse gas emissions on a global level would not completely prevent climate change but would only delay its effects due to the inertia of natural systems against CO_2 concentrations (DETR, 1999), combining our strength to control emissions is of strategic importance to reduce damage to the minimum. International prevention strategies must be combined with the definition and implementation of actions and policies at a regional, sub-regional and mainly local level that can mitigate or, in some cases, even eliminate the negative impact induced by climate change. These win-win strategies will prove useful to respond both to the current climate variability (extreme events such as drought and storms in particular) and to long-term changes characterised not only by weather changes but also by socio-economic factors.

For example, table 2 reports some possible measures that can be implemented in response to the main impacts of climate change for the Mediterranean basin and, in particular, for Italy.

Area	Impact	Possible adaptation measures
Water	• Water supply variability • Longer periods of drought in summer • Less water available from superficial aquifers • Uncertain water management • Increase in the risk of inundation • Lower air quality	• Increased flexibility in the management of water resources • Improvement of the efficiency of the water distribution network • Investments to improve the management of rainwater from extreme events • Improvement of ducts for the harvesting of rainwater • Increase investments to reduce water loss
Coastal areas	• Increased risk of flooding due to the rise of sea levels (increase in storms) • Change in the frequency of flooding return periods • Prolonged or permanent inundations with consequent loss of land (coastal habitats, dunes and humid areas in particular) • Saltwater intrusion into aquifers • Change in superficial water temperature and salinity • Lower sediment load in waterways • Increased coastal erosion	• Drafting and implementation of measures to adapt to climate change within coastal management strategies • Improvement of extreme weather events forecast (storms and intense rainfall) • Management and planning of moving coastal settlements where density is not too high. • Creation of coastal monitoring systems and mapping of areas at high risk. • Upgrading of coastal defence systems • Planting of vegetable species suitable to increase coastal resilience • Protection and artificial fixing of shorelines • Drafting of ICZM plans involving local stakeholders
Ecology	• Loss or reduction of protected areas • Loss of coastal habitats (coastal dunes and lagoons) • Change in ecological parameters (temperature, salinity, nutrient availability) • Change in the composition and distribution of species • Introduction of alien vegetable species • Increased risk of fire • Degradation of water quality (intensification and eutrophication due to algae)	• Review and increase of protected areas through the redefinition of coastal ecosystems. • Planning of new protected areas and ecological corridors between fragmented habitats

Agriculture	• Reduced water availability due to the increase in temperature and evapotranspiration, change in precipitations, drought periods and saltwater intrusion. • Increased superficial soil erosion • Increased variability of harvesting schedules • Increased working opportunities due to the availability of new agricultural areas at different latitudes	• Introduction of agricultural crops more resilient to intense periods of drought or floods • Monitoring of crop response to climate change • Implementation of agricultural techniques that limit soil erosion • Introduction of physical protection systems of coastal agricultural areas • Development of innovative irrigation techniques (combined with the upgrading of existing networks).
Human health	• Increase of heat islands • Worsening of air quality • Increased incidence of temperature on disease • Increased disease vectors • Higher risks connected to extreme events	• Strengthening of public health systems • Strengthening of vaccination programmes and of the surveillance on the increase of some diseases (e.g. malaria) • Training of health personnel specifically for problems connected to climate change • Health training to reduce the potential exposure of population at risk • Development of alarm systems in case of heat waves

Table 2 - Possible impacts and measures to adapt to climate change. Adapted from WISE, 1999 and Gabrielides, 1998, USAID 1999.

As regards adaptation, the first step is generally represented by the resolution or, at least, the mitigation of existing critical problems. These are often the result of strong human pressures and a stratification of different practices - defined by Burton as “maladaptation” (1996) - along the coast which, over time, limited the flexibility and natural coastal resilience to climate stress. Another important passage for climate-proof coastal planning and management is an assessment of vulnerabilities and the definition of suitable climate change adaptation measures within integrated coastal zone management (ICZM).

ICZM enables the analyses of the effect of pressure and stress factors on coastal systems, including climate change and sea level rise (EC, 1999), and is therefore increasingly recognised as the best tool to tackle current and long-term coastal problems (ECC, 1993). The actuation of the ICZM protocol and the implementation of climate change adaptation measures requires not only a significant change in perspective (long term rather than short term, prevention rather than emergency, integrated approach rather than single interventions) but actually, at least in some national contexts, a radical modification of institutional processes, legal and regulatory aspects and socio-economic development plans. Due to the political, cultural, economic and social differences within the Mediterranean basin, international cooperation and the transfer of technology and know-how are extremely important to construct a more resilient future for the entire region.

In this scenario, the scientific community is important to provide policies and decision makers with suitable support for what concerns the analysis of climate change impact (both on a sub-regional and local level) and for the qualification of said impacts, which requires the modelling of interrelationships on natural and human sub-systems. All efforts should focus on the elaboration of reliable local scenarios that describe how critical parameters will change in the future. However, the reliability of current scenarios is limited by the uncertainty that increases when passing from a global to a sub-regional or local scale. Regional and local studies are also bound by other factors, such as the increased natural variability of climate conditions and the influence on the climate system exerted by variations on local characteristics such as those regarding land use.

It is therefore necessary to elaborate not only sea level rise forecasts, but also a wide range of scenarios that can include possible future variations, as the current local impact of climate change is far from definitive. It is very important that adaptation and mitigation measures are drafted to be flexible and effective for a wide range of possible scenarios. To reach this flexibility, a gradual evolution of vulnerability studies will be necessary. As suggested by Klein (2003, 2007), this must be done first through a screening and then through an evaluation of vulnerabilities to reach a final project assessment. This final assessment, with its relative planning options, should be included in a wider ICZM protocol.

5 OVERCOME BARRIERS TO A PRACTICAL IMPLEMENTATION OF ADAPTATION MEASURES: THE ROLE OF MAINSTREAMING

It is important to recognize that climate change adaptation presents a fundamental challenge to managing the coastal resources and should be "mainstreamed" into coastal management and development at all levels. Mainstreaming means integrating climate concerns and adaptation responses into relevant policies, plans, programs, and projects at the national, sub-national, and local scales.

Mainstreaming recognizes that adaptation measures are seldom undertaken solely in response to climate change (IPCC, 2007b). Considering the scale of the problem and the linkages between climate change and development, coastal adaptation will happen as an overlay to other ongoing initiatives and governance frameworks. Existing institutions should be in the forefront of designing and implementing adaptation measures. This could include the managers of water resources, civil protection, public health and protection of coastal area. Successful mainstreaming requires reinforcing linkages between local and national level adaptation entry points. Together with non-governmental partners, the government must play a fundamental role to facilitate the connections between national, sectoral and local entry points (fig. 3).

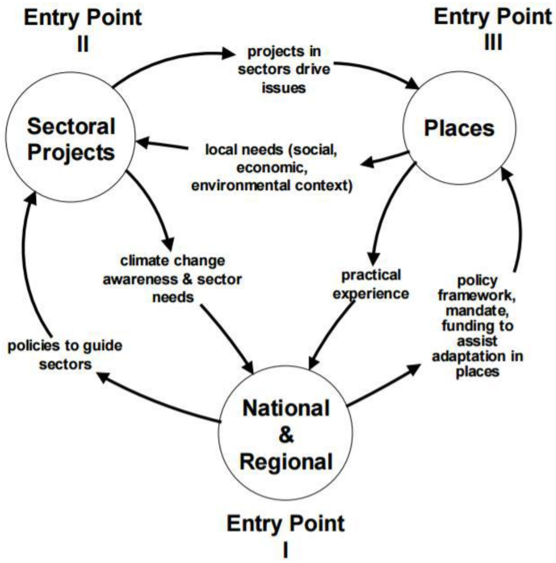


Figure 6 - Points of strength for an effective adaptation mainstreaming process.
Source: USAID Adapting to Coastal Climate Change - A Guidebook for Development Planners (2009)

Some examples include:

Creating enabling policy, finance and legal frameworks. This includes, for example, prioritizing adaptation in national planning and budgeting; harmonizing sectoral policies; creating national coordination committees, chaired by a ministry with power; and providing the financial and technical support necessary for adaptation measures to succeed.

Capturing local experience. Coastal adaptation in a specific place or area builds practical experience and a sense of ownership for those living and working there. This experience can be shared amongst different actors at the national level to build capacity. Linkages between local communities and government strengthen community voice in planning and national policy-making for coastal adaptation to climate change.

Rising public awareness. Awareness raising and education campaigns help convey information about the impacts of climate change and gain consensus on adaptation options. Governments need to engage more actively with the scientific community and provide easily accessible and up-to-date climate change information relevant to the needs of coastal sectors.

In order to be truly effective, mainstreaming requires forging agreements with a broad array of agencies and groups, each with different policies, approaches and objectives. Thus, mainstreaming can be time-consuming and challenging (from a political and economic perspective), especially due to the "normal" resistance to the introduction of any new policy ideas. In the case of climate change adaptation, this is exacerbated by the cumulative nature and long-term timeframe of climate change impacts. It is also complicated by the fact that different individuals and organizations will have different perceptions of the uncertainties surrounding climate change and its impacts and will have different tolerance levels for risk.

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