Pilot study 3 Report

Adaptation in water and coastal areas in Puglia, Italy

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1 Introduction

It is widely recognized that the global warming caused by the increasing presence of GHGs in the atmosphere is also leading to changes in rainfall patterns, sea levels and the frequency of extreme hydro-meteorological events (e.g. heat waves, droughts, heavy rains, storms). These changes are known to influence ecosystems, human activities and communities in areas ranging from inland to coastal territories, with effects that overlap with those due to population increase, habitat modification, overexploitation of natural resources, alteration of biodiversity and decline of water flows and quality.

Several studies have agreed that the Mediterranean Basin is a climate change hotspot (Diffenbaugh and Giorgi 2012; Giorgi 2006), with warming expected to be higher than the global average and mostly concentrated in summer (Giorgi and Lionello 2008). IPCC (2013) mentions *very likely*[1] increase in temperature throughout the 21st century, and also *very likely* increase of the number of warm days and nights, and decrease of the number of cold days and nights. Even though there is high level of uncertainty in predicting precipitation, there are signals for a future decrease of the annual precipitation amount, coupled with an increase in the intensity and frequency of rainfall extreme events (Garcia-Herrera et al. 2014; Giorgi 2006; IPCC 2013). Although the sea level in the Mediterranean did not change or even decreased in the recent past (Ramieri et al. 2011), a rise in the global mean sea level will allow the regional sea level in the Mediterranean to harmonize with the global trend, as projected in CIRCE project simulations (Gualdi et al. 2013).

The Pilot Study "Climate change adaptation in new water regime in Puglia region" of the Thematic Centre on *Drought, Water and Coasts*, was formulated to provide tools and guidelines for local and regional authorities to assess vulnerabilities and risks posed by climate change and related extreme events (with a focus on droughts). The aim was to support the improvement of planning for the integrated management of water resources and coastal zones, by providing scientific information which is both sound and updated in regard to expected climate terrestrial and marine hazards, and consequent impacts on domestic water supply, agriculture and coasts.

The region of Puglia was chosen in order to build on CMCC's previous experiences and collaborations with local authorities, and since Puglia's territory well reflects typical conditions of the Mediterranean region. In fact Puglia is exposed to hydro-climatic hazards associated especially to increasing temperatures, heat waves and droughts, which affect widely socio-economic sectors competing for water resources. Vulnerability concerns a region largely engaged in agricultural production, and also highly dependent on the surrounding regions for water resources (SOGESID 2009) that are crucial in order to sustain irrigation as well as domestic water supply, ecological function and lastly industrial and energy purposes.

Vulnerability to climate hazards also affects coastal zones where one can find many sectors such as tourism and fishery that are strategic for the socio-economic development of the region.

Risks, derived from the combination of hazards, exposure and vulnerability (IPCC 2014) are even higher over such a vulnerable territory when exposed to the negative consequences of additional climate-related hazards, like sea level rise, soil erosion, floods, fires, groundwater depletion and salt water intrusion into aquifers. Therefore, it becomes increasingly important to develop approaches and methodologies that are integrated, holistic, cross-sectoral and adaptive in order to efficiently support decision makers in the design and formulation of adaptation strategy plans which include climate change impact assessments.
In the following paragraphs, details on the Pilot Study's implementation are provided, about objectives and methodologies formulated which have been tailored and applied to the territory of Puglia, and about results achieved. Finally, the method by which results can be communicated and included in planning for climate change adaptation is summarized into key messages and recommendations for stakeholders and decision makers.

[1] The IPCC Fifth Assessment Report (IPCC 2013; 2014) defines likelihood as the probability of an event or outcome occurring. Very likely is used for an event or outcome having more than 90% probability to occur.


Photo: G. Galluccio

2 Rationale and objectives

Given the increasing concern in Puglia for climate change, its extremes and consequences, there is an urgent need to integrate adaptation to climate change as part of the traditional water and coast (and other territorial) management and protection plans. The integration process should follow for example the Integrated Coastal Zone Management policy cycle which is often used by coastal practitioners and includes five specific steps: 1) vulnerability assessment; 2) planning and selection of a course of action; 3) formal adoption of adaptation actions; 4) implementation; and 5) evaluation (USAID 2009). One of the key points of this approach is that the process of planning is gradually rather than radically changed by the introduction of the climate change component. In addition the Risk Governance Framework (IRGC 2005) and the Climate Risk Management framework (Martinez et al. 2012), both emphasizing the key role of "communication", could also be helpful if enlarged to cover not only disaster risk management but also adaptation, since adaptation should be understood as a precautionary risk avoidance or minimization strategy.

The Pilot Study in Puglia was conceived in order to address the need of including climate adaptation into planning, by concentrating on the step of vulnerability and risk assessment, in order to then foster the execution of successive steps concerning communication of climate trends, impacts, vulnerabilities and risks, and their consideration by decision makers. Proper vulnerability and risk assessment was thus intended as a mixture of a bottom-up approach (based on dialogue with stakeholders) and a top-down approach (based on indicators), and has been implemented by following some specific objectives:

1) Involving stakeholders at an earlier stage of the analysis to map their existing degree of awareness of climate change and its impacts, their current capacity in governance to address these issues, their requirements to understand and be updated on expected trends, and the degree of climate change consideration existing in the decision making processes.

2) Identifying priority areas for adaptation in terms of sectors, systems and resources exposed to climate change and variability: priorities should be selected through an on-going, iterative and inclusive process of consultation with stakeholders' groups and decision makers.

3) Reviewing historical records to reconstruct climate variability, hazardous events and their consequences, and to validate the area of interest's climate projections representative of a range of medium to long-term outlooks.

4) Converting each climate projection into the quantification of biophysical and socio-economic impacts and risks, by exploiting state-of-the-art and well consolidated procedures.

5) Providing a comprehensive view of the cascading phenomena that could be triggered by climate change, ranging from their physical impacts and processes to the evaluation of vulnerability of interacting systems, sectors and resources, in order to quantify the risk.

6) Synthetizing results into quantitative indicators, formulated also thanks to stakeholder consultation, for a concise and realistic description and communication of the climate change challenges that affect the addressed systems, sectors and resources.

Once vulnerabilities and risks under climate change are identified and communicated, needs and goals can be identified to support a "mainstreaming"[2] process for funding, implementing and testing of the adaptation measures.

[2] In the context of climate policies, mainstreaming means integrating climate concerns and adaptation responses into relevant policies, plans, programs and projects at national, sub-national, and local scales, better if cross-cutting multiple sectors, without allowing adaptation to get lost among many other competing priorities.

3 Pilot area description

3.1 CHARACTERISTICS, HAZARDS AND VULNERABILITIES

The territory of Puglia (Figure 3.1) has an area of about 19,345 km^2 and consists of a long and narrow region, bordered by two seas, the Ionian and Adriatic, with the longest coastline among Italian regions (865 km); Puglia is also the least mountainous region in Italy being mostly occupied by plains and hills.

Information extracted from the Regional Water Protection Master Plan (WPMP; SOGESID 2009) suggests that mean annual air temperature ranges from 10°C to 17°C, while mean annual precipitation varies from 400 mm to 1300 mm with 600 mm being the approximate average. The region's climate can be defined from arid sub-humid to arid according to temperature and precipitation regime.

Concerning the hydrogeological settings, the calcareous origin of Puglia's bedrocks have given rise to karstic phenomena which have limited the development of a superficial river network, except for the northern area; endorheic basins are numerous and the underground water circulation, one of the main water sources for the region, is well-developed.

In terms of land use/cover, more than 82% of Puglia's surface comprises agro-ecosystems, with about 7% of natural vegetation and 7% of mixed territories, while urban areas cover the remaining 4% (Zaccarelli et al. 2008).
From a socio-economic point of view, since the early 2000s the population of Puglia is above 4 million (ISTAT 2011) with an increasing, even if decelerating, trend maintained during the whole of the last century. The economy of Puglia is characterized by an emphasis on agriculture, favored by the gentle topography, generating a share of gross domestic product (GDP) above the national average (5.24% in Puglia vs. 2.65% in Italy), and driven principally by wine, olive oil and wheat production. Puglia also heavily relies on the touristic sector, which is a growing economic resource (OECD 2011). An always less role is played by industry, except for the food industry that emphasizes the importance of agriculture complemented by fishing.

Time series of observations from meteorological stations in Puglia show trends towards warmer and marginally drier conditions during the second half of the 20th Century. Combined trends of increasing evapotranspiration and decreasing precipitation implied a progressively larger water deficit (Hemming et al.

Figure 3.1 - Map showing location and topography of Puglia.

2013). While climate model projections suggest warmer and drier conditions also over the next few decades (Goodess et al. 2013), a further increase in the water deficit would not be sustainable and would have a large negative impact on human and agricultural sectors, and on the environment.

One of the major vulnerabilities of Puglia relating to climate change regards the use of water resources, whose share is about 54% for agriculture, 36% for domestic use and 10% for industry. Puglia is already forced to import water from nearby regions (up to 50% of the resource is traded in, with domestic use reaching 75%; SOGESID 2009) and to extract water from aquifers for irrigating crops because of the seasonal nature of many rivers.

Overexploitation of groundwater from private wells is already an issue at regional scale, since a regulation plan for groundwater exploitation is missing, leading to depletion of underground water bodies in quantity but even in quality especially favoring sea water intrusion (Polemio et al. 2007; Piccinni et al. 2008).

Concerning agriculture, results from the EU FP6 funded CIRCE project (http://www.circeproject.eu/) suggest that wine and oil production could be impacted in a negative way by the drier and hotter conditions expected to characterize Puglia in the first half of 21st Century (Reale et al. 2011). Other results (Mereu et al. 2008; Ponti et al. 2014) suggest that oil production could be favored by new climate regimes, as high temperatures are optimal for growth and development of olives, giving a higher yield and therefore greater profit. However, a new climate regime could also change the suitability of lands (Ferrise et al. 2013; Moriondo et al. 2013) and the crop exposure to new invasive pests (Ponti et al. 2014).

Regarding extreme events, recently Puglia region was alternatively affected by out-of-normal climatic years, e.g. droughts in 2011-2012, floods in 2013-2014 and fast fluctuations of droughts/floods in 2008-2009, that caused pollution in the Occhito reservoir (WHO 2011). This climate variability under opposite extremes endangers: i) the availability of (sub)surface water and soil moisture to offset the evapotranspiration demand from crops not fully satisfied by rain; ii) the temporal reliability of water yield from existing infrastructures for water accumulation/diversion (single and multipurpose dams); iii) the quality of water to be provided for agricultural production and domestic uses; iv) the standards required (e.g. minimum environmental flow) to maintain the ecological function of water in rivers and/or lakes. Population growth (recently mainly caused by immigration) and tourism (EUROIDEES 2013) worsen this situation increasing the region's overall vulnerability because of decreasing water availability and increasing water demand particularly during summer.

In this context, the increasing human presence and activity in Puglia's coastal areas makes them vulnerable to the occurrence of events of great impact and low frequency (e.g. extreme storm surge and tsunami tidal waves) (Mastronuzzi and Sansò 2012). Moreover, the state of the coast is seriously affected by modifications due to erosion (Fiore et al. 2010): 65% of coasts are undergoing erosion processes (Antonioli and Silenzi 2007).

Finally, long parts of the coasts and especially the Salento peninsula are also vulnerable to relative sea level rise (Sansò and Mastronuzzi 2013; Antonioli and Leoni 2007), increasing the coastal vulnerability to salt water intrusion being already a widespread problem in Puglia (Polemio et al. 2010).

3.2 STATUS OF CLIMATE ADAPTATION INITIATIVES IN PUGLIA

In July 2014, the Italian government concluded the elaboration of a National Adaptation Strategy (NAS), accepted by the State-Region Conference in October 2014, and whose completion was supported by the establishment of a technical, scientific and legal expert panel and by involving stakeholders early on in the process.

A National Adaptation Plan (NAP) is still missing, while regional to local adaptation strategies and plans are rare. Some adaptation initiatives have already been implemented in the context of the existing policies for environmental protection, natural hazards prevention, sustainable management of natural and water resources and of coastal areas, fight against desertification and health protection. Those initiatives can be found at national and sub-national scale in some cases responding to EU Directives' requirements or international agreements.

While at the national level Italy is required to prepare a strategy on Integrated Coastal Zone Management (ICZM), including prevention and/or reduction of the effects of natural hazards and of climate change, the Italian Ministry for the Environment Land and Sea (IMELS) has already started an overall institutional coordination, through the involvement of regional and local authorities dealing with planning and management of coastal areas. Some Italian regional governments have started approaching the ICZM to different extents: Puglia activated preliminary testing of the ICZM approach or plans for land protection and spatial planning and, in 2012, the region signed the agreement, known as "Bologna Charter 2012", to promote a common framework among European regions, for strategic actions aimed at the protection and sustainable development of coastal areas.

As far as hydraulic risk is concerned, Puglia region has started the process of implementation of the Flood Directive (2007/60/EC) by providing a first release of regional flood hazard and risk maps in 2013. According to the directive, flood risk assessments should also consider the impacts of climate change on the occurrence of floods. Accordingly, next steps will be the evaluation of climate scenarios and of their influence in the frequency and intensity of floods and finally in the assessment of risks.

As requested by the United Nation Convention on Combating Desertification (UNCCD), Italy developed and approved the National Action Programme to Combat Drought and Desertification. To support achievement of its goals, the Regional Governments and River Basin Authorities were delegated with the responsibility to accordingly develop Local Action Programmes (LAPs), aimed at: identifying specific regional areas sensitive and/or at risk of desertification through the application of a methodology supported by an appropriate set of indicators at the regional scale; define specific action plans for the prevention, mitigation and adaptation to drought and desertification; and provide guidance for quantification of the financial needs and the identification of funding sources. Currently, ten Italian Regional Governments adopted their LAP, comprising Puglia in 2008.

In this context, and under the guidance of the National Committee to Combat Desertification, IMELS promoted a number of Pilot projects to combat desertification that go beyond the LAPs. In fact, they are extended toward the use of experimental techniques and methods (e.g. use of indicators for environmental monitoring, mapping boundary of areas sensitive/at risk of desertification from different processes) for actions aimed at improving knowledge and directly intervening in the territory. To date, six Italian Regional Governments carried out such pilot projects, with Puglia starting in 2008.

Further initiatives aimed at protecting soil and restoring its stability have been and will be included respectively in the 2007-2013 and 2014-2020, Rural Development Plans. Puglia's initiatives in particular will entail: improving soil quality and reducing the organic content loss; renewable energy production plants from biomass and other renewable sources; water resources management and water saving technologies.

The projected increase of drought frequency and water scarcity, especially localized in Southern Italy, are of particular interest for the local policy agenda. Such issues are driving the development of suitable responses in combination with the other components of EU water regulation. Implemented initiatives include the establishment of ad hoc organizations for crisis management in order to regulate the use of water and take the necessary measures to prevent water crises, like a "Coordination Unit for the management of water resources" shared between Puglia and Basilicata Regions.

4 Methodology description

The overall methodology for Pilot Study 3 was designed and conducted through a comprehensive integrated approach connecting data, models, downscaling procedures, spatial analysis techniques, decision support tools and indicators, into a chain of activities ranging from hazard quantification (at process level: climate and hydrology) to vulnerability and risk assessment (at resource/sector level: water, agriculture and coasts). Links among these components are strongly based on the use of indicators, aimed at synthetizing complex scientific information into quantities easy understandable and communicable to stakeholders and policy makers (Martinez et al. 2012). To effectively promote the integration of knowledge into decision making, indicators have been grouped into hazard, exposure, vulnerability and risk categories[3], in order to classify the information to be used and guide in identifying priorities for regulations and investments.

The overall integrated approach can be articulated into five main modules schematized in Figure 4.1. Starting from the main component represented by climate modeling, providing simulations about current and future atmosphere and ocean regime for the Puglia Region (Modules 1 and 2), the risk assessment is performed considering drought hazards, scenarios (both for the agro-meteorological and hydrological component) (Module 3) and the consequent impacts on rainfed/irrigated agriculture (Module 4), as well as quantifying the potential consequences of rising sea levels on low-lying coastal areas (Module 5).

The spatial domain of the Pilot Study was outlined to cover from the inland to the coastal territory of Puglia and its contiguous areas that contribute to water provision to the region. At temporal level, a baseline reference period (from 1976 to 2005) and two future periods in the medium term (from 2021 to 2050) and long term (from 2041 to 2070) were considered. In each future period the exemplification of a possible range of future conditions was allowed thanks to updated and high resolution climate and impact projections under RCP4.5 and RCP8.5 emission scenarios. The RCP4.5 is a stabilization scenario where total radiative forcing is stabilized shortly after 2100 to 4.5 W m^2 (approximately 650 ppm CO_2 equivalent) by employing technologies and strategies to reduce greenhouse gas emissions. The RCP8.5 is a business as usual scenario and characterized by increasing greenhouse gas emissions and high greenhouse gas concentration levels, and representing a rising radiating forcing pathway leading to 8.5 W m^2 in 2100 (approximately 1370 ppm CO_2 equivalent).

Concerning water resources, attention was paid to the investigation of the complex interactions between water and drought in its main dimensions: a) meteorological, defined by the degree of dryness (in terms of lack of rain) compared to the average, and by the duration and the frequency of the dry periods; b) agricultural, where meteorological drought reflects into drop of soil moisture leading to negative impacts especially for rainfed agriculture; and c) hydrological, when precipitation shortfalls affect surface or subsurface water bodies, impacting domestic, industrial and ecological water uses and also agriculture in its irrigated component. Such drought dimensions can both be triggered in cascade and exist simultaneously, and since their impacts are a complex mixture of water availability and water demand, this leads to a fourth dimension known as socio-economic drought, which occurs when water supply is not sufficient to meet human needs and causes a decrease in the provision of goods and services.

As far as coastal areas are concerned, Mediterranean simulations of sea level rise along Puglia's coasts were combined with topographic and land use layers to investigate the risks that could arise from the permanent submersion of productive or significant areas (for tourism, agriculture, transports, industry) with consequent losses of land and related economic revenues.

Here we present a brief description of the main modules of the integrated approach, to provide a quick overview of the methodologies and tools applied in the case study. More details about the methodologies applied for the assessment of climate change and its impacts on water resources, agriculture and coastal zones are reported in Annex A.1, A.2, A.3 and A.4, while the list of used indicators and indices is reported in Annex A.5.

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[3]According to IPCC (2014): Hazard is the potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. In the IPCC Fifth Assessment report, the term hazard refers to climate-related physical events or trends or their physical impacts; Exposure is the presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected; Vulnerability is the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt; Risk is the potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard. In this report, the term risk is used primarily to refer to the risks of climate-change impacts.

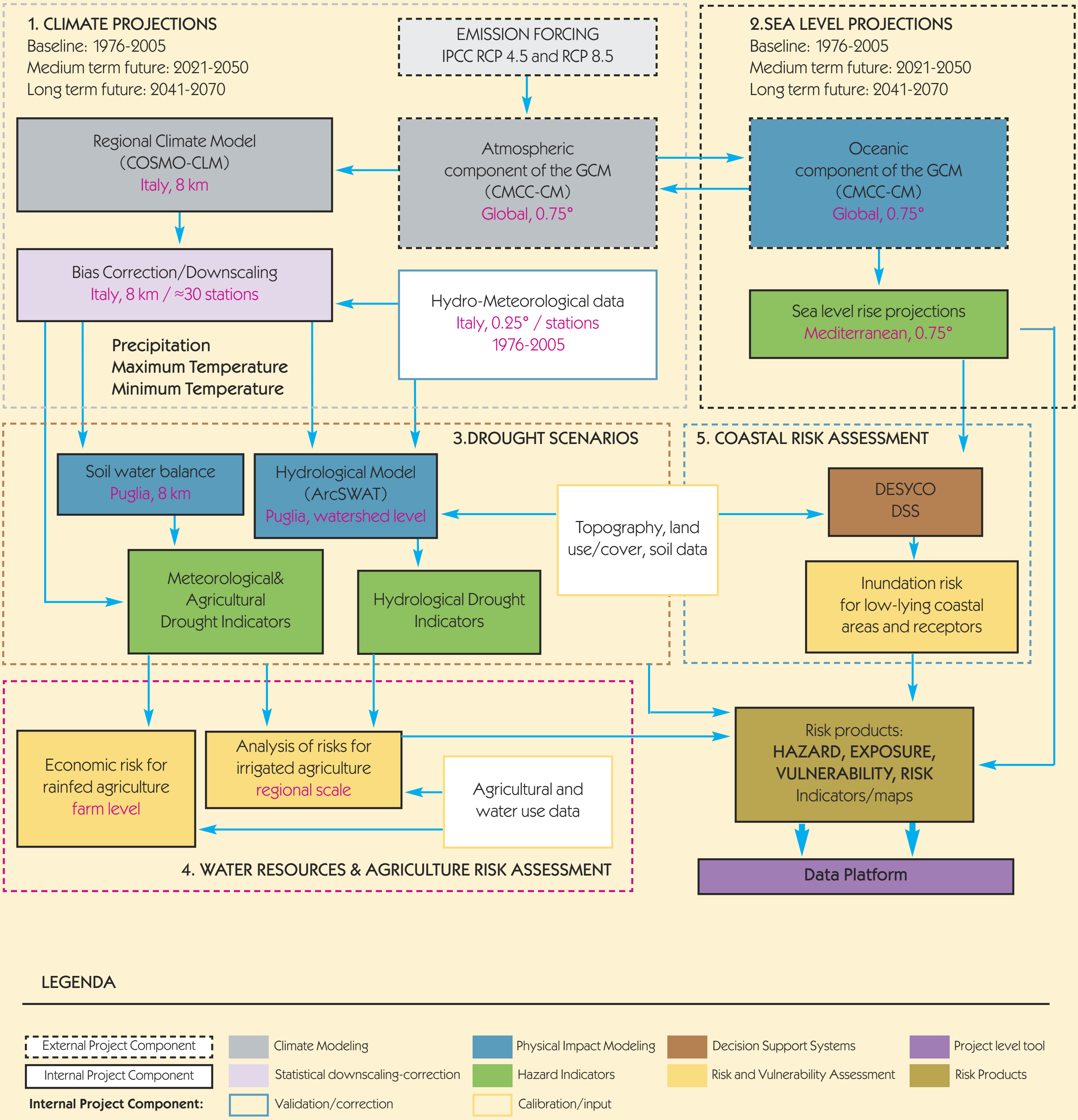

Table 4.1 - *Flow diagram showing the framework and its modules and components.*


Photo: G. Galluccio

4.1 MODULE 1 - CLIMATE PROJECTIONS

Regional Climate Model (RCM) simulations with COSMO-CLM[4] were first conducted, at project level for the westernmost part of the SEE domain (Italy and surrounding), to dynamically downscale (at 0.0715°, ca. 8 km horizontal resolution) the atmospheric component of GCM projections performed with CMCC-CM[5] at 0.75° horizontal resolution in the context of CMIP5 experiment (http://cmip-pcmdi.llnl.gov/cmip5/). Further, statistical downscaling was performed at site level for 31 and 21 meteorological stations for precipitation and temperature, respectively, to support basin scale hydrological analyses in *Module 3*. Over these site level data, some extreme indices were calculated from downscaled simulations across time frames and scenarios.

4.2 MODULE 2 - SEA LEVEL PROJECTIONS

CMCC-CM outputs representing trends on sea surface height above the geoid (ZOS), as simulated by the ocean model component of CMCC-CM, have been clipped and resampled to the Mediterranean domain and processed into indicators of Seal Level Rise (SLR) scenarios for the entire coastal areas (Adriatic and Ionian) of Puglia. SLR was assumed as the anomaly between ZOS calculated for two different time periods. Four different approaches were applied to calculate the anomaly via statistical indicators representing conditions ranging from average and full precautionary: 1) "*maxmin*", difference between the maximum of the considered future period and the minimum of the baseline period (full precautionary circumstance); 2) "*mean*", difference between the mean of the considered future period and the mean of the baseline period; 3) "*median*", difference between the median of the considered future period and the median of the baseline period; 4) "*pctl*", difference between the 90th percentile of the considered future period and the 10th percentile of the baseline period (highly precautionary circumstance).

4.3 MODULE 3 - DROUGHT SCENARIOS

Relying on RCM simulations performed in *Module 1* and concerning atmospheric variables, a set of hazard indicators was selected and calculated, through simple equations or by feeding a vertical soil water balance scheme and a semi-distributed hydrological model (ArcSWAT; http://swat.tamu.edu/software/arcswat/) to quantify and analyze changes in terms of: i) average trends (annual, seasonal, monthly) of agro-meteorological and hydrological conditions; and ii) occurrence of extreme events of temperature, precipitation, streamflow (e.g. heat waves, dry spell, low flow periods).
The most appropriate indicators were identified to represent conditions of meteorological, agricultural and hydrological droughts (see Annex A.5 for full indicator list and acronyms), and a sub-set of them was chosen as representative of the variability of water inputs to sustain domestic purposes and crop evapotranspiration (in both rainfed and irrigated agriculture). Changes in these indicators across emission scenarios and time frames were assumed as proxies of changes in the spatial variability of soil moisture deficit in cultivated fields, and in the streamflow annual mean and inter-annual variability at the location of 8 dams of interest for serving the Puglia aqueduct, public irrigation infrastructures and industrial purposes, plus for 6 basins (and 2 tributary sub-basins) of interest for private irrigation from surface water sources. To move forward from hazard to risk analysis, a crucial step was thus connecting the upstream availability of water resources (supply level) and the downstream use (demand level).

4.4 MODULES 4 AND 5 - RISK ASSESSMENT FOR AGRICULTURE AND COASTAL AREAS

The quantification of risks for irrigated agriculture and coastal areas was performed adopting a Regional Risk Assessment (RRA) procedure, aimed at providing a quantitative and systematic way to estimate and compare the impacts of climate-related hazards that affect large geographic areas (Landis 2005; Pasini et al. 2012). The RRA procedure (see Box 1) uses Multi Criteria Decision Analysis (MCDA) to identify and rank targets at risk (e.g. beaches, infrastructures, wetlands, cultivated areas) and localize priority areas where adaptations strategies could be required.

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[4] http://www.clm-community.eu/index.php?menuid=198; Rockel B., and B. Geyer (2008), The performance of the regional climate model CLM in different climate regions, based on the example of precipitation, Meteorologische Zeitschrift, 17(4), 487-498.

[5] http://www.cmcc.it/it/models/cmcc-cm; Scoccimarro E., S. Gualdi, A. Bellucci, A. Sanna, P.G. Fogli, E. Manzini, M. Vichi, P. Oddo and A. Navarra, 2011: Effects of Tropical Cyclones on Ocean Heat Transport in a High Resolution Coupled General Circulation Model. Journal of Climate, 24, 4368-4384.

BOX 1

The RRA methodology was developed upon the three main pillars of risk defined by UNISDR (2009) and by IPCC (2012; 2014) (i.e. hazard, exposure, and vulnerability) and is composed of four main steps:

- *Hazard Assessment*, aimed at defining hazard scenarios representing the physical phenomenon related to climate change (i.e. sea-level rise inundation, water deficit) that can cause damages to affected regions and targets. This step requires the definition of hazard metrics derived from climatic and/or physical impact models (e.g. atmospheric, ocean or water cycle models) or from statistical analysis of time series. In OrientGate, the hazard assessment phase in RRA integrates selected metrics (indicators) from sea level rise and drought scenarios produced in *Modules 2* and *3*.

- *Exposure Assessment*, aimed at identifying and localizing the receptors (i.e. elements at risk) that can be subject to potential losses due to climate change impacts. This step requires the analysis of land use/cover datasets for the localization of people, environmental resources, infrastructures, social, economic or cultural assets that could potentially be in contact with a given climate hazard.

- *Physical and Environmental Vulnerability Assessment*, aimed at evaluating the propensity or the predisposition of a receptor to be adversely affected by a given climate hazard. Generally, this step requires the analysis of vulnerability indicators represented by geophysical or ecological factors (e.g. geomorphology, slope, vegetation cover, land use) and used to measure the degree to which a receptor could be affected, either adversely or beneficially, by climate-related stimuli.

- *Relative Risk Assessment*, aimed at identifying and classifying areas, receptors and hotspots at risk in the considered region. This phase combines the information about the climate hazard scenarios with the exposure and the vulnerability assessment, providing a relative evaluation of risks for each analyzed receptor.

Relevant outputs of the RRA are GIS-based hazard, exposure, vulnerability and risk maps and statistics, representing the ensemble of risk-based products that can be used to mainstream climate change adaptation in the development of territorial plans, policies and programs considering the potential threats posed by climate change.

The risk assessment on water resources and irrigated agriculture (*Module 4*) was conducted considering that Reclamation Consortia, the bodies which coordinate public interventions and private activities in the areas of water protection and irrigation, are normally supplied by multiple reservoirs through a complex pattern of distribution systems. With the same complex network, each reservoir supplies different consortia with different volumes of water according to their specific demand and availability. The hazard index has been calculated as the degree of fulfilment of the consortia's demand, in terms of volume of water per year, if compared with the (projected) total water availability stored in the different reservoirs. Current water demands are assumed to be constant over time, while the availability in the various reservoirs is extracted from hydrological simulations for the different scenarios. Lower is the degree of fulfilment, expressed as the ratio between the forecasted water availability for that particular consortium with its theoretical (current) water demand, higher is the hazard score.

Exposure patterns are identified with irrigated lands belonging to 3 Reclamation Consortia supplied by the reservoirs taken into account in the post-processing of hydrological model results: Capitanata; Stornara and Tara; and Terre d'Apulia. These Consortia cover the Central-Northern territory of Puglia being the area mostly served by superficial water resources. If the risks for water resources could appear overestimated from the analysis not considering the groundwater that has high potential to sustain irrigation, such an overestimation could be largely offset by the limit of not having considered diffuse superficial water withdrawals in the hydrological modeling, and that part of the groundwater domain is also subject to overexploitation and is becoming less and less usable because of saltwater intrusion.

According to the regional land use map elaborated in 2006 (http://webapps.sit.puglia.it/freewebapps/UDS2006/) the most irrigated areas are represented by four crops: olive groves (401'197 ha), vineyards (127'242 ha), vegetable crops (71'639 ha) and fruit trees (10'627 ha).

The vulnerability score is calculated as the multiplication of three factors that are classified, ranked and then normalized in the range 0-1, namely:
i) Hydro-demand (V1) to evaluate the degree to which the crops are influenced by the water stress (decrease of availability for irrigation), this score is related to the Yield-Response factor (Ky) indicator that captures the essence of the complex linkages between production and water use by a crop, where many biological, physical and chemical processes are involved (Steduto et al. 2012); irrigational crops considered are vegetable, fruit trees, vineyards, and olive groves;
ii) Degree of efficiency (system losses, V2): losses decrease the efficiency of the system and increase their vulnerability to climate change impact;
iii) Degree of diversification of sources (V3): diversifying the sources tends to mitigate the risk and therefore, lower vulnerability is associated with the degree of diversification of the sources relied upon by the different Reclamation Consortia to fulfil their demand.

Concerning the assessment of economic risks on mostly rainfed agriculture more at local scale, an exemplificative study on wheat was conducted, as it is one of the principal crops in the region (occupying around 22% of the utilized agricultural area in 2010) and whose annual production represents a 20% share of the whole Italian production.

A statistical model was formulated that takes into account the wheat yield's dependency on climate variability and farms' performances. To estimate the relationship between the weather conditions and the crop yield, seasonal average of temperature and precipitation amount, and their combination, were considered. Climate variables were obtained from data from Module 1 and 3, after a zonal aggregation based on "agricultural regions", i.e. grouping in the same spatial unit the municipalities, where farms are located, sharing similar environmental conditions.

The analysis was also fed with data from the Italian Farm Accountancy Data Network (FADN; http://www.inea.it/en/rica). Selected control variables encompass farm's structural, technological and management variables such as: irrigation quota, cost of seeds, fertilization costs, pests and pathogens cost of control, machines, cost of rental machines, flat lands, specialized farm on arable crop production, breeding activities, wheat cultivated surface, wheat cultivated surface squared, family farm, less favored area, organic farm, low environmental impact. Some other variables have been dropped by the final models because non-significant.

The analysis focuses on the period 2001-2007 to allow a more robust view, as the farm sample is strongly unbalanced and the number of observations for each year range between 298-445.

The analysis of coastal risks (*Module 5*) was performed with the aim of producing information for local stakeholders and decision-makers about targets and areas that are likely to be submerged by sea-level rise in the future: the DEcision support SYstem for COastal climate change impact assessment (DESYCO)[6] was applied with this purpose. The assessment followed a RRA approach considering a variety of environmental targets potentially exposed to sea level rise in low-lying areas (e.g. beaches, wetlands, protected areas, agricultural and urban areas, terrestrial biological systems) and compared different sea-level rise scenarios for the Mediterranean region, in the medium and long term timeframes (i.e. 2021-2050 and 2041-2070) (*Module 2*). A Digital Elevation Model (DEM) with a spatial resolution of 8m for the Puglia Region was used to evaluate areas and targets that could be submerged by rising water levels.

[6]DESYCO is a GIS-based Decision Support System (DSS) aimed at the integrated assessment of multiple climate change impacts on vulnerable coastal systems (e.g. beaches, river deltas, estuaries and lagoons, wetlands, agricultural and urban areas); http://www.cmcc.it/it/models/desyco. Torresan S., Rizzi J., Zabeo A., Critto A., Gallina V., Furlan E., Marcomini A., 2013. Assessing environmental impacts of climate change at the regional scale to provide adaptation services: the DEcision support SYstem for COastal climate change impact assessment (DESYCO). Proceedings of the first annual conference SISC on climate change and its implications on ecosystem and society, 23- 24 September 2013, Lecce, Italy, pp. 468-476, ISBN 978 - 88 - 97666 - 08 - 0

5 Results

According to the chain of activities from climate hazard to risk analysis, the main results of Pilot Study components are summarized in the following section, while details are given in the respective Annexes. Regional climate model projections (*Module 1*; Annex A.1) produced in the context of OrientGate for 1971-2070 under RCP4.5 and RCP8.5 emission scenarios, and then bias-corrected, suggest a trend of increasing mean annual temperature (MAT) from 1.4-1.7 to 2.3-3° C, and decreasing annual precipitation amount (APA) from 3-11 to 14-19%, for the medium to long term future (2021-2050 and 2041-2070 time horizons) (Table 5.1). The trends respectively have the potential to worsen and/or accelerate the effects on the unpredictability of water availability, and affect the reliability of both the quantity and quality of the resource, and thus its sustainable use.

Indicator	Baseline	Anomaly wrt. Baseline			
	1976-2005	2021-2050		2041-2070	
		RCP4.5	RCP8.5	RCP4.5	RCP8.5
Mean Annual Temperature	15.4°C	1.4	1.7	2.3	3
Annual Precipitation Amount	348.3 mm	-11.2	-3	-14.4	-19.1

***Table 5.1** - Averaged results and trends of Mean Annual Temperature (MAT) and Annual Precipitation Amount (APA) indicators as averaged over Puglia. Anomaly is in °C for MAT and % for APA.*

The new climate regime is especially evident from some basic climate indicators, and in the monthly climatological mean of 2-meters air temperature and precipitation, averaged across Puglia and nearby territories. Warming seems concentrated in summer and more evident in the long-term time frame, when also differences between the two emission scenarios are more noticeable; differently, coldest months differ between emission scenarios also along the medium term period (Figure 5.1). Intra-annual and inter-scenario variability of precipitation is larger, with a low to moderate drop under both periods for RCP4.5 scenario (with exception of few months appearing wetter), while the RCP8.5 scenario reveals a low wetting to moderate drying on the medium term, and moderate to high drying (in winter) and wetting (in summer) on the long term (Figure 5.2). However the drying affects the most humid season, establishing a greater impact on rainfall input to the whole water balance.

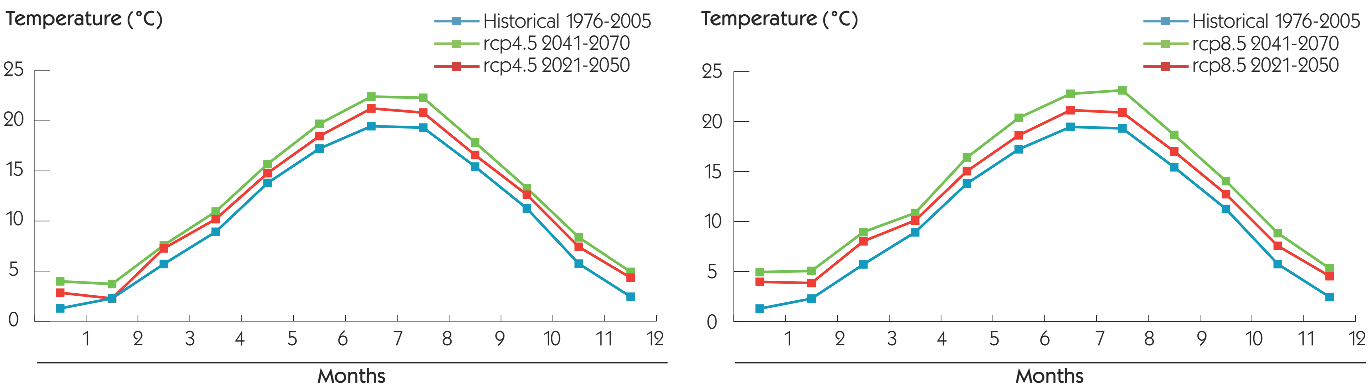

***Figure 5.1** - Monthly average of mean air temperature under RCP4.5 (left) and RCP8.5 (right) emission scenarios over Puglia and nearby territories.*

Larger periods of Consecutive Dry Days (and longer Warm Spell Duration Index) are predicted especially in the long term, indicating higher chances of more severe droughts. Similarly, the number of Consecutive Wet Days is expected to decrease slightly, associated as well with a slight decrease of the number of days characterized by consistent rain (i.e. > 5 mm/day).

Selected indices of extremes were calculated at station level indicating:

- for *temperature*, an increase of minimum, maximum, 10^{th} and 90^{th} percentiles of daily values, and of summer days and tropical nights; and a decrease of frost days and icing days. All these changes are more evident for the RCP8.5.
- for *precipitation*, a general decrease of number of rainy days, of consecutive wet days, of number

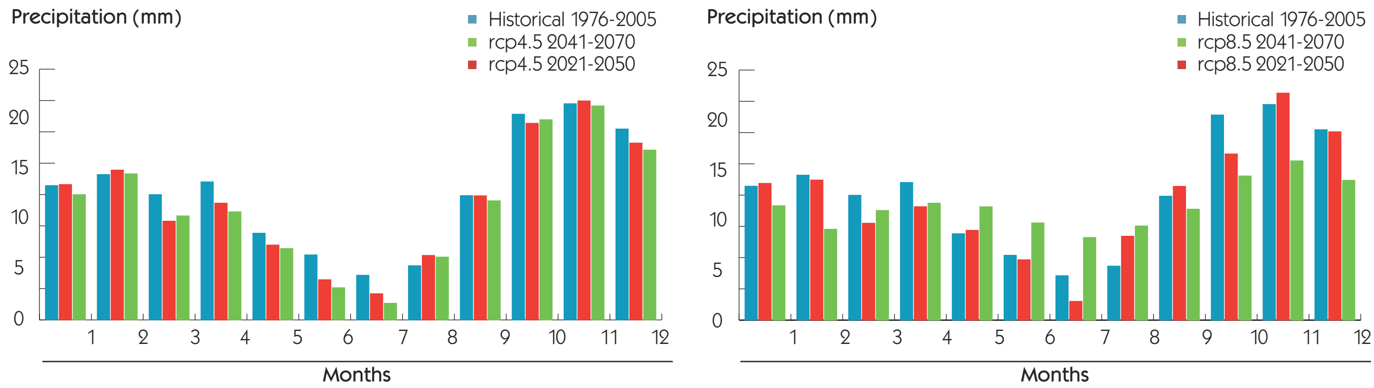

Figure 5.2 - Monthly average of precipitation amount under RCP4.5 (left) and RCP8.5 (right) emission scenarios over Puglia and nearby territories.

of days with precipitation over 10 and 20 mm/day, and of 90th and 99th percentiles of daily amount.
On the other hand, there is a general increase of mean precipitation amount on wet days, of consecutive dry days and of precipitation maximum in 1 and 5 days.
Indicators describing agro-meteorological conditions (*Module 3*; Annex A.2), include a mix of the new regimes for temperature and precipitations. Increasing temperature will lead to relevant increases of potential evapotranspiration (PET-HA indicator), similar between the scenarios in the medium term (+ 5%), while more differentiated between scenarios (+ 7-10 %) in the long term. The most significant increase of evapotranspirative demand is concentrated in the northernmost, agriculturally productive, area. The Aridity Index suggests how warming plus drying will facilitate a potential increase in evapotranspiration with respect to water available from precipitation, and again in the long term, associated with decreases in precipitation, a noticeable spread of arid conditions all over Puglia is expected, especially under RCP8.5 scenario.

The potential soil moisture deficit (PSMD), indicating the soil water stress cumulated during the growing season and largely correlated to crop water requirements and consequent irrigation applications, identified larger water stress for crops that need to be compensated by larger irrigation applications (+ 7-20%) and/or increased water use efficiency: most critical worsening conditions seem occurring in the northern agricultural plains.
Increasing temperatures will raise the heat accumulation (summarized as indicator by the Growing Degree Days; GDD), which will shorten crop growing seasons and accelerate rates of crop development thus not necessarily accomplishing proper fruit maturity and ripening. Changes of GDD levels will modify the thermal climate suitability of crops, inducing adoption of new crops and cultivars more adapted to new future heat regimes in Puglia. Hydrological modeling of inflow series driven by above climate projections (*Module 3*; Annex A.3) for six significant river basins in Puglia allowed characterizing trends in terms of water availability and variability.

Stat-RO indicators, representative of percent changes in the average inflow available to reservoirs compared to the driest year, confirm a large dominance of moderate to high severity of reduction in ca. 80% of cases, with worsening from RCP4.5 to RCP8.5 and from medium- to long-term (Table 5.2).

Stat-Ro	River Basin	2021-2050		2041-2070	
		RCP4.5	RCP8.5	RCP4.5	RCP8.5
% change in mean	Carapelle	-15,0	-18,3	-17,3	-33,3
	Cervaro	-10,0	-14,7	-21,1	-33,8
	Fortore	-25,5	-31,4	-31,7	-47,6
	Ofanto	-23,6	-31,5	-30,0	-42,6
	Bradano	-18,3	-18,1	-23,9	-35,5
	Candelaro	-11,7	-10,9	-10,6	-26,7
% change in 10th pctl	Carapelle	-25,0	-21,8	-25,1	-47,0
	Cervaro	-10,8	-10,5	-26,3	-44,7
	Fortore	-24,0	-28,6	-28,4	-43,7
	Ofanto	-29,3	-33,7	-31,1	-49,8
	Bradano	-26,2	-34,5	-35,2	-53,2
	Candelaro	7,3	-9,6	-12,5	-27,8

Table 5.2 - Results of the Stat-RO indicator for the analyzed river basins. Colors represent classes of inflow change (hazard) from null reduction (green; changes ≥0%), to low (yellow; - 10 % ≤ changes < 0%), medium (orange; -25 % ≤ changes < - 10%), high (red -40 % ≤ changes < -25%), extreme (dark red; changes < -40%).

Stat-Ro	Dam	River	Water use	2021-2050		2041-2070	
				RCP4.5	RCP8.5	RCP4.5	RCP8.5
% change in mean	Occhito	Fortore	Human-Industrial-Agriculture	-27,9	-36,5	-35,5	-51,9
	Locone	Ofanto	Human-Agriculture	-19,9	-19,2	-24,0	-31,0
	Marana Capacciotti	Ofanto	Agriculture	-13,6	-8,8	-2,1	-23,7
	Traversa Santa Venere	Ofanto	Agriculture-Industrial	-29,3	-40,4	-37,5	-53,4
	San Giusto o Capaccio	Candelaro	Industrial	-16,8	-13,2	-24,9	-31,2
	San Giuliano	Bradano	Agriculture	-18,6	-22,3	-27,9	-40,3
	Pertusillo	Agri	Human	-16,9	-25,8	-26,8	-40,5
	Monte Cotugno	Sinni	Human-Industrial-Agriculture	-27,2	-30,4	-35,2	-46,0
% change in 10th pctl	Occhito	Fortore	Human-Industrial-Agriculture	-29,7	-31,5	-30,6	-46,9
	Locone	Ofanto	Human-Agriculture	-20,9	-29,7	-28,4	-41,4
	Marana Capacciotti	Ofanto	Agriculture	-25,9	-41,8	-25,2	-50,1
	Traversa Santa Venere	Ofanto	Agriculture-Industrial	-33,9	-30,5	-38,9	-56,2
	San Giusto o Capaccio	Candelaro	Industrial	6,4	3,0	-29,1	-23,9
	San Giuliano	Bradano	Agriculture	-21,4	-39,5	-38,1	-56,1
	Pertusillo	Agri	Human	-27,1	-31,3	-39,0	-47,0
	Monte Cotugno	Sinni	Human-Industrial-Agriculture	-24,0	-34,2	-36,2	-49,3

Table 5.3 *- Results of the Stat-RO indicator for the analyzed dams. For the legend see Table 5.2.*

The same indicator calculated for eight dams confirmed a noteworthy distribution (ca. 70% of cases) of high to extremely severe reduction (percent change) of water availability (Table 5.3).

The slightly contrasting trends of Candelaro in terms of smoothing of the driest year occurrence could be due to the fact that it is the one with the largest surface under arid conditions among the investigated basins, and this makes it more sensible to initial changes in rainfall patterns.

By examining other indicators that quantify monthly, seasonal and inter-annual inflow trends, the general worsening is especially confirmed in the long term RCP8.5, with fluctuating outcomes if the medium term (both RCP4.5 and RCP8.5) and long term RCP4.5 are considered. A transition toward more severe classes of streamflow drought is noticeable from Streamflow Drought Index (SDI). Natural Variation of Potential Water Resources (NVPWR) and Storage Yield Curve (SYC) indicators suggest a progressively lower reliability in water resources, with reduced total volume discharge and increased duration of low flow periods, respectively. Caution is due in considering NVPWR indicator as based on monthly FDCs that misses the daily variability; the same attention is valid for the Sustainability of the Minimum Environmental Flow indicator, which however confirms more serious conditions to be expected for the maintenance of the ecological function of water on the long term RCP8.5. Less informative, also because of the climate regime of the Pilot area (from arid sub-humid to arid, with many seasonal rivers) and its hydrogeological composition (karstic underground aquifers), is the indicator Base Flow Index representing the underground component contributing to the river streamflow, that was estimated as currently extremely low, and not really significant under future climate, so that changes are not noticeable.

The assessment of risk due to hydrological drought (*Module 4*) for the irrigation compartment in Puglia was based on the evaluation of the change of available volume of surface water distributed for the irrigation purposes from upstream reservoirs (Table 5.2) to the downstream Reclamation Consortia, for the different time frame and emission scenarios. The analysis was based on the Regional Risk Assessment method (Landis 2005) and the risk results from the interaction of hazard, exposure and vulnerability (IPCC 2014).

Results confirmed the general tendency of a decrease of water availability for irrigation purposes: the three Consortia will not be able to fulfill completely their pattern of water demand with different magnitude according to the specific emission scenario and time-frame. Generally, the RCP8.5 within the 2041-2070 timeframe was assessed to be the most severe scenario for the hazard and risk scoring. In particular, the northern part of the Puglia region will be the most affected from the hazard: the Capitanata Consortium will suffer from a severe decrease of water with a hazard score from 0.19 (RCP4.5, 2021-2050) to 0.46 (RCP8.5, 2041-2070). This means that in the worst scenario it will be able to fulfill 54% of its current water demand.

The simulation results for the central Puglia region, where two Consortia are present, was slightly better, with a decrease of water availability ranging from 9% (Terre d'Apulia, RCP4.5, 2021-2050) to 35% (Terre d'Apulia, RCP8.5, 2041-2070).

By combining the hazard with the vulnerability assessment, the risk computation (Figure 5.3) confirmed that the northernmost agricultural areas of Puglia are more at risk among those considered in the analysis, in particular as far as its vegetable crops that are considered more vulnerable than others. Moreover, some limited areas at risk are also present in the area of the Stornara and Tara Consortium that is particularly vulnerable because of its high degree of system losses and low (zero) degree of diversification of sources.

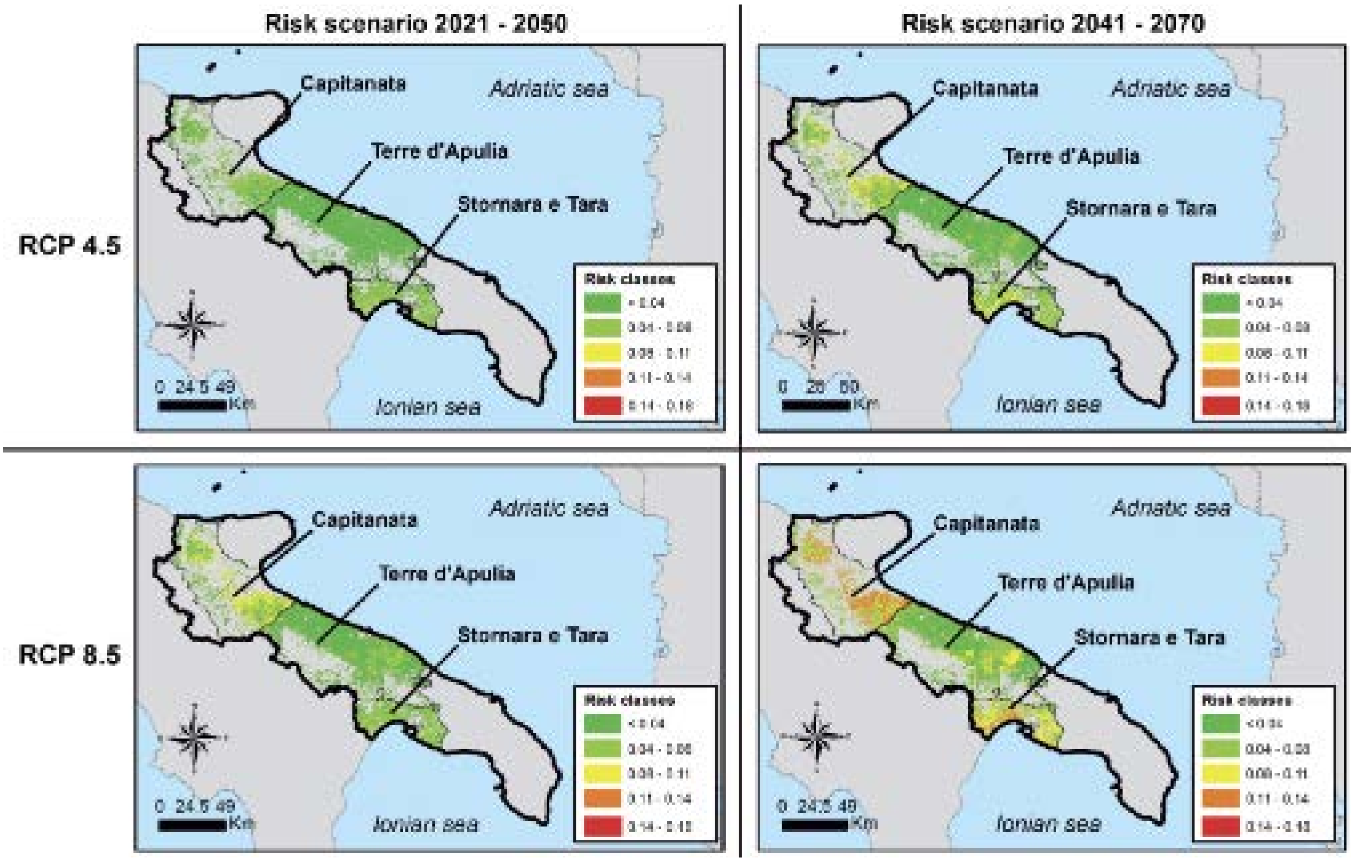

Figure 5.3 - *Risk maps of hydrological drought for the Reclamation Consortia in Puglia by means of Regional Risk Assessment approach.*

Results of the econometric analysis on wheat at local scale show that significant control variables with a relevant effect of the yield value are those relative to the farm's location, with flat lands being the most favored (+20.34 q/ha), even if probably this variable catch other aspects of the yield' variability. The source of labor is also important, with a family farm more exposed to yield losses (-14.09 q/ha).

The irrigation quota improves wheat productivity (+8.49 q/ha), while the presence in the farm of livestock decreases the wheat yield (-3.90 q/ha), probably due to the sharing of the fixed factors and of the farmer's activity and ability among different production and breeding activities.

Farms employing agricultural practice with low environmental impacts obtain lower yield (-2.57 q/ha), and the same effect is registered for organic farms (-1.82 q/ha). Farm' specialization on arable crop production implies a slight increase in the crop yield (+1.73 q/ha). The coefficients relative to the wheat cultivated surface, the cost of seeds and of rental machines are all significant, although the estimated impacts seems to be less important (-0.11, +0.03; +0.04 q/ha respectively).

In terms of climate influence, the analysis reveals that the relationship between the crop yield and the weather variables is not homogeneous for the four seasons. A linear and negative relationship is estimated for the temperature during the period between November-January (-3.51 q/ha); this may mean that higher temperature than usual during these months accelerates the plant growth, making the plants more vulnerable in the later stages of the production cycle. An increase of precipitations during these same months also reduces yield, even if the coefficient value show that this effect is less relevant (-0.13 q/ha) and with a low significance. The temperature effect seems to be more relevant during other seasons, such as in the period March-May (+15.22 q/ha) and June-August (+11.99 q/ha). The role of precipitations is positive, but less important, for the period June-August (+0.14 q/ha) and September-November (+0.02 q/ha). The coefficient of the interaction between temperature and precipitation is also relevant for all the season, especially in November-January and except for the months September-November.

The risk assessment on coastal areas (*Module 5*; Annex A.4) was focused on SLR projections related to the RCP8.5 scenario, selected as the worst emission scenario, with mean sea level anomalies offshore the Puglia region of about 10 cm for the timeframe 2021-2050 and 21 cm for the timeframe 2041-2070.
Resulting hazard maps showed that only 2% of coastal areas of the Puglia Region is hazard prone both for the mid-term and the long-term scenarios. Most of these areas are located near the Lesina-Varano lakes (about 9 km^2) and in the Gulf of Manfredonia, where about 13 km^2 of the territory is prone to hazard. Risk mapping in these sub-areas allowed to identify wetlands (including the Salinas of Margherita di Savoia) and protected areas as higher risk targets, with relevant percentages of the surface that could be submerged by sea-level rise projections.

Lesina-Varano and Manfredonia areas represents 12% and 6% of the surface at risk (low and very low risk classes) for the receptor "beaches". Considering the total length of the Puglia coastline (865 km), about 25% (212 km) resulted to be at risk (low and very low risk classes) in the mid-term scenario, up to 29% (250 km) in the long-term sea-level rise scenario.

Risk maps and statistics for beaches and wetlands, can be used to support coastal managers and administrators to identify natural systems potentially submerged (and/or retreating) in relation with future sea-level rise and to define appropriate adaptation or pathways (e.g. construction of artificial barriers, nourishment, dune restoration).

Despite the relatively low surface at risk in both scenarios (i.e. up to 4.85 km^2 and 1.45 km^2, respectively), risk maps for agricultural areas and terrestrial biological systems can be useful to localize the territory that could be affected by losses of productivity or ecosystem services due to sea-level rise inundation, where adaptation measures (e.g. shift to salt tolerant agricultural crops, reforestation in areas not at risk) could be required.

All results, besides being better described in the Annexes, are shared through the project Data Platform, also linked to European Climate Adaptation platform (Climate-ADAPT; http://climate-adapt.eea.europa.eu/).

6 Stakeholder participation

In order to enable stakeholders, decision makers and their technical staff, to actively guide in the formulation of Pilot Study activities such as selecting data and indicators and collecting their feedbacks in terms of needs (data access, formats etc.) and project results, two workshops were organized in the middle and the end of the project.

The first workshop, held on October 24th 2013 in Bari at the Regional Government premises, was conceived as a consultation with stakeholders selected among technical agencies and research institutions working on environmental, water resources and agricultural issues (ARPA Puglia, IAMB, CNR), plus regional authorities and services (River Basin and Civil Protection), already active and experienced in using data and developing methods for monitoring territorial vulnerability and risk.

The main goal of the first workshop was sharing information on a preliminary selection of indicators in order to collect doubts and/or suggestions for a final set of indicators, considered feasible as measurable, verifiable and repeatable without the need for excessively sophisticated post-processing tools or infrastructures. Moreover indicators need to be representative of the area under study and valuable to synthesize the scientific information on climate change and its impacts and risks to local experts, technicians and policy makers.

Besides presentations about the overall OrientGate project, highlighting similarities and differences of Puglia with other SEE territories, and about approaches, tools and data to be provided from the Pilot Study, a questionnaire was distributed to explore: i) the awareness of topics treated; ii) the degree of access and use of data ad tools; iii) the familiarity with terminology on vulnerability, risk and adaptation; iv) the knowledge of the EU Climate-Adapt platform. The answers to the questionnaire and the conducted debate with discussions regarding the main issues and approaches, revealed many interesting points:

- All participants commented that Puglia is (very) highly affected by climate change and extremes; most of them recognized that agricultural and domestic water uses are the most impacted sectors, but also coasts require protection against erosion, sea level rise, seawater intrusion and safeguard of tourism.
- Most produced and accessed data are on climate, land use, agriculture, hydrology, while information about socio-economy is less used and widespread. Several pieces of advice were given by technical staff on the reliability and completeness of all this data.
- Impact models/tools are more known and used than those on climate, and GIS-based database management and interface seem nowadays common for application of models and tools.
- Participants said that useful output types for decision making could be first descriptive statistics, then probability-based. In terms of format, maps are more comprehensible and immediate than graphs or tables, better if under qualitative classification (e.g. from null to extreme risk) rather than with absolute values. It is highlighted how pursuing the best way to communicate results is crucial to avoid that the use of information is postponed or abandoned.
- Vulnerability and risk concepts seem equally known even if some confusion and misunderstanding was discovered during the group discussion.
- Environmental, water resources and agriculture themes are well covered by regional agencies but participants highlighted that these themes are often neglecting climate change with very few initiatives for its consideration in the regional directives.
- EU Climate-Adapt platform is not yet really known, and is considered as needing a lot of improvements in terms of simplification, instructions and territorial representativeness.
- Further projects and/or collaborations among the workshop participants have been recognized of interest, like the importance of coupling water quantity and quality topics, the consideration of the opposite extremes (i.e. floods) or fluctuation among droughts/floods, and the focus on specific areas of the region already identified vulnerable.

After this first workshop, some exchanges continued among project partners and technical offices, especially to share and have suggestions on data to be used, their limits and contingency plans.

A second two-day event was held in Bari on November 11th - 12th 2014 and comprised a first workshop for policy makers, to present overall results in terms of projected climate scenarios for the next decades, potential new trends in extreme events of the area, and the integrated approach developed and applied to gain a wider understanding of the effects of climate change and to supply useful information for adaptation strategies in collaboration with the local stakeholders. A questionnaire was circulated to monitor likely changes in conditions detected one year before, and the points above were largely confirmed, especially about perception of climate change and more frequent extremes, incompleteness and scarce accuracy of multi-thematic data, and about the missing knowledge of Climate-Adapt or other platforms-initiatives.

During the second day, a training seminar was conducted especially for experts and technicians of public bodies and territorial agencies, as well as for private companies, first presenting more technical details about methodology and results, and then organizing two sessions to promote practice on drought indicator calculation and on RRA and on the DSS DESYCO used to evaluate climate change vulnerability and risk coastal areas. Two questionnaires were also circulated to collect feedbacks on what have been presented during the workshop.

Concerning water resources the survey revealed a strong perception of agro-hydrological droughts and their physical and socio-economic consequences, and participants judged that the synthesis of methods and results through indicators and user friendly tools seems highly comprehensive and promising when all the limits and advantages of the approach are made clear.

Besides evaluating risks for domestic use and ecological functions of water, more emphasis on groundwater and water distribution infrastructures is desired, as well as focusing on local agricultural production systems is strongly suggested for next studies. Both the spatial and temporal resolution of the analysis should be increased in the future, with the need to focus on the shorter term, also including more local scenarios based on socio-economic local trends.

The questionnaire concerning coastal areas was distributed during the second workshop with the aim to evaluate the usefulness of sea-level rise inundation risk indicators and maps for local stakeholders of the Puglia region. The questionnaire was structured in three main sections covering the input data used in the assessment, the step by step application performed (i.e. hazard, exposure, vulnerability and risk assessment); and finally, the typology/format of output produced. The questionnaire and the debate which occurred during the workshop confirmed that stakeholders almost entirely agreed with the input dataset used in the risk assessment. However, some of them suggested to consider higher resolution data including a more detailed Digital Terrain Model (e.g. laser scanning data) and more precise information on the coastal geomorphology and morphotype at the local/administrative scale.

The receptors considered in the exposure assessment were considered almost exhaustive, however some stakeholders suggested to localize the receptors using a more detailed scale (i.e. local rather than regional) and to include also tourism and related elements (i.e. accommodation facilities, equipped beaches, docks and touristic ports) as key elements at risk. As far as future hazard scenarios are concerned, stakeholders suggested to consider also a shorter term scenario and to include some assumptions about phenomena happening at local level (i.e. storm surges, extreme events, subsidence rate) in the assessment. Some stakeholders suggested additional areas suitable to be included in the coastal risk assessment, like the protected areas of Torre Guaceto, and also some beaches located in the Ionian side of the region. Finally, all the involved stakeholders were interested in integrating the analysis with an evaluation of the potential damages related with sea-level rise inundation, especially for what concerns the wetlands and the Salinas of Margherita di Savoia and the agricultural areas.

7 Interactions among Thematic Center Pilots

Frequent meetings allowed constant interactions among the three Pilots of Thematic Center 2 on Drought, Water and Coasts, facilitating partners to implement the Pilot Studies and making their outcomes comparable and harmonized in order to be integrated in the production of the final project results.

Initially it was jointly decided to find a common strategy for considering a plausible range of future developments by adopting climate projections under multiple scenarios and time frames, i.e. a medium-term more relevant for policy and a longterm
to emphasize divergence in results among emission scenarios. All future time frames needed to be compared to a baseline reference period covering as much as possible the recent decades, like 1976-2005 or 1981-2010, being aware that, from the climate modeling side, the RCMs used simulated GHG emissions from 2006 onwards. Thematic Center 2 participants decided together the list of required climate variables and their formatting to be provided, also discussing technical details in terms of needed software or tools to manipulate such data.
Still concerning climate projections, downscaling and bias-correction issues were widely debated among Thematic Center 2 participants to find the right compromise between scale of Pilots' areas, the resolution of RCM projections (inhomogeneous among Pilots), and the availability of observed data for validation.
From a conceptual point of view, it was discussed how to reach a similar methodological structure to quantify vulnerability and/or risks for each pilot study, via appropriate indicators. It was understood that there are few (at least 2, i.e. from UNISDR and IPCC) different approaches that can be adopted. Since many difficulties arise from potential misunderstandings, as the definitions of "vulnerability" and "risks" are often confusing and potentially overlapping, an explanation of the terminologies was promoted, guiding the partners to approach one of the two frameworks, but recognizing that the different Pilots can prefer one or another approach (or a mixture of both), also depending on requirements from stakeholders and their familiarity with the frameworks.

Given the strong connection among the three themes of TC2, drought, water and coasts, extensive discussions were dedicated to clarifications and choices of suitable impact indicators, like the meteorological drought indicators shared among Pilot Studies 3 and 4, and those based on streamflow in common between Pilot Studies 3 and 5. However, the full set of indicators under calculation across all Pilot Studies was continuously revised to avoid redundancy of indicators, missed description/references and in particular to agree in their classifications into single/compound indicators and into UNISDR or IPCC frameworks on vulnerability and risk. Not only similarities, but alto differences among Pilots' analyses were carefully detailed, according to their different purposes (irrigationdomestic
water use in Pilot 3, ecological water function in WP4, hydropower water use in Pilot 5) and use of data (e.g. including or not human water withdrawal in the water cycle).

Interactions among Pilots also included feedbacks during the construction of the Data Platform structure, providing advices on how effectively link the platform to EU Climate-ADAPT or other existing web visualization tools for easy access and consultation by stakeholders and policy makers.

8 Translating results into actions

In Puglia, water shortages, consequential imports from nearby regions and overexploitation of aquifers (whose composite effects are expected to become unsustainable) are strongly interconnected.

Stakeholders relying on water should exploit present results and findings to encourage policy makers involved in water resources management and protection to consider the risk of increasingly frequent, intense and prolonged droughts that could reduce the reliability of water yield from dam infrastructures, and could deplete the water table favoring saline intrusion in coastal aquifers, both also facilitated by the accelerating overexploitation.
This requires a tailored planning toward improved efficiency of water distribution which prevents water leaks and loss, and a more regulated use of aquifers.

The issue of water availability is strongly interacting with agriculture, so that stakeholders and decision makers in that sector first of all have to face the risk of crop yield losses due to insufficient water availability, up to the impossibility of maintaining current crop varieties if poorly resistant to droughts, while more rapid heat accumulation may favor crops better adapted to newer climate conditions. In this context, agricultural policies should support adaptation by promoting the study and development of efficient irrigation schemes that optimize water input (e.g. emergency irrigation) and reduce losses in water supply. In addition, to enhance water use efficiency, techniques to improve soil fertility and water holding capacity should be promoted (e.g. minimum mechanical soil disturbance), as well as the research and demonstration on potential new cultivars, and their correct management, and more efficient farming practices. This can be done through rural development programmes or other regional/local funding schemes.

Shifting dates of sowing/harvesting could be also a strategy to adapt most vulnerable crops into temporal windows more suited to crop development, as well as investigating the potential and favoring the use of alternative water sources (e.g. waste water), and developing meteorological alert warning services to timely activate irrigation applications.

Hazard and risk maps produced for the coastal area of Puglia can be considered as a screening tool to make a first-pass assessment of critical vulnerabilities associated to sea level rise in the case study.
The products can support decision making and coastal management in a wide range of situations (e.g. shoreline planning, land use and natural resources management) and can be used to mainstream climate adaptation in the definition of plans, policies and programs at the regional scale.

Regional policy makers must take into consideration these crosscutting themes and sectors and should invest: in raising awareness on hazard occurrence and vulnerability of society, economic sectors, ecosystem services and the environment; in the improvement and provision of technical information and data; and in the establishment of monitoring programmes and networks.
Overall, it is recommended to: i)promote and conduct further investigations, building on the presented approaches and modelling chain, exploiting indicators and their integration into regional risk assessment procedures, and including complex topics requiring particular attention as e.g. groundwater depletion, sea water intrusion, competition for water resources, water quality, coastal erosion; and ii) enlarge the analysis so to include alternative scenarios and time frames, have a more comprehensive view of likely future outlooks, and sustain a more robust system for supporting decisions.

Annex A.1

Details on climate simulations and indices

A.1.1 INTRODUCTION

A set of climate projections produced in OrientGate with the RCM COSMO-CLM (Rockel and Geyer 2008), at 0.0715° of horizontal resolution (about 8km) for the Italian and nearby territories as shown in Figure A1.1, served as basis for impact to risk analyses in the Pilot Study in Puglia.

COSMO-CLM simulations were conducted in the configuration optimized at CMCC (Bucchignani et al. 2013), and using as boundary conditions the outputs of the GCM CMCC-CM (Scoccimarro et al. 2011) from the CMIP5 experiment (http://cmip-pcmdi.llnl.gov/cmip5/), under 20C3M emission forcing for the period 1971-2005 and under RCP4.5 and RCP8.5 emission scenarios for 2006 to 2070. From COSMO-CLM simulations, daily series of meteorological variables have been post-processed and delivered by CMCC for the Pilot area to feed the successive analyses on impacts and risks.

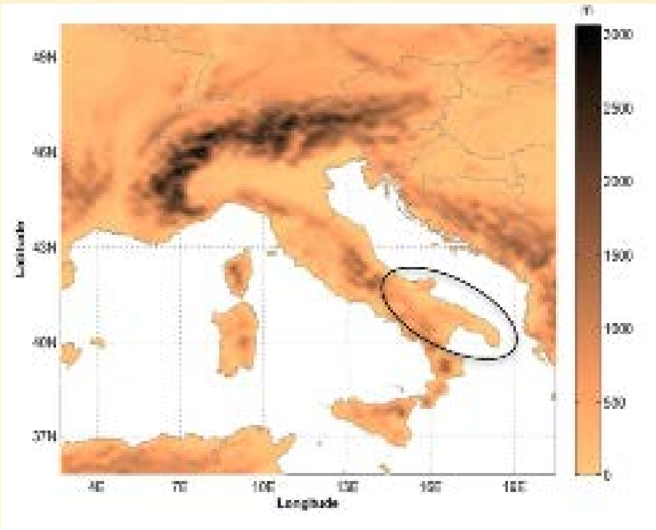

Figure A1.1 - Domain of COSMO-CLM simulations at about 8 km horizontal resolution. Black oval indicates the location of the Pilot Study 3.

According to the spatial discretization of the impact analyses, at gridded level for meteorological and agricultural drought and at basin level for hydrological drought, first simulations have been bias-corrected for temperature (minimum, maximum) and precipitation fields, at two levels:

- **Gridded level.** The daily series of the E-OBS dataset (v10.0; http://www.ecad.eu/download/ensembles/ensembles.php) were first converted into monthly series. To maintain the high spatial detail allowed by COSMO-CLM, the original resolution of E-OBS (0.25°) was resampled to the one of the COSMO-CLM simulation grid, using a bilinear interpolation technique.
- **Station level.** Observed monthly series of minimum and maximum temperature and precipitation, and of number of wet days, as provided by the Civil Protection Service of Puglia up to 2011 (http://www.protezionecivile.puglia.it/public/page.php?73) were used to downscale and correct COSMO-CLM simulations at the sites of several stations (31 for precipitation; 21 for temperature) chosen according to two main criteria: i) they are located in the watersheds considered for the hydrological modeling (see Annex A.3); and ii) their time series are quite complete along the baseline period considered.

In both cases the modified Linear Scaling method described in Sperna Weiland et al. (2010) was applied for bias-correction, by first computing the anomalies between modeled (COSMO-CLM) and observed (station or gridded level) monthly climatological average of maximum and minimum temperature and of precipitation amount along the 1972-2005 time frame. Then these monthly anomalies (handled as an addition and multiplication factor for temperature and precipitation, respectively) were back applied to the daily time series of original model data to obtain corrected time series. With respect to the original methods, an in depth analysis tailored to the study area allowed to set a threshold value for the multiplicative factor equal to 4 instead of 10. Moreover, the approach proposed by (Teutschbein and Seibert 2012) was used to adjust the wet-day frequency, taking into account observed monthly number of wet days in the bias-correction.

The climate change signal is generally similar among the original RCM outputs and the corrected values, indicating the capability of this bias-correction technique to preserve the signal of the RCM. Concerning the correction of other variables (e.g. solar radiation, wind speed, relative humidity), even if strategic for impact studies, literature does not provide well assessed approaches, thus specific choices were made for analyses also involving such variables and details are given in the specific impact analysis description annexes.

A.1.2 CLIMATE INDICATORS

Corrected data were first used to calculate some climate (including extreme) indicators at gridded level. According to climate simulations and correction, all indicators were assessed for the baseline period (1976-

2005, representing current conditions), and for the medium-term (2021-2050) and long-term (2041-2070) future periods, under two emission scenarios (RCP 4.5 and RCP 8.5).
Such indicators, also described in the Annex A.5, are:

- Mean annual temperature (MAT);
- Annual Temperature Range (ATR);
- Annual Precipitation Amount (APA);
- Days with Precipitation greater than 5mm (R5mm);
- Consecutive Wet Days (CWD);
- Consecutive Dry Days (CDD);
- Warm Spell Duration Index (WSDI).

The anomalies (absolute or percent changes) for each future period and emission scenario with respect to the baseline were assessed for all the indicators (Table A1.1).

Indicator	Baseline	Anomaly wrt. Baseline				
	1976-2005	2021-2050		2041-2070		Units
		RCP4.5	RCP8.5	RCP4.5	RCP8.5	
MAT	15.4°C	1.4	1.7	2.3	3.0	°C
ATR	8.5°C	0.0	0.0	0.1	0.2	°C
APA	348.3 mm	-11.2	-3.0	-14.4	-19.1	%
R5mm	25.9 days	-2.1	-2.3	-3.2	-5.5	days
CWD	5.4 days	-0.4	-0.4	-0.6	-0.9	days
CDD	64.6 days	4.2	2.4	14.5	16.3	days
WSDI	18.2 days	13.7	14.1	29.8	36.2	days

Table A1.1 - Average climate indicator values over Puglia under current climate (baseline, 1976-2005) and change projected along future medium-term (2021-2050) and long term (2041-2070) periods under two different emission scenarios (RCP 4.5 and RCP 8.5).

The same time series of corrected climate simulation data were then used as input to calculate agricultural (Annex A.2) and hydrological (Annex A.3) drought indicators.

Index	Description	Units
10p_tmin	10th percentile of daily Tmin	°C
Tnn	Annual minimum value of daily minimum temperature	°C
90p_tmax	90th percentile of daily Tmax	°C
Txx	Annual maximum value of daily maximum temperature	°C
FD	Annual count of days when the daily Tmin is below 0°	days/year
TR	Annual count of days when the daily Tmin is above 20°	days/year
ID	Annual count of days when the daily Tmax is below 0°	days/year
SU	Annual count of days when the daily Tmax is above 25°	days/year

Table A1.2 - List of indices calculated on daily minimum and maximum temperatures.

In addition, station level data were used to quantify the mean climate change signal of some extreme indices for temperature and precipitation, listed in Tables A1.2 and A1.3.

Index	Description	Units
PRCPTOT	Total precipitation	mm/day
	Number of days with precipitation over 1 mm/day	days/year
R1	(i.e. rainy days)	
SDII	Mean precipitation amount on wet days	mm/day
CDD	Consecutive dry days (< 1 mm)	days/year
CWD	Consecutive wet days (> 1 mm)	days/year
RX1DAY	Maximum precipitation in 1 day	mm/day
RX5DAY	Maximum precipitation in 5 days	mm/5days
R10mm	Number of days with precipitation over 10mm/day	days/year
R20mm	Number of days with precipitation over 20mm/day	days/year
PREC99P	99th Percentile of the total daily precipitation	mm/day
PREC90P	90th Percentile of the total daily precipitation	mm/day

Table A1.3 - List of indices calculated on daily precipitation.

The average climate change signal projected for temperature (Figure A1.2) indicates a significant increase of both minimum and maximum temperature for all considered indices. Moreover, there is a decrease of frost days (FD) and icing days (ID) and an increase of summer days (SU) and tropical nights (TR).

The comparison between the RCP4.5 and RCP8.5 scenarios indicates that in all the cases the sign of the climate change signal remains the same, but the magnitude of the change is much higher for the RCP8.5. The climate change signal projected for precipitation (Figure A1.3) indicates a general decrease of total precipitation, number of rainy days, consecutive wet days, number of days with precipitation over 10 and 20 mm/day, 90th and 99th percentiles, while there is a general increase of mean precipitation amount on wet days (SDII), consecutive dry days (CDD) and maximum of precipitation in one and five days (RX1DAY and RX5DAY).

The comparison between the RCP4.5 and RCP8.5 scenarios indicates that, except for one case, the sign of the climate change signal remains the same, and again more evident under RCP8.5.

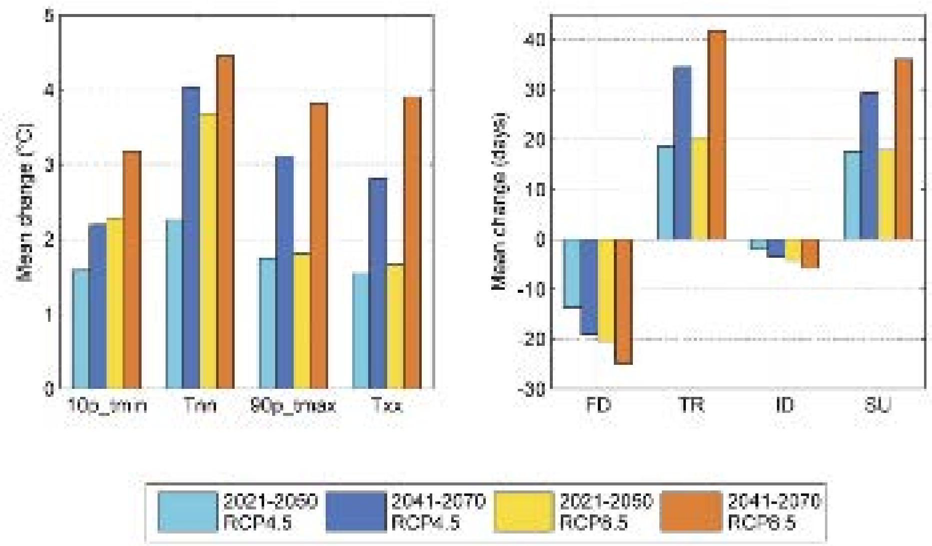

Figure A1.2 - *Mean changes of indices based on minimum and maximum temperature across time frames and scenarios.*

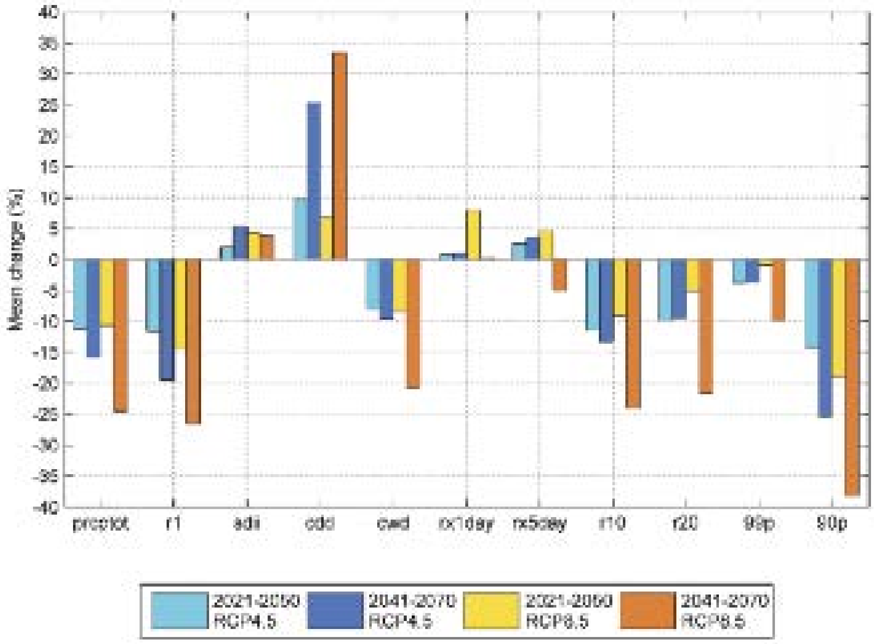

Figure A1.3 - *Mean changes of indices based on precipitation across time frames and scenarios.*

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Annex A.2

Agricultural drought scenarios

A.2.1 INTRODUCTION

The objective of this Annex is employing and describing a set of climate indicators relevant to the agricultural sector, especially in terms of agricultural drought conditions, and reconstructing their trends based on high resolution projected climate change for the Puglia region.
In particular, some agro-climate indicators are described that were applied in the Pilot Study to indicate climate change impacts affecting irrigation water requirements for the most common irrigated crops cultivated in Puglia (such as vegetables, olive trees, fruit trees, grapevines). The implementation of these indicators in the Pilot Study supported a more comprehensive water resource risk assessment in agriculture combining climate related hazards with exposure and vulnerability aspects depending on the characteristics of crops and water distribution systems.

A.2.2 DATA AND METHODS

A combination of monthly time series of temperature and precipitation, as bias-corrected from COSMO-CLM outputs (see Annex A.1), were used to calculate several yearly to monthly based agro-climate drought indicators, including those defining general heat accumulation conditions, water demand and water stress of vegetation. Climate model data were processed with CDO (Climate Data Operator; https://code.zmaw.de/projects/cdo), a collection of routines to manipulate and analyze mostly climate data files, including the standardized NetCDF climate model data format. Python scripts were thus used under the ArcGIS environment (ESRI©) to convert monthly and annual averages into ESRI grids format and calculate potential evapotranspiration and soil moisture based indicators via simple water balance algorithms.

All agro-climate indicators were calculated for the baseline period (1976-2005, representing current conditions), and for the medium-term (2021-2050) and long-term (2041-2070) future periods, under two emission scenarios (RCP 4.5 and RCP 8.5; IPCC 2014). The main characteristics of these indicators are reported in Annex A.5, and their meaning can be summarized as follows.

- Growing Degree Days (GDD; °C) is a measure of heat accumulation used to predict crop growth and development rates, and it is defined as the cumulated sum of temperature degrees for each day in the season above a certain base temperature threshold. The base temperature indicates the threshold above which crop growth takes place, and is most commonly assigned to 10 °C for GDD calculation for most generic assessments, although it may vary for specific crops.
GDD is used to define generic indications of suitability of a region to crop climate requirements, to estimate length of growth stages and rates of crop development, predict

planting dates and maturity, heat stress and best timing for fertilization and pesticide application.

- Potential Evapo-Transpiration (PET; mm), it is a measure of the ability of the atmosphere to remove water through Evapo-Transpiration (ET) processes. Among several equations to estimate PET, the Hargreaves Potential Evapo-Transpiration (PET-HA) model (Hargreaves 1994) was chosen as the most suitable as it requires a simplified parameterization based on temperatures, and performs almost as well as other more complex methods requiring additional climate parameters (Hargreaves et al. 2003), (like wind speed, relative humidity, solar radiation), whose accuracy is generally less reliable because a limited number of meteorological observations are available for validation and bias correction purposes. Hargreaves (1994) uses mean temperature (Tmean) mean temperature range (TD), available as bias corrected, and mean extra-terrestrial radiation (RA, radiation on top of atmosphere) to calculate mean PET, as shown below:

$PET-HA=0.0023*RA*Tmean+17.8*TD^{0.5}$ (mm/day)

Extra-terrestrial radiation (RA) is calculated using a methodology presented by Allen et al. (1998). Temperature range (TD) is an effective proxy to describe the effect of cloud cover on the quantity of radiation reaching the land surface and, as such, it describes more complex physical processes with easily available climate data at high resolution.

- Aridity Index (AI; unitless), was used to quantify precipitation availability over atmospheric water demand, thus annual precipitation over annual PET (UNEP 1997). The Aridity Index shows moisture availability for potential growth of vegetation excluding runoff events when rainfall exceeds soil infiltration. UNEP (1997) breaks up Aridity Index, in the traditional climate classification scheme, as: < 0.03 "Hyper Arid"; 0.03 - 0.2 "Arid"; 0.2 - 0.5 "Semi-Arid"; 0.5 - 0.65 "Dry sub-humid"; > 0.65 "Humid".

- Potential Soil Moisture Deficit (PSMD; mm) is a measure of the climatological wetness or dryness (Mkhwanazi 2006; De Silva et al. 2007; Rodríguez Díaz et al. 2007) and it has been evaluated and used to quantify the impacts of climate change on crop irrigation demand. To estimate PSMD, a monthly time-step water balance model was established, using spatial data on precipitation and PET. When monthly PET exceeds monthly precipitation, PSMD is cumulated month by month until a maximum PSMD is reached. The maximum PSMD is used as agro-climatic indicator.

The anomalies (absolute or percent changes) for each future period and emission scenario with respect to the baseline were assessed for all the indicators.
In order to delineate the explanatory capability of the PSMD in climate change impact studies for agriculture in the pilot study, an analysis investigated the relationships between this indicator and the irrigation water requirements, on a provincial and regional basis, relying on data derived from the latest Italian census on Agriculture (ISTAT 2012), which reflects conditions for agriculture and irrigation uses for the year 2010. The analysis concentrated on the main 4 irrigated crop types for the Puglia region, covering about 85% of the irrigated land (Table A2.1): olive trees, grapevines, fruit trees and vegetable crops. Strong linear relationships between PSMD and irrigation needs have been verified: the goodness of fit of the regression analysis using the R-squared method shows high levels of confidence (R^2 0.62÷0.9), suggesting that the developed linear regression models at both scales (regional and provincial) could be used for projecting how the changes of PSMD can reflect in changes of crop irrigation requirements. The variation of PSMD has been then related to variation of irrigation and scaled in classes of impact for the adoption and use in the Regional Risk Analysis in agriculture, as described in the main text.

Irrigated Surface (Ha)							
Crops	**Puglia**	**Foggia**	**Bari**	**Taranto**	**Brindisi**	**Lecce**	**Barletta-Andria-Trani**
Vegetable crops	**46,925**	28,746	4,189	2,536	5,887	3,202	2,365
Olive trees	**81,737**	11,059	19,235	7,008	10,781	11	22,654
Grapevine	**63,088**	19,843	11,649	11,989	2,697	1,05	15,86
Fruit trees	**12,231**	1,219	6,115	547	607	161	3,582
Cereal for production of grains	**14,926**	8,749	821	1,773	1,499	1,293	792
Citrus	**7,949**	167	163	7,299	48	267	5
Sugar beet	**3,644**	3,603	4	36	-	1	-
Green fodder from arable land	**3,517**	1,517	144	900	311	628	17
Potato	**1,377**	427	417	46	7	443	36

__Table A2.1__ - Agricultural irrigated land (Ha) in Puglia, at regional and provincial level in year 2010 and by crop types (source ISTAT 2012). Only relevant irrigated crops, for which extent of irrigated area is greater than 1000 ha, were considered.

A.2.3 RESULTS

According to the climate change projections elaborated within the Orientgate project, the Puglia region will undergo an average increase in mean annual temperature of 1.4 to 1.7 °C in the medium- term (2021-2050, RCP4.5 to RCP8.5) and 2.3 to 3.0 °C in the long-term (2041-2070, RCP4.5 to RCP8.5). Seasonally, increases in temperature will be greater than annual averages in summer and fall, and lower in winter.

This increase in temperatures will lead to increasing evapotranspiration for both natural vegetation and crops. Increasing temperatures will also raise the heat accumulation, summarized as indicator by the Growing Degree Days (Figure A2.1), which will shorten crop growing seasons. The projected precipitations, although subject to model uncertainties, will show a moderate average decrease in the short term (10 to 40 mm/year) and slightly stronger decrease in the long term (50 to 66 mm/year). Higher temperatures will increase potential evapotranspiration, and consequently, together with reduced precipitations, will augment aridity conditions (Figure A2.3), soil water deficit (Figure A2.4) and thus final vegetation water requirements. The Potential Soil Moisture Deficit (PSMD), the soil water stress cumulated during the growing season, suggests increasing crop irrigation requirements, which need to be compensated by larger (sustainable) water exploitation and/or water use efficient agronomic practices.

Results of calculated indicators, and anomalies as change compared with baseline, are summarized in Table A2.2 as averages for the whole Puglia.

Indicator	Baseline	Anomaly wrt. Baseline				
	1976-2005	2021-2050		2041-2070		Units
		RCP4.5	RCP8.5	RCP4.5	RCP8.5	
GDD	2208 °C	18.9	22.3	31.5	41.8	°C
PET-HA	1007 mm	4.3	4.8	7.2	9.7	%
AI	0.4	- 15.0	-7.5	-20.1	-26.1	%
PSMD	744 mm	8,7	6.9	13.5	19.2	%

Table A2.2 - Average agro-climate indicator values for the Puglia region under current climate (baseline, 1976-2005) and change projected along future medium-term (2021-2050) and long term (2041-2070) periods under two different emission scenarios (RCP 4.5 and RCP 8.5).

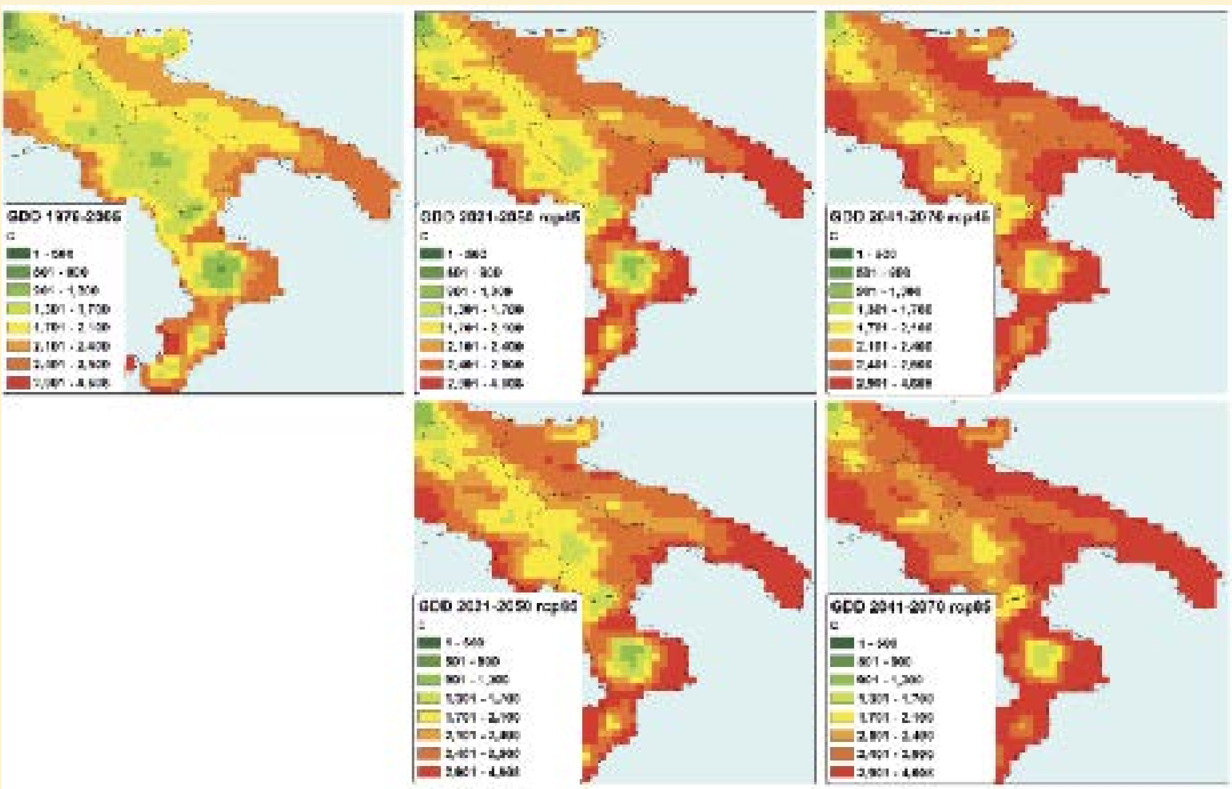

Figure A2.1 - Changes in annual GDD for future (average 2021-2050 and 2041-2070) as for two emission scenarios (RCP4.5 and RCP8.5) compared to baseline (average 1976-2005).

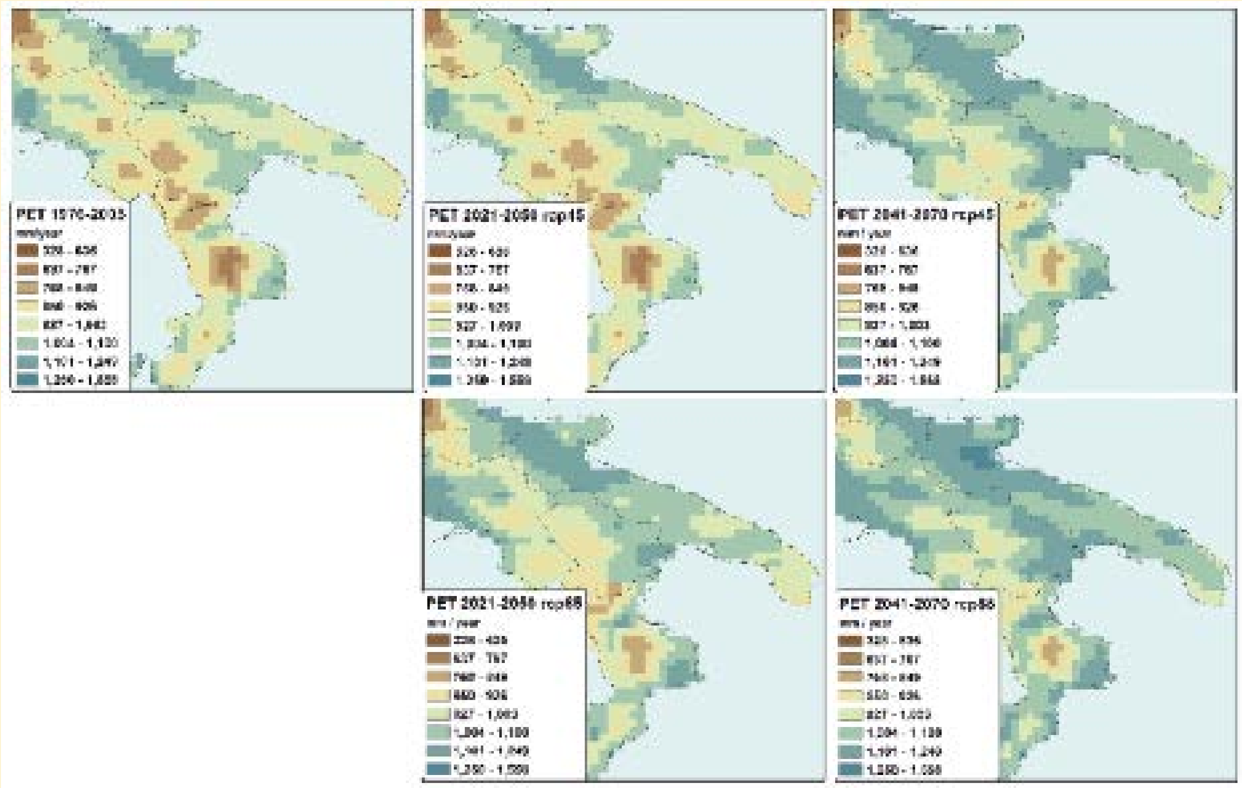

Figure A2.2 - Changes in annual PET for future (average 2021-2050 and 2041-2070) as for two emission scenarios (RCP4.5 and RCP8.5) compared to baseline (average 1976-2005). PET has been calculated according to the Hargreaves method.

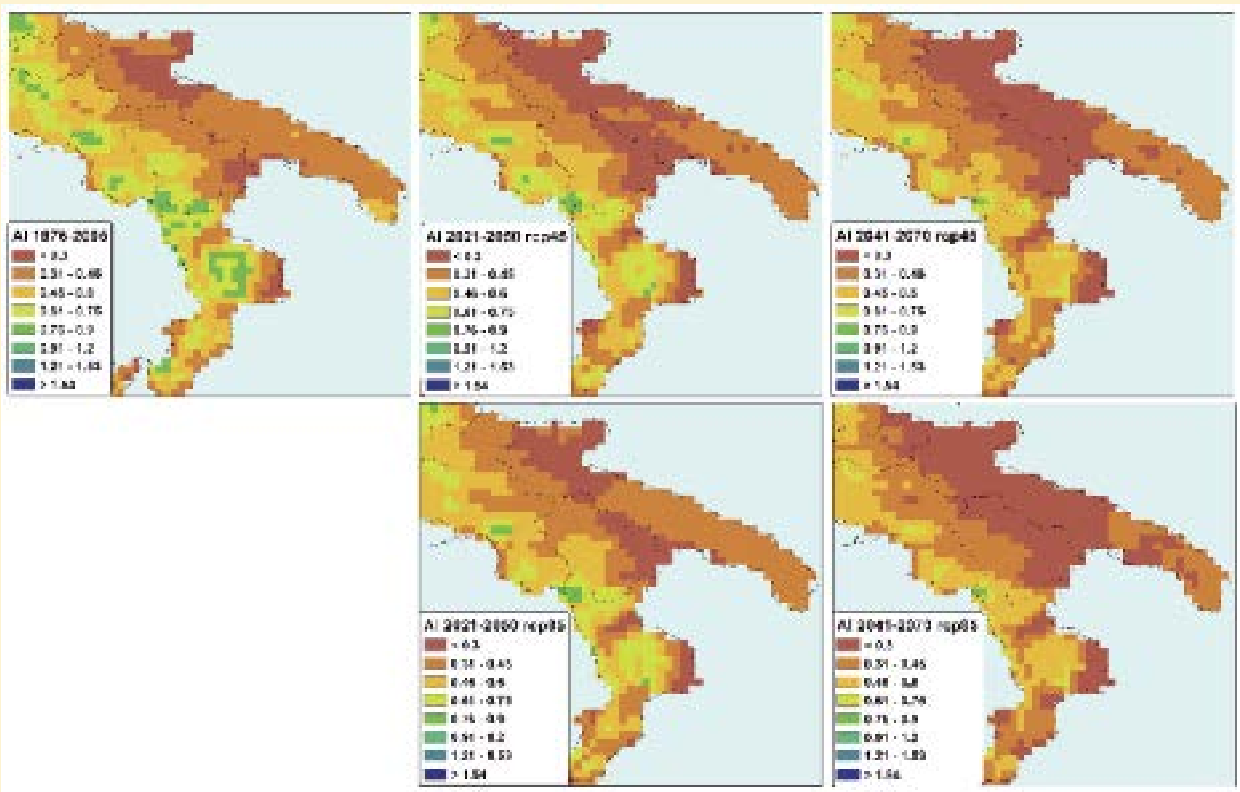

Figure A2.3 - Changes in annual Aridity Index for future (average 2021-2050 and 2041-2070) as for two emission scenarios (RCP4.5 and RCP8.5) compared to baseline (average 1976-2005). AI has been calculated as the ratio of PET-HA over annual precipitation amount.

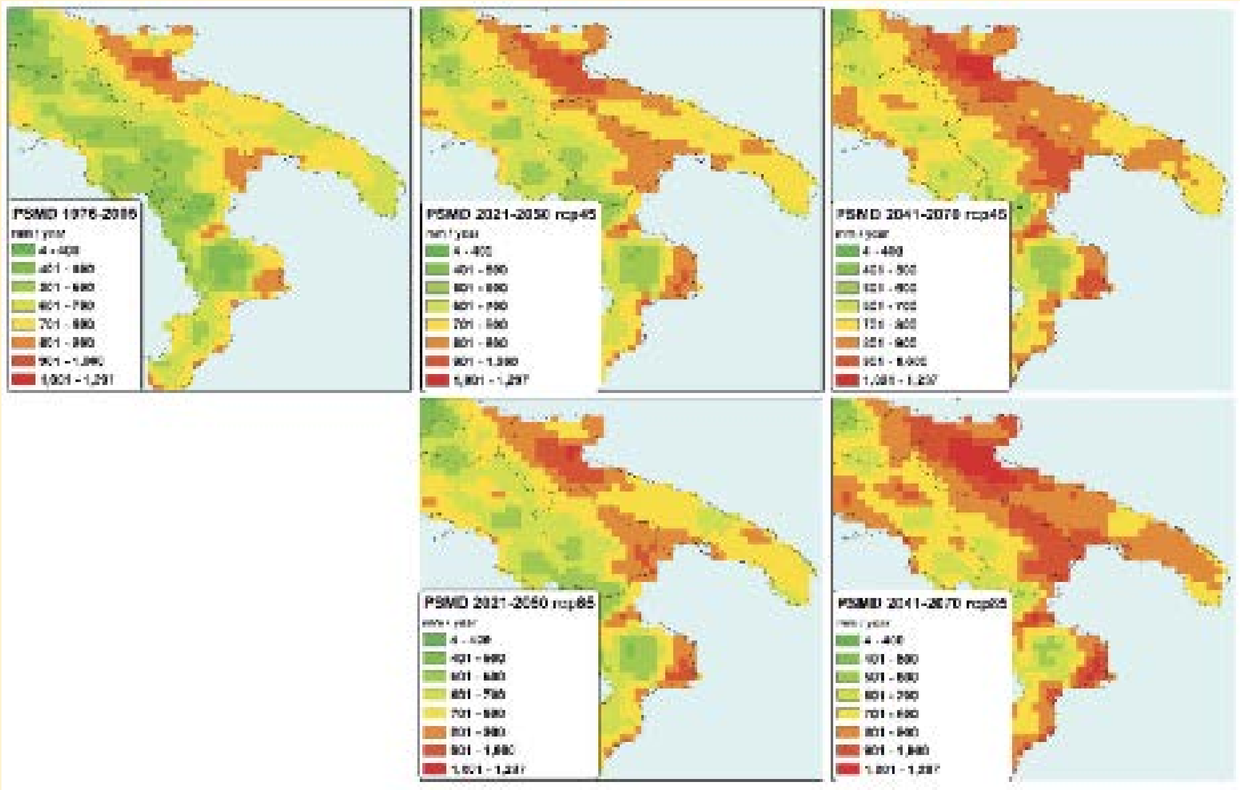

Figure A2.4 - Changes in Potential Soil Moisture Deficit for future (average 2021-2050 and 2041-2070) as for two emission scenarios (RCP4.5 and RCP8.5) compared to baseline (average 1976-2005). PSMD is calculated as the maximum cumulated soil moisture deficit in a simplified monthly soil water budget.

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Annex A.3

Hydrological drought scenarios

A.3.1 INTRODUCTION

The analysis on hydrological drought hazard assessment and projections was conducted relying on climate simulations produced in OrientGate and described in Annex A.1. Daily series of these simulations allowed set up and running a semi-distributed hydrological model providing time series of runoff for selected basins and their sub-basins. Runoff data were post-processed and synthetized into known or new formulated indicators of hydrological droughts at watershed level for significant river basins in Puglia, and for upstream drainage area of several dams strategic for water accumulation serving different purposes. In the following some details on the methodology are given and results presented and discussed.

A.3.2 DATA AND METHODS

A set of indicators to investigate the occurrence and attributes of hydrological drought episodes in Puglia were selected and applied, building on their usefulness established in previous studies, and thanks to exchanges with stakeholders and other Pilots in OrientGate, especially Pilot Study 5; these interactions in fact favored the appropriate adoption of shared existing and new formulated indicators.

Hydrological drought indicators, whose characteristics are reported in Annex A.5, are all based on runoff (or streamflow) series and their meaning can be summarized as:

- Stat-RO (Statistics of RunOff), indicating streamflow trends in terms of changes in average annual amount and in the 10^{th} percentile, representing the low flow degree of the driest year in the considered period.
- NVPWR (Natural Variation of Potential Water Resources), based on the (monthly) Flow Duration Curve (FDC), it represents changes in the area under the FDC, function of the frequency distribution of monthly discharge values.
- SMEF (Sustainability of Minimum Environmental Flow), based on the FDC, it indicates changes in the streamflow values actually having the frequency considered vital for maintaining the ecological function of water.
- SDI (Streamflow Drought Index), representing the frequency of occurrence of episodes that deviates, with different severity degrees, from the climatological average of runoff values, for different (3, 6, 9, 12 months) time periods.
- SYCn (Storage Yield Curve, based on natural "n" streamflow); it indicates the area under the SYC, standardized over the mean annual runoff, and representing the basin water yield achievable from a hypothetic given level of water storage.
- BFI (Base Flow Index), indicating the portion of the streamflow assumed being base flow, and probably representing the groundwater contribution to streamflow.

Runoff series to calculate above indicators for the baseline and future periods/scenarios were obtained by hydrological modeling with ArcSWAT (http://swat.tamu.edu/software/arcswat/) driven by daily series of bias-corrected simulated data with COSMO-CLM (see Annex A.1). The model was first parameterized in terms of topography, soil and land cover/use attributes into hydrological response units (HRUs), relying on the combination of three spatial datasets: 1) the digital elevation model at 20 m resolution (source National Geographic Military Institute); 2) the land use layer from CORINE Land Cover product for 2006 at 100 m resolution (http://www.eea.europa.eu/data-and-maps/data/corine-land-cover-2006-clc2006-100-m-version-12-2009); 3) the Harmonized World Soil dataset storing soil attributes at 1 km resolution (http://webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/). To find a right compromise among the different spatial resolutions of such layers, a resampling to 100 m was conducted to then extract sub-basins polygons and their HRUs.

Given the limits in model calibration and validation because of lacking or incomplete series of river discharge covering the same period of interest, the approach adopted was based on applying the monthly climatological anomaly calculated between modeled and observed discharge to the full simulated time series of runoff, at eight important hydrological stations (considered sufficiently complete in terms of data), being the most downstream (i.e. closest to the outlet) of as many significant river basins (Figure A3.1). These significant river basins, according to the Regional Water Protection Master Plan, are: Fortore, Candelaro (and its tributaries Salsola and Celone - not shown in the Figure), Cervaro, Carapelle, Ofanto, Bradano.

Concerning the workability of indicators, for those based on annual to monthly climatological average of streamflow (Stat-RO, NVPWR, SMEF) basic statistic knowledge is necessary including construction of monthly FDC, for more complex indicators based on entire monthly (SDI, SYCn) or daily (BFI) time series, excel sheets were set up for easy application also by not expert users, and tested in training seminars (See Sect. 6 in the main text).

Stat-RO indicators were also calculated for the river sections corresponding to the location of eight dams (Figure A3.1) reported by the *Feasibility study on the Hydro-Potable balance* (Regional Government and River Basin Authority of Puglia 2012) as the ones providing water for domestic, irrigation and industrial purposes. Two of these dams belong to another rivers' system located completely outside Puglia territory, the Agri-Sinni, that thus was included in the analysis on risks for water resources, integrating quantitative information on water delivered and area irrigated from each water accumulation/diversion infrastructure.

Figure A3.1 *- Map showing the significant river basins (cyan boundaries) and the dams (wave icons and yellow labels) considered.*

A.3.3 RESULTS AND DISCUSSION

The simplest indicators calculated (Stat-RO) refer to percent changes in some descriptive statistics on annual inflows, among which the mean and the 10th percentile of the annual value of the climatological period have been chosen to represent the overall superficial water availability and the one in the driest year, respectively; they are thus indicators of average trends. Concerning changes in the annual average a worsening situation from RCP4.5 to RCP8.5, and from medium term (2021-2050) to long term (2041-2070) period is evident. The 'moderate hazard' (-25 % ≤ changes < -10%) dominates in the RCP4.5 (both periods) and in the medium term RCP8.5, with few 'high hazard' (-40 % ≤ changes < -25%) cases however affecting the most water providing rivers (Fortore and Ofanto). In the worst case scenario (long term RCP8.5) there is a spread of 'high hazard' cases up to also occurrence (still for Fortore and Ofanto) of 'extremely high hazards' (changes < -40%). In general, almost half of scenarios project 'high' to 'extremely high hazards'.

In terms of driest years, results are very similar but more worrying, if considering that 'high hazard' cases are more occurring in the medium term, while in the long term periods (under both emission scenarios) 'high' to 'extremely high hazards' cover almost all the cases. The only exception is Candelaro river that, follows the worsening trend of other rivers although in a weaker way. In terms of driest year, highly worrying is the behavior, besides Fortore and Ofanto, of Bradano that supply especially water for domestic purposes through its dams.

These statistical indicators were also calculated for the upstream area of eight dams serving irrigation, domestic and industrial purposes. Results show that when concentrating on smaller and higher elevation parts of the basins, changes (almost all reductions) appears more critical, still with the exception of Candelaro but only in the medium term period. The contrasting trends of Candelaro both in terms of annual mean and driest year occurrence could be due to the fact that it is the one with the largest surface under arid conditions among the investigated basins, so more seasonally variable in terms of inflow reliability, and this makes it more sensible to more fluctuating changes in rainfall patterns.

Aggregated results on Stat-RO indicator, both for basins and dams, are reported in the main text.

More discussion has to be paid to the SDI indicator, that allows investigating the potential deviation of cumulated inflow from its own climatological period. More frequent low values (< 0) of such indicator reveal an increase of occurrence of hydrological droughts at different degrees of severity. To simplify results' communication, in the following for each period (3, 6, 9, 12 months starting the hydrological year from October) a standardized value from 0 to 1 is given to indicate full improvement and full worsening, respectively, of drought conditions, with respect to the baseline period (Table A3.1). This further index was derived by summing, for each period, discrete scores flagging changes in percent occurrence of drought classes (-1 for drought increase, +1 for drought decrease, 0 for no change, for each class and future period comparing the average occurrence between RCPs vs. the baseline period); these scores were weighted according to their severity degree (i.e. highest weight for changes of extreme severity drought, lowest for the low severity drought). It is clear a more evident worsening in the autumn suggesting that drought are expected to particularly affect the most humid period. However, it has to be clarified that, as implemented here, SDI is an indicator of variability, more than trends: indeed even when there could be a decrease of severer classes, this information should be integrated with the one in terms of the average trends (e.g. Stat-RO indicators) with respect to the deviation is calculated: e.g. less occurrence of droughts but less annual amount of inflow could however represent a worsening situation.

Basin	2021-2050				2041-2070			
	SDI (oct-dec)	SDI (oct-mar)	SDI (oct-jun)	SDI (oct-sep)	SDI (oct-dec)	SDI (oct-mar)	SDI (oct-jun)	SDI (oct-sep)
Candelaro	0.54	0.61	0.32	0.32	0.54	0.61	0.32	0.32
Cervaro	0.54	0.54	0.61	0.32	0.54	0.46	0.61	0.32
Carapelle	0.61	0.46	0.46	0.39	0.57	0.61	0.46	0.32
Ofanto	0.54	0.32	0.61	0.61	0.54	0.32	0.61	0.61
Bradano	0.46	0.68	0.61	0.54	0.46	0.68	0.61	0.39
Fortore	0.54	0.46	0.39	0.43	0.54	0.61	0.39	0.32

Table A3.1 - Summary of SDI results in terms of average changes per drought classes across RCP emission scenarios. Red (green) values indicate worse (better) situation conditions wrt. baseline.

Both NVPWR and SYCn (Table A3.2) suggest a progressively lower reliability in water resources, with reduced total discharge volume and increased duration of low flow periods, respectively. NVPWR is very simple and communicative, and it represents an yearly-average comparison (ratio) between the areas under the (future and historical) monthly FDCs. In the present case results are alarming for all scenarios and future periods, but users need to be aware that this indicator, if taken alone could be not really informative, indeed a lower value could be due to a lower overall discharge but less variability that could be seen as beneficial situation if not integrated with additional evaluations. An interesting indicator to improve such information is the SYCn, not only looking at the intra-annual (monthly) variability but also at the inter-annual variability of monthly inflow, and representing the water yield (as percentage of the Mean Annual Runoff, MAR) attainable from a given basin assuming to maintain a given level of storage exploitation (still as percentage of the MAR). This is the standardized version of the SYCn, constrained by the fact that no clear absolute values are known about the effective water diversion from each basin for the cumulative downstream uses. If the (standardized) area under the curve diminishes, this means that even assuming a constant capacity and relative exploitation of storage, a basin is less reliable in providing, regularly during each single month of the whole period, the desired level of water. In Table A3.2 the standardized area was further processed as normalized according to the standardized area for the baseline, so that values < 1 represent worsening conditions (red), and those > 1 improved conditions (green).

Moving the attention to water functions rather than uses, the same monthly FDCs served the evaluation regarding the reliability, in the future, of the minimum environmental flow (via the SMEF indicator). The most cautionary (highest) value between the one reported by the Regional Water Protection Master Plan and the one calculated from simulated monthly FDCs, in both cases representing the discharge value present in the river for at least 335 days (or 11 months) in one year, was considered for the historical period and compared with the discharge value having the same occurrence in the future. Results (Table A3.2) are highly fluctuating in this case, but showing worrying conditions for almost all the basins in the long-term RCP8.5.

BASIN	Indicator	RCP45_2021_2050	RCP45_2041_2070	RCP85_2021_2050	RCP85_2041_2070
Candelaro	NVPWR	0.91	0.89	0.91	0.77
	SYCn	0.39	0.52	0.89	0.34
	SMVF	0.90	0.86	1.10	0.80
Cervaro	NVPWR	0.81	0.71	0.79	0.63
	SYCn	0.64	0.69	1.01	0.42
	SMVF	1.75	1.30	1.77	1.12
Carapelle	NVPWR	0.80	0.70	0.78	0.66
	SYCn	0.83	0.96	1.31	0.79
	SMVF	1.18	1.00	1.41	0.87
Ofanto	NVPWR	0.70	0.64	0.69	0.58
	SYCn	1.65	1.19	1.62	0.94
	SMVF	1.09	0.89	1.06	0.71
Bradano	NVPWR	0.82	0.77	0.88	0.66
	SYCn	0.62	0.56	0.78	0.53
	SMVF	1.03	0.90	1.05	0.60
Fortore	NVPWR	0.70	0.63	0.63	0.50
	SYCn	0.65	0.81	1.20	0.56
	SMVF	0.92	1.02	1.27	0.97

Table A3.2 - Summary of NVPWR, SYCn and SMEF results. Red (green) values indicate worse (better) conditions wrt. baseline.

Less informative, also because of the climate regime of the Pilot area (from arid sub-humid to arid, with many seasonal rivers) and its hydrogeological composition (karstic underground aquifers), is the indicator BFI representing the underground component contributing to the river streamflow, that was estimated currently very low, and seems continuing to be not really significant under future climate, so that changes are rather imperceptible.

Being aware that caution is due in considering NVPWR and SMEF indicators as based on monthly FDCs, and considering the limitations of choosing indicators mostly based on monthly inflow, thus missing the daily variability, all that was: i) dictated by the easier availability and usability of observed monthly series of meteorological (precipitation, temperature) and discharge data used for hydrological model calibration and validation; and ii) partially compensated by the less computationally expensive and more user-friendly tools developable for indicators' calculation by not expert users. On the other hand, the single indicator based on modeled daily streamflow (BFI) could have suffered from the constraint of calibrating hydrological model parameters at monthly level rather than optimizing them for daily level simulations.

However, the noteworthy utility of the analysis is maintained thanks to the consideration of information coming from different indicators, giving importance to annual mean as well as to intra-annual and inter-annual variability, thus avoid missing some key components of the complex system of water resources availability and variability.

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Annex A.4

Risk analysis for coastal areas

A.4.1 INTRODUCTION

Coastal zones represent highly vulnerable systems as they are characterized by the equilibrium between terrestrial and aquatic environments, playing a crucial ecologic and socio-economic role in the development and production of ecosystem and productive services (e.g. agriculture, tourism, biodiversity, fishing, leisure) (IPCC 2014). Climate change, with its potential negative effects (e.g. sea-level rise inundation, drought, alteration in water quality and quantity), is posing additional pressures to this fragile environment and, together with increasing exposure and vulnerability patterns, can affect different coastal natural and human systems and sectors causing losses and damage both in monetary and not monetary terms.

The objective of this Annex is to describe the risk assessment approach applied for the identification and prioritization of targets and hotspots at risk from sea-level rise inundation in low-lying coastal areas of the Puglia region. Specifically, the report describes how Regional Risk Assessment and the DEcision support SYstem for COastal climate change impact assessment (DESYCO) were applied for the assessment of sea-level rise risk for significant targets in the Puglia coastal areas (i.e. beaches, wetlands, urban areas, agricultural areas, terrestrial and biological systems) providing impact and risk indicators and maps for local stakeholders and coastal managers in the case study. As described in Sect. 4.4 of the main text, the indicators and maps produced for coastal areas are part of a broader approach developed for the Puglia case study for the integrated assessment of climate change impacts on water and coasts and provide a quick scan tool for the definition of adaptation priorities and pathways aimed at increasing the resilience of coastal systems to climate change and at planning precautionary measures for the sustainable management of coastal resources, in view of climate change.

A.4.2 DATA AND METHODS

The methodological approach applied to evaluate coastal risk was based on a Regional Risk Assessment procedure composed of four main phases (Figure A4.1) that - according to the latest definitions proposed by the IPCC (2014) and UNISDR (2009) - builds upon the main pillars of risk (i.e. hazard, exposure and vulnerability).

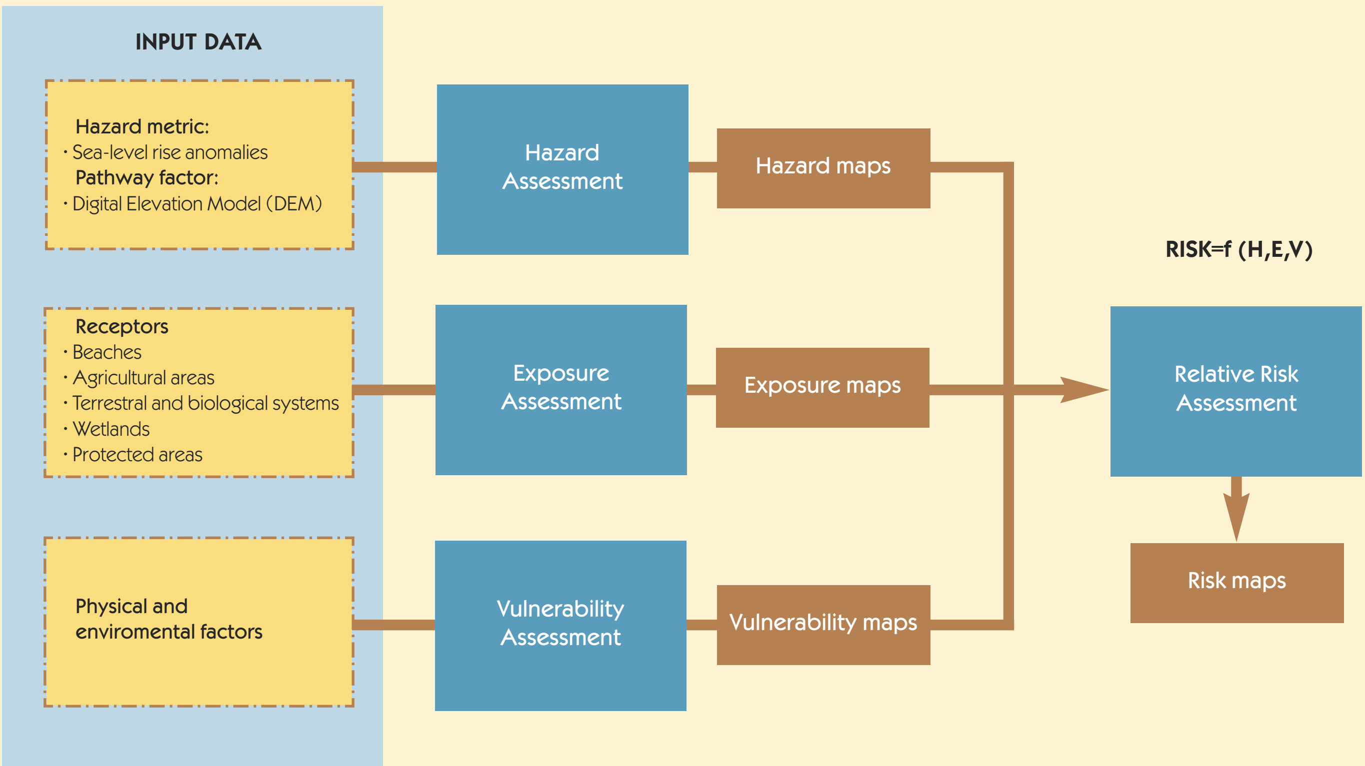

Figure A4.1 - Main steps of the RRA methodology applied for the evaluation of sea-level rise inundation in coastal areas.

The hazard assessment allows to identify low-lying coastal areas that could be potentially submerged by sea level rise, according to future climate scenarios. Considering the preferences of local stakeholders and the coherence of choices across Pilot studies in the Thematic Center 2 of OrientGate on Drought, Water and Coasts two thirty year periods were selected for the analysis: the medium-term timeframe 2021-2050 and the long term interval 2041-2070.

The hazard assessment was performed aggregating sea-level rise projections for the medium and long term periods, with topographic information coming from Digital Elevation Model (DEM). Sea level rise anomalies were provided by the Global Climate Model (GCM) CMCC-CM with a regular grid of about 80 km for the Euro-Mediterranean region. Specifically, for the considered case study area 12 grid points were selected in front of the coastline of Puglia region (Adriatic and Ionian sides). The analysis was focused on the results obtained for the RCP8.5 scenario, selected as the worst case with mean sea level anomalies of about 10 cm for the timeframe 2021-2050 and 21 cm for the timeframe 2041-2070. The hazard assessment was then performed applying a simplified approach that projects inland the sea water height (represented by the sea level anomalies) related to the mid and long term scenarios (i.e. 10 and 21 cm), and inundates all land areas at an elevation below this level using the topographic information coming from the DEM.

The exposure and vulnerability assessment allowed to identify and select the receptors (i.e. elements at risk) that can be subject to potential sea level rise inundation in the considered case study. For the Puglia case study the analysis was focused, considering the availability of homogeneous territorial data at the regional scale and the priorities expressed by local stakeholders, on several coastal receptors including beaches, wetlands, urban areas, protected areas, agricultural areas and terrestrial biological systems. The following assessment of vulnerability was focused on the evaluation of physical-environmental aspects determining the predisposition of a receptor to be adversely impacted by sea-level rise. Particularly, it was precautionary assumed that sea level rise affects all the receptors in the same way, causing a permanent loss (submergence) of receptors based on their elevation. The same vulnerability score equal to 1 was therefore assigned to each cell of the receptors localized in the case study area. Finally, the risk assessment phase integrated information about the sea-level rise hazard with the exposure and vulnerability of coastal receptors, in order to provide an integrated risk score, allowing to rank sub-areas at risk from permanent inundation due to sea level rise, according to the selected scenarios.
The methodology to evaluate the effect of sea-level rise in coastal areas was applied in Puglia by means of the DEcision support SYstem for COastal climate change impact assessment (DESYCO) (Torresan et al. 2013). Considering the availability of data and projections for the Mediterranean Sea side within the OrientGate project (see Section 4 of the main text) and the spatial resolution of the available data for the land side at the regional level (i.e. Regional Land Cover map (1:5.000); Digital Elevation Model 8m), the assessment was carried out at the meso-scale level (i.e. sub-national scale), adopting the land use/land cover classes proposed by the CORINE Land Cover dataset, as major spatial units of reference (Büttner et al. 2007). However, the methodology and the tool are sufficiently flexible to be applied at different spatial levels (e.g. micro scales) based on the purposes of the assessment, the geographical extent of the case study and the level of detail of input dataset. Moreover, the spatial resolution of the assessment was performed based on geographical units (i.e. raster cells) of 8m, representing the highest feasible detail according to the available land dataset. The geographical limits of the analysis were set according to the Coastal Regional Plan (PCR) (2009). A region of about 2.563 km^2 was defined, including a territory of variable length from the shoreline, following the pattern of important physical and socio-economic characteristics (i.e. geology, geomorphology, hydrography, vegetation system, presence of water bodies and lagoons, human use) of the Puglia coastal systems.

A.4.3 RESULTS

The application of the RRA methodology and DESYCO to the case study area produced a range of risk maps and statistics useful to synthesize the information about potential land (and receptors) losses due to sea level rise, and to facilitate the communication of results to stakeholders and decision makers. For what concern the hazard assessment, most of the coastal zone of the case study area (i.e. about 98%) resulted to be not exposed to sea level rise inundation in future timeframes. More precisely, only about 2 % of the coastal territory is hazard prone both for mid-term scenario (2021-2050) and for the long term one (2041-2070).

The exposure assessment highlights that wetlands and protected areas are widely represented in the case study area, especially in correspondence with the lakes of Lesina-Varano and the Gulf of Manfredonia. Agricultural areas (i.e. permanent crops, stable meadow-pastures, arable land) are spread all over the coastal territory while terrestrial and biological systems (i.e. natural grasslands and meadows, shrubs and forests) are distributed in small surfaces fragmented in the case study area. Finally, small surfaces of urban areas (i.e. residential, commercial and industrial areas) are located along the whole coastline mainly in correspondence with touristic urban

centers (i.e. Manfredonia, Otranto, Gallipoli). After the assessment of hazard and exposure, the following analysis of risks was focused on the evaluation of receptors at higher risk to be submerged by sea-level rise. The ranking of targets at risk at the regional scale showed that urban areas present very small surfaces at risk (only about 0.35 km^2 for the low and 0.89 km^2 for the medium SLR scenario). The other receptors (i.e. wetlands, protected areas, beaches, agricultural areas, terrestrial and biological systems) are mainly located in correspondence with Lesina and Varano lakes and around the Manfredonia Gulf, therefore specific statistics and maps of risk were produced for these two focus areas.
The analysis showed that "wetlands" is the receptor characterized by higher percentage, about 70%, of surface at risk for both scenarios and focus areas. Protected areas in Manfredonia show about 23% of surface at risk while only about 5% in Lesina-Varano. The receptor beaches, presents the 12% and 6% of surface at risk in Lesina and Manfredonia concentrated in small strips (10-40m) of territory in correspondence of low-lying sandy beaches (Figure A4.2).

The risk assessment for this receptor allowed to estimate also the length (km) of beaches at risk to be submerged by rising sea-levels, at the regional scale. About 25% (212 km) of the total length of the Puglia shoreline (865 km) resulted to be at risk (low and very low risk classes) in the mid-term scenario, up to 29% (250 km)

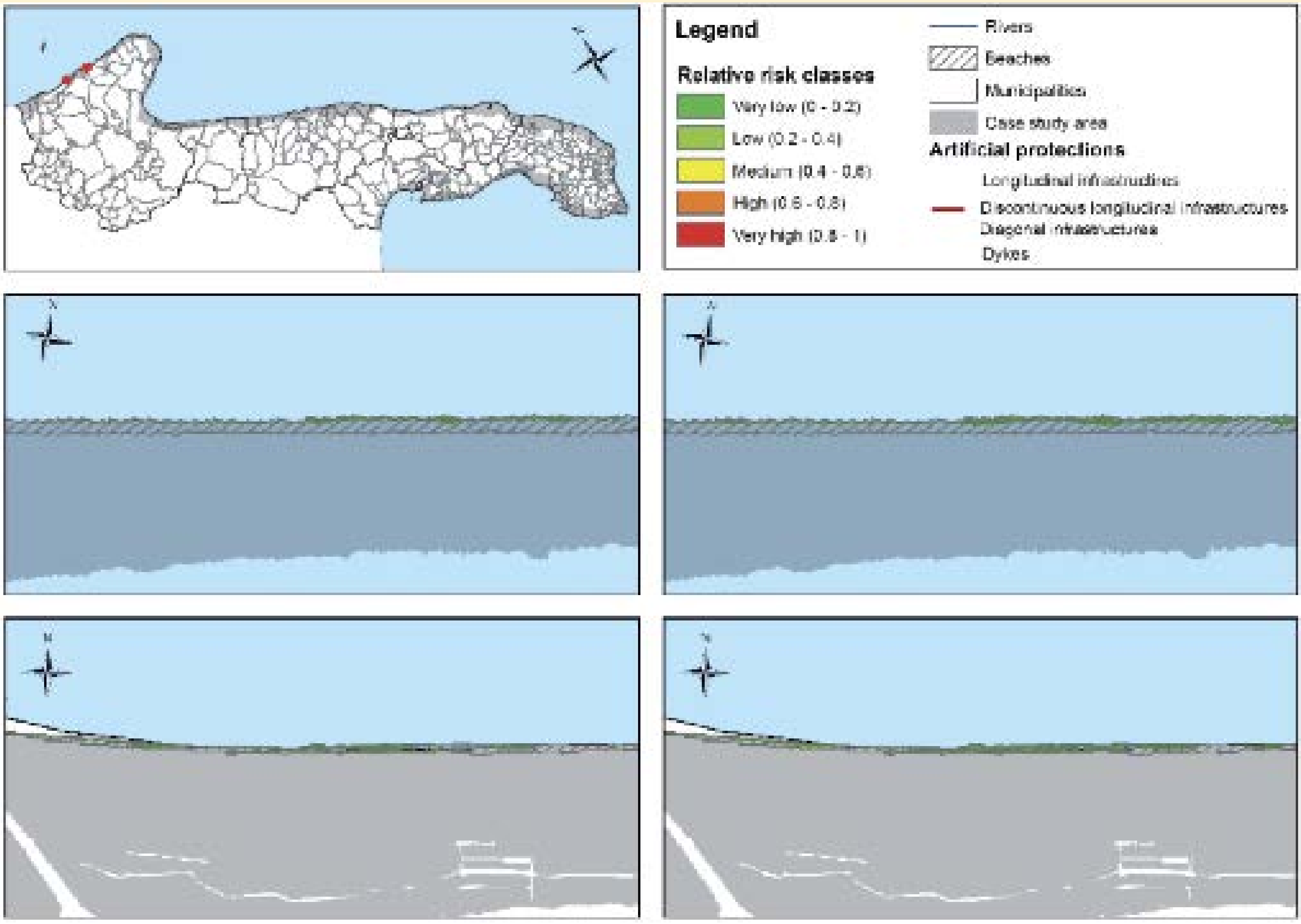

Figure A4.2 - Risk map for the receptor beaches, showing coastal parcels at risk in the focus area of Lesina- Varano, mid (a) and long-term scenario (b).

in the long-term sea-level rise scenario.

Finally, as far as agricultural areas are concerned, the surface at risk resulted less than the 4% (4.85 km^2) in the 'Lesina/Varano' focus area; and about 1% in Manfredonia (2.89km^2) while terrestrial biological systems present less than 1% of surface at risk in the Lesina - Varano area and about 10% (1,45 km^2) of surface at risk in the Manfredonia area.

A.4.4 CONCLUSION

The spatially resolved regional risk assessment approach applied to the coastal zone of the Puglia region allowed to produce screening risk maps and statistics supporting the identification and ranking of key areas and sensitive targets at risk to be permanently submerged by sea-level rise. The present assessment provides a first step analysis of potentially submerged areas, however, the results could be refined with higher resolution territorial data (e.g. high resolution laser scanning data) and with the evaluation of the role of existing defense barriers and subsidence phenomena influencing hazard intensity and exposure at the local scale. Moreover, a multi-stressor perspective should be adopted with the aim to provide a more integrated view of the multiple threats and coastal dynamics related to climate change in the investigated area (e.g. coastal erosion, storm surges, salt water inclusion into groundwater). Finally, considering the importance of specific productive activities in the case study area (i.e. tourism, salines, tourism, agriculture) an assessment of socio-economic value of receptors (i.e. touristic and recreative value of beaches, value of different crops' typologies) should be performed in order to estimate potential damages related to sea-level rise inundation.

The fruitful process of involvement of local stakeholders in the OrientGate project should also be empowered in the future, encouraging the development of a knowledge network between scientists and policy makers aimed at guaranteeing that the available climate information are used in the more efficient way to improve solutions for coastal adaptation.

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Annex A.5

Indicator list

SHORT NAME	SHORT DESCRIPTION	REFERENCE
BFI	Base Flow Index: The ratio of the base flow to the total flow.	Institute of Hydrology (1980)
SYCn	Indicator based on the area under the Storage Yield Curve (natural), representing the storage capacity needed to provide a given basin yield or, alternatively, the firm basin yield produced from a given level of water storage. Only based on natural inflow and calculated both on absolute and standardized (i.e. over Mean Annual Runoff) yield and storage.	New formulated indicator based on Thomas & Burden (1963).
SDI	Streamflow Drought Index: drought severity index based on the cumulative streamflow for overlapping periods of 3, 6, 9, 12 months within the hydrological year. Positive SDI values reflect wet conditions while negative values indicate a hydrological drought. Based on the SDI, five states of hydrological drought are defined.	Nalbantis and Tsakiris (2008)
SLR_HAZ	Sea level rise hazard: it aggregates sea-level rise projections with topographic data (e.g. DEM, Lidar) in order to identify and prioritize areas and targets that could be submerged by rising water levels, under changing climate conditions.	This report
SLR_RISK	Sea-level rise risk: it integrates information about the hazard (i.e. sea-level rise projections and topographic data) with the territorial exposure and vulnerability, in order to identify and prioritize receptors and coastal areas at risk of inundation due to sea-level rise.	This report
CDD	Consecutive Dry Days: maximum length of dry spell. It counts the largest number of consecutive days in chosen period where RR < 1 mm.	See OrientGate report on "Proposed set of indicators"; http://www.seevccc.rs/ORIENTGATE/
AI	Aridity Index: it is a numerical indicator of the degree of dryness of the climate at a given location. Let P be accumulated precipitation and PET potential evapotranspiration (under various formulations) in the chosen period, the aridity index for the period is given by P/PET.	See OrientGate report on "Proposed set of indicators"; http://www.seevccc.rs/ORIENTGATE/

SHORT NAME	SHORT DESCRIPTION	REFERENCE
NVPWR	Natural Variation of Potential Water Resources: it is the ratio between the area below the actual and future flow duration curves both derived in the natural scenario.	OrientGate report on the Pilot "Water resources and the use of hydroelectricity in Autonomous Province of Trento" and this report
SMEF	Sustainability of Minimum Environmental Flow: this index compares the actual and future frequency of occurrence of the minimum environmental flow (MEF) as described in the provincial/regional regulation by analyzing the actual and future duration curves evaluated at specific control sections over the basin in natural conditions.	OrientGate report on the Pilot "Water resources and the use of hydroelectricity in Autonomous Province of Trento" and this report
WSDI	Warm Spell Duration Index: it is a count of days in a span of at least six days where TX > 90th percentile.	See OrientGate report on "Proposed set of indicators"; http://www.seevccc.rs/ORIENTGATE/
PSMD	Potential Soil Moisture Deficit: it is the cumulated soil water shortage during the growing season.	See OrientGate report on "Proposed set of indicators"; http://www.seevccc.rs/ORIENTGATE/
SLR	Sea Level Rise: it represents the anomaly of the sea surface height above the geoid (ZOS variable in IPCC-AR5). The anomaly can be calculated as difference between the mean or median of two periods or, for a more precautionary choice, as maximum minus minimum of two periods, or the 90th percentile minus the 10th percentile of two periods.	This report
Stat-RO	RunOff Statistics: they include mean and percentile (indicating a ranking of runoff anomalies in the normal distribution fit of runoff events).	This report
ATR	Annual Temperature Range: difference between annual absolute maximum and annual absolute minimum temperature.	See OrientGate report on "Proposed set of indicators"; http://www.seevccc.rs/ORIENTGATE/
MAT	Mean Annual Temperature: mean temperature for the year.	See OrientGate report on "Proposed set of indicators"; http://www.seevccc.rs/ORIENTGATE/
APA	Annual Precipitation Amount: total precipitation in a year.	See OrientGate report on "Proposed set of indicators"; http://www.seevccc.rs/ORIENTGATE/
GDD	Growing Degree Days: the number of temperature degrees above a threshold base temperature (8°C or 10°C) in a chosen period.	See OrientGate report on "Proposed set of indicators"; http://www.seevccc.rs/ORIENTGATE/
R5mm	Precipitation days with a daily amount (RR) ≥ 5 mm. It counts the number of days in chosen period (during growing season; other seasons).	See OrientGate report on "Proposed set of indicators"; http://www.seevccc.rs/ORIENTGATE/
CWD	Consecutive Wet Days: it counts the largest number of consecutive days in chosen period where RR ≥ 1 mm.	See OrientGate report on "Proposed set of indicators"; http://www.seevccc.rs/ORIENTGATE/

SHORT NAME	SHORT DESCRIPTION	REFERENCE
PET-HA	Potential Evapotranspiration - Hargreaves: the Potential Evapo-Transpiration (PET) is a measure of the ability of the atmosphere to remove water through Evapotranspiration processes. The Hargreaves method requires monthly average of mean temperature, daily temperature range and extra-terrestrial radiation (RA, radiation on top of atmosphere expressed in mm/month as equivalent of evaporation). Daily temperature range is an effective proxy to describe the effect of cloud cover on the quantity of extra-terrestrial radiation reaching the land surface and, as such, it describes more complex physical processes with easily available climate data at high resolution.	Hargreaves (1994)
Ky	Yield-response factor: a yield response factor representing the effect of a reduction in evapotranspiration on yield losses. Captures the essence of the complex linkages between production and water use by a crop, where many biological, physical and chemical processes are involved.	FAO, Land and Water Division, Rome, Italy, 2012
HyDemCro	Hydro-demand of crops: It represents the degree to which the crops are influenced by the water stress. Vulnerability score is related to the Yield-Response factor (Ky) that indicates the relation between the water deficit and the reduction of efficiency.	This report
SystLoss	System Losses (Degree of efficiency): it represents the level of efficiency and robustness of the irrigation networks by losses' value of each Reclamation Consortia. System losses decrease the efficiency of the system and increase their vulnerability to climate change impacts.	This report
DiverSrc	Degree of diversification of sources: It represents the degree of which the different Reclamation Consortia tends to rely their demand on different sources (reservoirs or groundwater) to fulfil water demand for irrigation.	This report
HyDroHaz	Degree of fulfilment of the Consortia's demand (Mm^3/year): it represents the degree of fulfilment of water demand for irrigation due to changes in the hydrological pattern in selected river basins (Mm^3/year) compared with the total water availability stored in the different reservoirs.	This report
HyDroRsk	Hydrological drought risk: it integrates information about the hazard (i.e. fulfilment of water demand) with the territorial exposure and vulnerability, in order to identify and prioritize receptors (i.e. Reclamation Consortia, irrigated lands) at risk of hydrological drought for the irrigation compartment.	This report

Annex A.6

Glossary (list of definitions and acronyms)

20C3M	20th Century historical GHG concentrations
ARPA	Regional Environment Protection Agency
CMCC	Centro Euro-Mediterraneo sui Cambiamenti Climatici
CMIP5	Climate Model Intercomparison Project 5
CNR	Italian National Research Council
DEM	Digital Elevation Model
FDC	Flow Duration Curve
GCM	General Circulation Model
GDP	Gross Domestic Product
GHG	Green House Gas
HRU	Hydrologic Response Unit
IAMB	Istituto Agronomico Mediterraneo Bari
ICZM	Integrated Coastal Zone Management
IMELS	Italian Ministry for the Environment Land and Sea
IPCC	Intergovernmental Panel on Climate Change
LAP	Local Action Programme
MCDA	Multi Criteria Decision Analysis
NAP	National Adaptation Plan
NAS	National Adaptation Strategy
RCM	Regional Climate Model
RCP4.5	Representative Concentration Pathways 4.5 W/m^2
RCP8.5	Representative Concentration Pathways 8.5 W/m^2
RRA	Regional Risk Assessment
SEE	South East Europe
SLR	Sea Level Rise
UNCCD	United Nations Convention to Combat Desertification
UN-DRR	United Nations Office for Disaster Risk Reduction
UNISDR	United Nations International Strategy on Disaster Reduction
WPMP	Water Protection Master Plan
ZOS	Sea Surface Height above the Geoid

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