Climate Change Impacts on Water and Security in Southern Europe and neighbouring regions

A Summary for Policymakers from the CLIWASEC cluster of projects

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Contents

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Research highlights

CLIMB

■ Quick facts

FP7-Topic:	ENV.2009.1.1.5.2
Funding period:	01/2010 – 12/2013
Coordinator:	Ludwig-Maximilians Universität München (LMU, Germany)
Partners:	19
Website:	www.climb-fp7.eu
Contact:	Prof. Dr. Ralf Ludwig (project co-ordinator), ludwig@lmu.de Dr. Thomas Ammerl (project manager), ammerl@bayfor.org

- Climate change contributes, yet in strong regional variation, to water scarcity in the Mediterranean; other factors, e.g. pollution or poor management practices are regionally still dominant.
- Rain-fed agriculture needs to adapt to seasonal changes; stable or increasing productivity likely depends on additional irrigation.
- Tourism could benefit in shoulder seasons, but may expect income losses in the summer peak season due to increasing heat stress.
- Local & regional water managers and water users, lack, as yet, awareness of climate change induced risks; emerging focus areas are supplies of domestic drinking water, irrigation, hydro-power and livestock.
- Data and knowledge gaps in climate change impact and risk assessment are still wide-spread and ask for extended and coordinated monitoring programs.

CLICO

■ Quick facts

FP7-Topic:	SSH.2009.4.2.1
Funding period:	01/2010 – 12/2012
Coordinator:	Universitat Autònoma de Barcelona (UAB-ICTA, Spain
Partners:	14
Website:	www.clico.org
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- There is no evidence of a link between hydro-climatic variability and domestic water conflicts.
- Democracies are likely to have more domestic water conflicts than autocracies, but autocracies are likely to have more violent water conflicts than democracies.
- Wars and violence increase the vulnerability of the population to hydro-climatic hazards.
- States often maladapt, that is they pursue adaptation policies that end up increasing, instead of decreasing, the vulnerability of large parts of their population.
- Social security and civil security institutions – such as entitlement schemes, unemployment insurance, universal health care, or flood relief agencies – are central for reducing vulnerabilities and providing human security.

WASSERMed

■ Quick facts

FP7-Topic:	ENV.2009.1.1.5.2
Funding period:	01/2010 – 12/2012
Coordinator:	Centro Euro-Mediterraneo per i Cambiamenti Climatici (CMCC, Italy)
Partners:	12
Website:	www.wassermed.eu
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- The warming trend and changes in precipitation patterns could affect the composition and functioning of natural & managed ecosystems.
- Growing non-agricultural water needs will strongly affect agricultural water shortages in the Southern Mediterranean; Water resources for environmental preservation, are likely to de-crease, especially in the MENA region.
- Intra-Mediterranean virtual water trade is likely to decline, with virtual imports from central and northern Europe increasing.
- Improved water efficiency appears to significantly mitigate the economic impacts of water scarcity, especially in the Northern areas.
- A seasonal change in tourism is probable due to improving climate conditions in spring and autumn and a slight deterioration in summer.
- Crop water requirements are very likely to increase in all case studies, requiring specifically adapted management practices.

CLIWASEC – A research cluster on Climate Change Impacts on Water and Security in Southern Europe and neighboring countries

The Mediterranean region is experiencing a broad range of threats to water security. According to climate projections, the region is at risk due to its pronounced susceptibility to changes in the hydrological budget and extremes, which is expected to have strong impact on the management of water resources and on key strategic sectors of regional economies. Related developments have capacity to exacerbate tensions, and intra- and inter-state conflict among social, political, ecological and economic actors. Effective adaptation and prevention policy measures call for multi-disciplinary analysis and action.
This document is intended as a comprehensive summary for policymakers, highlighting the scientific results elaborated in the research cluster CLIWASEC, composed of three research projects, all funded under the Seventh Framework Program for Research and Technological Development (FP7).

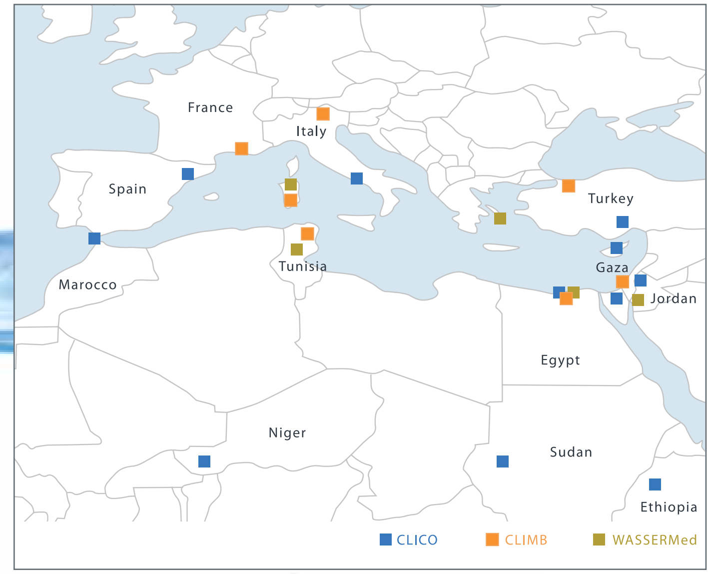
The research cluster CLIWASEC

The European Commission actively prepares Europe and neighboring regions for climate induced ecological and socio-economic challenges that lie ahead and has placed related priority research topics in the Seventh Framework Program for Research and Technological Development (FP7). In order to better assess the consequences and uncertainties regarding climate impacts upon human-environment systems, a coordinated topic had been launched in 2009 between Theme 6 ('Environment (incl. climate change)') and Theme 8 ('Socio-Economic Sciences and the Humanities') of the programmatic setup of FP7.

Three independent projects formed the research cluster CLIWASEC (CLimate change Impacts on Water and SECurity, www.cliwasec.eu) for multi-disciplinary scientific synergy and improved policy outreach. The cluster comprised a critical mass of scientists from 44 partners (29 institutions from the EU, 5 institutions from S&T countries and 10 international institutions) to build relationships with relevant policy representatives and stakeholders at EU level and Mediterranean and neighbouring countries covered by the projects. It tackled most relevant research questions with regard to climate change impacts on water resources as a threat to security in an integrated way:

- **WASSERMed** – Water Availability and Security in Southern Europe and the Mediterranean (funded under FP7-ENV), co-ordinated by Prof. Roberto Roson (CMCC, Italy)
  www.wassermed.eu
- **CLICO** – Climate Change, Hydro-Conflicts and Human Security (funded under FP7-SSH), co-ordinated by Prof. Giorgos Kallis und Dr. Christos Zografos (UAB-ICTA, Spain)
  www.clico.org
- **CLIMB** – Climate Induced Changes on the Hydrology of Mediterranean Basins (funded under FP7-ENV), co-ordinated by Prof. Dr. Ralf Ludwig (LMU, Germany)
  www.climb-fp7.eu

Endangered: agricultural productivity, drinking water supply



1. Cyprus
2. Andalusia-Morocco Biosphere
3. Sarno – Italy
4. Niger – Niger
5. Alexandria – Egypt
6. Sudan
7. Seyhan – Turkey
8. Jordan River – Jordan
9. Sinai Desert – Egypt
10. Nile – Ethiopia
11. Ebro – Spain

1. Thau – France
2. Rio Mannu, Sardinia – Italy
3. Chiba, cap Bon – Tunisia
4. Noce, Trentino – Italy
5. Izmit Bay, Kocaeli – Turkey
6. Nile Delta – Egypt
7. Gaza – Palest.-admin. areas

1. Syros Island – Greece
2. Merguelli – Tunisia
3. Sardinia – Italy
4. Jordan River – Jordan
5. Rosetta area – Nile Delta – Egypt

Scientific Synergy and Policy Outreach

The three projects joined forces to identify and foster scientific synergies and to establish a more focused and efficient policy outreach strategy. Major building blocks of this collaboration contained scientific exchange and review, identify and utilize complementary monitoring and modeling methods, harmonize and share data and discuss dissemination strategies or elaborate and propose adaptation alternatives. The projects agreed on joint annual general assemblies, a joint dissemination plan for presenting the results of the three projects in the scientific literature and the setting up a cluster project web-portal, which hosts and advertises further related projects. Policy briefs of the projects findings were prepared and posted on the cluster website on an event basis. At any time, regional, national and international stakeholders and policy bodies were and are still invited to express their research needs and recommendations.

To optimize benefits from the variety of cluster partners' competences, joint research must be devoted towards a better understanding and description of interfaces in such complex systems. Two main challenges lie ahead: i) bridging scales and ii) quantifying and reducing uncertainty. Integrating different methods from natural and social sciences can contribute to better conceptualize each project's research findings and propose solutions for water resource management under climate change, especially when a variety of different situations can be covered in complementary case studies.

The case studies

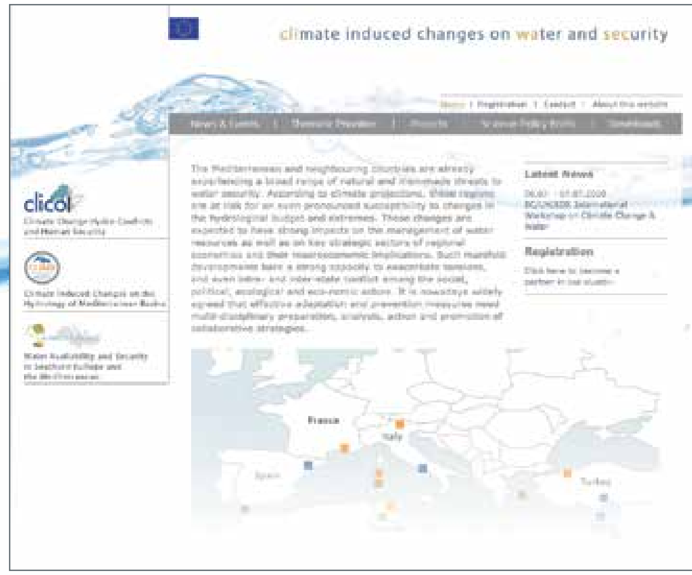
The analysis of climate change impacts on available water resources and security is targeted on Southern Europe and neighbouring regions. The case studies, selected according to project specific criteria, are complementary in either scope, region or scale.

- **WASSERMed:** Syros Island (GR), Merguellil (TN), Sardinia (IT), Jordan River (JO), Nile (EG)
- **CLICO:** Cyprus, Andalusia-Morocco biosphere, Sarno (IT), Niger, Alexandria (EG), Sudan, Seyhan (TR), Jordan River, Sinai Desert (EG), Nile (ET), Ebro (ES)
- **CLIMB:** Noce (IT), Rio Mannu (Sardinia, IT), Thau (FR), Chiba (TN), Izmit Bay (TR), Gaza (Palest. Adm.), Nile Delta (EG)

Bridging Scales

Besides the different perspectives on climate induced changes as a threat to water security, the CLIWASEC projects were considering different scales, as processes with a pronounced spatial character (e.g. precipitation, evapotranspiration) interact with linear processes (e.g. river runoff) as well as with processes without any direct connection to one specific spatial scale (e.g. economic, political or social decision making, where impacts are spatially disaggregated to various scales). Depending on selected process and scale, these processes can be described i) explicitly (microscale – field to small-sized catchments in the range of up to several 100 km²), ii) mechanistically (mesoscale – in the order of medium sized river catchments in the range of up to several 1.000 km²) or iii) effectively (macroscale – in the order of regions, possibly ranging up to over 100.000 km²). The transition from microscale to macroscale and back is always complex if the described processes are not linear and the case studies being investigated are heterogeneous, such as the ones proposed by the CLIWASEC projects. While maintaining project research focus, one great opportunity for project collaboration comprises improved descriptions of scale interfaces. The spatially explicit results of distributed scale-crossing (environmental) models, such as the ones used in CLIMB (micro- to mesoscale) and WASSERMed (meso- to macroscale), can support and feed a yet largely unused interface to socio-economic sciences, which transfer the high-resolution signal of climate induced hydrological change into relevant socio-economic information at the appropriate scale. Decisions and courses of action which are consequently derived, such as any change in management practices, can in return be spatially disaggregated using the same interface to provide an additional external force for the hydrological/environmental models operating at the small scale. In this way, research groups can follow their sectoral expertise and joint efforts can focus on the definition of interfaces and their functionality to bridge scales.

Two study areas: Sardinia, Nile River (Egypt)



Cagliari 2011: At the joint General Assembly of CLIMB-CLICO-WASSERMed

Quantifying and Reducing Uncertainty

The current potential to develop appropriate regional adaptation measures towards climate change impacts suffers heavily from large uncertainties. These spread along a long chain of components, starting from the definition of emission scenarios to global and regional climate modeling to impact models and a subsequent variety of management options. The critical mass of research capacity obtained through clustering the projects will allow for quantifying uncertainties in climate change impact analysis for the Mediterranean and neighbouring regions to a yet unprecedented level, as most of the inherent contributors to uncertainty are being addressed. Again, a specified definition of interfaces, linked to an exchange of data, methods and model results, is the key prerequisite. Most projects dealing with climate change impact analysis are usually making vast use of available Global and Regional Climate Model data (GCM and RCM respectively) without ever exchanging the methods and reasons for making their climate data selections. The audits that led to select the best regional performers as compared to observed values during the climatic reference period can be openly discussed and exchanged and thus contribute substantially to the reduction of uncertainty. Conjointly evaluated procedures for downscaling RCM data delivered the driving inputs for subsequent (hydrological) impact models, transferring a future climate signal into hydrological quantities at the catchment or landscape scale.

However, very limited quantitative knowledge is as yet available about the role of hydrological model complexity for climate change impact assessment, where predictive power becomes more and more important and raises the demand for process-based and spatially explicit model types. Hydrological model ensembles serve to analyse existing models and help to identify the appropriate level of model complexity, and thus to determine the data specifications required to provide robust results in a climate change context.

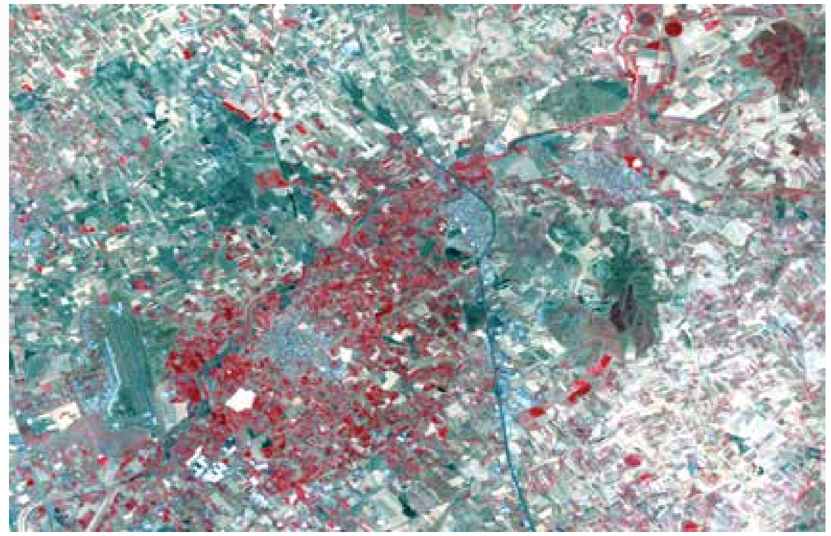
The joint research forces provided by clustering expands the possibilities for data mining and exchange. Data uncertainty can be reduced by creating a potent and multi-scale data repository that serves to parameterize integrated impact models and comprehensively describe the regions' vulnerability, associated risks and adaptive capacity. Further, the lack of awareness or understanding of the complex climate-resource-society dynamics often leads to take inappropriate or no measures at all. An inventory of international, national and regional policies dealing with responses to climate change, water resources management, responses to hazards and disasters, and security in the region, is essential for proposing a suitable policy framework to integrate security, climate change adaptation and water management issues and specific recommendations for policy streamlining at the UN, EU, national and regional levels.

Participation to CLIWASEC

The clustering of projects can help push forward current understanding of the interactions of climate change impacts on ecological, economic and social components of human-environment systems. Even though the individual research projects have come to a close, the CLIWASEC cluster still cordially invites other projects and initiatives active in these fields to cooperate and communicate under this common framework.
Please register at http://www.cliwasec.eu/registration/registration.php to become a partner in the cluster and to optimize communications, share and exchange knowledge and information and to discuss individual and common experiences. This is essential for advancing towards optimized regional solutions for water resources management under climate change.

CLIMB – Climate Induced Changes on the Hydrology of Mediterranean Basins – Reducing Uncertainty and Quantifying Risk

In its 4-year design, CLIMB, a network of 20 partners from 9 countries (Germany, Egypt, Tunisia, Turkey, France, Italy, Austria, Palest. Adm. Areas, Canada), analyzed ongoing and future climate induced changes in hydrological budgets and extremes across the Mediterranean and neighboring regions. The work plan was targeted to selected river or aquifer catchments, where the consortium employed a combination of novel field monitoring and remote sensing concepts, data assimilation, integrated hydrologic modeling and socioeconomic factor analyses to reduce existing uncertainties in climate change impact analysis. Advanced climate scenario analysis was utilized and available ensembles of regional climate model simulations were audited and downscaled. This process provided the drivers for an ensemble of hydrological models with different degrees of complexity in terms of process description and level of integration. The results of hydrological modeling and socio-economic factor analysis were applied to develop a risk model via a spatial Vulnerability and Risk Assessment Tool, serving as a platform for dissemination of project results, including communication and planning for local and regional stakeholders. An im¬portant output of the research in the individual study sites is the development of recommendations for an improved monitoring and modeling strategy for climate change impact assessment.



Sardinia, July 2010: Irrigated versus non-irrigated agriculture

CLIMB – Motivation and Structure

Climate change is impacting the Mediterranean region in manifold and distinct ways. Observed trends and projections for the future indicate a strong susceptibility to changes in the hydrological regimes, an increasing general shortage of water resources and consequent threats to water availability and management. However, it must be clearly stated that current uncertainties in climate projections and subsequent impact models, a yet incomplete understanding of the impact of a climate change signal on economic mechanisms or the lack of an elaborate and integrated human security conceptual framework are imposing strong limitations on water-related decision-making under conditions of climate change. This is particularly true due to the general lack of regional data and the yet unresolved mismatch of spatial and temporal scales of operation from different scientific perspectives.

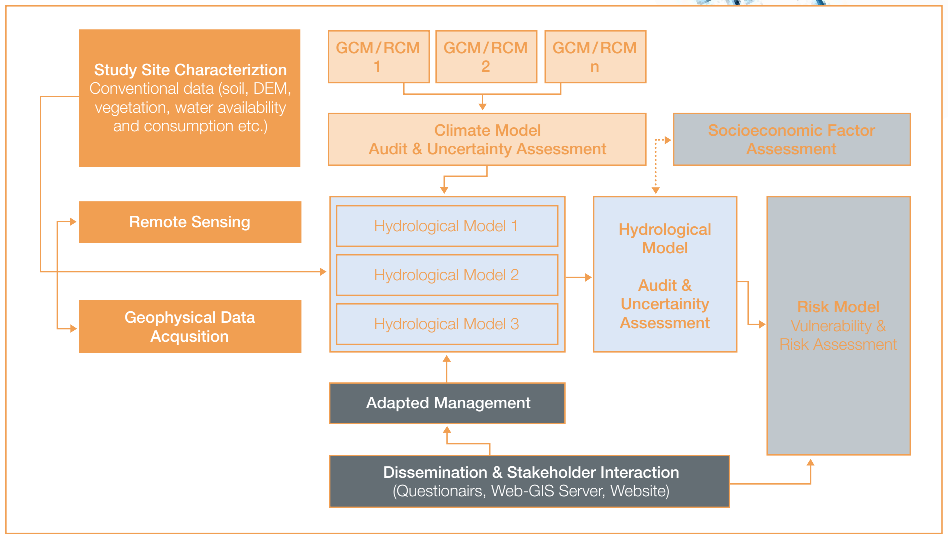
The structure and implementation of the CLIMB project was setup to address the above mentioned issues, focusing on its inter-linkages and interdisciplinary analyses around the quantification of uncertainties in climate change impact and risk assessment.

Data Access – The CLIMB Geoportal

In order to discover, visualize and provide access to selected main results of the project, a Geoportal has been established under http://lgi-climbsrv.geographie.uni-kiel.de. The focus group of the Geoportal are regional planners and stakeholders.

The CLIMB Geoportal

The CLIMB-Geoportal serves as the central platform for interchanging spatial data and information. It stores and provides spatially distributed data about the current state and the future changes of the hydrological conditions within the seven CLIMB test sites around the Mediterranean. Maps of the outcome of the hydrological models – validated by the CLIMB partners – are offered to the public as web mapping services (WMS). Besides map information, the portal enables the graphical display of time series of selected climate impact and risk relevant variables.



The CLIMB conceptual framework

Environmental Monitoring and Data Collection

An early data availability assessment revealed serious informational, temporal and spatial hydro-meteorological data gaps in the investigated regions. Specific monitoring plans for climate change follow up studies must be established in the Mediterranean basin. The specific needs are often site-specific and thus need a local and regional approach. Research is still needed to better understand hydrological processes, specific to semi-arid regions.

Guidance report

A guidance report was elaborated to overview the main study site characterization requirements from the different CLIMB basins. The site attributes were selected in order to provide an understanding of the physical basin characteristics, harmonize socio-economic information, highlight individual basin management procedures, compare observations among study sites and establish a basis for the anticipated hydrological modeling activities.

Data collection and analysis

CLIMB specifically designed field campaigns and remote sensing data analysis to mitigate the deficiencies of limited data availability. These activities greatly increased the level of understanding of hydrological conditions at each study site and helped to determine the most sensitive parameters for the subsequent modeling phase. Field data collection efforts included topographic surveys, vegetation surveys, collection of water and soil samples and novel hydro-geophysics surveys.

Further, radar and optical remote sensing data were employed to provide crucial spatial information for the parameterization, calibration and spatial validation of the hydrological model ensemble. Focus was given to the following parameters and state variables (1) land use/land cover (LULC), (2) soil moisture, (3) vegetation parameters (albedo and leaf area index (LAI)), (4) infiltration information and (5) snow cover.

CLIMB Basin Information Repository

Finally, a CLIMB Basin Information Repository was constructed for all CLIMB basins. It provides a previously unavailable screening of all available information related to basic characteristics of topography, soils and land uses within the basins, available resources for surface water and groundwater, existing climatic data as well as general socio-economic conditions and sources of pollutions. It provides key site characteristics, the state of monitoring within each basin and a tool for comparison between the CLIMB case studies.

Climate Model Auditing and Downscaling

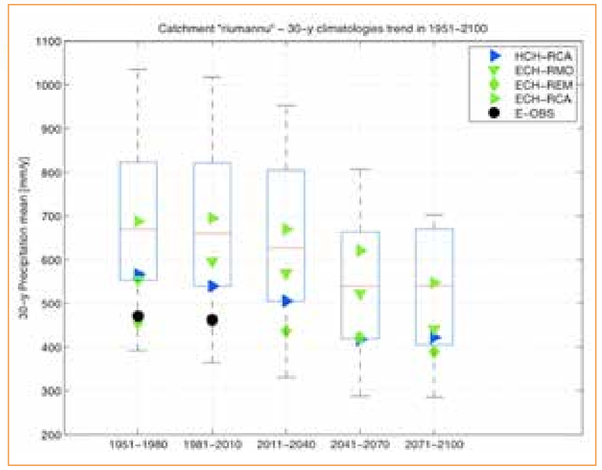
Climate model signals constitute the main forcing in a multi-model cascade (i.e. climatological, hydrological, socio-economical, crop evolution models etc.), implemented for the evaluation of climate change impacts. An auditing scheme and downscaling procedures have been developed to reduce uncertainties and provide reliable information at scales relevant for subsequent hydrological modeling. The selection and subsequent post-processing procedures in this CLIMB working task followed the following routine:

Climate Models selection

An intercomparison of the performances of several climate models was conducted, taking into account their effectiveness in reproducing the precipitation and temperature fields as well as the climatologies in all Mediterranean catchments considered in the CLIMB project. The set of climate model outputs was extracted from the FP6 ENSEMBLES project database, generated by coupling different GCM (Global Climate Model) and RCM (Regional Climate Models) outputs. To evaluate climate model performances, E-OBS precipitation and temperature datasets were used as reference fields to select the four best-performing GCM-RCM combinations in the region.

Large scale bias correction

Calibration and bias correction of the climatic signals were performed in each catchment area, using E-OBS precipitation and temperature data and a procedure based on probability distribution matching



Overall climate forcing uncertainty.
Boxplot of climatological means of precipitation (mm/y) over the five 30-year periods between 1951 and 2100 for the 14 ENSEMBLES models: lines of boxplots correspond to median and quartiles, while whiskers extend to the minimum and maximum values from the considered RCMs.

Local scale bias correction

Due to low station density, E-OBS failed in some sites to reproduce small scale features of precipitation and temperature fields. In order to overcome this source of uncertainty, the mean areal monthly precipitations and temperatures were calculated for each catchment area using local data (i.e. made available from CLIMB partners) to evaluate and properly correct the residual biases.

Small scale interpolation and downscaling

Different downscaling schemes were applied to interpolate from RCM to smaller scales (1-5 km resolution) to reproduce the small-scale variability introduced by orographic effects and the intrinsic intermittency of meteorological fields. For precipitation, the applied methods included a multifractal model for space-time rainfall downscaling.

Overall uncertainty of climate forcing

All steps described above aimed at reducing the uncertainties related to the climatic component, while introducing the natural small scale variability unresolved at climate model grid scales. Hence, the main achievement in this task is the evaluation of climate model uncertainties at local scales, and the quantification of their contribution to the overall uncertainty of climate change impact assessments. The figure above compares the initial spread in the climatology of all climate models extracted from ENSEMBLES, with the spread of the four best performing ones selected for subsequent hydrological simulations.

Climate change impacts on water resources in the CLIMB case studies

The CLIMB research framework is based on the implementation of multi-model hydro-meteorological ensembles in all seven case studies and the comparison of changing hydrological quantities from a reference (1971-2000) to a projection period (2041-2070).

The analyses reveal a general reduction in annual precipitation sum of varying magnitude and moderate shifts in the seasonal rainfall patterns and an overall increase in drought risk. In conjunction with higher temperatures in all seasons and the consequent increase in potential evapotranspiration (ETpot), the climatic water balance develops negatively and actual evapotranspiration (ETact) diminishes as a result of drier soils. An exception to this general behavior is the Noce catchment in the Southern Alps, where higher precipitation is expected for the future. The most relevant changes and impacts observed in the individual study sites are summarized as follows.

Thau, France

The reduction of precipitation in the future period by 6% is accompanied by an increase of the ETpot due to the increase of temperature. Consequently, a reduction of the ETact (3%) and a more significant reduction of surface runoff (13%) are projected. The significant reduction of available surface and subsurface water resources are expected to have impacts on freshwater discharge rates to the Thau lagoon.

Rio Mannu di San Sperate, Sardinia, Italy

Annual precipitation is expected to decline by about 12%, while ETpot increases slightly (1-14%) due to rising temperatures. Mean soil water content decreases by about -10% and a relatively strong reduction in ETact during the spring months indicates a potential threat to agricultural productivity in the growing season. Runoff is going down by 15-20% and all models agree on a substantial increase in the number of low flow days, further diminishing irrigation potential from surface runoff. Overall, the total available water reduces significantly (15-23%).

Noce, Trentino, Italy

The model ensemble projects a similar catchment functioning in the future scenario. Due to the combined effects of the rise of temperature and of the increase of precipitation (6-9%) both the actual evapotranspiration (10-12%) and especially total annual runoff (16%) increases. Strong consensus is reached in projecting a large reduction of snow water equivalent (-65% to -63%), supporting a much higher water availability for winterly hydropower production. As runoff is reduced in spring and summer months (May to August), reservoir management must be adapted to support an increasing irrigation demand during these seasons.

Kocaeli, Izmit Bay, Turkey

The model ensemble reveals little change for the Turkish case study. Growing temperatures, decreasing precipitation (-3%) and reduced ETact (-7%) neutralizes any change in annual runoff volume. However, a significant decrease in snow water equivalent imposes changes in the annual runoff cycle and allows for greater freshwater discharge into Izmit Bay during the winter months.

Gaza, Palestinian Administered Areas

Total annual precipitation reduces by 9%, reaching an average of 300 mm for the 2050-horizon. In reaction to decreasing soil moisture, ETact is further reduced. A 15% reduction of infiltration is expected to have a diminishing impact on groundwater recharge and subsurface water resources in this case study region. These results, in conjunction with an enormous population growth and demand for high irrigation for agricultural productivity, indicate that the existing water scarcity in the Gaza strip is likely to grow very rapidly.

Nile Delta, Greater Alexandria and Gharbia Governorate

Changes in in-situ hydrological quantities remain relatively small and certainly below the level of model uncertainty. Only temperatures increase considerably, the projected reduction of precipitation is very low (-2%) and results in a slightly decreased soil water content. Existing pressures on water resources, partly related to climate change, are however manifold and diverse; the region is highly vulnerable due to urbanization, soil and groundwater salinization, pollution, land degradation and poor management practices.

Chiba, Cap Bon, Tunisia

The multi-model ensemble projects mean annual precipitation to decline by 18%, while ETpot increases by 7-12%. Due to a reduction in soil water content (by 14-22%), ETact goes down by about 11%. Most importantly, surface runoff (39-51%) and groundwater recharge (22-52%) reduces significantly. In total, the projections reveal a partly dramatic reduction of about 30% in total available water, which imposes strong pressures especially for agricultural water uses, as much of the negative change is located in the fall and spring growing seasons.

Uncertainty Assessment and Risk Modeling

CLIMB focuses on investigating two kinds of uncertainties within the hydrological impact modeling and the socio-economic vulnerability factor/risk assessment (related to income loss) for the agricultural sector and tourism. One kind of uncertainty arises due to the effect of using several climate data sets on a final and robust model configuration of a respective hydrological impact model or vulnerability model, named Climate Signal Uncertainty Study (CUS). The second kind of uncertainty stems from the effect of performing CUS with several hydrological impact models or different settings of a vulnerability model named Model Structure Uncertainty Study (MUS). CUS and MUS are investigated in the case sites Chiba basin, Tunisia, as well as Rio Mannu di San Sperate, Sardinia, for a selected set of hydrological impact models.

Findings about climate induced changes derived within the hydrological impact modeling efforts and associated uncertainties are combined with the socio-economic vulnerability factor/risk assessment for the agricultural and tourism sector. This is used to create a comprehensive risk model of income loss for each sector. In agriculture, an empirical approach and the AQUACROP model are used to simulate crop yield responses associated to the simulated climate change impacts for two crops, namely tomatoes (Chiba basin only) and winter wheat (both super sites), and for two kinds of management practices, namely under rain-fed and irrigation conditions. For the tourism sector, temperature and precipitation data from climate models are driving a special tourism model which assesses the impact of changing climate conditions on revenues in tourism. This results in considerable uncertainty due to a span of simulated annual values, further used as input for the subsequent risk assessment. A series of quantitative (derived within preceding modeling efforts) and qualitative aspects (directly or indirectly derived from modeling work and local knowledge) are brought together to create a holistic picture for the risk assessment.

Risk is understood as a likelihood of occurrence that water supply cannot meet the water demand in a case study.

Risk assessment in Agriculture (example: Chiba basin, Tunisia)

Risk assessment for the agricultural sector in Chiba basin investigates climate change impacts on crop yields of tomato and wheat. The risk analysis indicates the following:

- Assuming unlimited water resources, tomato yields are expected to increase by 20-23% in 2041-2070, if the amount of water required for irrigation is increases by 11%
- An irrigation threshold exists, below which yields decrease and the risk of crop failure strongly increases:
  a. for constant irrigation and “business as usual management”, yields are expected to decrease by 2%.
  b. for irrigation decreasing by 10% and “business as usual management”, yields are modeled to decrease by 45%.

c. for irrigation decreasing by 10% and only August 15th plantings are allowed, yields are modeled to decrease by 24%.

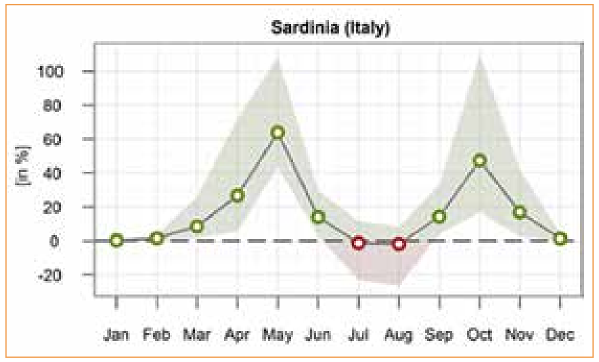
- As an adaptation measure, water efficiency of the tomato production can improve by using mulching.
- Wheat yields, without irrigation, are expected to increase by 7 – 16% by 2041-2070
- Introducing irrigation increases yields by 30%, but may require about 2,000 m3/ha/year by 2041-2070
- Using empirical modeling and assuming no increase in producing area or irrigation, climate change is expected to
  1. increase the production of vegetables by 12%;
  2. increase the production of citrus fruit by 2%;
  3. increase the production of legumes fruit by 8%;

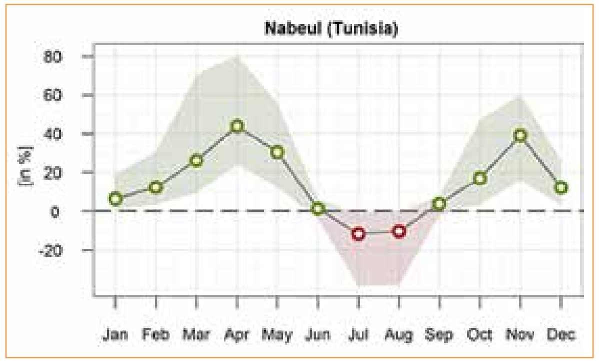
Risk assessment in Tourism

Using a simple climatic beach index about tourists' perceptions on unacceptably temperature and rain conditions for "sea, sand and sun" (3S) tourism, potential impacts of climate change on tourism in the wider surroundings of the two super sites were analysed. According to this index, climatic conditions for the dominant tourism type in the surroundings of the two super sites – i.e. 3S tourism – are expected to further improve in shoulder seasons, but may deteriorate in the current summer peak season (particularly in July and August) due to increased heat stress. Hence, based on the currently observed relationship between tourism demand (indicated by overnight stays) and the applied climatic beach index, there is a chance of climate-induced income gains during the shoulder seasons in spring and autumn and a risk of climate-induced income losses during the summer months. Annual net impacts are however expected to be (slightly) positive .

Stakeholder Interaction

In order to have an operational dissemination of hydrological modeling results, CLIMB addressed the question of security threats through an analysis of water uses and rivalries in each case study. Stakeholders have been considered in two main categories: water users and water managers. Individual interviews, meetings and implementation of questionnaires were conducted and provided the following results on:





Expected change in overnight stays due to a change from reference climatic conditions (1971-2000) to future climatic conditions (2041-2070). Shaded areas represent the uncertainty whereas circles indicate the average of the eight different modelling results.

- the ranking of priorities in water uses
- the main pressures on water resources for the past and the next 20 years

The ranking of priorities in water uses

Stakeholders have a clear perception of what is the first priority in water uses: domestic use to supply inhabitants' requirements. Several water uses compete for the second level of priority: irrigation, livestock supply or industrial needs. Water managers, however, consider irrigation and hydropower as 'their' second priority. In fact, some water users are neither aware of the multiplicity of water uses in their water basin nor of the origin of the water. This is not the case in the presence of efficient water governance, such as in the French or in the Gaza site. Rivalry between water uses is most prominent in low intense events of water scarcity, when existing water resources must be shared among different interests; tensions between water uses are unlikely during severe droughts events, when stakeholders accept the need to first supply domestic water use.

Main pressures during the past 20 years and for the next 20 years

Notably, the main pressure on water resources in the Mediterranean region during the last 20 years is linked to population growth and urbanisation, dominant even over agricultural irrigation. For the near future, stakeholders in the CLIMB study areas expect urbanisation rates to slow down but consider, at the same time, an increase in domestic water use. While local and regional stakeholders don't perceive tourism as a major source of water demand in the case studies, an important tourism pressure on water resources is undoubtedly present due to the interconnection with more remote areas. This mismatch reveals the difficulty to identify the appropriate scale for water resources management under and for climate change conditions.
Stakeholders are divided in their site specific assessment for future water needs:

- In the Noce case study, an entire conversion of apple trees to drop irrigation was performed and agricultural areas can not be extended.
- In the Gaza strip, population growth will imply new water demands for irrigation to supply the require agricultural production.

There are also multiple opinions around the potential evolution of water availability: Water managers trust water availability to increase, but also expect, in accordante with water users, that new water resources will be required. These results reflect a knowledge gap, especially among water users, around the variety of water management solutions, either already available or at least possible at the basin scale. In response to an increase in water demand, external water resources have already been integrated:

- In the Sardinian case study, water resources are regionalised by installing one responsible water authority and a technological hydraulic connection of different basins.
- In the French case study, to comply with population growth, the salinisation of local water resources and the connection between two external hydrological basins, the Hérault and the Rhône rivers, have been implemented.
- For the Tunisian case study, even while there is a local dam collecting surface runoff, water resources management is nationalized, installing major water transfer systems from the North to the South.
- In the Gaza strip and the Nile Delta case studies, the situation becomes even more complex due to geopolitical issues around transboundary river systems.

The use of water resources to support environmental requirements is expected to increase. This can be mainly attributed to the European sites, a san immediate response to the WFD and the corresponding ecological minimum flow. The deterioration of water quality, has been recognized by both water managers and water users and raises awareness about the direct impact and responsibility of human activities.

Overall, "climate change" has almost not been cited by stakeholders during both interviews and open questions in the questionnaires. This is even emphasized by the fact that decreasing precipitation is not considered a relevant or threatening issue in the coming 20 years. This confirms the need to continue all efforts to disseminate the state of knowledge on climate change impacts in the Mediterranean Region, especially to local water managers.
As of today, the main response to an increasing water demand in the Mediterranean, while not yet considering climate change as a driving force, is a progressive externalization of water resources. Many stakeholders do not seem to yet realize any limits to this extension within national borders and no clear limits even on international grounds. All case studies with an existing water management plan mention desalination as an option for the Mediterranean region to counteract water scarcity.
This important output raises some questions to water policy and governance:
i) Are the national and international legislations ready to answer potential issues linked to this new water resource? And ii) Should this new water resource be included in hydrological modeling for water management planning scenarios?

CLICO – Climate Change, Hydro-conflicts and Human Security

CLICO mobilized 14 research teams from Europe, North Africa, Sahel and the Middle East, bringing together experts in water resource, vulnerability, and peace and security studies. It sought to discover whether the effects of climate change in terms of water scarcity, droughts and floods in the region present a threat to human security by exacerbating social tensions and intra- and inter-state conflicts. The study also considered whether climate change might be a catalyst for cooperation and peace. In some places the lack of understanding of the complex climate-resource-society dynamics is used as an excuse for not taking measures, in other places inappropriate measures may be taken. The motivation for the CLICO project was to address this gap in basic knowledge and hence help design better policy responses. To achieve this aim, the project pursued two objectives: (i) Understand and model relationships between hydroclimatic hazards, climate change vulnerability, human security and conflict, on the basis of theoretically-informed, comparative empirical research, and (ii) map international and national policies for security and adaptation in water resources and hazard management, and develop a policy model for "hydro-security" in the region, applicable to the UN, EU and national states.

Climate change is expected to increase the frequency and intensity of water pressures upon human populations (IPCC, 2007). This raises security concerns and calls for urgent policy action (UN, 2007). The 'Climate change, hydro-conflict, and human security' (CLICO) FP7 SSH research project has explored the social dimensions of climate change and in particular the conditions under which hydro-climatic hazards, such as drought, floods and sea-level rise, may infringe upon the security of human populations. Such research is crucial, because the chain that links climate change to social impacts is long and uncertain, and there is inadequate scientific evidence or peer-reviewed studies to substantiate and elaborate claims beyond speculation or reasonable concern (Nordås & Gledisch, 2007). The motivation for CLICO has been to address this knowledge gap and hence help design better policy responses. The project has focused on the geographical areas of the Mediterranean, Middle East and the Sahel, and on water-related stresses such as droughts, floods and sea-level rise, which are expected to intensify with climate change. More specifically, the project has pursued the following objectives:

(i) To understand relationships between hydro-climatic hazards, climate change vulnerability, human security and conflict, through theoretically-informed, comparative, empirical, quantitative and qualitative social science research.

(ii) To map international and national policies for security and adaptation in water resources and hazard management, and develop policy priorities as regards hydro-climatic hazards ('hydro-security') in the region, applicable to the UN, EU and national states.

CLICO's scientific approach has been structured around one theoretical-conceptual and four empirical blocks of research, specifically:

- A conceptual framework developed at the initial stage of the project and updated at its end on the basis of project empirical findings.
- In-depth case studies on the links between climate change and human security in 11 climate change hotspots within the studied area.

Tata in Southern Morocco: Flooded street

- A statistical study of factors explaining domestic water related conflict and cooperation in 35 countries in the study area for the time period of 1997-2009, taking into account more than 10,000 water-related events.
- An inventory of international and national policies in the study area dealing with water resource management, and responses to climate change, security, hydrological hazards and disasters.
- An appraisal of transboundary policies, including an evaluation of the adaptive capacity of institutions in the 42 shared, international basins of the study area, and an assessment of mechanisms used to tackle climatic uncertainties in international water treaties.

Key findings

Notwithstanding a real concern with the social impacts of hydro-climatic change, an excessively simplified narrative linking climate change to conflict and security dominates the public and policy imaginary. Media and policy reports regularly assume a simple causal structure linking water, conflict and security: hydro-climatic change causes water scarcity which in turn increases conflict, and hence impacts negatively upon security. Insecurity may also be the direct effect of hydro-climatic change, unmediated by conflict, such as floods threatening or killing people in lowlands. More insecurity can cause more conflict and vice versa conflict breeds insecurity. Adaptive action is needed to reduce the likelihood of conflict and/or increase security. Nevertheless, this narrative is wanting.

To begin with, the nature of hazards influences the type of conflicts and insecurities produced. Extreme surpluses, i.e. floods, tend to cause sudden, grand-scale population dislocations and physical/infrastructure damages, whereas droughts are likely to lead to longer-term land-use changes and impacts through agricultural production or urban supply channels. Disasters are a combination of hydro-climatic and socio-environmental conditions: climatic changes combine with broader changes in land-use (e.g. urbanization) and the metabolism of societies through economic growth and global trade, or broader geo-economic developments such as globalization and economic crises to produce vulnerable and insecure people and places (Dalby, 2009). Beyond 'nature', globalisation and consumptive behaviours also comprise key sources of insecurity impossible to contain with military force or logic (Brauch, 2009). Putting those into the picture requires mobilising the notion of human security, which, instead of national security and the state, emphasises the individual and communities as referent objects of security, as well as developmental and justice interventions as a means to reduce insecurities (Adger, 2010).

However, human security can also have "securitisation" (Buzan & Wæver 2003) effects, i.e. be used to legitimise international development policies which are often at the heart of insecurities (Dalby, in press) as well as for individualizing hazard responsibility and privatizing risk prevention and insurance (Grove, 2010) with adverse distributional implications for those vulnerable to hydro-climatic hazards. Moreover, conflict is a multi-faceted social situation which, depending on context and scale, can have positive or negative socio-environmental effects. Conflict cannot be reduced to international and civil war only, i.e. conceived only at the nation-state level, as it often operates at sub-national scales ranging from inter-communal conflict down to the household scale (Crow & Sultana, 2002). Under certain circumstances conflict can be beneficial. "Adaptive" conflicts between herders and farmers in the Western Sahel have pushed for political change and State action to legitimise mobility, a vital adaptation strategy for drought-hit herders (Turner, 2004). Also conflict is not the opposite of cooperation as usually portrayed: cooperative and conflictive actions often coexist, and there is no simple escalating ladder from cooperation to conflict (Zeitoun & Mirumachi, 2008).

Climate change is one among many factors affecting human security, indeed less influential than other factors in causing or exacerbating water-related conflicts. For the majority of conflict situations studied in CLICO, political, economic and social factors were found to be of greater influence than water scarcity or climate-related stresses, although it is not clear how this balance may change in the future. An analysis of more than 78,000 newspaper articles on more than 10,000 water-related domestic conflict and cooperation events in 35 countries in the MMES region found that demand-side factors such as population growth, urbanization, and agricultural development have a stronger impact on water conflict than supply-side factors like climate change (Tribaldos, 2012). Violent water conflicts are extremely rare, and political and economic factors serve to restrain the potential for conflict. In countries with a high GDP per capita, the number of violent water conflicts is lower than in countries with lower per capita GDP, although low-intensity disputes may increase with economic development. In less democratic countries, there are considerably fewer water-related conflicts, possibly because authoritarian regimes can make decisions regarding water allocations with less opposition. Still, although rare, violent conflict over water is overwhelmingly a phenomenon observed in authoritarian regimes. Political stability has a conflict-reducing effect. By contrast, water supply is statistically less relevant in determining if water-related conflict (or cooperation) occurs.

Still, adaptation can increase insecurity and conflict, and state-led adaptation in particular, although crucial, cannot be considered as a silver bullet solution as it may have counterproductive effects ('mal-adaptation'). Adaptation measures do not automatically improve human security for all as they may lead to a deterioration of the security of some groups, even if increasing that of others. For example, in Niger, CLICO found that agro-pastoralists have adapted to poor yields from unreliable rainfall by expanding croplands and seeking payment in response to crop damage by grazing animals. These self-adaptations have lessened the adaptive capacity of other population groups in the area, such as pastoralists, who find the area of grazing lands that they have access to diminished and their expenses increased because they have to pay for crop damage by their herds (Snorek et al., 2012).

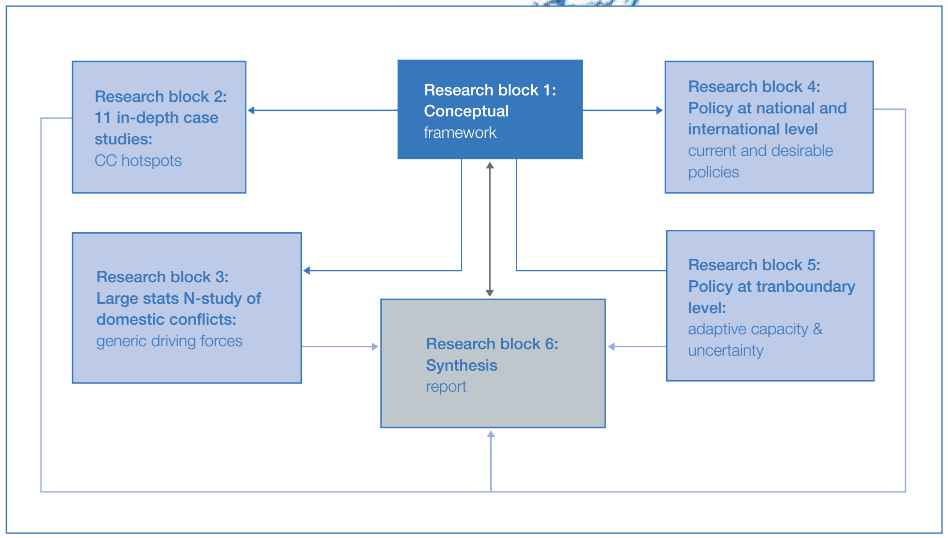
State-led adaptation plays a key role as states can provide the regulatory frameworks that govern adaptation actions by individuals, groups and communities and thus facilitate successful adaptation. States may also be more capable than individuals or communities to change wider socio-economic conditions that lead some population groups to be particularly marginalized and thus also vulnerable to climate change. Nevertheless, and similarly to self-adaptations, state-led adaptation responses may also produce controversial effects. For instance, in Alexandria, a coastal city in Egypt, CLICO found that state-driven relocation from low-lying coastal lands might reduce direct risks from sea-level rise, such as danger from flooding; however, it may also expose people to new risks associated with displacement and the need to secure sustainable livelihoods in new locations (Gebert et al., 2012). CLICO research in the Ebro Delta in Spain, found that sometimes state-led policies fail to address the root causes of vulnerability, and that both civil society and individuals may attempt to fill this gap and push for human security through informal action. Although welcomed in principle, such activities may raise broader questions regarding the proper relation between individuals and the state, and reflect broader disillusionment with a state that does not perform its duties toward its citizens (Gerstetter & McGlade, 2012).

Finally, CLICO research on transboundary river basins developed a typology of basins to help distinguish between basin contexts shaped by conditions such as varying patterns of authority, national-level governance, risk planning, and information exchange. Categories included Well Prepared, Good Neighbor, Mediated Cooperation, Self-Sufficient, Dependent Instability, and Ill Prepared. Results showed that the study region as a whole suffers systematically from a paucity of mechanisms for addressing uncertainty. Outside European basins, political instability and lower levels of governance pose a challenge for addressing the transboundary aspects of climate change adaptation. Thus improving both would likely benefit most basins in the study region. In addition, policies aimed at improving data sharing would benefit basins characterized as Good Neighbour, Dependent Instability, and Ill Prepared basins, but might not add to adaptive capacity in Mediated Cooperation Basins. In Mediated Cooperation basins, although there are currently high levels of formal agreements and data sharing, co-riparians do not hold shared water norms, which might be a point of contention. Lastly, adaptive capacity at the transboundary level may not be needed for all basins, as some basins where, although the river is transboundary by definition, the portion or significance of a river to some riparians may be such that few if any externalities would become a substantial threat.

Policy positions

CLICO's policy recommendations develop along two lines: first, they flag the need to consolidate some useful policy action and directions currently in place; and second, they set out priorities for improvements of existing policy approaches.

With regards to building upon existing capacities, CLICO research results emphasise the importance of an integrated approach towards adaptation. Different actors should cooperate, adaptation should be integrated into existing policies and the potential negative impacts of adaptation measures should be thoroughly considered before implemented. As with most public policies, there is a need to clarify and reduce the overlap of responsibilities by different governmental bodies. There is evidence that climate change adaptation benefits from linking it to existing policy agendas, such as human development and poverty reduction.

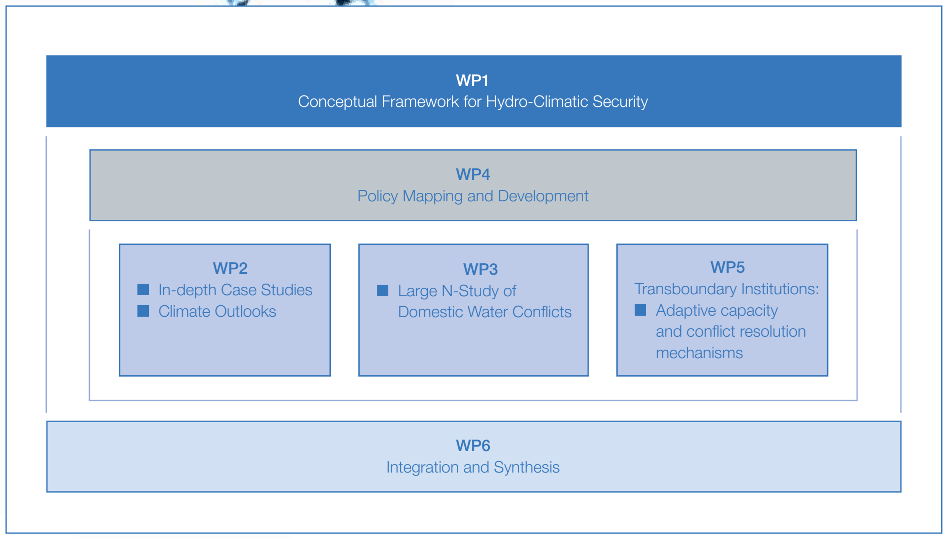


CLICO: Research approach and workflow

A more specific recommendation involves transboundary basin research, where CLICO has identified a variety of mechanisms and strategies available to address different types of uncertainty in international water treaties. Adopting one mechanism and strategy does not come at the expense of adopting another. This implies that policymakers should make sure that water treaties include a variety of mechanisms and strategies during negotiations over water treaties; otherwise they jeopardize the effectiveness of their treaties before the treaty comes into effect. Nevertheless, the adoption of mechanisms to deal with uncertainty is associated with transaction costs. Those costs impose a substantial barrier for the adaptation of these mechanisms, and increase when there is a lack of trust between parties, when the parties depend on water that originates outside their boundaries and when the level of water scarcity increases. Increased costs imply that policy makers must use windows of opportunity, such as increased water availability and improved political relations, to negotiate treaties. When these conditions change, it will become much harder for them to reach a water treaty.

Another CLICO recommendation is that implementing existing policies could improve human security. Several countries have useful policies in place, but have failed so far to implement them. This has, for example, been observed in Ethiopia, a country that has adopted quite a lot of adaptation relevant policies relatively recently. However, there is currently a lack of monitoring, compliance and legal enforcement of existing policies in various policy areas that leads to low effectiveness. The same is true for Niger, where the current legislation needs to be more effectively enacted and better communicated to key rural groups, such as pastoralists and agro-pastoralists.

A key CLICO recommendation is that strengthening social security systems is an effective way for improving human security. Social security systems are crucial for reducing vulnerability to climate change. For example, countries with well-established welfare and social security systems such as those in the North of the Mediterranean are less vulnerable to climate change and better positioned to cope with climatic extremes when compared to those in the South of the Mediterranean and the Sahel. In times of affluence, investment in civil protection reduces exposure whereas investment in education and human capital helps enhance the capacity of the population to cope with disasters. Unemployment security helps individuals to cope in times of hardship, be it economic or related to climatic events. In the event of a natural disaster, state-financed social security systems provide those affected with insurance and health support. States can also subsidise relief, recovery and reconstruction to provide an effective response to climatic stresses.



CLICO project structure

Hence, redistribution via the tax system from private wealth to public goods and to the protection of the most vulnerable is a good starting point for policies that aspire to improve human security. Unfortunately, not only this does not seem to be a priority for many developing countries, but what we observe is a weakening of state social security mechanisms and disaster relief/civil protection institutions within the EU and other developed countries in the context of the economic and public debt crisis. This trend should be stopped and reversed if policies are to seriously engage with action to cater for human security in the context of climate change.

As regards priorities for policy improvement, a key starting point is to avoid simplistic explanations of the impact of climate change on conflict. CLICO research indicates that climate change is likely to play a secondary role in creating or exacerbating water-related conflicts. Economic and political factors have been shown to be more influential in this regard. Consequently, policy discourses should not reiterate simplistic models linking climate change directly to conflict. Emphasis should shift to socio-economic (e.g. economic development and redistribution, social security) and political (e.g. levels of democracy) factors. Changes in socio-economic and political conditions are more likely to reduce the vulnerability of vulnerable groups, improve human security or make water conflict less likely. Existing and functioning institutions for resolving water-related conflicts and developing water cooperation should be maintained and strengthened.

Policy interventions should also strive to genuinely empower affected groups and enhance their capacity to influence adaptation decisions instead of e.g. treating them as beneficiaries. Local knowledge can inform and improve state-led adaptation efforts. For example, adaptation policies for the Sinai region in Egypt could build on local Bedouin practices for predicting flash floods and managing drought. Where different values, perspectives, cultures

and traditions are not taken into account in adaptation planning there is a risk of tensions and ineffective or maladaptation. States therefore have to establish mechanisms for public participation in decision-making which guarantee that different preferences and values are incorporated in the design of adaptation policies. It is important to keep in mind that those insights are not applicable only to non-EU countries. What is more, the legitimacy of state-led adaptation can be questioned where the views of state actors fail to consider the priorities of affected populations. This has been observed in CLICO in the case of rural resettlement in Ethiopia, the Bedouins in Egypt or seasonal migrant workers in Turkey. However, involving marginalized social actors in decisions is easier said than done. Often, their exclusion is not accidental, but goes hand in hand with their political and economic marginalization. Still, without empowering such groups, their vulnerability to climate change cannot be seriously addressed.

This relates to what is probably the fundamental principle which should be informing integrated and comprehensive policy attempts to deal with human security and climate change, namely seek to address the root causes of vulnerability. Although CLICO is by no means the first research to reach that conclusion, several CLICO case studies have also established that often certain root causes underlie the vulnerability of countries or population groups and the lack of adaptive capacity. Such root causes include poverty, lack of knowledge, institutions plagued by corruption, but also the broader political economic context of decisions concerning human security. Thus, there is a need for addressing these underlying causes in addition to taking measures aimed at adaptation of certain sectors or regions. For example, incorporating poverty alleviation campaigns in adaptation frameworks in Sinai (Egypt) is crucial since poverty is a major obstacle to successful adaptation in the region. The broader political-economic context of resource use oriented towards energy production and increasing agricultural production and which shapes vulnerability in the Ebro Delta reduces security options in the context of a changing climate. The need for better access to reliable environmental data and the fact that political or scientific uncertainty can prevent effective adaptation has also been highlighted in case studies in Sudan and Egypt. Improved accountability of state institutions, more universal access to justice, less corruption and adequate enforcement of appropriate rules are other requirements for improved adaptive capacity identified in CLICO.
Although we cannot safely predict the effects of future hydro-climatic change, we know the factors that aggravate the likelihood of conflict and the risks to social welfare. Poverty, inequality, lack of effective democracy, and lack of access to basic infrastructures of health, social and civil security, increase vulnerabilities and insecurities. Solving existing conflicts and addressing inequality-driven grief can go a long way towards reducing future risks. In this sense, climate change does not raise new, military of other, challenges; it only calls for more intensive action on existing social problems and goes against the current of dismantling institutions that have provided social security for long.

Key project results and messages

Climate and hydrological factors, socio-economic, institutional and political factors are all drivers of human security but their relative importance depend on the context. There are great uncertainties when assessing the relative importance of environmental risks as compared to social and political factors. Political, economic and social factors seem to be more important drivers of water-related conflict than climate-related variables. However, in future these relationships might change. States and state-led adaptation was found to play a prominent role in affecting human security: states can greatly facilitate adaptation, but policies are also prone to adverse effects.

Adaptation can both reduce and exacerbate insecurities for certain groups, although this depends to a great extent on factors such as power relations, marginalization and governance (role of the state). There are also varying capacities of states to implement effective adaptation policies. Analysing the political economy in an area or country helps to understand state-led adaptation. Currently, political discussions about winners and losers of climate change and adaptation and which dimensions and scales of human security are prioritized at the expense of others is often absent.

Climate change: a threat to human security

State-led adaptation

- Can facilitate adaptation, particularly if people are unable to adapt themselves (e.g., Alexandria);
- Can lead to unintended consequences;
- Is often found to be insufficiently implemented (Niger);
- Can completely transform existing traditional adaptations (Gambella);
- Might not reflect the preferences or needs of affected people (Gambella, Ebro);
- Can influence/suppress individual adaptive capacity (Sarno).

Inequality in bearing the costs and benefits of climate change and adaptation policies

- Can reinforce or enhance existing inequalities and marginalization of different social groups;
- Marginalized groups are more likely to be ignored by governments and adaptation policies (migrant agricultural workers in Seyhan, Turkey or Bedouins in Egypt).

Conflict and cooperation

According to CLICO research, there are slightly more cooperative than conflictive water-related events. However, in CLICO research, cooperation is less represented in case studies. With regard to conflicts, CLICO investigated a diverse set of 'conflict-contexts':

- not yet existing but future potential conflicts related to SLR (Alexandria);
- silent conflicts (Ebro);
- frequent and sometimes violent conflicts (Niger, Gambella);
- political conflicts arising from short-term politically-derived development goals vs. long term adaptation needs.

Uncertainty poses severe governance challenges:

- environmental/climate factors: difficult to predict the physical impacts of climate change and models lead to contradictory results;
- Social factors: socio-economic development, political instability, transformation and existing conflict(s) are very difficult to forecast.

The WASSERMed project

The WASSERMed consortium is implemented through the collaboration of 12 partners, from 9 countries (Italy, UK, Greece, France, Germany, Spain, Jordan, Egypt, Tunisia) and an international institution. The project follows two distinct streams of research: Mediterranean-wide analysis, focusing on strategic economic sectors, and case studies. It analyses, in a multi-disciplinary way, ongoing and future climate induced changes in hydrological budgets and extremes in southern Europe, North Africa and the Middle East. It builds on existing climate projections in order to assess present and future uncertainties in hydrological budgets in the Mediterranean area, and to provide an improved assessment of climate effects on water resources and use sectors. Climatic/hydrologic scenarios serve as baselines for impact assessment analysis and risk security analysis of the three targets of the project: (i) the five case studies, (ii) the strategic sectors and (iii) the macro-economic effects. The case studies are illustrative and represent situations, which deserve special attention, due to their relevance to national and human security. Furthermore, impacts on key strategic sectors, such as agriculture and tourism, are considered, as well as macroeconomic implications of water availability in terms of regional income, consumption, investment, trade flows, industrial structure and competitiveness.

Tunisia: Informal pumping from the Wadi

The WASSERMed project has analyzed, in a multi-disciplinary way, ongoing and future climate-induced changes in hydrological budgets and extremes in southern Europe, North Africa and the Middle East under the frame of threats to national and human security. This includes the assessment of changes in mean flows, frequency and magnitude of extreme precipitation (intensity and duration), surface run-off, stream flows ground water balance, as well as social and economic factors. A climatic and hydrological component has directly addressed the reduction of uncertainty and quantification of risk. This component provides an interface to other climatologic projects and models, producing climate change scenarios for the Mediterranean and Southern Europe, with special emphasis on precipitation. Modeling capabilities have been improved for water related extreme events (in particular droughts) by integrated simulation of climate - hydrology - vegetation interaction in a typical Mediterranean watershed. The climatic/hydrologic scenarios have then served as baselines for impact assessment analysis and risk security analysis of the three targets of the project: (i) the case studies, (ii) the strategic sectors and (iii) the macro-economic effects. These three dimensions are summarized below.

Five case studies (CS) have been considered: (1) Syros Island (Cyclades Complex, Greece), a region which is characterized by multiple water uses and experiences significant tourism development in recent years; (2) Sardinia Island (Italy), with huge water demand and conflicting water uses between agricultural and tourism sectors; (3) Merguellil watershed (Tunisia), a river basin which concentrates multiple and conflicting water uses; (4) Jordan river basin, where the Case Study will focus mainly on trans-boundary water management and conflicting water demands; and (5) the Nile River system, focusing mainly on Egypt and issues related to inter-regional water supply-demand balances and allocation.

Impacts on key strategic sectors have been considered such as agriculture and tourism. These sectors have been chosen because of their specific vulnerability to water scarcity, their quintessential importance in the Mediterranean economy, as well as because of their relatively high adaptation potential to strategic policies. In this context the project aimed at proposing adaptation strategies, technological solutions and management practices that could be employed to attenuate the negative impacts of climate change.

Macroeconomic effects of climate change in the Mediterranean region

WASSERMed analysed the impacts of water scarcity at the Mediterranean level, placing particular emphasis on two water-sensitive sectors: agriculture and tourism. The analysis was supported by a Global Computable General Equilibrium Model (CGE), which was developed specifically for the study of water-related issues and policies, on the basis of virtual water trading. The analysis was undertaken at the national level, with detailed data for the Mediterranean economies. Simulations were performed by assessing counterfactual scenarios, through changes in exogenous parameters and variables (e.g., changes in agricultural productivity induced by variations in water availability).

Macroeconomic effects on agriculture

Agriculture is a strategic sector in the Mediterranean economy. Our projections for the agricultural valued add-

ed in the year 2050 indicate that agriculture will more than double its value added in most southern Mediterranean economies. On the other hand, agricultural value added will only slightly increase in the northern Mediterranean countries, which implies a reduction of its share in the total Gross Domestic Product (GDP).

Several Mediterranean countries will likely face water shortages. This can have significant implications in terms of agricultural productivity, income and welfare. However, the water gap in the Mediterranean area will be affected by different external drivers. In Northern Mediterranean countries, this will be due to increased temperature and decreased precipitation. In Southern Mediterranean countries, the growing non-agricultural water needs (induced by strong economic and demographic development) will be the main cause of water shortages in agriculture.

Improvements in water efficiency appear to curb the economic impact of water scarcity quite significantly, especially in the Northern Mediterranean countries. Instead, the Middle East and North Africa economies will likely find it difficult to put aside precious water resources for the purpose of environmental preservation.

Summary of ssessment results for selected countries – Agricultural sector

Country	Reduction in agricultural productivity (%)	Variation in real national income (%)
Egypt	-20,25	-16,00
France	-16,81	-0,60
Italy	-13,86	-1,00
Morocco	-0,21	-0,20
Tunisia	-4,43	-1,30
Rest MENA	-3,99	-0,40

The analysis of the current virtual water flows reveals that most Mediterranean countries are net importers of virtual water, thereby realising sizable water "savings".

Much of the intra-Mediterranean virtual water trade occurs among the largest northern economies (Spain, France, Italy). However, in per capita terms, the country which gets the largest amount of virtual water from abroad is Cyprus.

This picture will likely change in the time ahead, because of the evolution of the world economy, as well as of international trade, which will ultimately be reflected in varying virtual water flows. Both northern and southern countries will be affected by water gaps, although for different reasons. Implications of this scenario in terms of virtual water entail a reduction of intra-Mediterranean trade and an increase in virtual imports from central and northern Europe, and from the rest of the world.

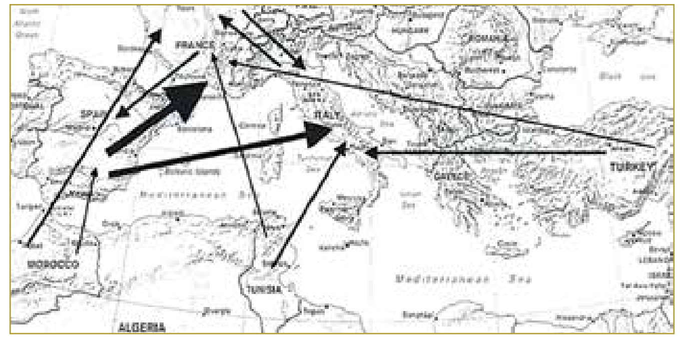
Macroeconomic effects on the tourism industry

Tourism contributed to the Mediterranean economy with 260 billion US$ in the year 2010. This has been steadily rising, although growth has somewhat slowed down recently in the last five years, particularly in some countries (Egypt, Italy, Turkey, Spain).

The WASSERMed analysis of climate change impacts on the tourism industry starts from the computation of a composite index of "climate suitability" for recreational activities, known as the Tourism Climate Index (TCI). The index measures the appropriateness of climate conditions for outdoor activities.

Estimates of monthly TCIs for the period 2036-2065 suggest that tourism flows are generally expected to increase, with only a few exceptions (e.g., Cyprus in July and August, Malta in April). The largest improvements in climate conditions and tourism flows are expected to occur in Malta (February, November, January and May), Cyprus (April), Spain (May), Greece (October), France (September), Croatia (May) and Slovenia (September), thus slightly benefitting tourism in the northern Mediterranean countries and penalising the southern side of the Mediterranean.

It may be expected that traditional destinations could respond quicker to the challenge of adaptation, for example by developing shoulder season tourism and all weather attractions and activities. This will probably lead to a marginal recovery of competitiveness for traditional Mediterranean destinations, at the expense of the emerging ones. This would therefore partly reverse the trend of the past decade that saw the emerging destinations as relative winners, and the traditional ones as relative losers in the global tourism market.



Largest flows of virtual water trade in the Mediterranean at the year 2050 (Mm^3)

A simple projection exercise highlights that the total number of international arrivals in the Mediterranean Area would almost double, from 160 million in 2010 to 340 million in 2020, increasing the total tourist expenditure from 220 billion US$ in 2010 to 660 billion US$ in 2020. This increase in tourist arrivals and stays would imply a higher demand for water by the tourism industry. Our analysis through a numerical macroeconomic model reveals that the tourism expansion (hotels, transportations, restaurants, etc.) would nevertheless bring about a reduction in production volumes for other sectors, among them agriculture, because it would trigger a real valuation of the national currency and a loss of relative competitiveness in international markets. However, even a small reduction in the agricultural output would bring about significant reductions in water consumption, as agriculture is the most water demanding industry. The analysis highlights some interesting and unexpected consequences in terms of water consumption, namely that a growth in the tourism industry may be associated with a net reduction in water consumption in many Mediterranean countries.

Climate change impacts on the Mediterranean agriculture

Mediterranean agriculture might be particularly vulnerable to climate change, particularly in areas already characterised by water scarcity and land degradation. In fact, the warming trend and changes in precipitation patterns might further affect the water balance, and the composition and functioning of natural and managed ecosystems.

Main results

By the middle of the century, reference Evapotranspiation (ETo) would increase over the whole region by 108 mm/yr (7.2%), from 3.9% in France to about 9.8% in Spain. In general, ETo shows an increasing trend from North to South and from East to West. Due to temperature increase, potentially cultivable areas could increase and the overall cultivation period be extended, particularly in the Northern countries (5-25%). However, the length of the crop growing season is likely to be shorter (in average by 15, 13, 12 and 9 days for winter wheat, maize, tomato and sunflower, respectively). For olive trees, the occurrence of flowering is likely to be anticipated on average by 9 days. Due to the shorter growing season, the average crop evapotranspiration (ETc) is expected to decrease on average by 8% and 4% for winter wheat and maize, respectively, while a 5% decrease is expected for sunflower and tomato. For perennial crops (e.g. olive trees), ETc could remain stable with slight regional variations. The average Net Irrigation Requirements (NIR) would decrease by 12% for winter wheat, 7% for sunflower and tomato, and 4% for maize. The NIR of olive trees could vary from place to place due to the spatial variability of precipitation change. In the future, yields should not decrease, as the increase of CO2 concentration could alleviate the negative effects of temperature increase and reduction of intercepted photo-synthetically active radiation. Future agricultural production could be strongly affected by frequent and intense extreme events.

Climate change impacts on tourism in the Mediterranean

The analysis of the interrelations between climate and tourism fluxes was performed using the Tourism Climate Index-TCI as the indicator of climate suitability for outdoor activities.

Through a dynamic, GIS-based tool and platform, WASSERMed assessed climate change impacts at two spatial scales. At the local level, a detailed impact assessment was carried out for the tourism industry of two islands, Syros (Greece), and Sardinia (Italy). For the Mediterranean region, projections of TCI values were used to indicate potential changes in preferences for summer tourism.

The assessment was based on historical (1961-2010) and future (2011-2065) climate datasets for the A1B SRES,

considering both mean model ensembles and ensemble top and bottom values.

Main results

Local level analysis

Results indicate that climate change can enhance the potential for tourism development, as the weather conditions will remain favourable in both Syros and Sardinia. Overall, the estimated positive trend becomes significant from 2030 onwards. A 10% increase in arrivals and overnight stays is estimated for 2051-2060 vs. the 1981-2010 period.
A prolongation of the tourist season towards spring and autumn can be expected. This will affect the seasonal variation of income generated by tourism and water demand. Further- more, the increase of TCI values for winter can provide the potential required for enhancing/investing in other outdoor activities (e.g. agro-tourism, trekking).

Mediterranean-level analysis

Results indicate that conditions will remain favourable for summer tourism in the Mediterranean basin. How- ever, a change in seasonality is probable, as there is an improvement in TCI values in spring and autumn and a slight deterioration in the summer.

In more detail:

- There is a notable winter increase in TCI values in the southern Mediterranean basin.
- In spring, the dominant trend is an improvement of TCI values.
- In the summer, the future trend is an improvement of conditions in northern Mediterranean and a slight deterioration in the southern part.
- In autumn, an increase in TCI values is noticed, except for some parts in Spain, Italy, Greece and Turkey, where a slight decrease of TCI values is calculated.

The WASSERMed case studies: development process and tools

In addition to Mediterranean-wide assessments, WASSERMed developed Case Studies in five different areas of the Mediterranean Basin. The 5 areas were selected to represent regions of different geo-climatic conditions, facing diverse water-related challenges and levels of susceptibility to climate variability and change.

The scope of the WASSERMed Case Studies

Area	WASSERMed Case Study scope
Sardinia	Impacts on agriculture and tourism; Water Supply enhacement and allocation
Merguellil (TN)	Impacts on agriculture, surface and groundwater availability; Resilience to extreme events
Syros (GR)	Impacts on tourism, agriculture; Water balance and supply capacity expansion; Enhacement of agricultutal activity and groundwater protection
Rosetta (EG)	Impacts of sea level rise and Nile water availability on agricultural and urban water use
Jordan Basin (JO)	Impacts on agriculture, water availability and water balance

Stakeholder involvement

Stakeholder involvement was pursued throughout the development of the WASSERMed Case Studies, in order to foster a mutual learning process and ensure that project approaches, methods and results inform and are relevant to local priorities. The process was articulated through dedicated events to which all local actors were invited to participate, to share their experience and knowledge and discuss the WASSERMed research results.

The Case Study development process

The Case Studies were elaborated in three distinct (3) Phases. Phase 1 concerned the "Establishment of a baseline", and was aimed at the framing of the Case Studies and the clarification of the focus of their analyses. During this Phase, a conceptual analysis of the factors that influence the current vulnerability of water systems and strategic economic sectors was developed, following a cause-effect (problem tree or DPSIR) analysis.
Phase 2 concerned the "Development of future scenarios", and involved the investigation of the impacts of climate change on hydrological patterns and on sensitive water use sectors, for a mid-term time horizon (2050). The analysis yielded a comprehensive assessment of the future vulnerabilities of the Case Study water systems, and of the threats that can potentially be faced under climate change conditions, accounting for the uncertainty associated with future climate projections and socio-economic developments.
Phase 3 dealt with the "Development of policy recommendations", through the identification and simulation of potential responses (adaptation measures) to enhance resilience and reduce long-term risks to water security and other sectors. The evaluation of options was made jointly with stakeholders, considering the costs, benefits and effectiveness in mitigating potential threats.

Climate change impacts and adaptation in Syros Island, Greece

- Climate projections (HIRHAM5 RCM driven by the ECHAM5 and HadCM3 GCMs, A1B SRES) indicate an increase in maxi- mum temperature of about 1.5oC and a decrease of annual precipitation of 30 mm by 2050.
- Climate change could have positive effects for tourism, particularly after 2030. An increase potential of about 10% for arrivals and overnight stays is estimated for 2051-2060 vs. the 1981-2010 period with a possible prolongation of the tourist season in spring and autumn, and a minor decrease of tourism flows during summer.
- The Net Irrigation Requirements for all major crop types would gradually increase due to climate change, resulting in higher water demands in the agricultural sector.
- Under all socio-economic scenarios and with no further integration of measures, water balance modelling results suggest that water security could gradually deteriorate in the future, for both the domestic and the agricultural sectors. From 2030 onwards, the domestic water deficit could be more pronounced, whereas the situation is worse for the agricultural sector.
- Results from the simulation of five adaptation measures, suggested by local stakeholders, show that water security threats cannot be alleviated without further investing in water supply technologies. Softer, low-cost interventions, such as cisterns, can improve reliability in water supply provision and resilience to extreme events, and should be considered as supplementary solutions.

Climate change impacts and development perspectives in Sardinia, Italy

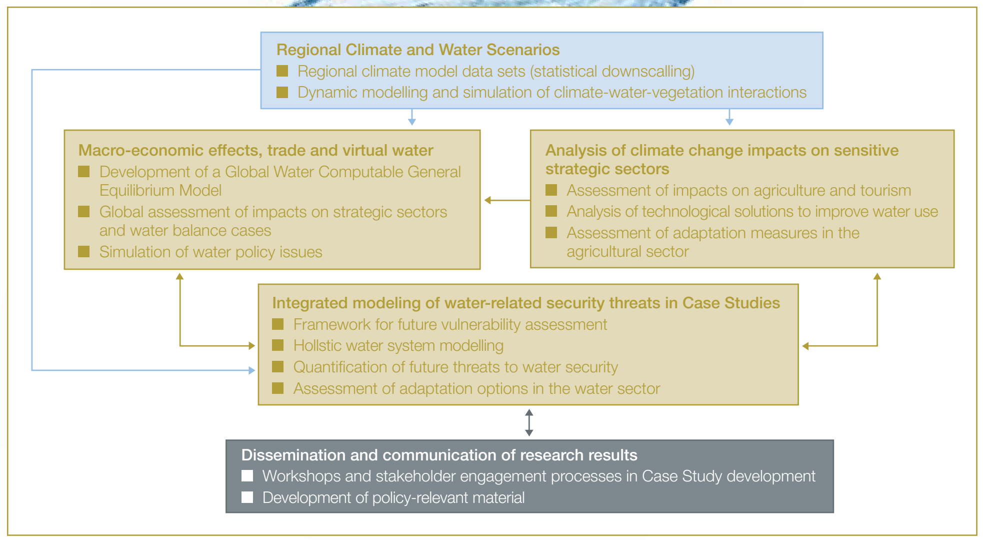
Projected climate trends forecast a slight positive increase in both mean annual temperature and precipitation (especially in summer) between 2005 and 2050. This is equivalent to sufficient rainfall to satisfy increasing vegetation water demand (ETo) in the agricultural sector. Although a conspicuous increase in irrigation needs (17%) is estimated between the baseline period (1960-1990) and 2005, the change in crop irrigation needs is negligible between 2005 and 2050. Spatially, irrigation needs show significant decreases in the large central plains, while increases are expected in the north-eastern part. The water requirements needed to expand irrigated areas by 15,000 ha correspond to (a) 50.8 million m3/yr, if applied across Sardinia only for irrigation efficient crops (ISC scenario), (b) 56.8 million m3/yr, if applied to dominant crops only across regions with limited climate change impact on irrigation requirements (ICP scenario), and (c) 59 million m3 /yr, if applied consistently across Sardinia to dominant crops (IWS scenario).
Per capita (tourist) water consumption (236 l/d on average) and regional projections of future overnight stays (predicted only on the basis of climate change-related effects) have been used to assess future trends of water demand for tourism in Sardinia. By assessing the direct impact of long-term climatic changes on tourist preferences and flows, TCI projections overall predict an enhanced tourist attractiveness and a positive trend of related overnight stays, The cumulative increase by 2050 is about 13%, mostly concentrated in shoulder and low seasons. The SCST and even more the BCSG scenarios are the ones that could better take advantage of this positive effect of climate change.
Current storage capacity is sufficient to satisfy the increase in water demands under all the combinations of development scenarios that have been considered. However, for some areas the network is inadequate to sustain peak demands; thus, local and temporal water shortages are likely to become more pronounced. Additionally, climate projections after 2050 indicate a decrease in rainfall, consequently bringing about higher irrigation needs and a decline in water storage.

Climate change impacts and adaptation options in the Rosetta area, Egypt

- Climate change could lead to:
  - increase in annual average air temperatures, up to +1.4°C.
  - reduction of the annual rainfall (-12.9 mm/ yr)
  - slight increase (+68.8 mm/yr) of annual reference evapotranspiration, especially during the spring-summer months (with values up to +9 mm/month in June), and with a "peak" of daily evapotranspirati on in July (7 mm/d).
  - decrease of yields of about 5.4%, from 5.1 tons/ha (2000) to 4.8 tons/ha (2050), depending on irrigation strategies and planting dates, as a consequence of the expected shortening of the crop growing cycle.
- Results from water balance modelling show that by 2050 there will be a water deficit ranging between 75 and 122 million m3/yr (best and worst case scenario respectively).
- The most important adaptation measures for the agricultural sector include changes in sowing dates and agricultural management practices.
- Shifts to more heat-tolerant crops and changes in cropping patterns are the most promising adaptation measures for the case study.
- Improved and more "professional" practices at the farm level and deficit irrigation can reduce the water deficit in the "old" agricultural lands, and help to overcome negative climate change impacts.
- Both for the Rosetta area, but also at the national level, several measures to enhance water supply can be considered "no-regret" actions, such as the development of new water supply sources in the upper Nile, rainwater harvesting, desalination, wastewater recycling, and the increased use of deep groundwater reservoirs.
- Soft interventions should also complement the above. Urgent actions include measures to enhance public awareness on the need for rational water use, the enhancement of precipitation monitoring networks in the upstream countries of the Nile Basin, the encouragement of data exchange between the Nile Basin countries.

Climate change impacts and adaptation in the Merguellil catchment, Tunisia

- Historical agricultural maps produced using remote sensing data from 1986 reveal an annual 2% increase in irrigated areas.
- A multi-temporal series of satellite SPOT-VEGETATION Normalized Difference of Vegetation Index (NDVI) data from 1998 to 2010 were used to analyze vegetation dynamics over the catchment and to propose a Vegetation Anomaly Index (VAI) for drought monitoring.
- Based on grain yield measures on test plots, a relationship was established between NDVI and grain yield. The results showed that earlier forecasts are possible from mid-March to mid-April with approximately a root mean square error (RMSE) equal to 8.5 quintals/ha and an average yield equal to 36 quintals/ha.
- The analysis of rainfall-runoff trends at the event scale reveals a 40% decrease in the runoff generated by rainfall events under 40mm. The decrease is a result of the construction of water and soil conservation works that drain 28% of the upper catchment.
- However, the large variations observed in catchment runoff were driven by changes in the number of rainfall events over 15 mm, and the conditions of these events (rainfall intensity & location, soil moisture and land cover).
- Statistical test on rainfall time series over the past 50 years reveal no significant shift of the long term average and of the number of extreme events. Projections with the regional climate model RCA (driven by ECHAM5) point to a 10% decrease in annual precipitation by 2050 and an increase in annual average maximum, minimum and average air temperatures, up to +1.7°C. This will induce an increase (+118.6 mm) of annual reference evapotranspiration.
- The WEAP model was used to simulate the influence of a 10% precipitation decrease and +2% increase in irrigated areas on groundwater resources, and to test adaptation measures, such as deficit irrigation, which can save up to 13 Mm3.
- The main projected climate change impacts on the agricultural sector concern the reduction in cycle length of wheat, tomato and potato. Suggested adaptation measures include the use of suitable late-maturing varieties (LMV), together with early sowing.



WASSERMed: Research approach and workflow

Climate change impacts and adaptation in the Jordan River Basin, Jordan

Impacts and adaptation in the agricultural sector

- An increase in maximum temperature of about 1.5oC and a decrease of precipitation of about 10-15% by 2050 are expected.
- By 2050, climate change can result in an increase of crop water requirements between 6.4% to 10.3%, depending on the type of crop.
- Earlier sowing dates for winter and spring crops (wheat, potatoes and tomatoes) can be effective in reducing maximum crop evapotranspiration.
- Earlier planting dates can be similarly effective in reducing seasonal evapotranspiration, due to the reduction of the total crop growing cycles), and the fact that growing cycles can thus coincide with high rainfall seasons, shorter daytimes and lower temperatures.
- The use of Late Maturing Varieties (LMVs) can be effective in increasing crop yields to levels similar to those of 2000.
- Deficit Irrigation (DI) strategies can allow control of the levels of effective evapotranspiration and net irrigation requirements, while achieving satisfactory yields.

Water balance modelling and future security

- For the worst case scenario, water security gradually deteriorates in the future, for both the domestic and agricultural sectors. This concerns both the average coverage of water demands and reliability in water supply provision. From 2030 and onwards, the domestic deficit is significantly more pronounced, whereas the situation is considerably worse for the agricultural sector.
- Areas planted with bananas could be reduced by 2.5%/yr up to a maximum reduction of 50%. Similarly, the area of palm trees can be increased by 3%/yr replacing banana cultivations, while the area of all vegetables should be reduced by 1%/yr for the next 40 years. These areas may be used for other fruit trees and vegetables.
- With the implementation of the new cropping pattern and more land conversion between crops types, water balance modelling results suggest that it would take about 30 years to reach water balance.
- This type of gradual, phased changes in agricultural cropping patterns could lead to net water saving. These will likely be more acceptable by the local farming community than suddenly imposed shifts.

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The Mediterranean region is experiencing a broad range of threats to water security. According to climate projections, the region is at risk due to its pronounced susceptibility to changes in the hydrological budget and extremes, which is expected to have strong impact on the management of water resources and on key strategic sectors of regional economies. Related developments have capacity to exacerbate tensions, and intra- and inter-state conflict among social, political, ecological and economic actors.

This document is intended as a comprehensive summary for policymakers, highlighting the scientific results elaborated in the research cluster CLIWASEC, composed of three research projects, all funded under the Seventh Framework Program for Research and Technological Development (FP7).

WASSERMed – Water Availability and Security in Southern Europe and the Mediterranean
www.wassermed.eu

CLICO – Climate Change, Hydro-Conflicts and Human Security
www.clico.org

CLIMB – Climate Induced Changes on the Hydrology of Mediterranean Basins
www.climb-fp7.eu