PROJECT FINAL REPORT

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Executive Summary

The impact of climate change on the Mediterranean agricultural sector will likely be affected by water availability and could be prevalently: (i) positive for the Northern Mediterranean countries and areas characterized by relatively cold and humid climate, and (ii) negative for the Southern Mediterranean countries and the areas already characterized by arid and semi-arid conditions.

The extension of the areas suitable for cultivation toward the Northern latitudes and higher altitudes and the overall expansion of the cultivation season could bring benefits especially to the Northern Mediterranean countries. Spontaneous adaptation through the anticipation of the sowing/planting dates for spring-summer crops could occur and cause the increase of frost risks in the Northern Mediterranean countries and the reduction of the intercepted photo-synthetically active radiation (PAR) in all areas with a negative effects on yield. On the contrary, keeping the actual start of growing season could result in the shortening of the crop growing cycle, lower seasonal evapotranspiration and irrigation requirements. Nevertheless, the rates of (peak) crop evapotranspiration and irrigation demands could increase, which will require the employment of more flexible and efficient water delivery systems.

The overall effects of climate change on water productivity could be positive whereas the effects on yield could be seen within a complex scenario that includes the combination of different strategies considering the starting of growing season, the selection of most adequate varieties, and adopted locally-tailored management practices. As a whole, the effect of adaptation measure should consider the adaptation capacity of each specific area and could have greater success in the Northern than in the Southern Mediterranean countries. Therefore, it is worthwhile to focus future challenges on the improvement of adaptation capacity to climate change in the areas already characterized by arid and semi-arid climate, scarce water availability and weak socio-economic and institutional setting. The analysis of climate change impacts on tourism indicate that conditions will remain favourable for outdoor activities in the Mediterranean basin; however a change in seasonality is foreseen. Particularly, negative impacts for summer tourism are foreseen in Southern Mediterranean countries, whereas the situation is different for northern countries.

Results of the macroeconomic analysis of the consequences of climate change on agricultural productivity and tourism attractiveness indicate that several Mediterranean countries will likely face water shortages with significant implications in terms of agricultural productivity, income and welfare. The water gap will be driven by increased temperature and decreased precipitation in Northern Mediterranean countries, by growing non-agricultural water needs in Southern countries. Improvements in water efficiency could help in curbing the negative impacts, yet all gains could be offset by growth in agriculture output. Also, Southern Mediterranean countries will likely find it difficult to put aside precious water resources for purposes of environmental preservation. The possible growth in total incoming tourists for many Mediterranean countries will increase income and welfare, but this phenomenon will also induce a change in the productive structure, with a decline in agriculture and manufacturing, partially compensated by an expansion of service industries. In most countries, the crowding out of agriculture would entail a lower demand for water, counteracting the additional demand for water coming from tourists and bringing about a lower water consumption overall.

Different policy and adaptation options have emerged in the five case studies. However, similarities and recurrent issues have also been noticed. For example, improvements in water efficiency are needed in all circumstances, to effectively adapt to the changing climate and reduced water availability. Another recurrent theme is the need to foster awareness and participation by all

stakeholders, possibly through water pricing; removal of market distortions and implicit subsidies; flexible, decentralized but coordinated decision-making.

Summary Description of Project Content and Objectives

The CLIWASEC Cluster, "Climate Change Impacts on Water and Security (in Southern Europe and neighbouring regions)", has been established among three FP7 Research Projects selected for funding through the 2009 FP7 Call for proposals: CLIMB and WASSERMed, which address Theme 6 ("Environment, including Climate Change), and CLICO, addressing Theme 8 ("Socioeconomic Sciences and Humanities"). The main objective of the Cluster, which brings together a critical mass of scientists from 44 partner institutions, is to identify and foster scientific synergies and to establish a more efficient policy outreach strategy, also forming a comprehensive representation of issues faced in the Mediterranean region. CLICO (Climate Change, Hydro-conflicts and Human Security) focuses on the political and social responses to the threat of water scarcity, while CLIMB (Climate Induced Changes on the Hydrology of Mediterranean Basins) focuses on scientific knowledge about current and future water availability in the Mediterranean. All three projects draw insight on specific aspects of the issues faced through the analysis of Case studies in the Mediterranean region.

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.

The case studies are illustrative and represent situations that deserve special attention due to their relevance to national and human security. Additionally, these case studies refer to varying problems and conditions within the Mediterranean region, in terms of scale, complexity, water use, and impacts as far as security threats are concerned, ranging from small touristic (Syros), to medium sized regional (Sardinia, Tunisia), to large interregional/trans-boundary (Nile, Jordan) water systems. All case studies refer to vulnerable Mediterranean regions, the first two in Southern Europe, and the remaining three in targeted SICA regions. They are considered as complex water systems, for which holistic integrated modeling have been applied, coupling climate change and water use scenarios, so as to study quantitatively the impacts of water related shortages and identify vulnerability and priorities with the introduction of specific technical indicators referring to water related security threats.

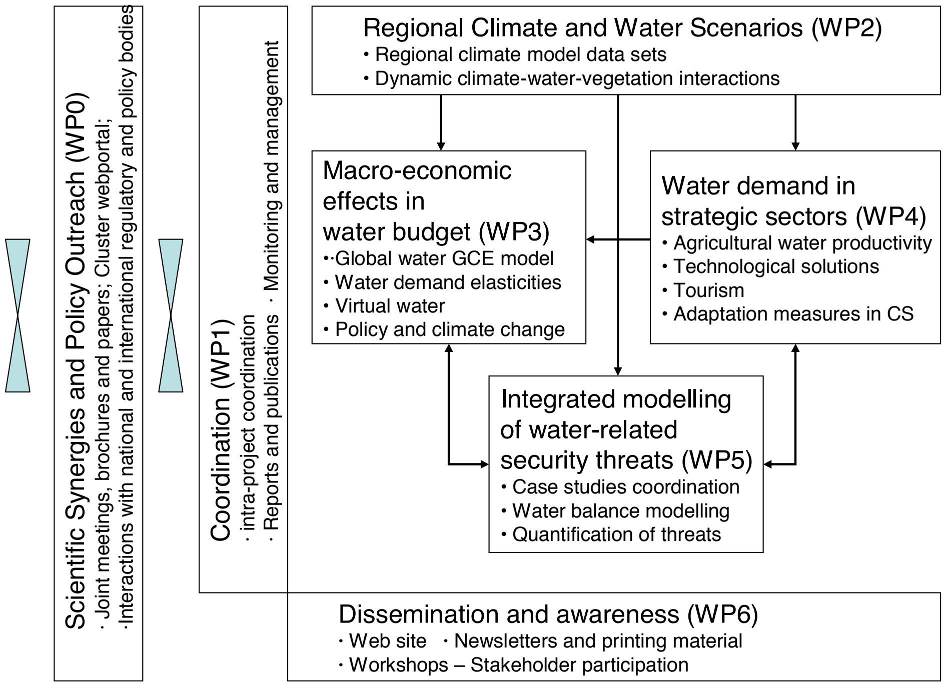
The case studies have addressed directly the response strategies and adaptation since they have been developed in close collaboration with the "Dissemination and Awareness" work-package. The results have been presented and discussed with local communities and stake-holders to enhance and validate the model outputs of the project at each stage of analysis. The objective of the stakeholder interaction was to promote best response strategies and adaptation, at the macro and micro levels, reducing uncertainty and achieving water security.

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 implications of water availability in terms of regional income, consumption, investment, trade flows, industrial structure and competitiveness have been analyzed by developing quantitative modelling tools and analytical approaches to the various aspects of water balance that are influenced by the economy and market-mediated adaptation mechanisms. The main modelling tool used in this analysis is a disaggregated general equilibrium model focusing on the Mediterranean area. The model has been used to evaluate the effects of changing water balance on risk to strategic sectors and the effects of water policies as strategic adaptation in the case studies and the Mediterranean wide scale and to assess virtual water trade, which is associated with the implicit water content of imports and exports. Changes in virtual water trade can indeed be considered as a major adaptation option to changing water availability. We regard this study as one of the distinctive and innovative characteristics of the project.

To summarize, ***WASSERMed*** has been an interdisciplinary project, which overall aimed at all three targets of the call through the integration of climate change scenarios, holistic water system modelling and interdisciplinary impact assessment, with three main contributions: (i) integration of climate change scenarios, holistic water system modelling, which provided results for reduction of uncertainties of climate change impacts on hydrology in the identified regions; (ii) interdisciplinary approach, coupling macroeconomic implications and technical indicators, which provided a better assessment of climate effects to water resources, water uses and expected security risks; and (iii) proposal of specific adaptation measures for key sectors of the Mediterranean economy, which provided better basis for achieving water security.

WASSERMed distinguishes four important working areas (see the figure below) corresponding to climate change and hydrological studies (WP2), macro-economic studies (WP3), sensitive strategic sectors (agriculture and tourism) (WP4) and integrated modelling of water-related security threats (WP5).



Workpackages and their interaction in WASSERMed

The research loop started at WP2 with the ensembles and synthesis of existing climate simulations from various other projects and models downscaling to the Mediterranean and CS areas and providing regional climate scenarios for other WPs. Moreover, WP2 has developed an integrated hydro-climatological scenario for one CS area (Merguellil watershed). The outputs of WP2 – weather data (precipitation and air temperature as average values and as extreme values) is available on a monthly basis for the period 2010-2050, and has been used:

(i) by WP3 for assessing, through economic macro-models, changes in competitiveness, economic structure, trade flows and implicit trade in water (virtual water), originated by changes in water availability;

(ii) by WP4 for assessing the climate change impacts on agriculture (focusing on crop water productivity) and on tourism (including direct and indirect effects) and for analyzing the adaptation strategies, technological solutions and management practices that could attenuate these impacts at regional and CS scale;

(iii) by WP5 for developing and implementing integrated water modelling, coupling water demand and climate change scenarios for the 5 CS areas with the aim to identify and quantify the vulnerability risk and priorities infrastructure investments through specifically introduced indicators, that will provide a comprehensive framework and upscale recommendations for modelling climate change impacts as security threats.

The analysis on climate change impact has been scaled down from the regional (WP2) to national level (WP3) and then after to the CS areas (WP4 and WP5) aiming to quantify the threats at CS scale and to identify the best options for adaptation and attenuation of negative impacts. These options have been agreed fostering the active involvement of stakeholders in CS areas (WP6) to ensure that the project methodologies and outcomes are adapted to the local context and priorities. In turn, this has increased awareness on climate-induced security issues among decision makers, water managers and citizens in CS areas. Intra-project coordination, preparation of reports and project management monitoring has been carried out by WP1, whereas WP0 has established an interface with other two projects through the joint meetings and workshops in CS areas, exchange of data, etc.

Description of the main S&T results/foregrounds Project

Climate change in the Mediterranean: observed trends and future projections

Climate change research in WASSERMed

The research objectives of WASSERMed included a synthesis of existing Regional Climate Model (RCMs) simulations to provide the basis for analysing climate change impacts for the Mediterranean Basin and for selected areas. This involved the extension of existing syntheses, which are mostly based on Global Climate Models (GCMs) and the identification of the most suitable dataset for the specific Case Study (CS) areas. In addition, and as resolution is considered a main issue in the Mediterranean region, it was important to assess the uncertainty of RCM results and the improvement compared to GCMs.

Furthermore, an analysis was carried out on observed precipitation trends, focusing on Northern Africa and the Middle East. This is considered particularly important, due to the increased water demand in these areas and the expectation of the onset of progressively drier climate conditions during the 21st century.

During the second half of the 20th century, the observed precipitation trend is negative over several areas, including the Balkan and Italian peninsulas, the southern Anatolian coast, and part of north- west Africa in winter. However, precipitation trends are not assessed with sufficient robustness over important parts of Northern Africa and Middle East, due to the limited records of long, reliable time series. As a result, and although there are gridded datasets that cover the entire Mediterranean region, their accuracy over the specific areas is not clear; this is due to the statistical methods used to compensate for the variable density of meteorological stations and for periods with no data in single time series.

Methods and tools

Observed precipitation trends

For the purpose of deriving current trends, datasets were first analysed in terms of quality, and time series with more than 25% missing values were re- moved. Three homogeneity tests were applied to test the presence of break points: (a) the Standard Normal Homogeneity test for a single break, (b) the Buishand range test, and (c) the Petit test.

For time series that passed all tests, monthly precipitation totals were computed. Trends were evaluated using the Sen's Estimate and statistical significance was assessed through the Mann-Kendall test. Additionally, the Spearman ranks correlation between precipitation data and the north hemisphere teleconnection patterns (NAO, Scandinavian pattern, Eastern-Atlantic-Western Russia, etc.) were computed.

Regional climate projections

Five models, whose domains include the entire Mediterranean region at high spatial resolution (25 km) were extracted from the set produced in the ENSEMBLES project. All simulations covered the period 1951-2050 and concerned the A1B

emission scenario. This RCM dataset would allow to analyse trends and regime shifts at high resolution. The reliability of simulations was assessed by comparing the monthly precipitation and temperature climatology produced by the RCMs with the gridded observational CRU dataset of the East Anglia University.

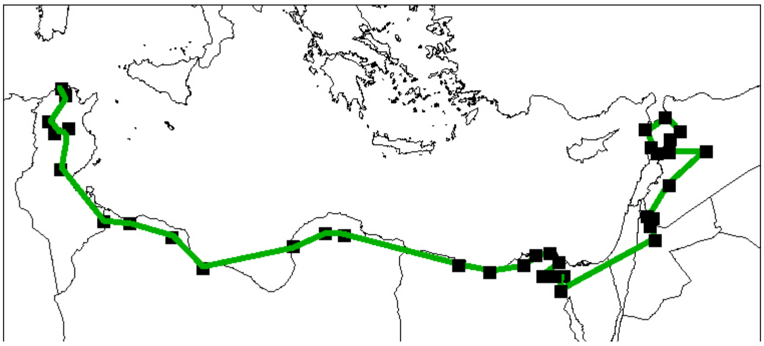
The five simulations were used for producing a multi-model ensemble, currently considered the most robust and reliable climate projection for all variables and statistics. Climate change was assessed by comparing the seasonal values of temperature and precipitation for the 2021- 2050 and 1961-1990 periods. The annual cycles of the same variables were computed for the same periods and for 1971-2100.

For each CS area a validation was per- formed to select the model that would most accurately reproduce local precipitation by comparing model results with “in-situ” data. The selected RCM was then used to produce continuous time series of climate variables, which were further analysed to assess potential trends.

Main results

Observed precipitation trends

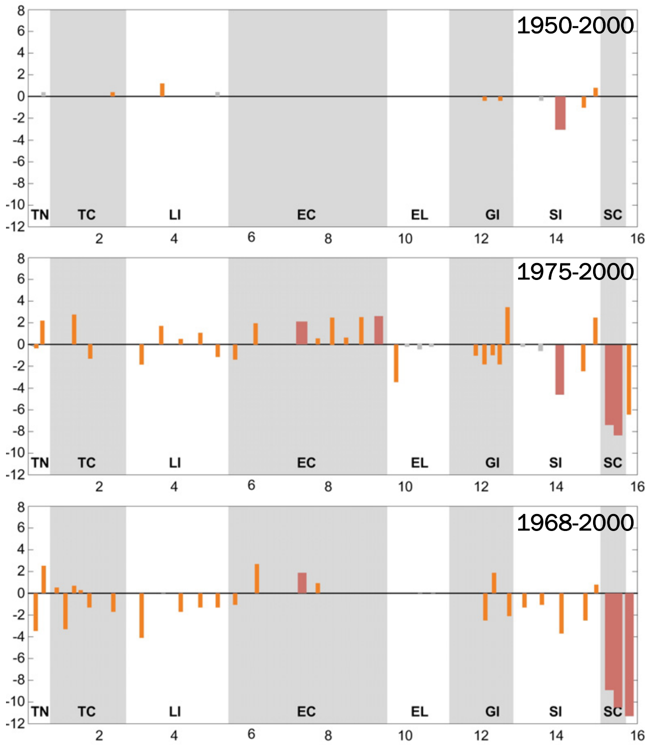
For precipitation, large coherent negative trends based on observed values concern only Syria. However, the large majority of trends in the latest period are negative (though mostly they are not statistically significant), suggesting the onset of progressively drier conditions in the last decades of the 20th century. The lack of data pre- vents the assessment of trends over long time periods, with few exceptions, which show very small trends at multi-decadal scale.



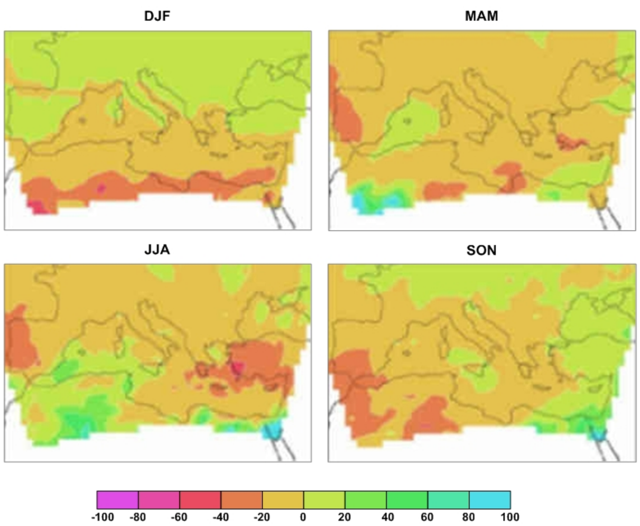
Location of meteorological stations used for the assessment of observed precipitation trends in Northern Africa and the Middle East

The NAO (North Atlantic Oscillation) is the teleconnection pattern that exerts the largest influence on precipitation and is positively correlated with precipitation patterns in the winter months from Libya to Jordan.

Regional Climate Projections The monthly precipitation and temperature climatology produced by RCMs for the Mediterranean region show that RCMs are very good at compensating the GCM bias for temperature, but less successful for precipitation. In fact, RCMs outperform GCMs quite convincingly in summer months for both variables, but not for winter precipitation. However, RCMs are very effective at reducing systematic GCM errors in coastal areas and over complicated orography. The results of RCMs using the A1B SRES show that in the mid 21st century the Mediterranean region will be warmer and drier than now. The most important feature is the contrasting precipitation change during the October-March period between the northern areas (that become marginally wetter than now) and the southern ones (that become drier than now). Temperature projections for the CS areas confirm for all a substantial increase in temperature in the range of 1.5 to 2.5oC and a wet season precipitation decrease by about 10-30% in the mid of the 21st century. Precipitation in the Jordan River Basin and in the Egypt hinterland shows a possible transition to a differ- ent (wetter) regime after the mid of the 21st century.



Precipitation trends for different periods; data are ordered from east to west along the green line in the map [TN: Tunisia North; TC: Tunisia Centre; LI: Libya; EC: Egypt Coast; EL: Egypt Interior; GI: Jordan; SI: Syria Interior; SC: Syria Coast]. Thick red bars represent statistically significant values at the 95% confidence level



Spatial distribution of the variation of total seasonal precipitation between the 2021-2050 and the 1961-1990 periods (DJF: winter, MAM: spring, JJA: summer, SON: autumn)

Key findings and considerations

- RCM simulations have some advantages over GCMs for regional and sub-regional applications. The most reliable RCM (i.e. the one that can better reproduce present climate) depends on the specific area. The ensemble mean does not necessarily produce more accurate climatology than the individual members of the ensemble.

- Existing public archives are not adequate for representing precipitation over Northern Africa and the Middle East because of data scarcity and misrepresentation of regional variability. Data from the WASSERMed Case Studies show that trends that are not spatially homogeneous and depend on the area considered. However, the bulk of data suggest the onset of dry conditions in the last two decades of the 20th century.

Macroeconomic effects of climate change in the Mediterranean region

The WASSERMed approach: premises and tools

Economic macro-models are used for assessing changes in competitiveness, economic structure, trade flows and implicit trade in water (i.e. virtual water), that can originate from changes in water availability.

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. The rest of the world economy was represented by a few blocks. Parameters for numerical models have been calibrated on the basis of national economic accounts and trade data. 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 added 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).

The analysis of climate change impacts on the agricultural industry starts from building scenarios on water availability for agriculture, considering estimates for future precipitation and temperature, as well as economic and demographic growth and environmental policies. On the basis of an estimated water productivity relationship for a range of crops, we examined how potential changes in water resources may affect industry production volumes, prices, income and well-being in the region.

It can be anticipated that 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 assessment results for selected countries — Agricultural sector

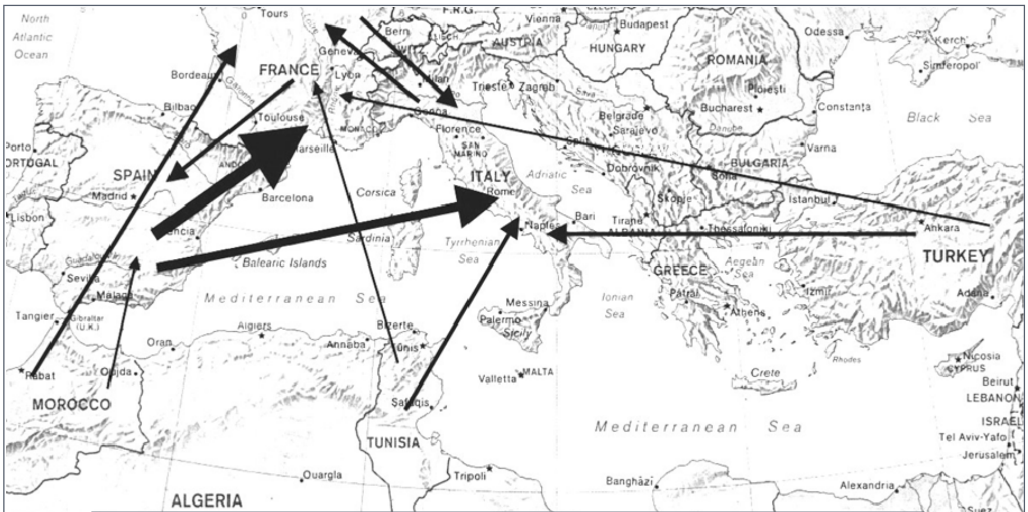
Country	Reduction in agricultural productivity (%)	Variation in real national income (%)
Egypt	-20.25%	-16.0%
France	-16.81%	-0.6%
Italy	-13.86%	-1.0%
Morocco	-0.21%	-0.2%
Tunisia	-4.43%	-1.3%
Rest MENA	-3.99%	-0.4%

Another issue which has been investigated is the analysis of virtual water trade flows in the Mediterranean. 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.



Largest flows of virtual water trade in the Mediterranean at the year 2050 (Mm³)

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.

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

Climate change in the Mediterranean: impacts for agriculture?

The analysis is based on A1B SRES and input climate data developed within the WASSERMed project. Analysis results have shown that, in the Mediterranean region, over the period of 50 years (2000- 2050) the annual mean temperature would increase on average from 0.8°C in Spain to 2.3°C in Morocco. The overall increase in air temperature would be the greatest in areas of Northern Africa and the Middle East and in Southern Turkey. Seasonal patterns indicated that, in winter, the continental interior of SE Europe and Eastern Mediterranean would warm more rapidly than elsewhere. On the other hand, in the summer, the western Mediterranean would warm more than the other regions.

For the same period (2000-2050), the average annual precipitation could have a decreasing trend of around 6%. The expected range of variation at the national level is between –21% (for Cyprus)

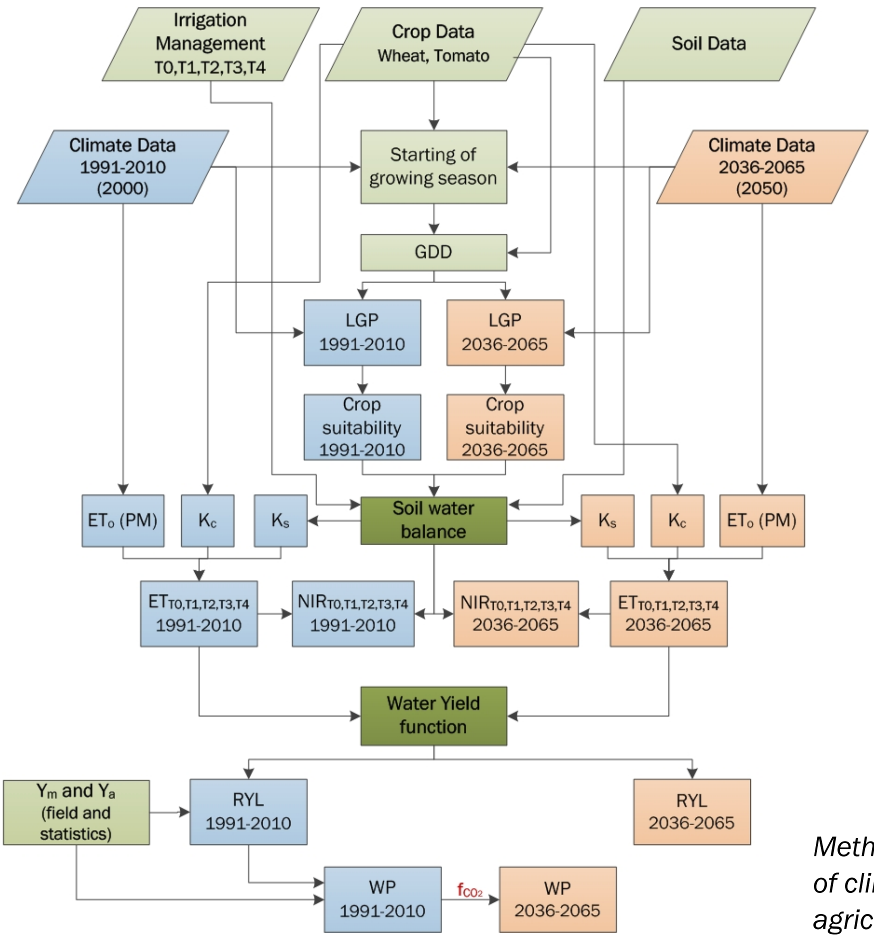
and +1% (for France and Slovenia). The spatial pattern of annual precipitation indicates an increase over most of France and the Alps, while a decrease is observed in almost all other regions. There is a marked contrast between winter and summer patterns of precipitation change. Most of Europe could get wetter in the winter season with the exception of Greece, Southern Italy and Turkey. In summer, a overall decrease of precipitation could be expected in Europe, while an increase is foreseen in some areas of Northern Africa and the Middle East.

Thus, 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.

The WASSERMed approach: methods and tools

The analyses were done on monthly and daily basis, using the support of different models (CROPWAT, AquaCrop) and of Geographical Information Systems. In particular, reference evapotranspiration

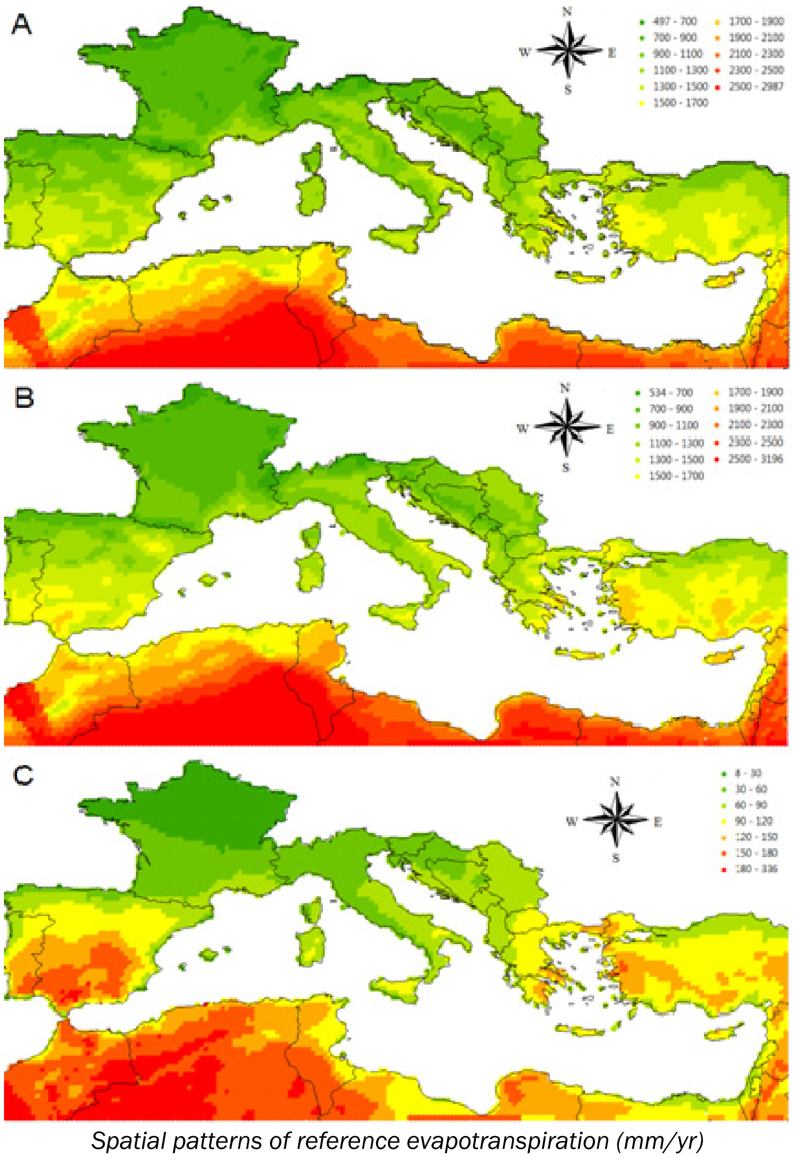
(ETo) was calculated using the Penman- Monteith method. The Growing Degree Day (GDD) concept was applied for estimating the length of the growing season and crop development.



Methodology for the estimation of climate change impacts on agriculture

Main results

By the middle of the century, 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.



Spatial patterns of reference evapotranspiration (mm/yr) for the baseline scenario (A), the future scenario following A1B SRES (B) and differences (C)

Key findings and considerations

- The results of simulations are in agreement with other studies. If no adaptation will occur, an overall reduction of Crop Evapotranspiration and Net Irrigation Requirements could be expected for most crops (except for perennial ones), due to the decrease of crop growing cycle. The air temperature increase could have a dominant role on the shortening of the crop growing cycle, rather than on the increase of Crop Water Requirements. Water Productivity (the ratio between yield and ETc) could slightly increase in the future, as a result of the combined effects of changes in air temperature, precipitation and CO2 concentration.

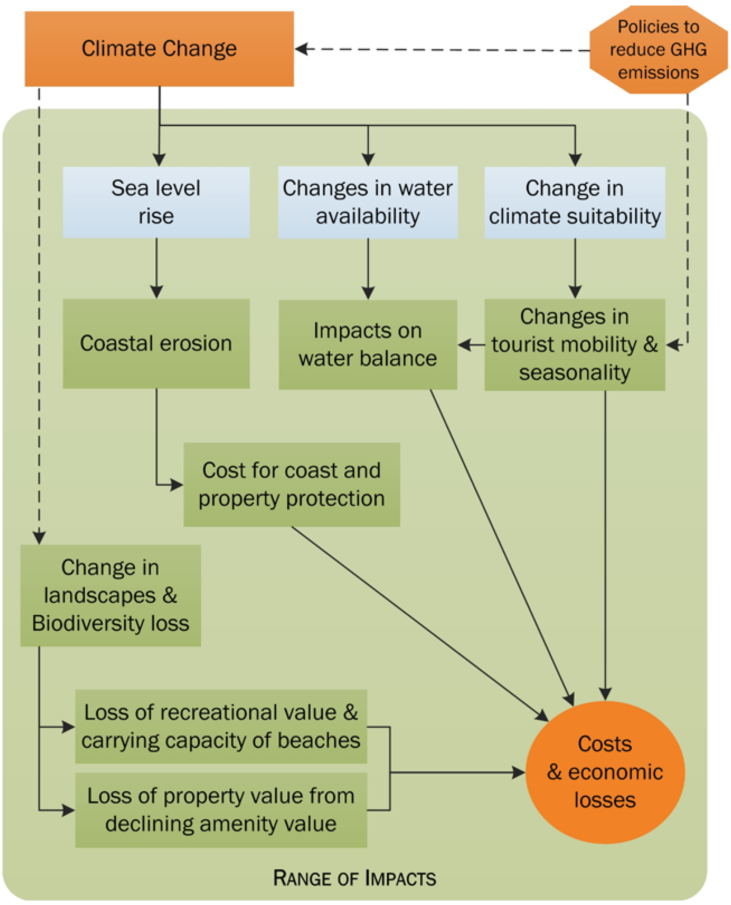
- The negative impacts of climate change could be more evident in the Southern countries, where water scarcity is already a limiting factor for agricultural production. Adaptation strategies should include: a) the anticipation of growing season, b) deficit/supplemental irrigation; c) application of more efficient irrigation technologies; d) introduction of new more resistant (to water/salinity/heat stresses) and slow-maturing crop varieties, e) smart, locally tailored, agricultural practices.
- The overall adaptation capacity is greater in the Northern than in the Southern Mediterranean countries, due to more favourable climate, resources availability and institutional setting. These results depict one of the possible future scenarios and should be integrated into a complex system linking bio-physical, socio-economic, and policy issues.

Climate change impacts on tourism in the Mediterranean

How can climate change impact on tourism?

Climate change is anticipated to have an impact on the tourism industry, as weather conditions influence the choice of destinations and the demand for different activities. Different studies indicate that regional and seasonal shifts in tour- ism flows should be expected, resulting to an alternative distribution of tourism- generated income.

Tourism in the Mediterranean is likely to be impacted. Direct impacts relate to the suitability of locations for tourism-related activities; they can be linked to changes in the perceived sense of comfort of tourists, due to the alteration of temperature and weather conditions. Indirect impacts concern wider environmental changes that can affect the attractiveness of a tourist destination. They include additional water availability constraints, biodiversity loss, reduced landscape aesthetic, and coastal erosion. Climate change mitigation policies can further affect tourist mobility, e.g., through increased travel costs related to policies incentivising the reduction of greenhouse gas (GHG) emissions.



A conceptual framework for analysing the impacts of climate change on the tourism sector

The WASSERMed approach: methods and tools

From the range of impacts and drivers, research in WASSERMed addressed the interrelation between climate and suit- ability of destinations for summer tourism (direct impacts for the Mediterranean basin). 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 (see Factsheet No 5), WASSER- Med 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 (see Factsheet No 1), considering both mean model ensembles and ensemble top and bottom values.

A short note on the Tourism Climate Index (TCI)

The Tourism Climate Index—TCI, which has been used in tourism-related assessments in WASSERMed, is an indicator used for describing the comfort sensation of tourists for outdoor activities. It has been widely used for assessing the attractiveness of a destination, and through its correlation to tourism-related data, such as arrivals and overnight stays, it can also be used to estimate the direct impact of long-term climatic changes on tourist preferences.

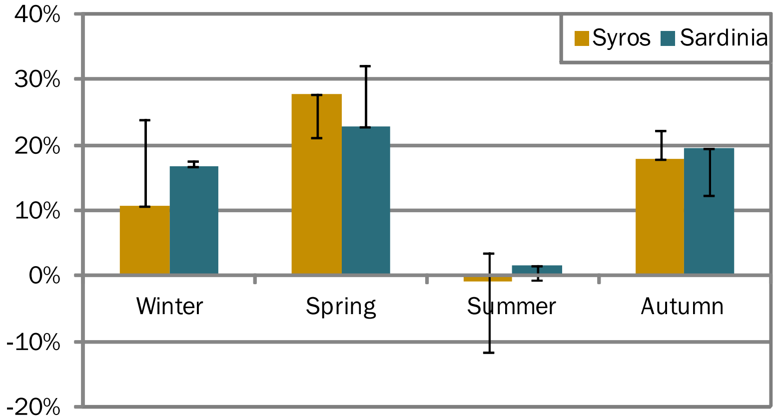
The TCI combines seven climatic parameters (monthly mean values for maximum daily temperature, mean daily temperature, minimum daily relative humidity, mean daily relative humidity, total precipitation, total hours of sunshine and average wind speed) in five sub-indices, the Daytime Comfort Index, the Daily Comfort Index, Precipitation, Sunshine, and Wind Speed. The maximum value is 100, with values over 80 depicting very favourable to excellent conditions for summer tourism.

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).



Estimated percentage change of seasonal tourist arrivals in Syros and Sardinia in 2051-2060 vs. 1980-2010

Mediterranean-level analysis

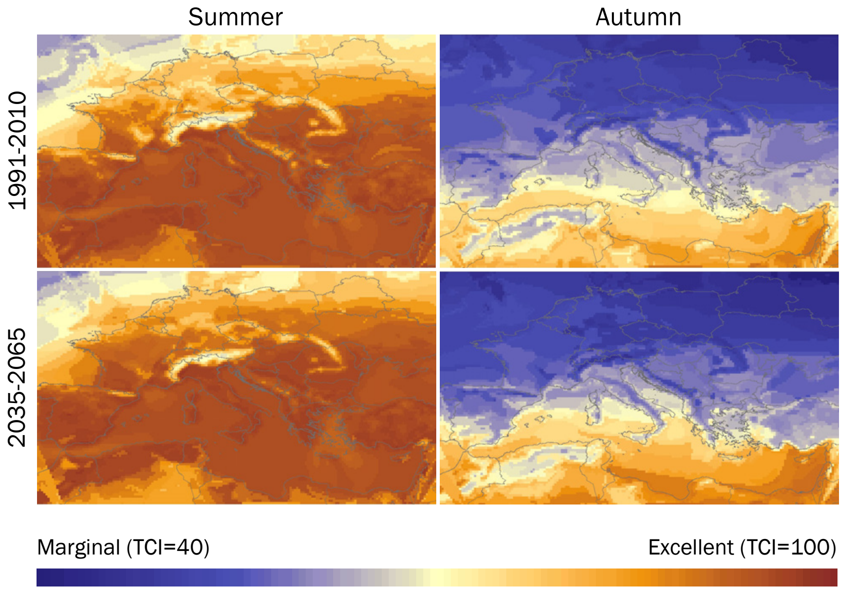
Results indicate that conditions will remain favourable for summer tourism in the Mediterranean basin. How- ever, a change in seasonality is probable, as there is an improvement in TCI values in spring and autumn and a slight deterioration in the summer.

In more detail:

- In winter, there is a notable 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.

Key findings and considerations

- An alternative distribution of Mediterranean tourism can be anticipated, particularly during summer. This would not necessarily impact negatively on the sector, but this information should be disseminated to authorities, tourism businesses and tourism service providers.
- The detailed assessment for two tourist destinations, Syros and Sardinia, portrays minor impacts on summer tourism and opportunities for a prolongation of the tourist season. Such opportunities would require investment in available infrastructure and services for the support of additional activities.
- The effect of other climate change impacts (e.g. sea level rise, change in the frequency of extreme events) should be considered in tourism development plans, particularly regarding the settling of tourism businesses and costs for the protection and restoration of coastal areas.
- Assessments based on climate comfort indices can adequately represent changes in seasonality and attractiveness of a region for outdoor activities. However, such indices alone cannot be used for estimating future tourism patterns. Tourist destination choices are not solely based on climate conditions, and other factors can have more significant influence (e.g. marketing of tourist destinations, improvement of access and tourism facilities).



Summer and autumn Tourism Climate Index values for the A1B SRES [RACMO2 model, driven by the ECHAM5 GCM]

A GIS-based tool for assessing climate change impacts on tourism

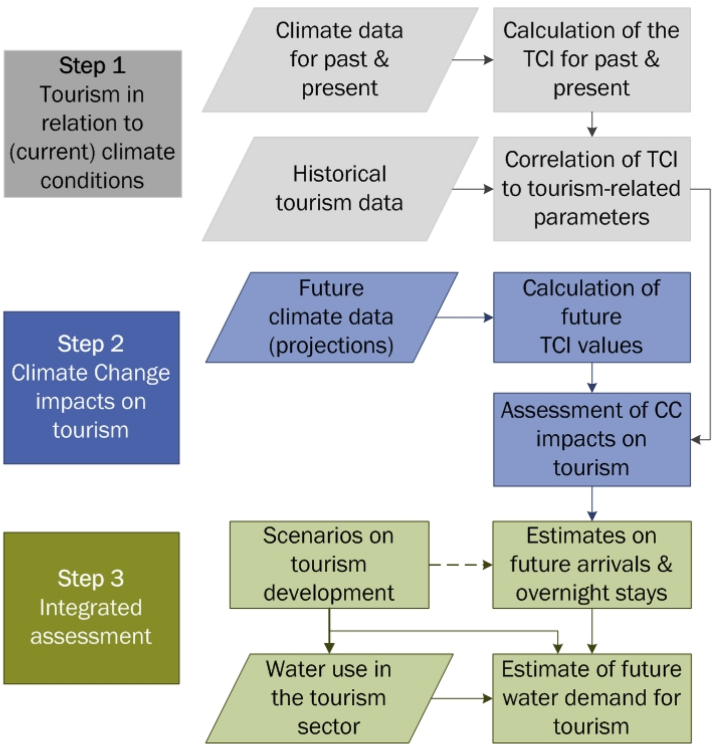
The tourism-CCIA tool: Methodology and structure

Within WASSERMed, the analysis of climate change impacts on tourism was based on a GIS-based tool, the Climate Change Impact Assessment (CCIA) Tool for Tourism, specifically designed for this purpose. The tool implements a stepwise methodology, based on the Tourism Climate Index (TCI), initially developed by Mieczkowski (1985).

Starting from the analysis and correlation of tourism-related information to current or historic climate conditions, the tool assesses the direct effects of climate change in the sector, as well as potential development opportunities (e.g. shoulder tourism). In a third step, it performs integrated assessments to assess indirect effects on income and water demand (magnitude and seasonality) with the aim to support informed planning for tourism and infrastructure development.

Two levels of analysis can be supported. At the local level, the emphasis is on the analysis of observational data and local- ised projections and impact assessments. At the regional level, the analysis is based on gridded datasets, referring to either historical data or future projections from different emission scenarios and climate models.

In the context of WASSERMed, the tool was used for the assessment of climate induced impacts on tourism in Syros, Greece and Sardinia, Italy and at the Mediterranean.



Methodological framework for the Tourism Climate Change Impact Assessment (CCIA) tool

Tool features

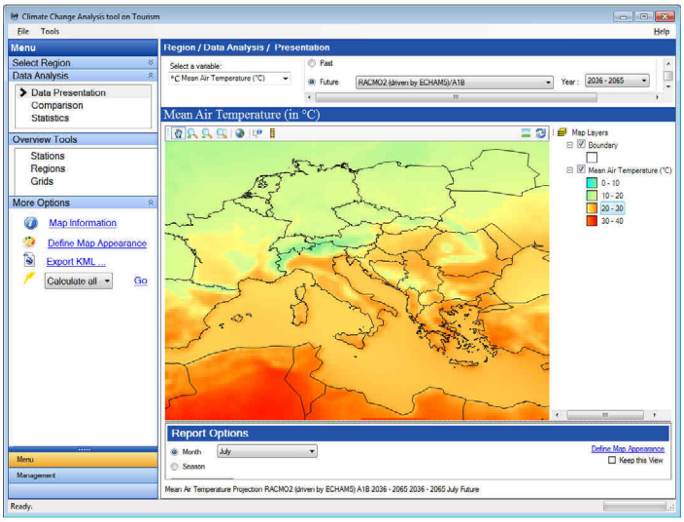
As mentioned above, the emphasis of the Tourism-CCIA tool is on the estimation of selected climate change impact-related indicators, the illustration of their temporal and spatial variation, and on the assessment of the significance of their changes for different timeframes and climate projections.

As such, the tool can be used as:

- A well-organized repository for storing and visualizing data related to climate and tourism;
- A platform for presenting future climate projections and formulating user-defined scenarios;
- An analytical framework for assessing climate change impacts on tourism, focusing on trends, seasonality, income and water demand.

A distinctively powerful feature is the ability to accommodate and fully describe different spatial and temporal datasets. In its current version, the platform incorporates climate datasets from a variety of sources (e.g. WorldClim, FutureClim, Rossby Centre , the E-OBS, the Prudence and

WASSERMed projects, for different periods and SRES). Time series for meteorological parameters, tourism, agriculture, water availability, etc, can be accommodated, offering the possibility to extend the tool application scope.

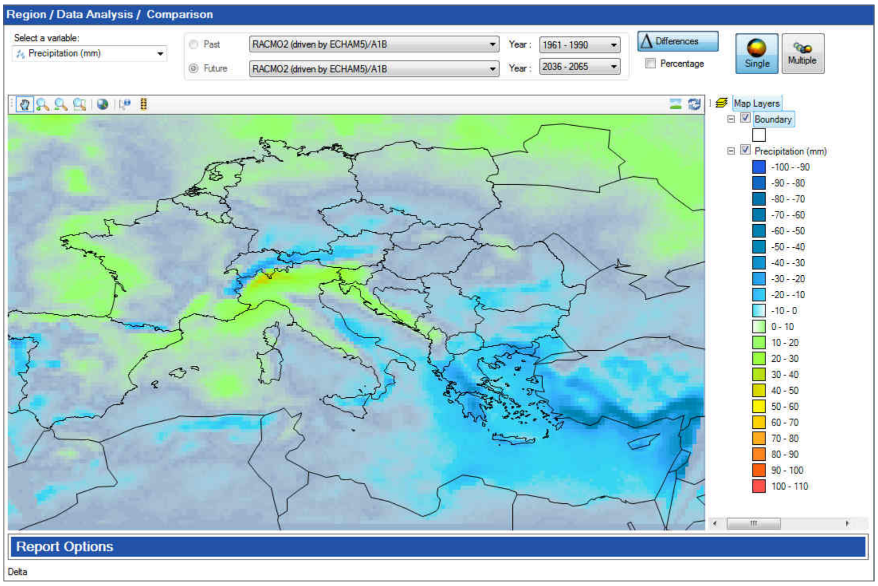


The Tourism-CCIA tool interface for the visualization of climate projections for the Mediterranean region

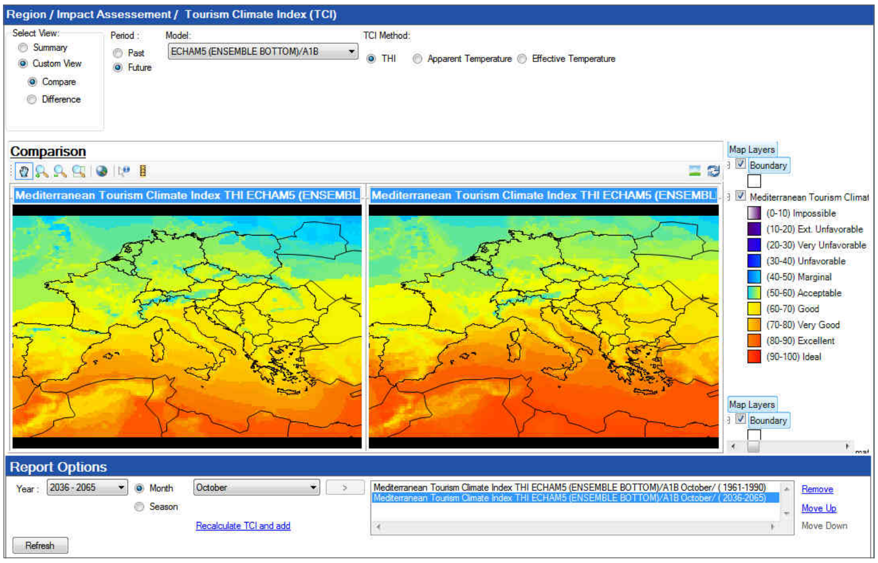
Assessments and application examples

Regional level assessments

Analysis and assessments at the regional level are mainly supported through gridded datasets, where users can visualise historical or projected climate data and estimates for the Tourism Climate Index. Data and results can be displayed for different time- frames and time steps (monthly, seasonal, yearly or longer periods). Furthermore, the platform can estimate the difference between datasets pertaining to different periods (historical or projected values), emission scenarios and RCMs/GCMs, thus helping to identify significant trends and differences between them.



Difference in winter precipitation (mm) between 2036-2065 and 1961-1990 [RACMO2 RCM driven by ECHAM5, A1B SRES]



Comparison of Tourism Climate Index values between 1961-1990 (left) and 2036-2060 (right) [RACMO2 RCM driven by ECHAM5, A1B] SRES]

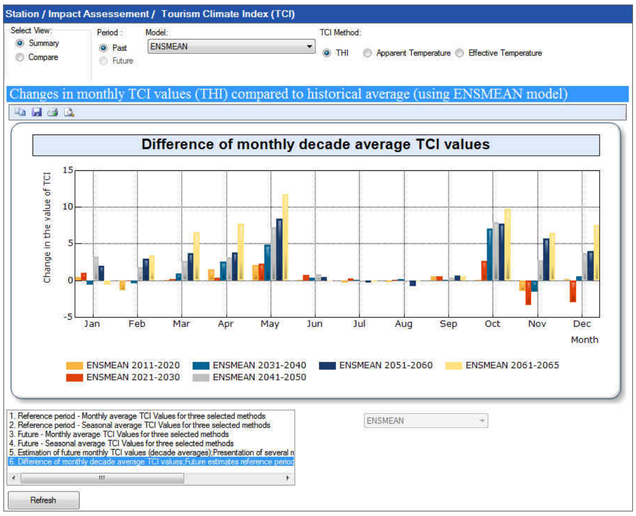
Local level assessments

Similar analyses can be conducted for observational data from individual meteorological stations, complemented with statistical analysis of the entire or a subset of the meteorological time series.

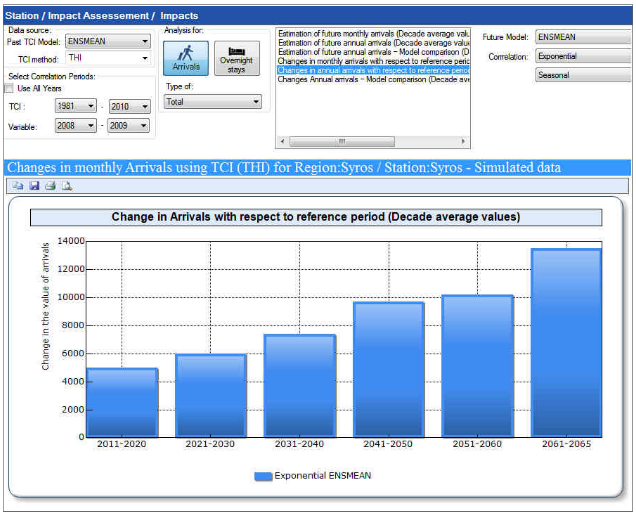
Climate change impact assessments

The assessment of the impacts of climate change on tourism for a specific area or region can be performed based on user-defined scenarios or on projected climate data. Historical data are used to derive correlations between the TCI and tourism- related data; the correlation model is then used to estimate future overnight stays, arrivals, income from tourism-related activities and water demand.

Results can be exported in a variety of formats, fully customizable to accommodate requirements for presentation and further analysis.



Estimation of Tourism Climate Index changes in Syros Island, Greece for 2011-2065 at decadal scale



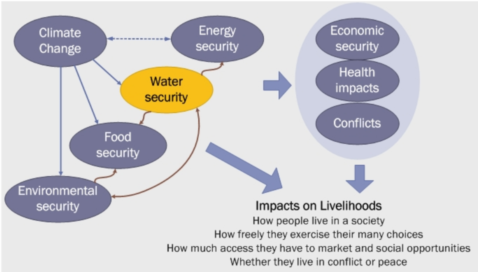
Climate-induced change in tourist arrivals in Syros, Greece, indicating the potential for prolongation of the tourist season

The WASSERMed case studies: development process and tools

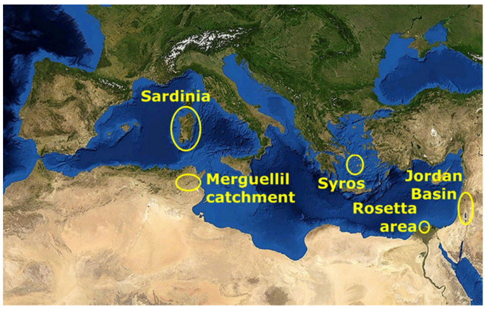
The WASSERMed case studies on water related security threats

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 objective behind the Case Study development was to assess, in an integrated way, the direct and indirect impacts of climate change, focusing on potential water-related security threats and adaptation measures towards their mitigation. As such, the corresponding Case Study themes were defined based on the current socio-economic profile, the range and impacts of water management issues, as well as local policy concerns and research priorities.



Water-related security threats,
as conceptualised in WASSERMed



The WASSERMed Case Study areas

The scope of the WASSERMed Case Studies

Area	WASSERMed Case Study scope
Sardinia (IT)	Impacts on agriculture and tourism; Water supply enhancement 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; Enhancement of agricultural activity and groundwater protection
Rosetta (EG)	Impacts of sea level rise and Nile water availability on agriculture 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.

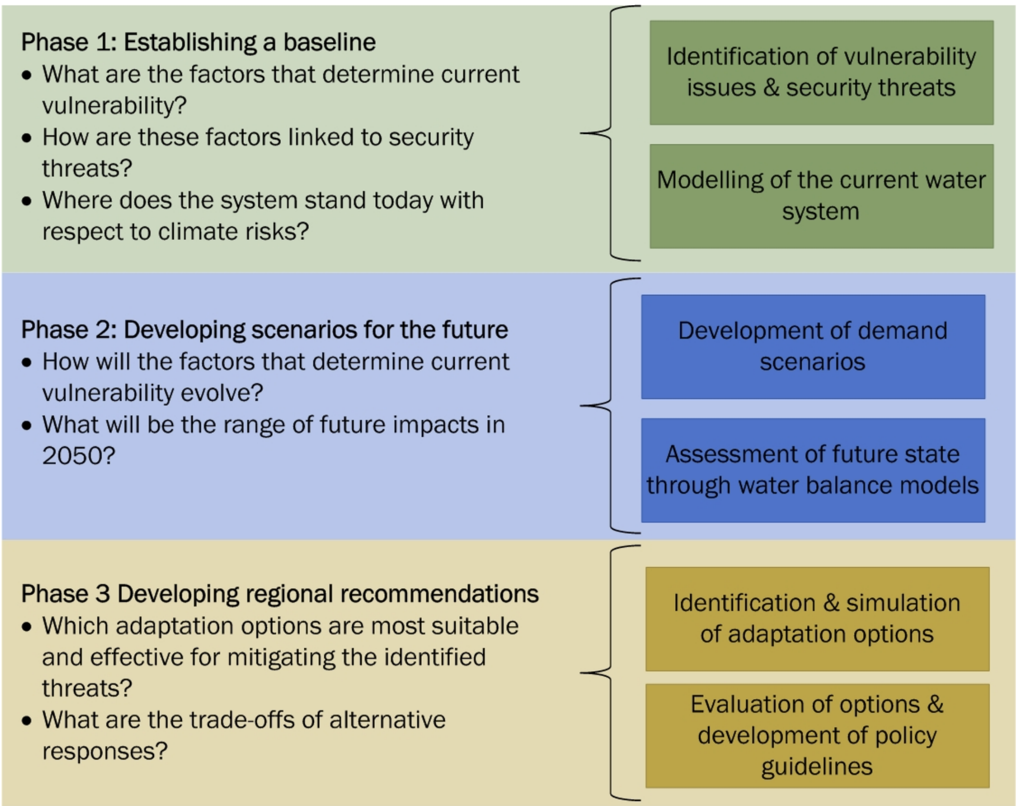
The process was articulated through dedicated events to which all local actors were invited to participate, to share their experience and knowledge and discuss the WASSERMed research results. Events were organized in 3 rounds. The 1st round concerned the framing of the Case Studies, in relation to local policy objectives and research, and the identification of factors that determine current and future vulnerability and how these can be linked to security threats, considering the current status of the system. During the 2nd round, the objective was to develop scenarios for the future by analysing how the factors that determine current vulnerability will evolve and affect the range of future impacts by 2050. Finally, the 3rd round of events focused on the discussion of simulation results and adaptation options, in terms of suitability and effectiveness in mitigating the identified threats, as well as the trade- offs involved in alternative responses.

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.

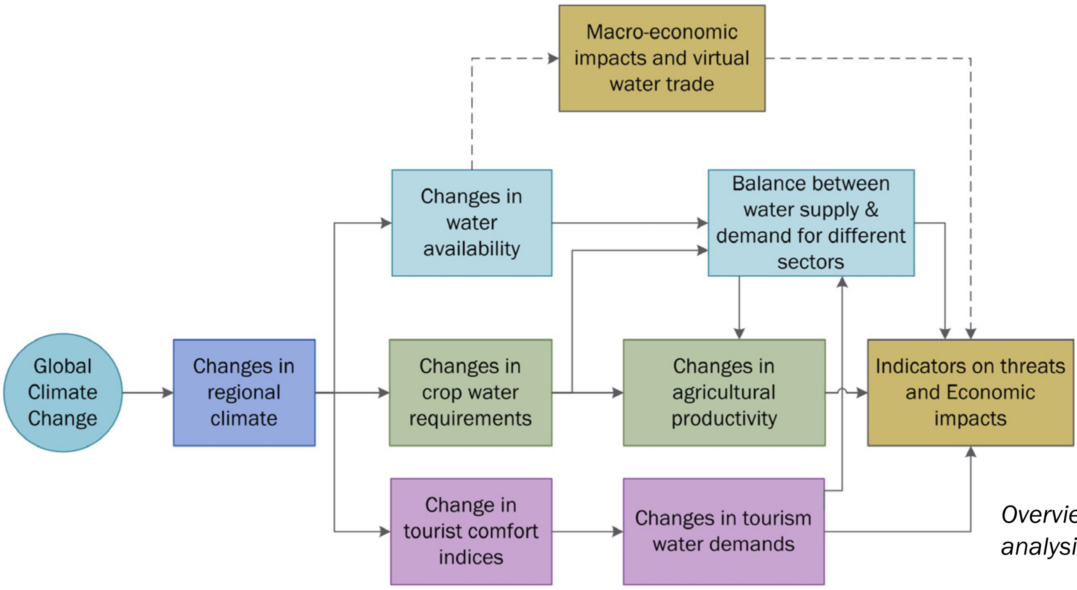
Phase 3 dealt with the "Development of policy recommendations", through the identification and simulation of potential responses (adaptation measures) to enhance resilience and reduce long-term risks to water security and other sectors. The evaluation of options was made jointly with stakeholders, considering the costs, benefits and effectiveness in mitigating potential threats.



Framing questions and phases in the development of the WASSERMed Case Studies

Methods and tools

For the above assessments, WASSERMed implemented a workflow based on the joint application of different tools and models, which were soft-linked to allow for the integrated assessment of climate change impacts in each region.



Overview of Case Study analysis workflow

Models applied to support Case Study analyses

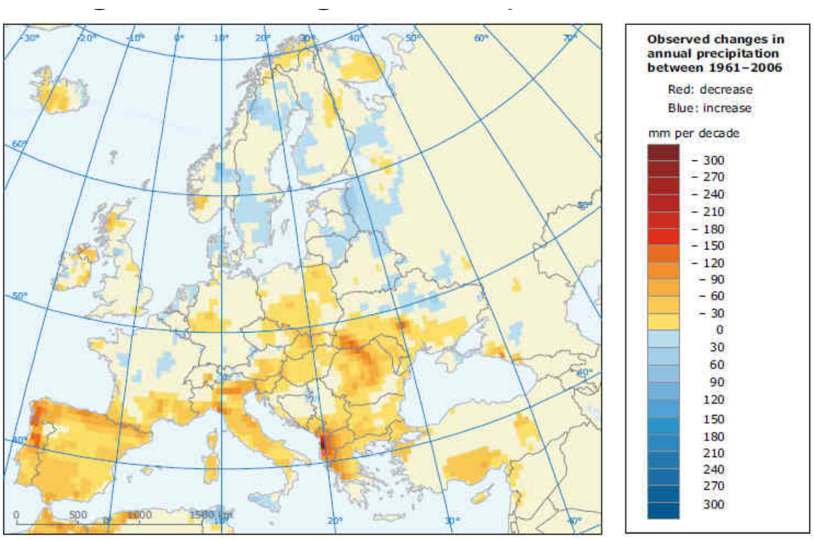
Workflow component	Models and tools
Regional Climate projections	FP6 ENSEMBLES project dataset
Crop water requirements and water productivity in the agricultural sector	CROPWAT, AquaCrop, SIMETAW, CropSyst, WOFOST
Tourism-comfort indices, water-demand patterns	GIS-based tool for the assessment of the Tourism Climate Index, Correlation models
Water balance	System Dynamics Modelling, WaterStrategyMan DSS
Macro-economic impacts	Global Water-Oriented CGE Model

Water Balance modelling in the WASSERMed case studies

How can climate change impact on water security?

Globally, water resources are being stressed and over-exploited. Numerous studies have shown that surface and groundwater bodies are being over- exploited. This leads to detrimental impacts on humans who have less resource per-capita, on agriculture which must either plant less crop or alter cropping patterns to match the available re- sources, and on development opportunities as water scarcity can impact on core economic activities and on 'ecosystem services'. It is likely that predicted global change will make the current situation worse for those regions already experiencing water shortages, and may lead to new regions experiencing water security issues. The Mediterranean is a global water security hotspot, with many areas being (close to-) over-exploitation. Climate change impacts are expected to be considerable throughout the region, affecting water security.

As a result, better modelling of the current and potential future water balance in various regions across the Mediterranean is important. In this way, policy makers will be better equipped when deciding how best to target resources in mitigating local water security issues.



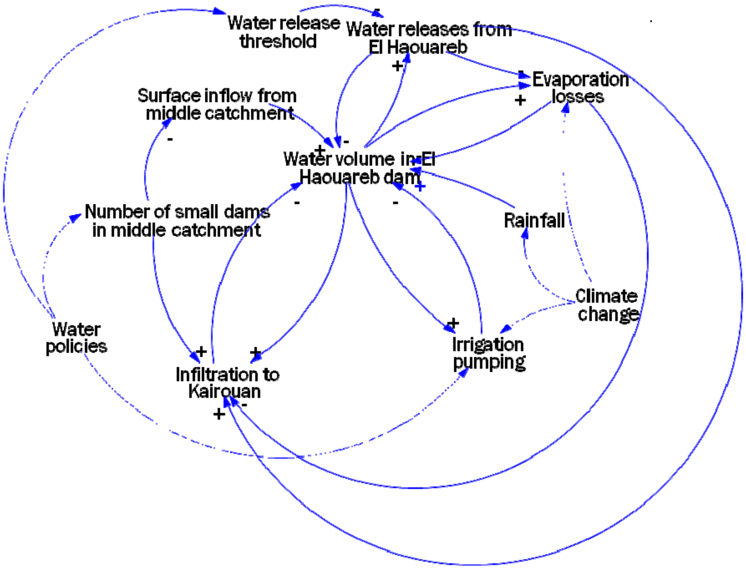
Observed changes in annual precipitation 1961-2006 (the data come from two projects: ENSEMBLES and ECA&D)

Modelling can also account for these policy measures, assessing their overall impact on water security in the future. However, water is not the only sector impacted by change. Changes in water availability also have consequences for food production and local economies. Integrated modelling that can reflect changes in all these sectors together is required for a full understanding of potential future situations and mitigation options.

The WASSERMed approach: methods and tools

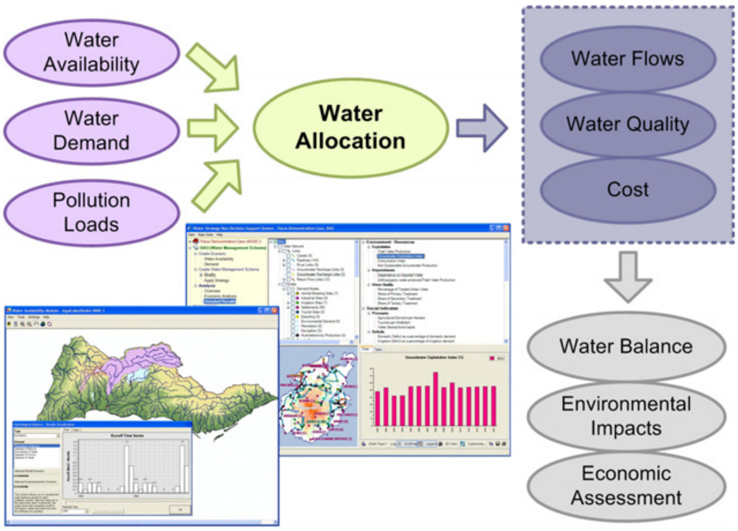
System Dynamics Modelling (SDM) was used in four of the five Case Studies developed in WASSERMed. SDM was used for its ability in modelling complex integrated systems that may be characterised by feedback and delays, such as the water systems analysed in WASSERMed. SDM uses the concepts of stocks (that store material), flows (that move material into and out of stocks) and converters (that alter the rate of flow) to create feed-back-driven systems models that can incorporate disparate sectors such as water, food and the economy in the same model.

The relationships between model elements can be summarised in the so-called causal-loop diagrams that qualitatively show how the elements influence each other. These are then used to construct the working simulation model(s). Results are output in graphical format to the user.



The Water Strategy Man Decision Support System (WSM DSS) was used in two Case Studies. This is a GIS-based package that emphasises on the conceptual links between different elements of water systems. The tool can assess water quantity and quality, and can output results as a suite of indicators. The WSM DSS has five main modules: water availability assessment, water demand assessment, water allocation and water balance estimation, economic analysis and multi-criteria analysis.

As with the SDM approach, baseline, climate-change and climate change with policy intervention scenarios were simulated. The objective was to provide policy makers with detailed information regarding the potential impacts of climate change on local water resources and the cost-effectiveness of potential policy measures.

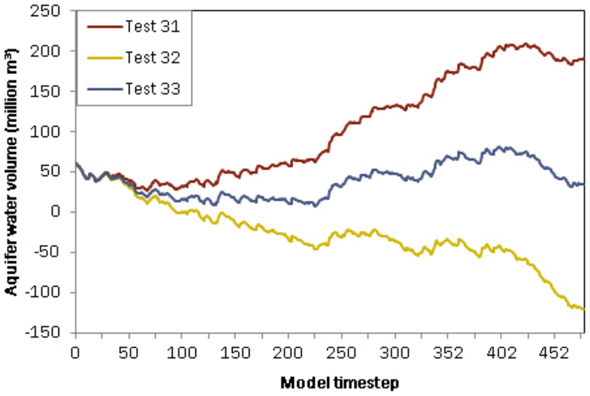


The framework of the WaterStrategyMan Decision Support System

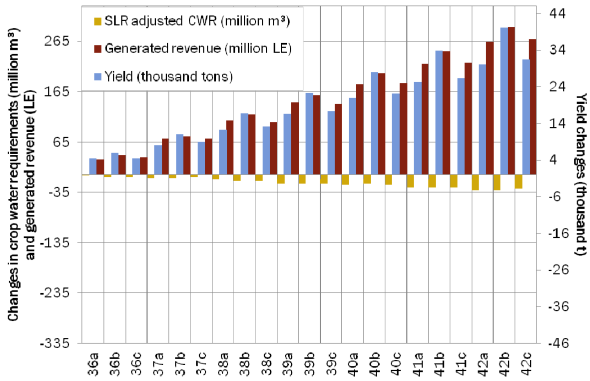
Main results

Results clearly show that throughout the Mediterranean, there is a wide range of diverse water-security problems, each having their own potential solution(s). The severity and complexity of the issues being faced are very diverse in different regions. Water is being over-exploited in most of the case study areas, and even where it is not, it is very close to being so. Therefore, water resources are under threat from future global change. Simulations of climate change impacts show that the current situation is expected to get worse, and that an inaction scenario is not viable for any of the analysed systems.

What-if testing of various policy options, however, showed that considerable improvements can be made, and in some cases, the situation can be turned into one of water surplus. In many of the case studies, this can be done through relatively simple measures, which may not encounter too much local opposition, especially if they are first fully discussed with local actors and users, and if they are gradually implemented. It is shown, however, that most policies may take years to show beneficial effects. Therefore a patient, long-term view is required, and high-impact, short-term changes should not be expected.



Potential policy impacts on the water balance of the Kairouan aquifer, Tunisia



Potential agricultural sector policy impacts in Rosetta, Egypt

Key findings and considerations

- There is no single universal, Mediterranean-wide policy solution for overcoming the various water-related security threats being faced. While the overall threats (i.e. population increases, agricultural demand increases, climate changes) are common among case study areas, their impacts are considerably different. As a result, while some policy measures may be applicable across the entire basin, such as the curbing of domestic and agricultural water demand, and the provisions for 'alternative' water supply, others are location-specific.
- In most regions, a single 'cornerstone' policy should not be implemented in isolation - the risk in the event of failure/underperformance is generally too great in terms of the impact on development opportunities. Multiple policies, which introduce redundancy should any single policy fail and amplify the effects of other policies, will bring about the best chance for a water-secure, sustainable future across the Mediterranean.

Climate change impacts and adaptation in Syros Island, Greece

Overview of climate-related challenges in Syros Island, Greece

The island of Syros is part of the Cyclades complex in the Southern Aegean Sea. It has an area of 84km^2 and a total population of about 22,000 inhabitants. The capital of the island, Hermoupolis, is the administrative centre of the Region of South Aegean, which includes the Cyclades and the

Dodecanese island complexes. Currently, the economy of Syros is based on the operation of the Neorion shipyard, agriculture (mainly greenhouse cultivations), livestock breeding, services and tourism.

The Syros greenhouses

Desalination in Syros

Syros is semi-arid, with dry summers and yearly average precipitation of 400 mm/ yr, 84% of which occurs between October and March. In response to increasing water scarcity, the island has turned to seawater desalination to satisfy domestic water demand. The traditional practice of rainwater harvesting through cisterns is still practiced by the local population; however, cisterns are not mandatory in new developments, gradually increasing the need for new investments in the public water supply system. Rainwater harvesting is also practiced in agriculture, where the main water supply source is groundwater. Over the years, aquifers have been intensively exploited, resulting in water quality deterioration.

Climate change may exacerbate current problems, contributing to the following issues:

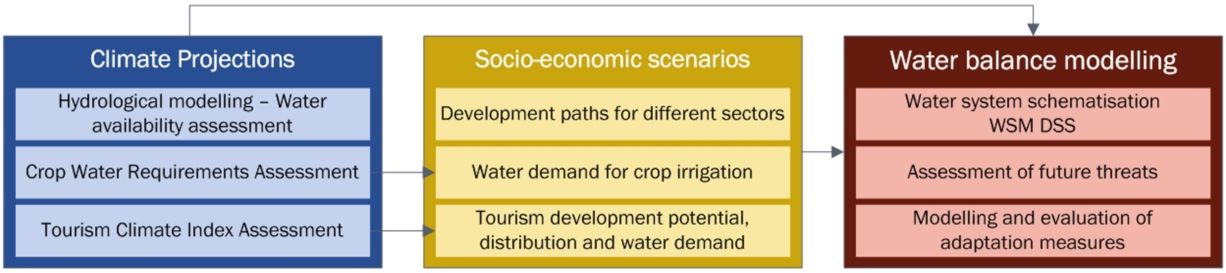
- Further limitations in freshwater availability resulting to the intensification of water scarcity problems, particularly for agriculture;
- Increased infrastructure requirements and costs to accommodate alternative tourism patterns, as well as changes in income distribution from tourism and agriculture;
- Increased overexploitation of ground- water resources, in order to meet water requirements for the different sectors.

Employed methods

For the purpose of gaining a better under- standing of potential climate change impacts, the WASSERMed Case Study for Syros focused on assessing direct impacts for tourism and agriculture, as well as indirect effects, based on water balance modelling.

Climate change impacts on tourism were examined based on the Tourism Climate Index-TCI (see Factsheet 4). Impacts on agriculture were assessed by estimating changes in Crop Water Requirements - CWR. Water balance modelling was based on the Water Strategy Man DSS. Simulations involved combinations of climate change and socio-economic development scenarios. These concerned alternative development paths for the tourism and agricultural sectors (unilateral or balanced sectoral development) and integration of environmental conservation measures.

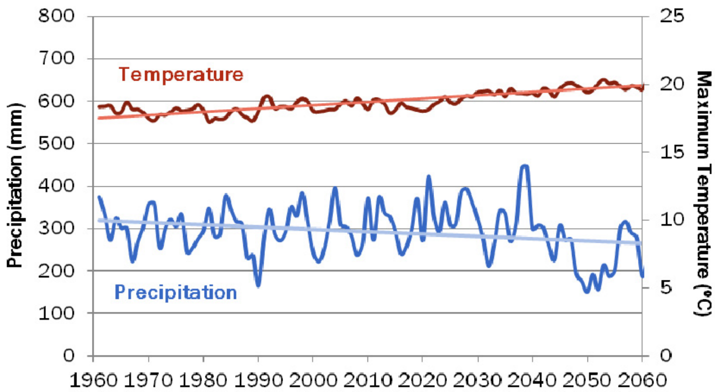
For all these scenarios, adaptation measures were modelled and assessed in terms of effectiveness, costs and benefits, and further discussed with local decision-makers and stakeholders.



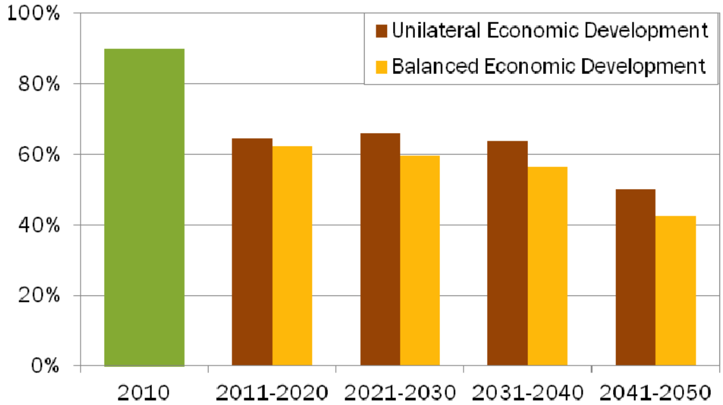
Integrated assessment of climate change impacts and adaptation options in the Syros Case Study

Main results

- Climate projections (HIRHAM5 RCM driven by the ECHAM5 and HadCM3 GCMs, A1B SRES) indicate an increase in maximum temperature of about 1.5^{o}C 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. This corresponds to a possible prolongation of the tourist season towards spring and autumn, and to 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. This refers to both the average coverage and to the reliability in meeting sectoral water requirements.
- 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.



Trends in yearly precipitation and maximum temperature in Syros [HIRHAM5 RCM driven by the ECHAM5 and HadCM3 GCMs, A1B SRES]



Estimated average decadal water deficits in the agricultural sector for a unilateral and a balanced socio-economic scenario, incorporating climate change impacts

Performance and economic assessment of adaptation measures.
Ranges refer to average values for 2020-2050 for different combinations of socio-economic scenarios and climate projections

Measure	Average coverage of irrigation demands	Reliability in domestic demand coverage [95% threshold]	Economic benefit-cost ratio
None [scenarios with no measures]	60-67%	78-81%	-
Rainwater harvesting—Agriculture	65-72%	81-84%	0.01-0.11
Rainwater harvesting—Domestic Use	57-67%	80-82%	1.31-3.35
Desalination capacity expansion	61-71%	84-95%	0.32-4.10
Wastewater reuse	72-77%	87-92%	2.00-2.32
Artificial aquifer recharge	69-74%	81-85%	0.98-1.12

Recommendations

- Climate change could have a positive effect on tourism, as the suitability of Syros as a summer tourist destination would not be significantly affected, and climate conditions could favour a prolongation of the tourist season towards spring and autumn. The realisation of this development potential would require additional investments in infrastructure and the enhancement of the offered tourism services.

- The agricultural sector would be negatively impacted; sustaining agricultural activities can only be possible through water supply augmentation measures, as demand management interventions have already been implemented to a significant extent.
- The further integration of non-conventional supply, and particularly water reuse, emerges as the most promising adaptation measure, as it would alleviate water scarcity in agriculture and improve resilience against future droughts.
- There is need for stronger collaboration among decision-makers and water users, particularly in the agricultural sector. The fostering of traditional water management practices and the re-integration of the agricultural sector in development plans would require coordination among authorities, and the representation of water users in relevant processes.

Climate change impacts and development perspectives in Sardinia, Italy

Sardinia: overview and climate-related challenges

Sardinia is located at the centre of the Mediterranean Sea. It has an area of 24,090 km^2, subdivided into plains (14%), hills (68%) and mountains (18%). The total resident population is 1.6 million, with 34% concentrated in Cagliari, the capital. The climate is typical Mediterranean, with an annual precipitation of 600 ± 400 mm/yr, mostly concentrated between October and March.

The economy is structured in different sectors, with tourism accounting for about 27% of Gross Domestic Product (GDP) and agriculture for 4%. Water requirements mainly rely on the numerous storage reservoirs, although some areas rely on spring water or groundwater.

Agricultural land accounts for about 47% of the total area of the island, but only 7% of this area is currently irrigated, using about 270 million m^3/yr of water. Tourist flows (38 million overnight stays were estimated in 2007) correspond to annual water demands of about 9 million m^3, with marked seasonal peaks in coastal areas. Competition for water is likely to increase as the two sectors expand.

Climate change scenarios forecast minor changes in water availability in Sardinia by 2050, while precipitations decrease in the following half century. The development of the tourism and agricultural sectors under climate change scenarios pose two threats related to water security: (a) reduced water availability for irrigation and urban use, and (b) environmental degradation, due to the high concentration of economic activities along the coast.

Employed Methods

Water demand projections for 2050 were calculated through water balance models, accounting for climate projections and different development scenarios for the tourism and agricultural sectors.

Climate change in Sardinia was represented by the RegCM3 regional climate model results (GCM ECHAM5-r3; 25 km resolution; A1B SRES) available through the Ensembles RT3 validation assess- ment. Irrigation requirements were estimated by soil water budget and crop evapotranspiration models (SIMETAW), driven by present (2005-2010) and future climate projections (2045-2050).

Four different scenarios were used to evaluate the viability of policies for irrigation expansion. Business-As-Usual (BAU) refers to a 20% expansion of irrigated areas (15,000 ha) for dominant irrigated crops (IWS), for selected water efficient crops (ISC) over the entire island, or for dominant irrigated crops in the central plains (ICP).

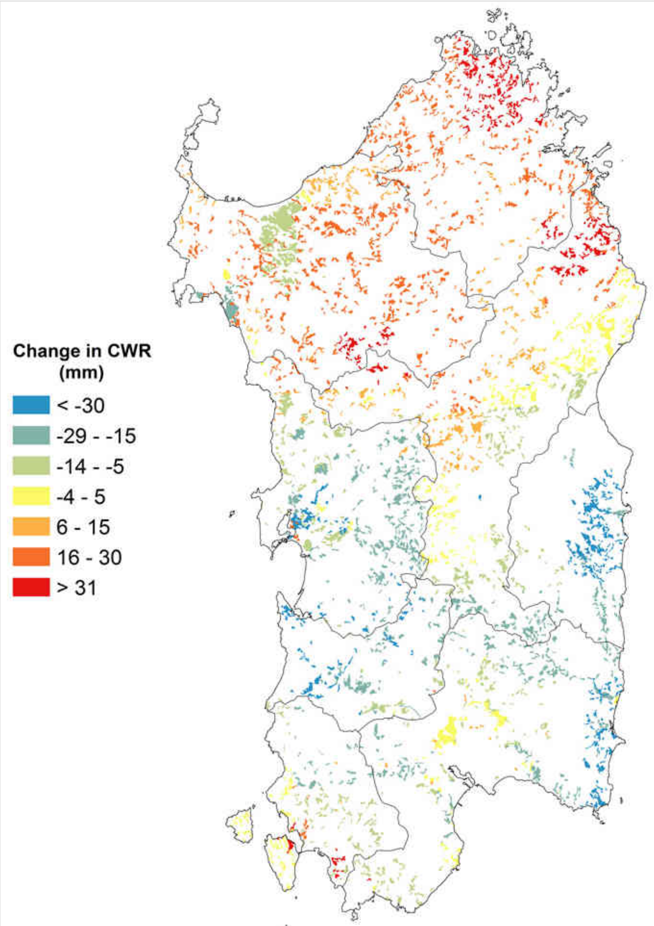
Climate change effects on tourism were assessed using the Tourism Climate Index (TCI). TCI values were calibrated using tourist flows for the period 1997- 2007, and projected for 2050. Water demands were estimated to accommodate four different development scenarios for the tourism sector: Business-As- Usual, Intensive Tourism Growth (ITG), Strictly Controlled Sustainable Tourism (SCST) and Balanced Competitive & Sustainable Growth (BCSG). Results were analysed to highlight potential conflicts and to help optimise development policies.

Main Results

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 m^3/yr, if applied across Sardinia only for irrigation efficient crops (ISC scenario), (b) 56.8 million m^3/yr, if applied to dominant crops only across regions with limited climate change impact on irrigation requirements (ICP scenario), and (c) 59 million m^3/yr, if applied consistently across Sardinia to dominant crops (IWS scenario).

Total irrigation needs under historical and present conditions and for future scenarios

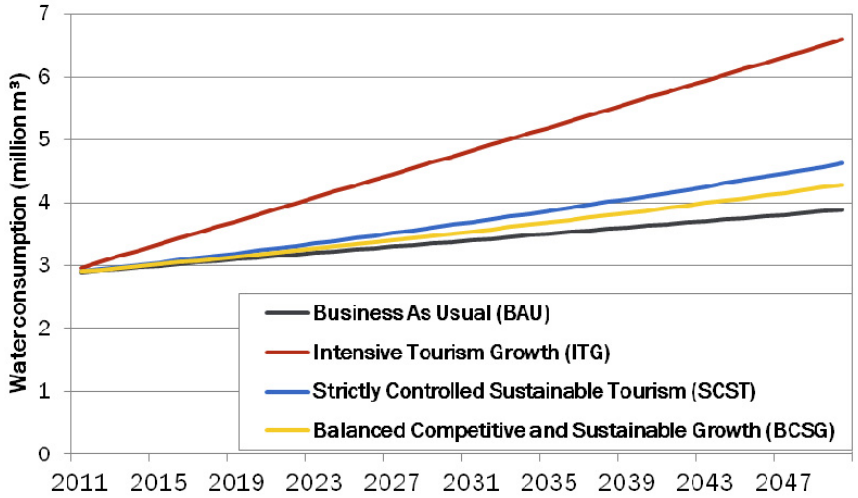
Period	Development Scenario	Total Irrigation Needs (million m^3/yr)
1960-1990	-	259.2
2005-2010	-	303.1
2050	BAU	294.6
	IWS	353.6
	ISC	345.4
	ICP	351.4



Changes in Crop Water Requirements (CWR)
for irrigation needs between 2010 and 2050

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.



Evolution paths for water demand levels relating to tourism flows per scenario (2011-2050)

Recommendations

- All development scenarios will require investments to implement and optimise water distribution networks. Among the possible tourist development, the SCST and the BCSG are suggested as they require smaller investments, and cause lower environmental impacts. Furthermore, the distribution network for these two scenarios partially overlaps with the present network and that necessary for agricultural development.
- Climate change scenario suggest that water requirements for irrigation will increase rapidly between 2050 and 2100.

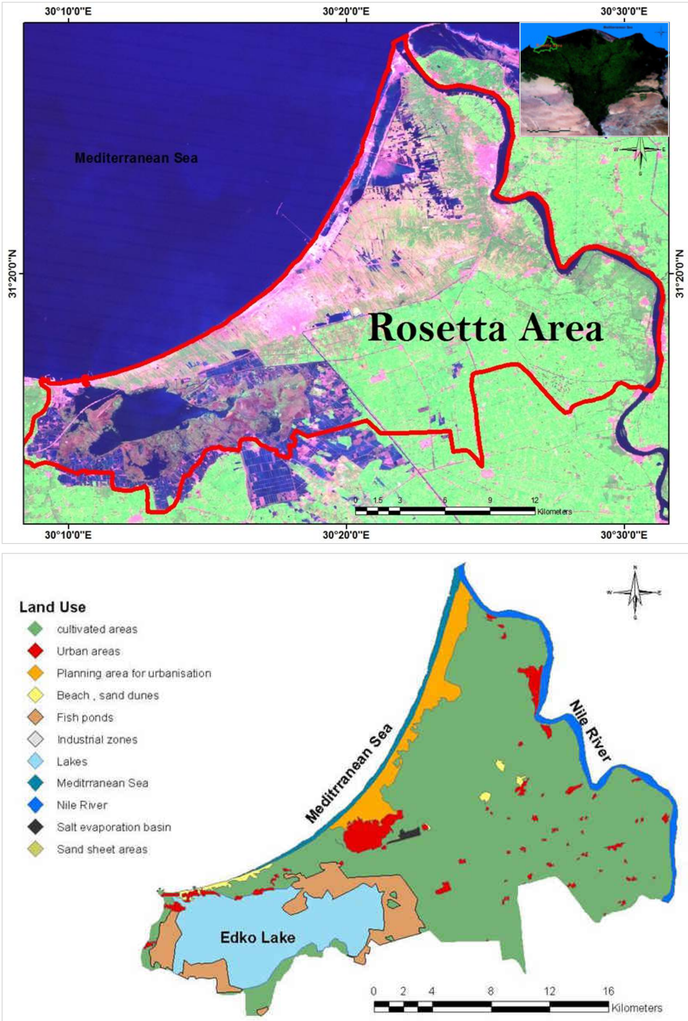
Climate change impacts and adaptation options in the Rosetta area, Egypt

The Nile Delta and the Rosetta area

The Nile Delta is a triangular area (25,000 km^2) in the northern part of Egypt, delineated by the two main branches of the Nile, i.e. the Damietta branch in the east and the Rosetta branch in the west, and by the Mediterranean Sea in the north. This location makes the area very unique, particularly in terms of interactions among sea water, groundwater, and surface freshwater.

The Rosetta area, which was the focus of the WASSERMed Case Study in Egypt, is located near the end of the Rosetta branch, between latitudes of 31°36' and 31°05' and longitudes between 30°33' and 30°43'. The area occupies a 40 km long strip of the Mediterranean coastal zone, with an area about 700 km^2.

Challenges facing the region include the low elevation, which makes the area and its groundwater resources particularly vulnerable to sea level rise, the water deficit, affecting agricultural activity, and the related socio-economic impacts. In WASSERMed, the main focus of the Rosetta Case Study was to analyse adaptation options in the water and agricultural sectors.



The Rosetta area: Location and land use

Employed methods

The first step for the development of the Rosetta Case Study was the establishment of a reference database, with all currently available data on climate, water resource management, agriculture and environmental parameters. Then, scenarios were simulated, considering:

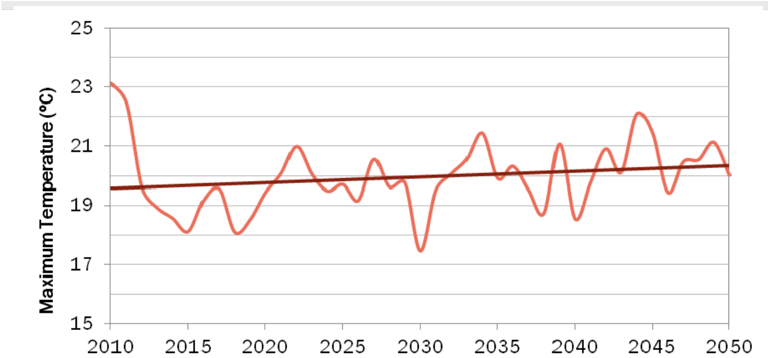
- Regional climate projections, as derived through the CLM model;
- Direct impacts of climate change on agriculture (i.e. changes in irrigation water requirements), using results from the SIMETAW model.

The simulation aimed at assessing indicators, quantifying potential threats, costs, and benefits for baseline conditions and future scenarios, through water balance modelling (SDM and WSM DSS tools). In addition, an optimisation model was developed, for identifying the best options to minimise the impacts of climate change in the water and agricultural sectors. This model, developed by ECRI, is distinctive, and includes several parameters and data on climate, crops and yields, fertilisers, costs, manpower, etc. Results were further synthesised into policy recommendations.

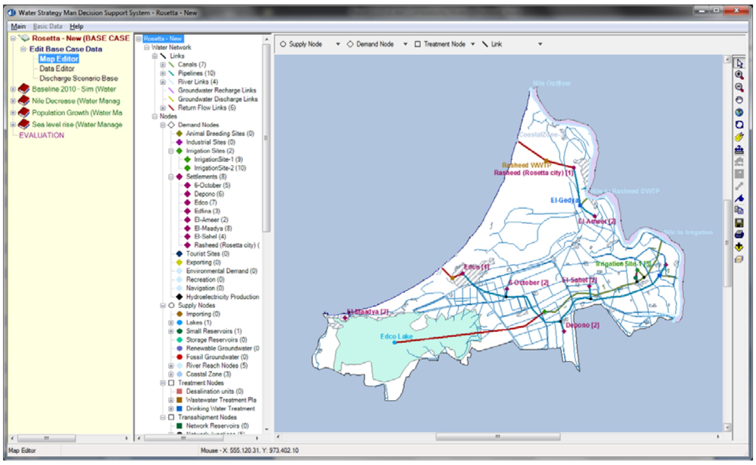
The Case Study built on the active involvement and participation of stake- holders, so as to support the develop- ment of outputs suitable to decision making needs. Several events were held at different levels, involving decision mak- ers and researchers, the local administration, and citizens.

Main Results

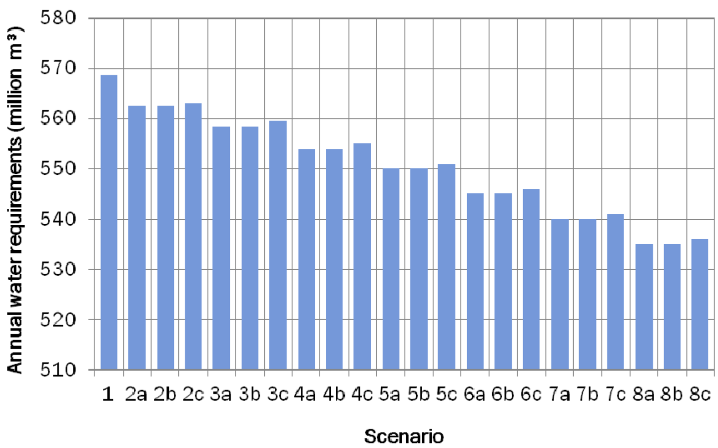
- Climate change could lead to:
  - increase in annual average air temperatures, up to +1.4°C.
  - reduction of the annual rainfall (-12.9 mm/yr), increasing or decreasing at monthly scale.
  - slight increase (+68.8 mm/yr) of annual reference evapotranspiration, especially during the spring-summer months (with values up to +9 mm/month in June), and with a “peak” of daily evapotranspiration in July (7 mm/d).
  - of wheat 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 m^3/yr, for a best and a worst case scenario respectively.
- Alternative cropping patterns were identified by the ECRI optimization model; these can compensate for profit losses due to climate change.
- 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. These can include 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, and the development of Circulation Models for predicting the impact of climate change on the local and regional water resources.



Maximum temperature trend in the coastal part of Rosetta, CLM model results



Water system modelling in Rosetta using the WSM DSS



Results from the simulation of scenarios using System Dynamics Modelling

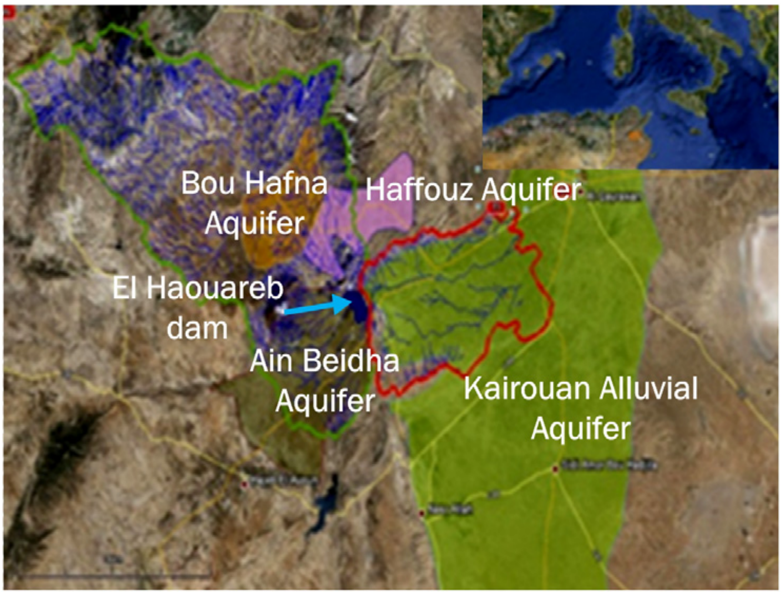
Recommendations

- The integrated study of sea level rise, water shortage issues and other climate change impacts should be further studied both at local and at national level.
- By combining changes to cropping patterns with more efficient water use, a more water-secure future could be achieved.
- Integrated water resources management and no-regret actions are highly recommended towards water and food security.

Climate change impacts and adaptation in the Merguellil catchment, Tunisia

An overview of the Merguellil catchment

The Merguellil catchment, situated in the central semi-arid region of Tunisia, suffers from increasing water scarcity as a result of climatic and human influences, including agricultural withdrawals and changes in land use. The upper catchment (1180 km2), which recharges the El Haouareb dam and the downstream aquifer, has seen the development of numerous water and soil conservation works. Ground water resources in the Kairouan alluvial plain (area of about 3000 km2) are heavily exploited for irrigated agriculture. Mean annual rainfall varies between 300 mm in the plain and 510 mm in the highest parts of the catchment, but is subject to large inter-annual variability. The mean temperature is 26.8°C in summer and 8.2°C in winter, and the mean annual potential evapotranspiration is around 1600 mm. Representative of many water re- sources issues in the Mediterranean basin, and designated as of major importance within the Tunisian national policy for maximal and optimal use of water resources, the Merguellil catchment has been the focus of several research projects at the national and international level.



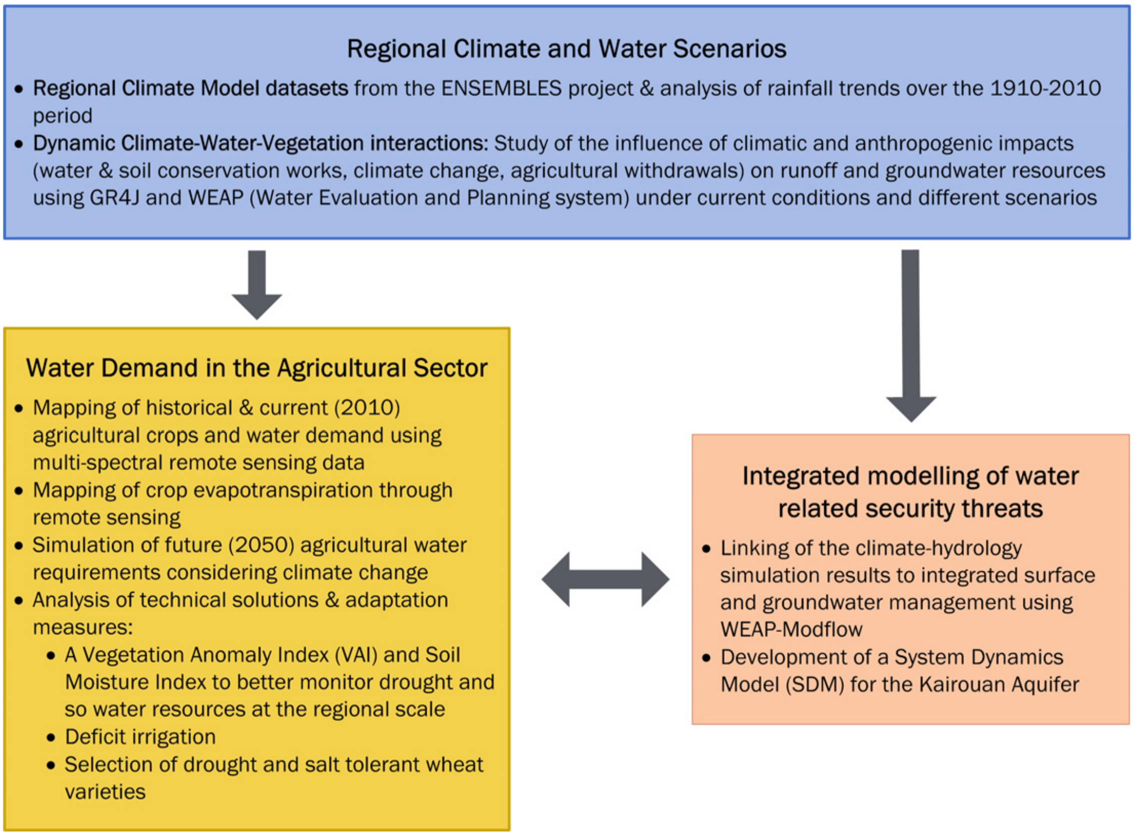
The Merguellil catchment and its main water supply sources

The available water resources comprise:

- Surface water supply from the El Haouareb dam with storage capacity of 95 Mm^3 and mean annual inflow around 17 Mm^3, but subject to high inter-annual variability.
- Ground water from phreatic and deep aquifers with renewable resources equal to 31 and 61 Mm^3 respectively. The thick phreatic aquifer of the Kairouan plain is overex- ploited (150% of annual renewal; annual decline of the water table between 0.25 and 1 m).

The water demand sectors include agriculture (80% of the total water usage), drinking water supply (for local cities and transfers to coastal towns), industry and tourism (local and transfer to tourist destinations at the east coast).

Employed methods

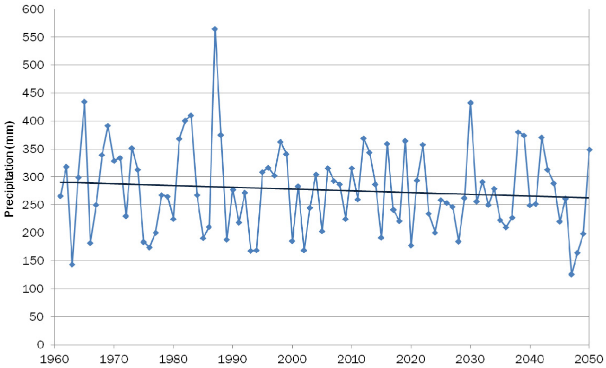


Main results

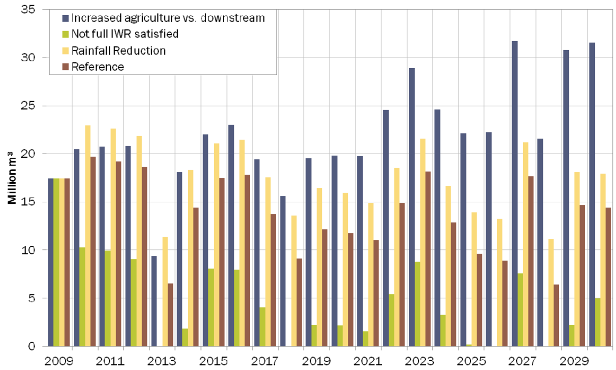
- Historical agricultural maps produced using remote sensing data from 1986 reveal an annual 2% increase in irrigated areas.
- A multi-temporal series of satellite SPOT-VEGETATION Normalized Difference of Vegetation Index (NDVI) data from 1998 to 2010 were used to analyze vegetation dynamics over the 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.
- A combination of chemical and isotopic approaches provided greater precision on evaporation losses from the El Haouareb dam and from small reservoirs in the catchment.
- 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.



Regional climate model RCA (driven by ECHAM5) projections show a 10% decrease in precipitation from 1960 to 2050



Unmet water demand in private irrigated areas under different scenarios generated and simulated by the WEAP model

Recomendations

- Further research is required to reduce uncertainties in crop water requirements and in the hydrological modelling of the catchment, notably the water balance and influence of small reservoirs and the El Haouareb dam on downstream groundwater resources under existing and future conditions.
- Deficit irrigation seems to be a good adaptation measure for water saving but its acceptability by farmers must be tested.

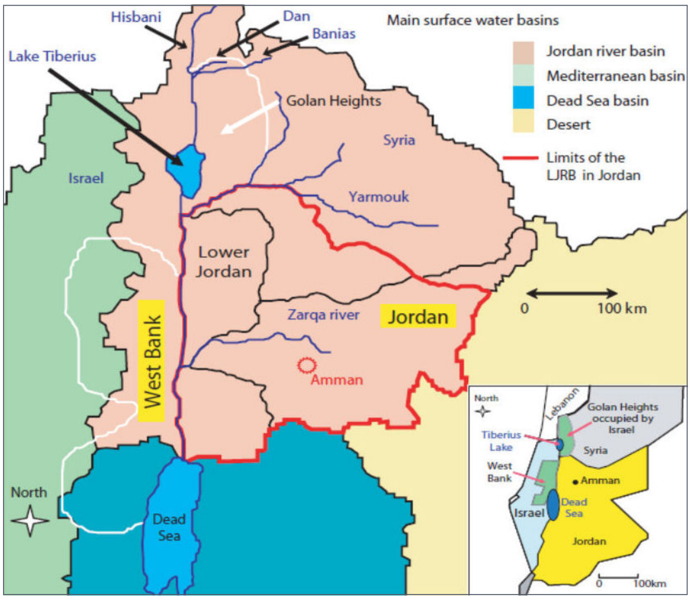
Climate change impacts and adaptation in the Jordan River Basin, Jordan

The Jordan River Basin – An overview of current issues

The lower Jordan River basin is part of the Jordan River system. The total area of the basin is about 18,300 km2 of which 7,627 km^2 are located in Jordan. About 90% of the population of the country is concentrated in the cities of Amman, Zerqa, Irbid, Sult, Ajloun and Jerash. The WASSERMed case study area includes the Jordan parts of Yarmouk basin, Zerqa River Basin and the sub-basins of other side-wadis that feed into the Jordan River. Two topographic units can be broadly distinguished in the Basin, the Jordan Valley and the Highlands. There is noticeable variation in climate from north to south and from east to the west.

The climate of the Jordan Valley varies from semi-arid (precipitation of about 400 mm/yr) in the north, to arid in the south (precipitation of about 100 mm/yr) but is considerably warmer than that of the Highlands. The average temperature varies from 15°C to 22°C during the winter, and between 30°C and 33°C in the summer. Rainfall in the Highland mountains ranges between 400 to 600 mm/yr, with peak values in January and February. Snowfalls are observed once or twice per year in elevations above 700 m.

Currently, the Jordan Valley experiences water scarcity, particularly during the summer. As a response, the Jordan Valley Authority imposed heavy restrictions on water supply during the summer months. In the past, the Jordan River flow (long- term average of 620 MCM) could allow for the irrigation of 54,000 ha at both banks of river. This flow has now declined to an average value of 200 MCM/yr for the Jordanian side of the Valley, which is hardly enough to irrigate 23,000 ha on average. In wet years, an additional 6,000 ha can be irrigated, whereas during droughts, deficit irrigation and water rationing are imposed. The decline of water availability in the Jordan Valley is mainly attributed to upstream uses in riparian countries, and partly to climate changes.



The Jordan River Basin

Employed methods

Climate data were collected for 6 stations representing different climatic zones of the Jordan River basin. Regional climate scenarios were provided for the period 1961-2050, based on a model ensemble (HIRHAM5, REGCM3, RACMO2, RCA), forced by the ECHAM5 GCM for the A1B SRES. Data representing the mean value of simulations from the different models were used to assess climate change and to evaluate direct impacts on agriculture, resulting from changes in crop water requirements. A significant part of the research focused on the mapping of water-related security threats and drivers of change that could further affect vulnerability and water security in the area.

A stakeholder workshop was organized to discuss future scenarios for the Jordan River Basin. Scenarios were further simulated through water balance modelling with the aim to identify potential adaptation options for mitigating potential threats to water resources.

Main Results

Impacts and adaptation in the agricultural sector

- An increase in maximum temperature of about 1.5^{o}C 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), which allow total or partial recovery of the crop cycle length, 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

- The Drivers-Pressures-State-Impacts-Responses (DPSIR) framework was used to map the water-related security threats and drivers of change that can affect the vulnerability of the Jordan River Basin to climate change. Identified drivers were further used to develop a best and a worst case scenario. Subsequently, through water balance modelling, the scenarios were used to quantify future water-related security threats and adaptation measures.
- 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.

Recommendations

- Water supply should be enhanced, through the desalination of brackish water, extraction and conveyance of fossil water, the building of new dams and further use of reclaimed wastewater.
- In addition to the above, different options should be explored in an effort to secure the water rights of Jordan for the shared water resources of the Jordan and the Yarmouk Rivers.
- For the agricultural sector, climate change impacts can be alleviated through shifts to earlier sowing dates and use of early maturing crops.
- Deficit irrigation strategies can be practiced in order to reduce evapotranspiration and net irrigation requirements, without significantly affecting crop yields.
- Based on stakeholder preferences, the cultivation of water intensive crops (e.g. bananas) should be reduced, while palm tree cultivations should be expanded.
- Significant investment should be made in demand management options, such as public awareness programmes, precision irrigation, and the improvement of conveyance and distribution efficiencies.

Potential impact and main dissemination activities and exploitation of results

Potential impacts on the analysed area

The Mediterranean regions of Southern Europe, North Africa and the Middle East are characterised by conditions of increasing water stress that already adversely affect the development of the two main economic sectors in the area, agriculture and tourism, and have wider environmental and societal impacts both at local and national scale. Such issues are expected to exacerbate as a result of climate change; according to the 4th IPCC Assessment Report (November 2007), the Mediterranean region will be highly influenced, experiencing a decrease in water resources. Furthermore, the rise in temperatures, the decrease in rainfall and the increase of the frequency and intensity of extreme events are bound to have significant impact on the vital economic sectors of the area, creating increased competition and potential conflicts over the allocation of scarce water supplies and adversely affecting agriculture, tourism, urbanized coastal areas and hydropower production. In this context, the better understanding of climate change effects is required to enable the formulation of the adaptation policies required to alleviate potential threats to the socio-economic development, stability and environmental sustainability that the region is trying to achieve.

The ***WASSERMed*** Project addressed the current and future uncertainties in hydrological budgets induced by climate change in the region. The overall approach delivered a high level of interdisciplinary research, combining climatic/hydrologic scenario building and modelling with macroeconomic analysis, and emphasizing on the most economically significant and at-risk sectors of the Mediterranean region. The overall scope of the analysis, which included the assessment of changes in mean flows, frequency and magnitude of extreme precipitation (intensity and duration), run-off, stream flows and ground water balance, as well as social and economic factors that may positively or negatively affect future threats, responded to the need for analysing the potential impacts of climate change within the context of wider institutional and social risks and assumptions.

Through the project realization the following specific objectives have been achieved:

- *Reduction of uncertainties of climate change impacts on hydrology in the identified regions*

Reduction of uncertainties has been achieved mainly by improving existing climatic and hydrological models, also through meta-analysis and ensembles, and by tailoring forecasts and scenarios to the specific regions under investigation.

- *Better assessment of climate effects to water resources, water uses and expected security risks*

A better assessment has been achieved in various ways: (a) through integrated research for the five case studies, where interdisciplinary work and involvement of local communities and stakeholders were pursued, (b) by focusing on especially sensitive and vulnerable sectors, like agriculture and tourism, for an improved understanding of the specific characteristics of water demand, technical solutions, cultural specificities, potential conflicts on water uses (e.g., between tourists and local residents).

- *Better basis for achieving water security*

WASSERMed was aimed at improving water security, in two dimensions. First, resilience to short-term water shocks for especially vulnerable regions and sectors. An important aspect of the better resilience is related to social capital, understanding and awareness. This was especially evident in the five case studies under investigation.

Second, the project aimed at improving long-term adaptation to climate change and its impacts on water availability. Climate change is a slow process and does not only affect extreme events. Slow changing climatic conditions will require a response in terms of new infrastructure, modification of production and trade patterns, and even political and socio- cultural changes. ***WASSERMed*** contributed also by improving our understanding of water availability on the economic systems, as well as on the relative competitiveness of regions and industries.

The **specific steps** that were undertaken in contribution to the expected impacts of the work programme has been achieved through a **Case Study approach.** The five Case Studies of WASSERMed utilised the developed climatic scenarios as baselines for impact assessment analysis. The geographic scale of the Case Studies varies from a small island to the Jordan River basin and Nile River system; these different scales have ensured that impacts both at the macro- and micro- level are considered and adequately addressed in the project. The impacts of climate change on water resources and uses were assessed in each Case Study area, aiming at a global, in-depth perspective of the security risks posed. Key strategic sectors were considered, selected using the criteria of vulnerability to climate variability, economic importance to these areas and adaptation potential. Furthermore, the project also investigated the **macroeconomic implications** of changes in climate and water availability, by assessing virtual water trade as an innovative adaptation option, a new field which has yet to be researched in depth, and performing a wider assessment of anticipated climate change impacts on tourism and agriculture across the Mediterranean Basin.

WASSERMed has enabled a better understanding of the on-going and future effects of climate change on water resources and important water use sectors. Impacts were also analysed from a broader viewpoint that took into account relevant socio- economic drivers of change, and anticipated environmental and socio-economic implications. Towards this end, the project also highlighted available policy options in terms of changes in the productive structure in vulnerable regions, in an effort to further enhance research on adaptation responses aimed at alleviating water security threats. Additionally, through the adaptation and application of modelling tools for water balance, impact assessment and simulation of water policies, the project created resources necessary for supporting future research that will be required for supporting adaptation options and wider policy reforms at local, national and regional context.

Through the adopted interdisciplinary approach, ***WASSERMed*** further promoted information sharing and exchange among institutions working on diverse issues related to water management and climate change across Europe and in Mediterranean Countries. Enhanced collaboration and interdisciplinarity maximized the potential impact of the work undertaken. Additionally, the direct and continuous involvement of stakeholders in the project raised social awareness on the very real threats faced today due to the impacts of climate change, and provided insight on water security threats. The fostering of mutual learning processes yielded high quality results and establish a better understanding of impacts in relation to the overall socio-economic and environmental context.

Water security and climate change are issues that span all geographic scales and ranges, to a certain extent affecting the populations of all regions. Therefore, the analysis and assessment of risks and impacts at the local level can yield valuable outcomes that can be used to support the formulation of wider adaptation policies. The integration of these results and outcomes across areas facing diverse water management problems enables a global view of the issues faced and potential adaptations for risk minimization. However, the already undertaken research in the area of water management and climate change is often characterized by fragmentation and limited interdisciplinarity. A consistent, holistic approach integrating different research results across socioeconomic environments would be most effective in addressing the complexity of the climate impacts on water availability and security.

To that end, the Project Case Studies reflect a variety of conditions faced in the Mediterranean, in European and partner countries, ensuring that the anticipated results will cover a wide range of conditions both in terms of climate change impacts and in terms of socio-economic environments. A European approach is selected as a means to yield cross-sectoral and integrated results that could contribute to the development of appropriate policies at the European level.

Link with international and national research activities

WASSERMed tried to maximize integration and interdisciplinary. This applies not only within the Project work packages, models and Case Studies, but extends to the establishment of an active cooperation in the analysis of case studies with a "twin" project on the same topic, funded under the Theme 8 "Socio-Economic Sciences and Humanities" programme, concentrating on political tensions and sociological dynamics.

The Project cooperated with other EC-funded and national projects, and payed special attention to the findings of Projects such as ENSEMBLES and CIRCE. ***WASSERMed*** also aimed to promote information exchange with other research efforts, by producing data in suitable format for potential use as input in subsequent analyses/projects, an issue that has thus far not been adequately addressed in other research projects.

Furthermore, the Project also built on the knowledge amassed and collaborations established through previous EC-funded Projects, including AquaStress, SWITCH, NeWater, INECO, SCENES, NOSTRUM-DSS, the ARID Cluster and HARMONIQua Cluster, and WaterStrategyMan, to avoid duplication of existing work and further enhance scientific knowledge and research towards the assessment of climate induced impacts on water management and use. Throughout the project duration, the Consortium actively supported, according to the Commission's recommendations, linkages with other relevant research initiatives; furthermore the partners responsible for the development of the ***WASSERMed*** Case Studies pursued, where relevant and required, links with ongoing national research and policy initiatives.

Main dissemination activities

Within the scientific community, the Project methodologies and results was disseminated through **scientific publications** in peer-reviewed journals and Conferences (see Table). Principally, publications were developed during the second and mainly during the third year of project implementation.

In addition, ***WASSERMed*** produced data in suitable format for potential use as input in subsequent analyses/projects. By enhancing the suitability of information available to the research community for use in further initiatives, the project has foster the exploitation of its results in future research work.

Work Package 6 of ***WASSERMed*** was specifically dedicated to raising awareness on climate-induced changes and impacts, and to disseminate the project outcomes. Activities that have been undertaken within the framework of this WP are structured along three main axes, described in the paragraphs that follow:

1. The development, maintenance and regular updating of a Project web site to openly disseminate

the project development and results to the wider public;

2. The development and circulation of electronic and printed dissemination material, including newsletters;

3. The implementation of local Workshops at the project Case Study regions, to facilitate interaction and open discussion with local stakeholders.

Throughout the implementation of the project's dissemination activities, emphasis has been placed on developing more simplified and comprehensive language to reach different audiences and effectively communicate the ***WASSERMed*** approach and outcomes to potential users of different backgrounds.

Development of dissemination material and the WASSERMed Newsletters

WP 6 also developed appropriate dissemination material, in printed and electronic format to enable reaching diverse target groups, including interested research institutes, public authorities, stakeholders and local actors, and decision-makers, outside the (limited) geographical scope of the ***WASSERMed*** Case studies and beyond the scientific community.

The disseminated material comprises:

- A project flier, produced in the first years of ***WASSERMed*** implementation, introducing project objectives and research approach;
- An annual electronic newsletter with short articles on activities and achievements of WASSERMed, which circulated through the e-mailing lists of the project participants;
- Printed material (fact sheets and booklet), synthesizing information and outputs from major project tasks and summarizing the main outcomes of the work undertaken, in order to facilitate interaction and information sharing with stakeholders and to arise the overall awareness regarding the climate change.

Especially with regard to the dissemination of final project outputs, attention has been given to producing material that is easily interpretable and comprehensive, so that it can be used in the decision-making process. For this purpose, content and format were extensively discussed in the 2nd year stakeholder workshops of ***WASSERMed;*** additionally consortium-wide and experts' review of contributions were implemented so as to ensure the quality of outputs produced.

Stakeholder workshops

WASSERMed is not a primarily stakeholder-driven project; however, given the need of also responding to wider societal and policy-making concerns and needs, the project implemented three rounds of stakeholder workshops at the ***WASSERMed*** Case Studies, to foster collaboration with local actors and adequately diffuse project-generated knowledge to a wide range of water management authorities, policy makers, actors and decision-makers from Southern Europe and the Mediterranean Basin. The first round of workshops, which was implemented during the first project year, introduced the ***WASSERMed*** approach to local stakeholders and establish collaboration, exploring local views on potential security threats and impacts arising from climate change, and fostering the exchange of knowledge and know-how on current water-related policies and socio-economic development patterns that can shape future water demands for significant water use sectors. The subsequent, second year workshop events focused on disseminating the mid-term progress of ***WASSERMed*** in terms of analyzing climate change impacts and the corresponding security threats at local, regional and national level. Both during these events and through individual consultation with local stakeholders, emphasis was placed in exploring ways through which achieved and foreseen research outputs can be translated into substantive information, to enable their use in the overall formulation of relevant adaptation policies. Recommendations from these events helped in the consolidation of research outcomes in relation to the local and wider context, and at the definition of an appropriate structure and format of the dissemination material on the final project outputs. Finally, the workshop event that was scheduled at the completion of the Project has been oriented towards the wider dissemination of ***WASSERMed*** outputs and to further advance dialogue on broader policy recommendations for addressing water-related security threats arising from climate change

Address of the project public website and contact details

Project Web Site and the WASSERMed logo

For the purpose of disseminating the project activities and outputs to all interested parties and the general public, ***WASSERMed*** developed and maintained a project-specific website platform (www.wassermed.eu) comprising a public portal and a private section.

The Public web site portal was devoted to making general information about the project available to the general public: project aims, partnership, preliminary results, deliverables, working papers, awareness material, information on meetings and other activities.

The public website platform was widely promoted through related initiatives and newsletters, mailing lists and cataloguing in popular search engines to ensure maximum exposure, and will continue to operate after the end of the Project. Throughout the course of ***WASSERMed,*** material has been regularly updated to reflect achievements-to-date, according to information received from all members of the Consortium.

The members-only Private section of the site is available to the Project Partners, and was used for the internal communication of the consortium and the monitoring of project progress.

The WASSERMed logo

Dissemination activities of the WASSERMed project (pictures from some workshops)

List of Beneficiaries and contact person

N°	Name	Country	Contact name
1	CMCC (Euro-Mediterranean Centre for Climate Change)	Italy	Prof. Roberto Roson
2	UNEXE (Center for Water Systems, University of Exeter)	UK	Prof. Dragan Savic
3	CIHEAM-IAMB	Intergovernmental	Dr. Mladen Todorovic
4	CLU srl	Italy	Luisella Bianco
5	NTUA (National Technical University of Athens)	Greece	Prof. Dionysis Assimacopoulos
6	UPM (Universidad Politecnica de Madrid)	Spain	Prof. Ana Iglesias
7	NCARE (National Centre for Agricultural Research and Extention)	Jordan	Dr. Ghada Al-Naber
8	PIK (Potsdam Institute for Climate Change Research)	Germany	Holger Hoff
9	IRD (Institut de Recherche pour le Développement)	France	Christian Leduc
10	ECRI-NWRC (Environment and Climate Research Institute)	Egypt	Maha Tawfik
11	INAT (National Agronomic Institute of Tunisia)	Tunisia	Zohra Lili Chabaane
12	FAUJ (University of Jordan)	Jordan	Prof. Muhammad Shatanawi