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**Euro South Mediterranean Initiative:
Climate Resilient Societies
Supported by Low Carbon Economies**



Connecting Downscaling, Impacts and Adaptation: A Summary

Highlighting Related Capacity Needs for Adaptation Strategy Development

Project funded by the European Union

Project implemented by
AGRICONSULTING CONSORTIUM
Agriconsulting Agrer CMCC CIHEAM-IAM Bari
d'Appolonia Pescares Typsa Sviluppo Globale

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The content of the report is based on presentations delivered by speakers at the seminars and discussions triggered by participants.

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FOREWORD

The Mediterranean region has been identified as a climate change hotspot by the Intergovernmental Panel on Climate Change (IPCC). Most countries in the region are already experiencing rising temperature, increasing water scarcity, rising frequency of droughts and forest fires, as well as growing rates of desertification. A common understanding is thus emerging in the region that fighting climate change is essential, by employing both mitigation and adaptation measures. These may also open new opportunities for further economic development, particularly those associated with low carbon options.

The EU-funded ClimaSouth project supports climate change mitigation and adaptation in nine Southern Mediterranean partner countries: Algeria, Egypt, Israel, Jordan, Lebanon, Libya, Morocco, Palestine and Tunisia.

The project assists partner countries and their administrations in transitioning towards low carbon societies while building climate resilience and promoting opportunities for sustainable economic growth and employment. The project also supports South-South cooperation and information sharing on climate change issues within the region as well as closer dialogue and partnership with the European Union.

As part of its efforts to enhance climate change strategic planning, the ClimaSouth project is producing a series of handbooks tailored to the needs of the South Mediterranean region. The key users targeted include relevant government departments at operational and policy levels, climate change units and committees, decision makers, meteorological services, and members of local government, the private sector and civil society. The ClimaSouth handbooks are based on peer-to-peer seminars and training sessions held by the project, which are designed to support national administrations in the development and implementation of climate change policy; they further help stakeholders in the region to engage more effectively in the global climate change framework.

This seventh handbook builds on the previous ClimaSouth E-handbook N.6 "Downscaling Climate Modelling for High-Resolution Climate Information and Impact Assessment". It provides an overview across the spectrum of downscaling/impacts/adaptation, emphasising the role of high-resolution climate data, and its contribution to the evaluation of required capacity for national adaptation strategies. Concepts are illustrated primarily by drawing on longer climate change timescales and in particular on impacts/adaptation for agricultural water. We hope this handbook will contribute to an overall understanding of downscaled climate information and risk management on all timescales.

May your reading be informative and interesting.

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CLIMASOUTH HANDBOOKS

Handbook N. 1: Building Capacity & Mainstreaming Climate Change Policy
Handbook N. 2: Improving Climate Information
Handbook N. 3: An Introduction to Greenhouse Gas Inventories and MRV
Handbook N. 4: Long-range Energy Alternatives Planning System (LEAP) & Greenhouse Gas (GHG) Modelling
Handbook N. 5: Low-Emission Development Strategy (LEDS)
Handbook N. 6: Downscaling Climate Modelling for High-Resolution Climate Information and Impact Assessment
Handbook N. 7: Connecting Downscaling, Impacts and Adaptation: A Summary

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CONTENTS

LIST OF SELECTED ACRONYMS

AR5	IPCC Assessment Report 5
CMCC	Euro-Mediterranean Center on Climate Change
CORDEX	Coordinated Regional Climate Downscaling Experiment
CPT	Climate Predictability Tool
ECMWF	European Centre for Medium-Range Weather Forecasts
ERWR	External Renewable Water Resources
EURO-CORDEX	Europe - CORDEX
GCM	General Circulation Model
GHG	Greenhouse Gas
IPCC	Intergovernmental Panel on Climate Change
IRWR	Internal Renewable Water Resources
IR	Irrigation Requirement
MED-CORDEX	Mediterranean - CORDEX
MENA-CORDEX	Middle East North Africa - CORDEX
PC	Personal Computer
RCM	Regional Climate Model
RCP	Representative Concentration Pathway
SIMETAW	Simulation of Evapotranspiration of Applied Water
TRWR Total	Renewable Water Resources
WCRP World	Climate Research Programme
WL	Web Link

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1. INTRODUCTION

The second ClimaSouth workshop on Downscaling Climate Modelling was conducted through the collaboration of CMCC, a leading technical partner, during November 2 - 6, 2015 in Lecce, Italy. The workshop consolidated the concepts of downscaling and high-resolution impact assessment, building on a previous workshop (March 2015, see ClimaSouth EHandbook N.6[WL1]). A major theme to emerge in the second workshop was the importance of downscaling with impact assessment in order to support adaptation strategies, which often rely on actions at the local level. Plausible high spatial resolution climate scenarios are critical for elaborating the development of robust adaptation strategies to cope with climate change now and in the coming decades. In addition to lectures covering key scientific topics, the workshop assisted participants in making illustrative impact assessments using downscaled climate scenarios, which in some cases represented the continuation of work begun during supervised homework analyses prior to the workshop. Indeed, this second workshop was the conclusion of an integrated ClimaSouth program covering these topics, including the first workshop (ClimaSouth E-Handbook N.6[WL1]) and subsequent participant analyses conducted at their home institutions with the supervision and collaboration of experts from the first workshop.

The interface of downscaling/impacts/adaptation is especially critical for much of the domain covered by the

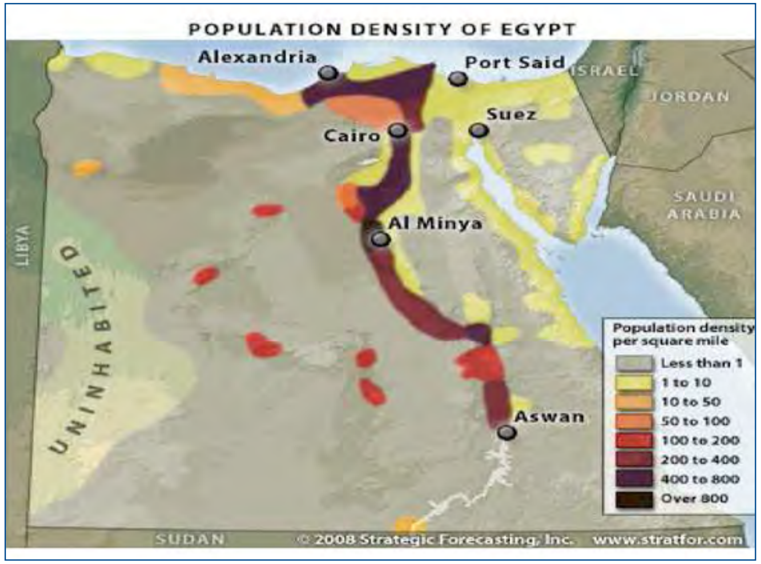

Figure 1. Population Density of Egypt, evidencing the environmental influences found in the Middle East/North Africa region
(As presented by the Egypt participant team in their discussion of downscaling/impacts/adaptation at the workshop).

ClimaSouth project, given the existence of high spatial variation in climate/environment conditions, with the associated strong correspondence of societal activity. Examples include strong spatial gradients in precipitation, temperature, soil moisture, land use, water availability and population density, all strongly tied to gradients from the Mediterranean coastline to the desert interior, interspersed with variations related to major rivers, oases and mountain chains. As an example, Fig. 1 shows the high spatial variation of the population density of Egypt. It is evident that population, social activity and human well-being will be very sensitive to projected climate changes, and that high spatial resolution must be present in climate change projections to properly evaluate the range of possible impacts and to allow countries in the region to develop robust adaptation strategies.

This handbook provides an overview of the concepts across the spectrum of downscaling/impacts/adaptation. It emphasises the role of high-resolution climate data, and its contribution to the evaluation of required capacity at this critical nexus, for national adaptation strategies. It is mostly intended for technically informed policy-makers. This handbook has been prepared in concert with the ClimaSouth E-Handbook N.6[WL1] that provided a more technical discussion of the downscaling/impacts topic with associated references, targeting an audience of professionals involved in undertaking downscaling/impact analyses. The first handbook was more comprehensive in covering downscaling at both the climate change and seasonal forecast timescales, and for a range of impacted sectoral issues. Here, in this shorter review, concepts are illustrated primarily by drawing on longer climate change timescales and with an emphasis on impacts/adaptation for agricultural water. However, Section 5 offers conclusions from the overall programme, covering downscaled climate information and risk management on all timescales.

The ClimaSouth team is grateful to the following CMCC experts for their lectures and support to workshop participants in illustrative analyses during the second workshop: climate experts E. Bucchignani, M. Montesarchio, A. Zollo and impact/adaptation experts N. Mancosu and A. Trabucco. Access to the CMCC's computing facilities and the technical/administrative support expertise in Lecce (Italy) were also critical for the success of the workshop.

2. DYNAMICAL DOWNSCALING

Basic Concepts

The warming of the climate system in recent decades is evident from observations and is mainly related to increasing anthropogenic greenhouse gas (GHG) concentrations (IPCC 2013). Consequently, precipitation will also be altered, partly because a warmer atmosphere will hold more water vapour, resulting in heavier rains. The main tool for providing insights into possible future climate changes is *climate modelling*. Climate models are mathematical models that simulate the behaviour of Earth systems based on the fundamental laws of physics. More specifically, General Circulation Models (GCMs) are computer models that mathematically represent various physical processes of the global climate system. These processes are generally well known but often cannot be fully represented in the models due to limitations on computing resources and input data. Thus, GCM results should only be considered at global or continental scales for climatic conditions averaged at monthly, seasonal, annual, and longer timescales.

To respond to the needs of decision-makers to plan for climate change, a variety of tools and datasets have been developed to provide climate information at spatial and temporal scales much finer than those at which global projections are made. The process used to obtain climate information at a higher resolution than that of GCMs is called “downscaling” (Fig. 2).

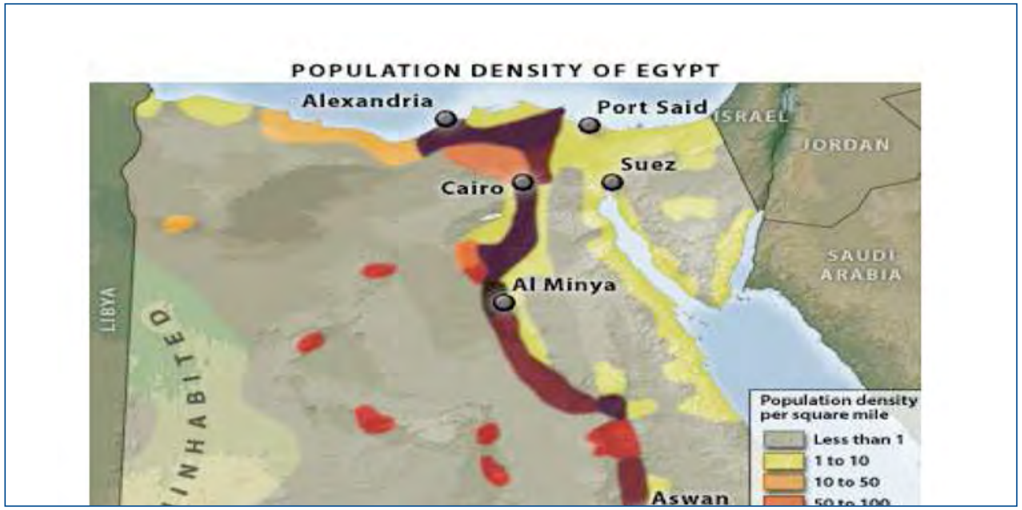

Figure 2. A schematic representation of the dynamical downscaling technique.

The downscaling methods can be distinguished into two main categories:

– *statistical methods*, which apply statistical transformations to the GCM output based on relationships calculated with observations;

– *dynamical methods*, which explicitly solve for the process-based physical dynamics of the regional climate system at high spatial resolution. One of the most effective tools, providing high-resolution climate analysis through dynamical downscaling, is the Regional Climate Model (RCM) (Giorgi and Mearns 1991).

Statistical methods are used to obtain climate information at very high resolution (about 100 m) starting with output from RCMs. The present handbook is mainly focused on dynamical methods, even if most of the following considerations apply also to statistical methods (see ClimaSouth E-Handbook N.6 [WL1]).

Considerations for the Effective Use of Dynamically Downscaled Information

While it produces climatic information at scales finer than the initial projections, downscaling involves additional information, data, and assumptions; these lead to further uncertainties and limitations in terms of results. Some of the drawbacks of dynamical downscaling include:

- *Dynamical downscaling is computationally expensive, needing large computing resources.*
- *Dynamical downscaling is strongly dependent on the boundary conditions provided by GCMs.* (GCMs may simply make incorrect projections of future large-scale conditions. Also, GCMs are not constrained by atmospheric observations during their integration, and so they may develop systematic errors, which can contribute to errors in the RCMs.).
- *The spatial resolution of most current-generation RCMs is limited to about 1 km* (as a result of the huge amount of computational resources required by finer grids, and also due to difficulties with suitable numerical models for some processes with such resolution values).
- *The difficulty of modelling high-resolution climate processes adds to the uncertainty of high-resolution projections by RCMs.* Integrations from several different RCMs should be consulted to help assess these uncertainties.

A major source of the uncertainty in RCMs arises from the large number of parameterized physical processes within the climate model and the associated unconfined model parameters.

Several studies have demonstrated the importance of this "parameter uncertainty" for the simulation of present and future climates, by perturbing single and multiple model parameters within plausible parameter ranges determined by expert judgment (Giorgi and Mearns 1991).

Since uncertain model parameters are responsible for a large part of modelling errors, the parameter uncertainty is typically constrained by calibration or tuning methods to improve the agreement between the climate model and the available observations. This tuning process is one of the aspects that requires highly skilled technical resources in order to effectively implement and run the RCM.

International organizations currently do not provide official guidance to assists researchers, practitioners and decision-makers in determining climate projection parameters, downscaling methods, and data sources that best meet their needs. Since the research community is still developing downscaling methods, users often need to read highly

Box 1. Parameterization

Climate models are based on a system of governing equations. However, these equations are not sufficient to give a complete description of the phenomena that take place in the atmosphere. Some phenomena, such as turbulent diffusion in the atmosphere, interaction with the orography and convection, have a significant impact and cannot be neglected. In order to improve the quality of the model's forecasts, it is important to include the statistical effects of these phenomena. Parameterization is a technique that, using simplified sub-models, allows the representation of the effects of a process rather than the modelization of the process itself.

technical and specialized explanations in order to understand and adequately apply the results for impact studies, planning, or decision-making. The following points provide some important considerations and recommendations that should be kept in mind when using/designing fine-scale information tools for studying climate change and its impacts:

- Downscaling relies on the assumption that local climate is a combination of local conditions (topography, land surface properties, etc.) and large-scale atmospheric features (global, continental, regional). Representation of the local aspects is beyond the capacity of current GCMs.
- Obtaining climate projections at local scales is a multi-step process. At each step, assumptions and approximations are made. Uncertainties are intrinsic in projections of changes in climate and their impacts (see Fig. 5 and related discussion in Section 3).
- When downscaled information is presented, supporting information on the downscaling methods used, the limitations of the results are often not appropriately highlighted, leading the user to believe that the results at the given resolution are "true" and valid (i.e., need no further adjustments). On the contrary, dynamically downscaled information usually requires further statistical correction before application in impact assessments (see ClimaSouth E-Handbook N.6[WL1], Section 2.5, and as presented to participants at the workshops; see Fig. 3).

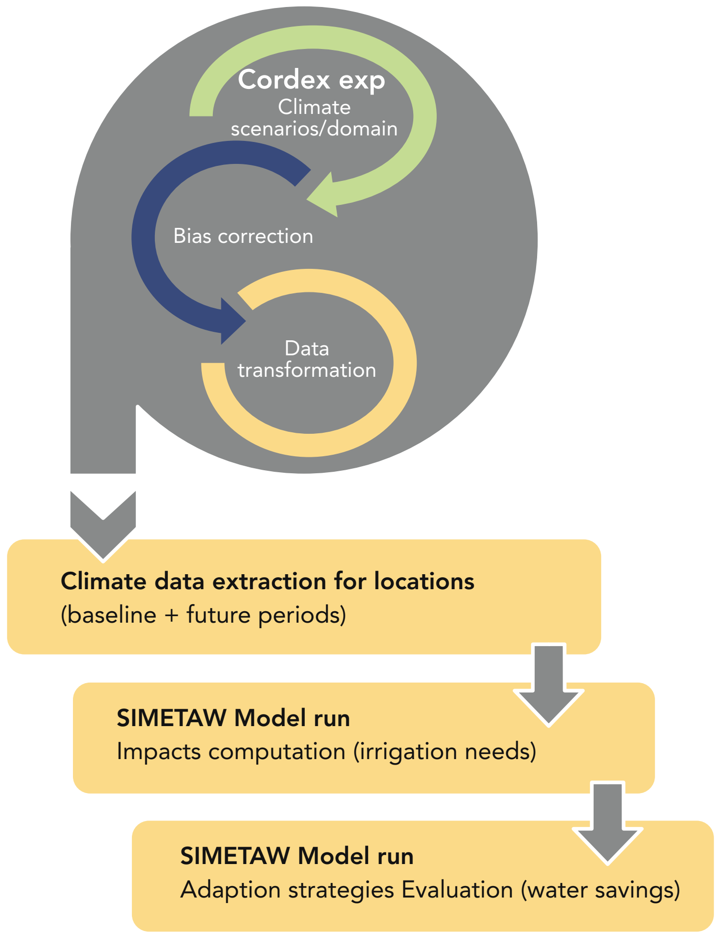

Figure 3. Schema of the downscaling impacts/activities applied to case studies in the ClimaSouth workshops and for some of the participant homework analyses.

The ClimaSouth Regional Setting and Available Data

The domain covered by the ClimaSouth project is located in a transition zone between the arid climates of North Africa and the temperate climates of central Europe. Anticipating climate change in the region is further complicated by the existence of a major enclosed sea (the Mediterranean) with very active regional oceanic (thermohaline) circulation, and linkage to the Atlantic Ocean through the Straits of Gibraltar. However, it is already very clear that the broader Mediterranean region is very sensitive to climate changes induced by increases in GHG concentrations and it has been identified as a "Hot Spot" for future climate change. Major impacts on society are expected, including on agriculture, tourism and water resources. Many GCM climate change projections have been analysed for the Mediterranean under different GHG forcing scenarios.

A generally consistent picture has emerged over recent IPCC assessments, culminating in the recent AR5 (IPCC 2013). Overall, increasingly drier and warmer conditions are projected: these conditions are particularly evident in summer. In the Mediterranean area, downscaling is particularly important for assessing regional climate change, since this region is characterized by high space variability and many climate types. Some of the features that RCMs must represent for good downscaled information in the ClimaSouth domain include:

- Strong land-sea contrasts
- Land-atmosphere feedbacks (including representation of albedo effects)
- Intense air-sea couplings
- Aerosol-radiation interactions

These are just some of the challenging regional characteristics to take into account when dealing with high-resolution climate modelling of the region. The WCRP CORDEX[WL2] project (Giorgi et al. 2009) archives many relevant state-of-the-science RCM simulations driven with the new Representative Concentration Pathway (RCP) emission scenarios (van Vuuren et al. 2011). Participants at the ClimaSouth workshops were shown how to access experiments with data for the region, including the domains of MED-CORDEX, EUROCORDEX (covering much of the ClimaSouth domain at about 10km resolution) and MENACORDEX. Analysing multiple models and ensembles of the same model (run with small changes in initial conditions) is important to building an impression of uncertainty, which is an important component in order to arrive at appropriate adaptation actions (e.g., Vermeulen et al. 2013).

3. WATER IMBALANCE AND THE NEED FOR HIGH-RESOLUTION CLIMATE INFORMATION FOR IMPACT ASSESSMENTS

Water scarcity is one of the main issues in the world today, and because of the background environment and the climate change projections for the Middle East and North Africa (MENA), it will be even more important for this region in the future (e.g., Wallace 2000; RockstrÖm et al. 2009). Water for agriculture was therefore selected by the ClimaSouth project to illustrate the linkages between downscaling and impact assessment (with a view to informing adaptation strategies). In fact, changes in precipitation patterns, the intensity and frequency of extreme events, soil moisture, runoff, and evapotranspiration have already occurred (Jiménez Cisneros et al. 2014). In the future, agricultural areas are projected to shrink with resulting changes in cropping systems (summarized in Fig. 4).

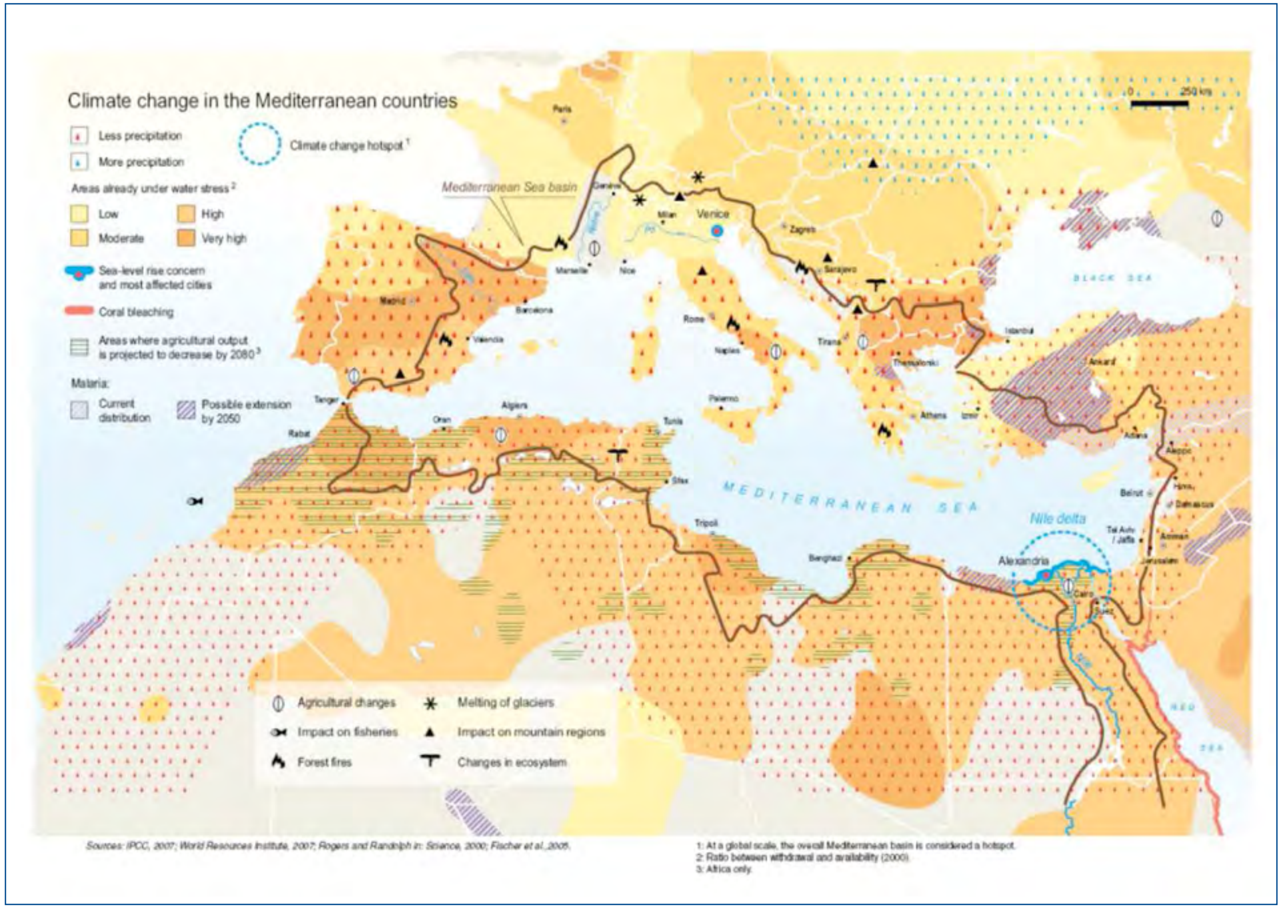

Figure 4. Projected climate change impacts on the Mediterranean basin (Based on: MEDSEC 2009).

Because of projected water deficits and the nature of agriculture in the region, there is a need to focus attention on irrigation requirements (IR). Water balance models are a suitable tool to support water agencies in the better management of agricultural water resources. In fact, the use of climate data as input in such impact models, allows their use for simulating both current and future water needs as well as associated yields. However, the accuracy of model outputs depends on climate data reliability, and especially, resolution. Since many modeling steps are needed, from future emission scenario development to impact assessments, there is growing uncertainty along the information flow (Fig.5).

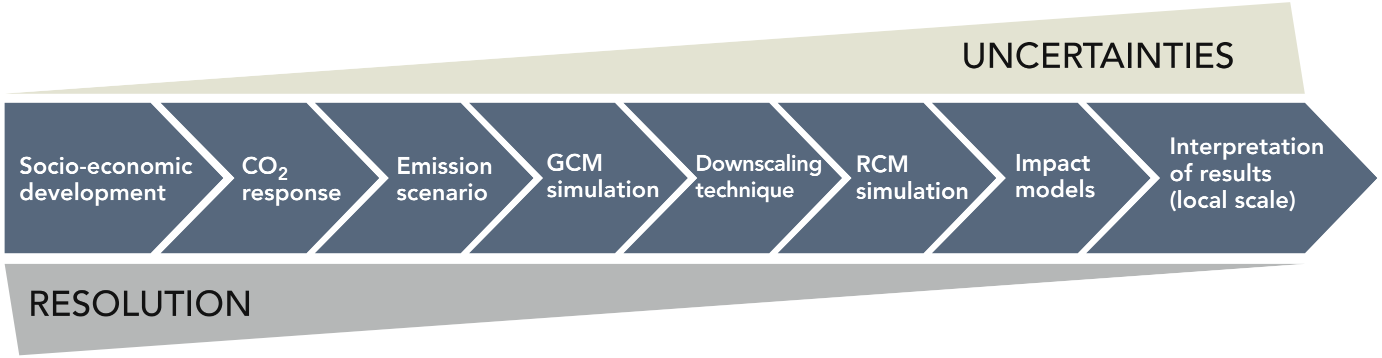

Figure 5. Flow of growing uncertainty, from socio-economic assumptions to interpretation of impact results, going from GCMs to RCMs.

Nonetheless, high-resolution climate data are critical to effectively modelling localized conditions. The use of high-resolution climate data quantifies site-specific climate change impacts, needed for developing more appropriate adaptation strategy plans. As part of the ClimaSouth workshops, participants were shown how to undertake such analyses, transforming the output of dynamical downscaling experiments from CORDEX to minimize bias and uncertainty, and to make assessments of future irrigation requirements at high spatial resolution at selected locations in the domain covered by the ClimaSouth project (see Fig. 3).

The use of climate data developed by different GCMs and different RCMs/statistical downscaling approaches, is a way to account for some of the uncertainties of climate change impacts on future irrigation needs. Recognising uncertainties is necessary in order to be ready to cope with the range of plausible future climate conditions. In this way, it is possible to offset some of the climate change impacts on agriculture by implementing site-specific adaptation strategies.

When integrated up to country-level situations, the MENA countries display particularly challenging needs in the future, compared to most other regions in the world. For each country, the *Total Renewable Water Resources* (TRWR) is the sum of (i) *Internal Renewable Water Resources* (IRWR), i.e., fresh water resources generated from precipitation within a country, and (ii) *External Renewable Water Resources* (ERWR), i.e., fresh water resources from upstream countries through rivers or aquifers naturally or through formal or informal treaties (FAO/BRGM 1996). For countries of the MENA region, the TRWR per inhabitant is less than 500 m^3 (FAO/BRGM 1996), a level that corresponds to the water scarcity threshold (Falkenmark, 1986). In terms of IRWR (Fig. 6), MENA countries are considered amongst the most critical cases, with values that range from 0 to 1000 m^3 $year^{-1}$ per person, where the threshold of 1000 m^3 $year^{-1}$ per inhabitant is considered the water stress level.

Water balance models (such as implemented in the schema of Fig. 3) empower decision support tools for regional and on-farm system management; they are therefore helpful in managing sustainable farming systems. Water delivery agencies use IR in conjunction with irrigation system distribution efficiency to estimate the water diversions needed for irrigation.

Downscaled climate information is therefore critical for the assessment of IR in irrigation systems and real-time water resource management (e.g., to assist in managing droughts in real-time). It also supports assessments of the range of future IR patterns that can inform the development of robust adaptation strategies for the future.

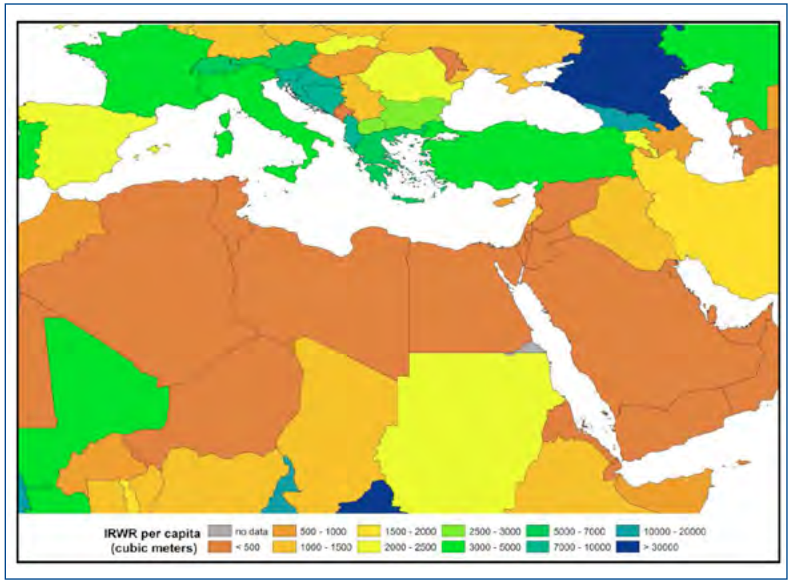

Figure 6. Map of internal renewable water resources (IRWR) per person in each country in 2012
(Source: Mancosu et al. 2015).

4. ADAPTATION AND THE ROLE OF HIGH-RESOLUTION CLIMATE DATA

Conceptual Introduction

Whereas mitigation primarily involves reducing the emission of greenhouse gases into the atmosphere, adaptation involves adjusting human activities and productive processes to reduce their vulnerabilities to the harmful effects of actual or expected future climate. Mitigation is a measure more effectively controlled and encouraged at the global level through coordinated international efforts; while adaptation is generally promoted and implemented locally within specific on-site activities that are sensitive to climate change. Adaptation therefore places a strong demand on local climate information, i.e., the capacity to downscale the output from GCMs.

Key global change factors related to adaptation include hazards, exposure and vulnerability. All have important high-resolution spatial scale aspects. Some aspects relate to climate information (e.g., high-resolution precipitation events, 1-10 km), while some aspects relate to the receptor (e.g. structural elements or socio-economic activities at risk due to climate hazards). For risk maps, it would be important to overlay climate information on highresolution information about the receptor. This may involve land use/cover datasets for the localization of people, environmental resources, infrastructures, social, economic or cultural assets that could potentially be in contact with a given climate hazard,. In addition, it is also important to evaluatethe degree to which the receptor could be affected, either adversely or beneficially, by the climate-related stimuli.

By way of example, and to clarify the relevance of high-resolution climate data, Fig. 7a-b shows a surface temperature climate change scenario (2071-2100 compared to present-day conditions) in summer and autumn, based on one of the CORDEX archives (as analysed at the first workshop by the Tunisia participant; see ClimaSouth E-Handbook N.6[WL1] for details). The result displays both spatial heterogeneity and variability as a function of time-ofyear. Fig. 7c provides an estimate of the spatial distribution of land use activities (indicative of the receptor). Both the maps of changes in mean daily temperatures and the land use show their extreme spatial variability, when expressed with high-resolution data (climate data at 10km and land-use data at 1km). Risk assessment with such resolution can identify more precisely the crop typologies or vulnerable infrastructures, and prioritize target areas or activities that should become hotspots for adaptation policies and support initiatives to cope with climate change.

Agriculture Adaptation and the Water Challenge

As described in Section 3, water availability under climate change is expected to strongly affect agriculture. Stakeholders and decision-makers have to face the risk of crop yield losses due to insufficient water availability, or failures of current crop varieties if not droughtresistant. Additionally, higher temperatures and more rapid heat accumulation by plants may favour different crops or varieties better adapted to newer climate conditions. Public bodies should encourage the establishment of programmes to investigate and spread knowledge about newer cultivars and their proper management, and to provide demonstrations of more efficient agronomic practices. Shifting sowing/harvesting dates could also be a strategy for adapting the most vulnerable crops into temporal windows more suited to crop development, as well as investigating the potential for, and favouring the use of, alternative water sources (e.g., wastewater). These actions represent long-term adjustment strategies. They demand high-resolution climate change scenarios (like Fig. 7a-b) and knowledge of local water usage to determine robust actions at the local level. A further response to climate change is developing/enhancing meteorological alert warning services to activate irrigation applications in a timely fashion. These also demand high-resolution climate information, in terms of realtime monitoring and seasonal forecasting (as discussed in ClimaSouth E-Handbook N.6 [WL1], Section 3).

The adaptation response should be multi-sectoral and integrated, and the role of the highresolution climate information should be both mainstreamed and seamless.

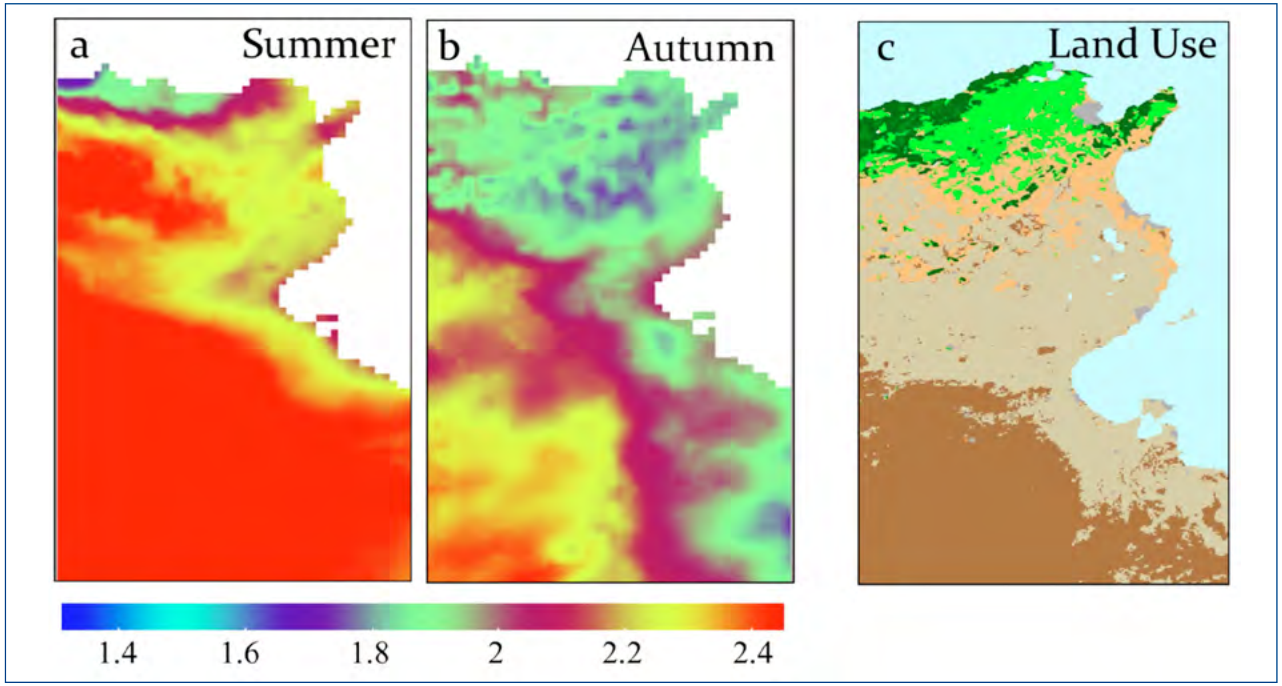

Figure 7. (a-b) Mean change in daily surface temperature (degrees Celsius) by 2071-2100 over Tunisia (example from EURO-CORDEX data, about 10 km resolution) in summer and autumn. (c) Distribution of land use activities (indicative of the receptor) over Tunisia (GLC2000, year 2000, resolution 1km), where dark brown are bare areas; light brown, sparse vegetation; orange, shrub cover; light green, cultivated areas and dark green, forest.

Adaptation measures may be supported by agricultural policies, promoting the study and development of efficient irrigation schemes that optimize water input (e.g., emergency irrigation) and reduce losses in water supply, while maintaining crop productivity under climate change. In addition, to enhance water use efficiency, techniques to improve soil fertility and waterretention capacity should be promoted (e.g., minimal mechanical soil disturbance), as well as research into, and demonstration of, potential new cultivars, and their correct management, and more efficient farming practices. However, the costly introduction of new technologies requires a better link to financing schemes, as well as the availability of sound knowledge for efficient management so that interventions are cost-effective. Rural development programmes or other regional/local funding schemes may be engaged to assist in the process.

5. CONCLUSIONS

The workshop on downscaling has addressed a key perceived gap in the process of translating climate knowledge into actionable climate information that could help with the development of possible adaptations. Participants from ClimaSouth partner countries benefited from lectures which covered the full landscape of technical downscaling techniques. Strong emphasis was placed on the interpretation of uncertainties and the appropriate integration of high-resolution (downscaled) information into impact assessments.

Adaptation involves actions to improve the resilience of societies in the face of possible climate changes over relatively long-term horizons (such as 2030-2100). However, climate is already changing, bringing unprecedented magnitudes and frequencies of extreme weather and seasonal climate events such as floods and droughts. Adaptation therefore also involves the enhancement of early warning systems to better manage individual climate events as they occur in real time. Therefore, there is a need for high-resolution climate information based on (i) scenarios for the long-term (e.g., 2030-2100), (ii) expectations for the coming season ("seasonal forecasts"), (iii) monitored information for very short-term assessments. The overview in this handbook has focused on option (i), with particular regard to agricultural water. The concepts are largely transferable across timescales (more details of (ii) and (iii) are contained in ClimaSouth E-Handbooks N.6 [WL1] and N.6 [WL3]). It would be important to have the capacity to generate information at each of the above timescales to support national adaptation strategies. For seasonal forecasts, relatively simple processing of climate datasets (or output from GCMs) was illustrated using the Climate Predictability Tool (CPT[WL4]) (details in ClimaSouth E-Handbook N.6 [WL1]).

For global change scenarios, the workshop demonstrated that archived high-resolution climate projections (e.g., CORDEX[WL2]) contain valuable information to support impact assessment. Thus, capacity to appropriately access, process and analyze these experiments can make a valuable contribution to the development of adaptation strategies. Nonetheless, the value of the archived projections is greatly enhanced by the availability of local station climate data, to enable tuning of the direct climate model output for impact assessment.

Participants noted that often the available station data are not ideal for this step, mostly due to data gaps, leaving uncertainties around the reliability of downscaled projections. Discussion at the workshop illustrated how national station data may be complemented with globally available gridded datasets and, in particular, reanalysis products (the workshops widely used the ECMWF reanalysis products[WL5]). One encouraging result at the workshop quantified how station monthly series from areas with relatively problematic station records nonetheless closely matched the monthly variability in ECMWF reanalysis data for the overlapping years available. This encourages the use of reanalysis to extend data coverage. It also indicates how reanalysis data may assist in the development of real-time monitoring products.

Integrating the downscaled information into impact assessments that can support adaptation strategies brings a further set of capacity needs. Areas include:

i) Capacity to conduct further scientific investigations, building on articulated and crosssectorial approaches and modelling chains, exploiting high-resolution climate data and their integration into regional risk assessment procedures.

ii) Capacity for more comprehensive integration that can better support decisions, including complex, multi-sector topics requiring particular attention, such as groundwater depletion, seawater intrusion, competition for water resources, water quality and coastal erosion.

iii) Capacity to enlarge analyses, so as to include a full range of alternative scenarios and timeframes, to capture the range of plausible futures. In this way, the sensitivity of different socio-economic activities (such as the provision of irrigation water for agriculture) may be evaluated, identifying hotspots of vulnerability where development of robust adaptation interventions can be expected to be most effective.

The existing capacity varies substantially across ClimaSouth partner countries. The programme has provided insights into areas where capacity advances may quickly reach minimum levels for the development of high-resolution insights. The ability to access and process GCM and RCM data, and compare them with station observations, provides a basis for better information at seasonal- and global-change timescales. The application of relatively simple impact models (such as the SIMETAW^{WL6} water balance model) can lead to substantial additional insights for adaptation strategy development. Relatively basic statistical concepts and computer resources (PC-level) are sufficient for the above climate information – impact assessment steps. Higher level capacities (e.g., to undertake dynamical downscaling) can clearly enhance the ability to tailor information to specific sectoral problems and to build deeper understanding of uncertainties. In some situations, this capacity is not practical or is at modest levels, but the programme has been able to demonstrate that progress is still possible in the development of high-resolution climate information and impact assessment.

6. SELECTED WEB LINKS

[WL1]**ClimaSouth E-Handbook N.6**, Downscaling Climate Modelling for High-Resolution Climate Information and Impact Assessment (Link under development)

[WL2]**CORDEX information and RCM data:** http://www.cordex.org/

[WL3]**ClimaSouth E-Handbook #2, Improving Climate Information:** http://www.climasouth.eu/drupal/en/node/242

[WL4]**CPT Tool for Seasonal Forecasting:** http://iri.columbia.edu/our-expertise/climate/tools/cpt/

[W5]**Reanalysis data from ECMWF:** http://www.ecmwf.int/en/research/climate-reanalysis/era-interim

[WL6]**SIMETAW model:** http://www.water.ca.gov/landwateruse/models.cfm

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