2018 JOINT CALL

Part C

WATER JOINT PROGRAMMING INITIATIVE

WATER CHALLENGES FOR A CHANGING WORLD

2018 JOINT CALL
Closing the Water Cycle Gap

"STRATEGIES FOR INCREASING THE WATER USE EFFICIENCY OF SEMI-ARID MEDITERRANEAN AGROSILVOPASTORAL SYSTEMS UNDER CLIMATE CHANGE"

"FLUXMED"

Table of Contents

1. EXCELLENCE

1.1. Introduction

The Mediterranean regions are subjected to a large variety of climates, ranging from arid to sub-humid with summers characterized by high temperatures and low precipitation (Spinoni et al., 2015[1]; Deitch et al., 2017[2]). At the same time the water scarcity highlights the need for careful water resources management and planning in Mediterranean regions (Rana and Katerji, 2000[3]). In the Mediterranean regions there is a persistent declining trend of precipitation and runoff decreases (Giorgi et al., 2008[4]; Martinez-Fernandez et al., 2013[5]), contributing to a desertification process with dramatic consequences for agricultural and water resources sustainability. Recently, for instance in Sardinia Montaldo and Sarigu (2017)[6] showed that runoff decreased drastically over the 1975-2010 period, with annual values 40% lower than the 1922-1974 period. Climate change projections point to an amplification of changes in global precipitation patterns and trends (Giorgi et al., 2008), with further drier trends for the Mediterranean area (Ozturk et al., 2015[7]) and dramatic consequences on water resources for managed and natural systems. To face the upcoming water crisis, there is a need to develop stronger international cooperation in water research and enhance the resilience of agricultural and natural systems to climate change. In water-limited regions the conservation of water through improving agriculture and environmental management practices is highly needed, and the use of water-efficient and drought-tolerant tree and crop species a prerequisite. Land planning strategies need to be investigated under both current and future scenarios, due to the impact of these strategies on the environment and the water resources.

1.2. State-of-the-art and relation to the work programme

A central element of any improvement and climate change adaptation in water management is the understanding of the role of the vegetation dynamics and their interactions with atmosphere and soil, which need to be accurately quantified through both monitoring and predictive models. Evapotranspiration (ET) is a leading loss term of the soil water budget, and in semi-arid regions may reach a yearly magnitude equal to the precipitation. Mediterranean ecosystems are commonly heterogeneous savanna-like ecosystems, with contrasting plant functional types (PFT) and agricultural systems (e.g., crops) competing for the water use (Scholes and Archer, 1997[8]; Montaldo et al., 2008[9]). Despite the attention these ecosystems are receiving, a general lack of knowledge persists about the relationship between ET and the plant survival strategies under water stress, and ET component relationships with soil moisture (sm). Coupled land surface models (LSMs) and vegetation dynamic models (VDM) have been developed (e.g., Montaldo et al., 2008) for simulating both soil water balance and vegetation dynamics. Current distributed hydrological models enable the prediction of runoff generation and propagation for all the basin sizes (Montaldo et al., 2007[10]). There is a need for innovative distributed LSM-VDM models for investigating the impact of climate and land cover changes on the basin water balance. At the same time new technologies allow the accurate monitoring of ecohydrological processes. Remote sensing technologies monitor key LSM variables, such as surface temperature (Ts) and leaf area index (LAI), and are a powerful tool for both monitoring and the use with ecohydrologic models (data assimilation, DA, Montaldo et al., 2007[11]). The monitoring through extended field campaigns remains fundamental for the understanding of the physical processes of the land surface interactions, and for the validation of models and remote sensing. Nevertheless, further developments are needed. The innovative combined use of the eddy covariance (EC) technique and sap flux sensors (Domec et al 2010[12]) have the potential to estimate ET components and water use efficiency (WUE), but sap flux-based method may underestimate high flux rates (Bovard et al., 2005[13]). In Mediterranean regions, trees developed on thin soils above fractured bedrocks or cemented horizons, where water uptake of roots in the rock storage can be predominant (up to 70-90%, Schwinning, 2010[14]). This is a significant term usually

[1] https://doi.org/10.1002/joc.4124
[2] https://doi.org/ 10.3390/w9040259
[3] https://doi.org/10.1016/S1161-0301(00)00070-8
[4] https://doi.org/10.1016/j.gloplacha.2007.09.005
[5] https://doi.org/ 10.1177/0309133313496834
[6] https://doi.org/10.1016/j.jhydrol.2017.08.018
[7] https://doi.org/10.1002/joc.4285
[8]. https://doi.org/10.1146/annurev.ecolsys.28.1.517
[9]. https://doi.org/10.5194/hess-12-1257-2008
[10]. https://doi.org/10.1002/hyp.6260
[11] doi: 10.1175/JHM582.1
[12] https://doi.org/10.1111/j.1469-8137.2010.03245.x
[13] Bovard, B.D., et al., 2005. Environmental controls on sap flow in a northern hardwood forest. Tree Physiology 25, 31–38.
[14] https://doi.org/10.1002/eco.134

neglected by ecohydrologists, so that a challenge becomes the "ecohydrology of roots in rocks" (Schwinning, 2010). Innovative techniques combine geophysics methods (Rodriguez-Robles et al., 2017[15]), and sapflow sensors installed also in tree roots (Domec et al., 2010) for estimating these contributions. The scientific base for improving water resources management lays in the development of fully functional, satellite observations, terrestrial monitoring systems and models that can predict the effects of land use and climate changes.
The proposal relates to Theme 1 (Sub-theme 1.1), Theme 2 (Sub-theme 2.4), and Theme 3. In the following we explain how our proposal addresses the challenge and scope of the Topics.
Sub-theme 1.1 - Promoting adaptive water management for global change: We will define innovative strategies for the water sustainability in the Mediterranean region under current and future climate change scenarios (WP5 and WP6), optimizing the management of water infrastructures (e.g., reservoirs, wells network design) and uses (irrigation, livestock, domestic and industrial). We propose innovative water management and planning approaches for answering the predicted global change impacts on the hydrologic balance. For improving technical tools for water resources quantification, we aim to develop innovative methodologies and techniques for the quantification, estimation and monitoring of ET, the main loss term of the basin water balance in semi-arid and arid climates (WP2 and WP3). New and advanced technical tools will be developed for monitoring main state variables of energy and water balance at the land surface (remote sensing observations), and assimilating the observation in real - time DA systems for watershed hydrologic predictions (WP4).
Sub-theme 2.4 - Promoting new governance and knowledge management approaches: We will develop innovative water management strategies and tools with stakeholders (both public and private companies) and government authorities (WP5 and WP6), which will be actively involved in the project. We will include both water resources management, agricultural and environmental authorities (Table 1) because all management and planning strategies need to preserve the extraordinary natural environments and agro-ecosystems, which are essential for the economic and social values of the Mediterranean regions.
Theme 3 - Supporting tools for sustainable integrative management of water resources: We will establish a transnational Mediterranean watershed monitoring network for gathering and sharing data (WP2), which will be available through an open access online database. Methodologies and tools for hydrologic data analysis and methods will be shared across the partners, giving the outstanding possibility to investigate the wide range of climates and biome of the Mediterranean basin, including the agrosilvopastoral systems of two main Mediterranean islands located on the west (Sardinia) and east (Cyprus) areas of the sea basin.

1.3. Objectives and overview of the proposal

The overarching goal is to develop and apply innovative methodologies to increase the social-ecological WUE of managed ecosystems along the Mediterranean biome and climate types. Case studies will examine the Mediterranean Sea basin from west to east providing the exceptional opportunity to develop and compare water resources management and planning strategies, and develop a wide monitoring network for contrasting climate conditions (mean annual rain from 35 to 780 mm/y) in the Mediterranean region. The specific objectives are:
OB1: to develop and implement innovative methodologies for evapotranspiration measurements and estimate in typical heterogeneous Mediterranean agrosilvopastoral systems;
OB2: to improve the eco-hydrologic monitoring in ephemeral rivers and wadis along the Mediterranean biome and climate types, establishing a transnational Mediterranean watershed monitoring system;
OB3: to develop data assimilation systems for assimilating remotely sensed and field data into ecohydrological models at the watershed or agricultural district scales for optimal characterization of soil water balances;
OB4: to identify the impacts of contrasting vegetation and crop types on the soil water balance, surface runoff, and water use under current and past Mediterranean climates;
OB5: to predict the impact of future climate scenarios on soil water balance, runoff, and water use;
OB6: to develop a set of land cover change strategies (e.g. forestations/deforestation, use of more drought-tolerant crops and woody vegetation) for climate change scenarios that optimize the water uses and increase system resilience;
OB7: to improve the multipurpose and multiuser water resources management and planning systems for the optimization of the water infrastructure (e.g., reservoirs, groundwater recharge, water harvesting) and uses (irrigation, animal production systems, drinking and industrial activities) under current and future climate change scenarios.

[15] Rodríguez-Robles U. et al., 2017. Technical note: Application of geophysical tools for tree root studies in forest ecosystems in complex soils. Biogeosciences, 14, 5343-5357.

1.4. Research methodology and approach

The methodologies and approach are described distinguishing the research activities according to the work programme. The rationale of the individual work packages is given below.

Experimental fields and watersheds: a new transnational Mediterranean river monitoring network (WP2)

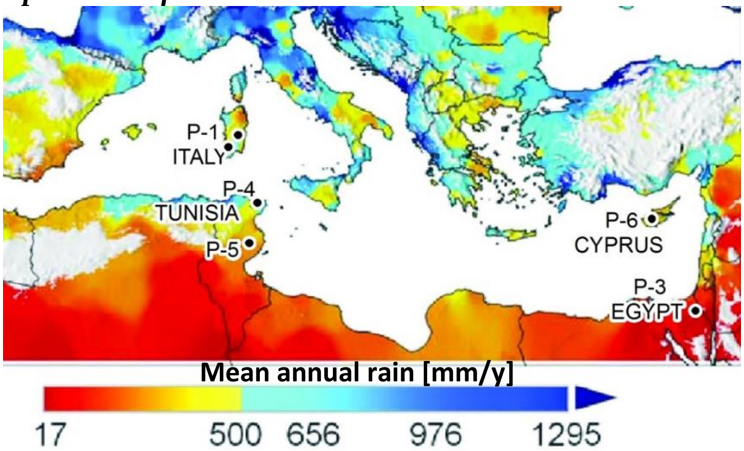

Fig. 1. *Rainfall in Mediterranean area and case studies*

For reaching OB1 and OB2, monitoring is planned in the watersheds and agrosilvopastoral systems (Fig. 1). Some sites are already instrumented and some will be instrumented during the project (Table 1). At the basin scale rain and streamflow will be monitored. sm and vegetation growth will be also monitored in selected representative areas of the basins using TDR portable sensors for sm. sm, Ts and LAI will be monitored using also remote sensing information. At the field scale the sites are or will be instrumented with eddy covariance (EC) towers to measure water, CO_2 and energy balances. In some of the fields geophysics methods (e.g., ground - penetrating radar, electrical resistivity tomography, and electromagnetic induction) and root sapflow sensors, installed both in tree roots and trunk (Domec et al., 2010), will be used for the assessment of the subsurface settings and the estimation of the water uptake of tree deep roots in rocks. Data will be shared through an internet database, with different security levels for sharing data between partners and the general scientific community. The case studies are in Table 1. Using EC observations and the 2D foot-print model, ET components will be estimated and the impact of water uptake of tree deep roots in the rocks will be quantified.

Ecohydrological modelling (WP3) Innovative spatially distributed versions that couple LSM-VDM and rainfall-runoff hydrologic models for simulating also runoff propagation at the basin scale will be developed. Runoff propagation along the river network will be computed through a modified version of the Muskingum –Cunge method already used successfully by Montaldo et al. (2004) and Montaldo et al. (2007). Models will be calibrated and validated at the field and basin scales (WP2). The model will be coupled with remote sensing observations (WP4) for surface flux and ET estimates. A model intercomparison will allow to identify the vegetation, climate and land use features crucial for the correct determination of the key ecohydrological variables (OB1).

Remote sensing and data assimilation (WP4). The estimate of vegetation indices and Ts will be obtained from images of ASTER, NOAA AVHRR, SEVIRI and SENTINEL. Ts and LAI estimates from remote sensing will be tested with the observations of the field campaigns. The remote sensing observations and monitoring results will be used for developing a DA system (OB3). Montaldo et al. (2007)[16] developed an assimilation framework for assimilating surface sm observations into the LSM using the Ensemble Kalman filter (Enkf). In the proposed project we will further improve this DA system algorithm for the assimilation of Ts and LAI observations from remote sensors. We will evaluate if the assimilation of LAI and Ts is enough for guiding the models and if there is the need of a minimum frequency of assimilation or a minimum spatial resolution of the images.

Analysis of land cover change strategies and climate change scenarios (WP5). Future climate scenarios will be generated starting from historical climate data perturbed following the IPCC future climate scenarios of the Fifth Assessment report. First historical hydrological data will be analysed. Following the approach of Montaldo and Sarigu (2017), annual, seasonal, monthly and daily statistical series for precipitation, runoff, and temperature and annual and seasonal trends will be computed. We will select the climate models for future scenarios after comparing the models' outputs with the observed data in each investigated region. We will use an opportunely adapted stochastic generator for accounting the unstationarity of the climate processes and the climate changes. The use of ecohydrological models, DA system and IPCC scenarios will allow to reach OB4, OB5 and OB6.

WP6: Development of water management and planning systems. The results of WP5 will be input of multipurpose and multiuser water management system, which will be improved for reaching OB7. Water resources management optimization models (WARGI by UNICA, Hec-ResPRM, and others) will be applied and improved to define the economic efficiency and the optimal water allocation in the water system configurations throughout the evaluation of multiple planning and management rules.

[16] Montaldo N. et al., 2007. Dynamic Calibration with an Ensemble Kalman Filter Based Data Assimilation Approach for Root-Zone Moisture Predictions. Journal of Hydrometeorology, 8, 910–921.

Quantifying benefits and sharing methodologies with stakeholders and dissemination (WP7)

A main part of the proposed project will be the dissemination and exploitation activities to stakeholders (both public authorities and companies and private companies) and scientific community. In particular we will: organize start-up stakeholder meetings in all case studies to tap into the knowledge and experience of all local stakeholders and fine-tune the planning of the monitoring and modeling activities; conduct participatory seminars; identify acceptable scenarios in view of simulated impacts; conduct participatory seminars for discussing possible configurations; share methodological developments; deliver results and disseminate outcomes. Project results will be made available to the scientific community, to foster the development of multidisciplinary activities focusing on hydrology, climatology, hydraulic construction, environmental sciences, water and irrigation management. Scientific publications in international and national journals, participation to the main international conferences (e.g., EGU and AGU), a final report of the activities and three public workshops will be the way to disseminate and communicate the results also beyond the scientific community. A project web site, a "Google" research page and a "Facebook" page will be created for an effective communication and transfer of the results. The project results will have implications in the operative water management of single farmer, irrigation consortia and water basin and environmental authorities.

Table 1. *Case studies of Fig. 1.*

Name, country, partner	Scale/ Area	Mean Precip. (mm/y)	Principle land uses	Monitoring	Hydro-agricultural infrastructures	Stakeholder
Flumendosa basin, Italy, UNICA, *P-1*	Field and watershed 1000 km^2	690	Agricultural, forests, rocky soil	Meteo, EC tower, sm, LAI, sapflow, streamflow	3 large dams, irrigation system	ENAS, ACQUAVITANA
Marganai Park, Italy, UNICA, *P-1*	Field and watershed 80 km^2	780	Forest agro-silvopastoral, rocky soil	To be installed: EC tower, sm, sapflow; geophysics	Dams. Natura 2000 site	FORESTAS, ENAS
Wadi Watir basin, Egypt, UNIAS, *P-3*	watershed 3520 km^2	35	arid upstream, agriculture	Rain and streamflow. Meteo and sm will be installed	5 dams, 2 reservoirs, flood diversion dikes	WRRI
Béni Khalled Tunisia, *P-4* INRGREF	Field, watershed 100 km^2	400	Drip irrigated citrus	Meteo, EC tower (H, LE, Rn,G)	Irrigation system, groundwater, reservoir	CTA, GDA, CRDA, TDS
Taous Sfax site, Tunisia, CESBIO *P-5*	Field	220	Rainfed olive	EC tower, sm, sapflow, and radiometric instrum.	Complementary irrigation (olive);	Institut de l'Olivier, TDS
Peristerona basin, CyI, Cyprus, *P-6*	Field and watershed 110 km^2	270-750	cropland; forests	sapflow, throughfall, sm, meteo, runoff. EC tower will be installed	Groundwater, dams, irrigation, boreholes	Farmers, Water Dev. Agriculture, Forestry Departments

The proposal is an innovative research project, that includes the analysis of basic physics principles and observations (e.g., ET estimates in heterogeneous ecosystems and tree water uptake from roots in rocks, a transnational Mediterranean watershed monitoring system) (TRL1), several new concepts (TRL2), including remote sensing observations and innovative DA, and experimental proof of concepts (TRL3), such as land-use strategies for water use optimization under current and future climate scenarios. At the same time the final results, water resources management and planning tools, will be available for stakeholders so that the research will be finalized for being applied in the actual water resources management (TRL5 and TRL6). At the end of the project we will produce water management systems for operational environment (TRL7).

1.5. Originality and innovative aspects of the research (ambition)

Despite ET being the leading loss term of the soil water balance, there persists a general lack of knowledge about the relationship between ET and the plant survival strategies for the different plant functional types under water stress in forestry and agricultural systems. With this in mind, we propose an innovative methodology based on the coupled use of EC measurements, sap flux sensors, high resolution satellite images and a 2D foot-print model for estimating total ET, its components and its relationship with sm. In semi-arid and arid regions, a key contribution of tree transpiration has been neglected by hydrologists, which is the water uptake of roots in the rock storage (up to 70-90% of total ET), so that a new challenge in ecohydrology becomes the "ecohydrology of roots in rocks" (Schwinning, 2010).

We propose an innovative approach that uses geophysics methods (e.g., ground-penetrating radar and electrical resistivity thomography), and root sapflow sensors for measuring the flux in the roots directly, and EC, sm and sapflow sensors for land surface ET. Furthermore, the development of an innovative DA system, able to assimilate the remote sensing information and field monitoring data into the developed distributed ecohydrologic models, will provide an innovative approach for the water resources management and planning. We will evaluate the minimum frequency of assimilation and the minimum spatial resolution of LAI and Ts images for guiding the models. The use of the proposed DA system will allow to develop innovative strategies of environmental planning for increasing the resilience of the agrosilvopastoral systems, also for future drier climate scenarios. In this way we will develop the essential future scenarios and provide the management and planning of possible solutions to the water basin and regional authorities, who need to elaborate and revise the water resources planning. We propose to develop a new and innovative transnational Mediterranean watershed monitoring network for gathering and sharing data, which will be available through an open access online database. This river monitoring network will provide for the first time the possibility to share, cooperate and improve scientific progress across the wide range of climates and biome of the Mediterranean basin spanning a large gradient of mean annual rainfall (from 35 to 780 mm/y), including the two main Mediterranean islands located on the west (Sardinia) and east (Cyprus) areas of the sea basin.

1.6. Clarity and quality of transfer of knowledge for the development of the consortium partners in light of the proposal objectives

FLUXMED represents an opportunity to gain new knowledge for all partners while building upon previous experiences (see Table 2). All partners will undertake tasks within their areas of expertise and will benefit from pre-existing infrastructure and tools. At the same time, they will address new challenges and will share a common, innovative, perspective. Besides, the project has a unique cross-disciplinary conception by putting together hydrologists, agriculture, engineers, ecologists, micrometeorologists, geophysics, and socio-economists. This inter-disciplinarity traverses all the activities of the project and involves all the partners, since it is necessary for achieving the main goals of the project.

The FLUXMED strategy and work plan has been conceived to foster cooperation and promote synergies between the partners, who will cooperate in order to achieve the common goals. Partners are committed to interact in terms of data, information and methodological approaches to attain the overarching objectives of the project. The shared contribution will also allow that different partners to gain new knowledge from the collaborative effort, since a complete understanding of the different stages of the project workflow will be necessary for its application in the different case-study sites. Each partner will gain a comprehensive knowledge regarding the entire project tasks and methods, not only of the specific tasks that it will conduct, thus benefiting from methods and knowledge acquired by the different partners from previous projects related to the research objectives. The partners will also gain from the broader perspective to water resources management that is in the core of FLUXMED, ensuring that the common result will be much more valuable than the simple integration of their individual tasks.

All the outcomes and basic data will be shared among the partners also using the internet database, including cooperation on technical documents and scientific articles in international journals, with a mutual benefit and gain in the positioning of the partners in the international scientific arena.

1.7. Quality of the consortium partners and collaborative arrangements. Capacity of the consortium to reinforce a position of leadership in the proposed research field

The FLUXMED consortium is composed by a multidisciplinary team of scientists and is very well balanced in relation to the needs of the project (Table 2). FLUXMED draws upon the individual expertise of teams of scientists representing top-level research institutions at national and international levels, to constitute a broader international group with a stronger multi-disciplinary character and increased scientific potential. Table 2 provides a clear view of partners expertise, and the areas where some partners are less proficient and who are the partners that can help in collaborative efforts.

Many past and current research activities are linked to the research project. Main previous (P) and current (C) projects are: - "IDROSAR: remote sensing soil moisture estimation and data assimilation system", CRP2_708, LR 7/2007 (UNICA, C); - "Monitoring and modeling for water resources estimate in the Flumendosa basin under climate and land use change scenarios", LR 7/2007 (UNICA, P); - "Micrometeorological and remote sensing measurements integration within distributed hydrological modelling for the evapotranspiration assessment", FIRB (UNICA, P); - "CLIMB: Climate Induced Changes on the Hydrology of Mediterranean Basins: Reducing Uncertainty and Quantifying Risk through an Integrated Monitoring and Modeling System", FP7-ENV-2009-1, (UNICA, P); - "BINGO: Bringing Innovation to ongoing water management - a better future under climate change", H2020 641739 (CyI, C);

- "RECARE: Preventing and remediating degradation of soils in Europe through land care", FP7 603498 (CyI, C); - "BEWATER: Making society an active participant in water adaptation to global change", FP7 612385 (CyI, P); - "ENORASIS: Environmental Optimization of Irrigation Management with the Combined Use and Integration of High Precision Satellite Data, Advanced Modeling, Process Control and Business Innovation", FP7-282949 (CyI, P); - "Joint research project U.S.-Egypt Science & Technology Joint Fund Program "Flood Risk Map for Sinai Governorates" at Iowa Flood Center at IIHR-Hydro science and Engineering" (UNIAS, P); - "AMETHYST: Assessment of changes in MEdiTerranean HYdroresources, in the South: river basin Trajectories", ANR TRANSMED (CESBIO, C); - "REC: Root zone soil moisture Estimates at the daily and agricultural parcel scales for Crop irrigation management and water use impact – a multi-sensor remote sensing" H2020 RISE (CESBIO, C); - "CHAAMS Global Change: Assessment and Adaptation to Mediterranean Region Water Scarcity, ERA-NET MED (CESBIO, INRGREF, C); - "ACCWA Accounting for Climate Change in Water and Agriculture management", H2020 RISE (CESBIO, C); - "ALMIRA Adapting Landscape Mosaics of Mediterranean Rainfed Agrosystems for a sustainable management of crop production, water and soil resources", ANR TRANSMED (INRGREF, P); - SICMED/Mistrals: Biophysical and socio-economic approach to water management in the Cape Bon region (INRGREF, P).

Table 2*: Expertise of the partners. blue/yellow: strong/moderate expertise; red: areas in which the team is less proficient and will benefit most from the collaborative effort.*

Expertise	*Coordinator (UNICA)*	*Partner 1 (CyI)*	*Partner 2 (UNIAS)*	*Partner 3 (CESBIO)*	*Partner 4 (INRGREF)*
EC and ET monitoring at field scale	blue	blue	yellow	blue	blue
Ecohydrological modeling	blue	yellow	red	blue	yellow
Remote sensing	yellow	red	yellow	blue	red
Data assimilation	blue	red	yellow	blue	red
Climate change, adaption to climate change	yellow	blue	blue	red	yellow
Irrigation strategies	red	blue	blue	yellow	blue
Water resources management and economics	blue	blue	blue	yellow	blue
Design of hydraulic infrastructures	blue	yellow	blue	yellow	yellow
Stakeholder facilitation	blue	blue	yellow	blue	blue

2. IMPACT

2.1. Impact of the proposal

The proposal will have positive social and economic impacts. The project objectives respond to priorities of H2020 Societal Challenge 5, Call topic SC5-11-2016 because we propose to increase the efficiency of Mediterranean water resources and innovate the approach for water resources planning and management for both current and future climate change scenarios. The proposal supports the requests of innovative solutions of the UN SDG6, providing new techniques and methodologies for increasing the water-use efficiency of water-limited Mediterranean regions, which are suffering water scarcity. We will implement integrated water resources management, linking Southern European and North African partners, and address the need of international cooperation in water research. In most Mediterranean regions water and environmental plans are missing and when available they don't properly include future scenario impacts. One key objective of the research project is to combat climate change impacts, supporting the UN SDG 13, because future climate change scenarios are predicting a decrease in water resources availability. As consequence existing water resources plans are wrong, because these are based on water input (surface and groundwater) that will not be any longer available. At the same time environmental plans need to consider the climate change effect on both CO_2 budget and water resources use of vegetation and water resources availability to vegetation growth, which can impact on species type (in drier climate more resistant species should survive) and their spatial distribution (less water implies less density). Instead, our proposed methodology is strongly innovative and integrate new knowledge, allowing to adequately develop water resources and environmental planning also for future climate change scenarios. The project's economic impact will be significant for agricultural development and its sustainability because the project aims to increase the system efficiency and decrease the costs. Stakeholders will be involved and will have a main role in the project. The project will provide the stakeholders the scientific approach and results for defining the planning and management strategies for both current and future climates. A main part of the project will be the dissemination of the results to the stakeholders and to the society in general, due to the impact on social customs and traditions.

The strong international cooperation of this project is a central tenet. Climate change is affecting water resources in Mediterranean region, and there is the need to develop international cooperation in water research between Mediterranean countries. In the project Southern European partners will collaborate with North African partners providing a unique opportunity for knowledge and experience exchanges. Indeed, the wide and international partnership of FLUXMED is a key point of the project. All the academic partners have strong expertise formed at the best international schools, with aspiration to collaborate for knowledge and experience exchanges. Experts of a wide range of complimentary fields, e.g. hydrology, hydraulic, ecology, forestry, agronomy, micrometeorology, geophysics and environmental economics are involved, providing an excellent opportunity to advance water resources science of semi-arid and arid Mediterranean regions. This project offers a unique opportunity of exchanges of research and knowledge, which is the base for increasing the research development in water resources. Only through analyzing sites with contrasting spatial scales, vegetation covers and climate will be possible to understand deeply the complex ecohydrologic processes, and the strongly nonlinear dynamics between soil, vegetation and atmosphere, which is the key element of environmental planning strategies for optimizing the water use and increase the resilience of agrosilvopastoral systems. To prove the international scientific interest for the proposal project, word-renowned professors from top USA Universities (Ram Oren and Gaby Katul at Duke Univ., and John Albertson at Cornell Univ.) are also cooperating as scientific staff in the project.

2.2. Expected outputs

The team members will be encouraged to publish scientific articles in top-level international journals. It is expected that at the end of the project the team will publish around 11 scientific articles in journals listed in the ISI's Journal Citation Report. A special issue on a peer-reviewed international journal will be coordinated, which will serve as a showcase of the main scientific findings of the project. Also, the overall approach will be to publish in at least one article in a top-ranked multidisciplinary journal during the duration of the project or shortly after its end. Three workshops will be organized, and the last one will be an international workshop, and a specific session in a broader conference will be organized at the end of the project. Project partners will also participate in sessions at international conferences such as the EGU, AGU or IAHS, contributing to the scientific visibility of the project. Software and data generated within the project will be made available in the FLUXMED web – based database.

Students and technicians of the Partner teams will be incorporated into different tasks of the project, thus improving their skills. Specific training seminars and field visits for students will be organized during or immediately after the project meetings. Mobility of young researchers will be fostered within the consortium through a specific exchange program for PhD students and post-docs, making also use of other funding opportunities, such as ERASMUS. Results of the project will be incorporated into current collaborations by the consortium researchers in university and extracurricular courses. Training issues will constitute a relevant part of the annual Progress Reports. Water management optimization models will be provided to the involved stakeholders (e.g., WARGI by UNICA will be used by ENAS for the water management of the Flumendosa dam system).

2.3. Exploitation and communication activities (measures to maximize impact)

Project results will be made available to stakeholders (local, regional and national water and environmental authorities, environmental NGOs, farmers, consortia, private companies, etc.) in their own language and to the scientific community. Dissemination, exploitation and communication activities are distinguished and summarized below.

Dissemination activities

The dissemination activities are designed to maximize the impact of project results, and will provide information to the scientific communities and relevant stakeholders. Dissemination targets and means are summarized in Table 3.

Table 3. Target audience and dissemination means of FLUXMED

Target audience	Dissemination Means
Water, environmental and agricultural international and European associations	Workshops and reports, Strategic Research Agendas, Policy briefs, Project news/ Newsletters, Tailored updates on the results, Website
National, regional and local authorities	Workshops, Trainings, Policy briefs, Website
Scientific community, academics or non-academics, students, engineers	Scientific journal articles, Data portal, Workshops, Conferences, Strategic Research Agendas, Newsletters, Trainings, User manuals, Website
Farmers, irrigation consortia, technology providers, industrial, water management private companies	Targeted publication material, Representation at relevant conferences and fairs, Newsletters

General public	General Information Material, website, Project news/ Newsletters, Dissemination Material, Press releases

Dissemination Instruments: 1) FLUXMED website and internet actions ("Google" research page, "Facebook" and "Instagram" page); 2) Journals, Conferences and Workshops (3 workshops: at the start of the project in Italy, after 15 months in Tunisia and at the end of the project in Cyprus); 3) Flyers, posters and brochures; 4) Newsletters.

Exploitation activities

The exploitation activities will ensure the transfer of project results to appropriate stakeholders and decision-makers thus getting integrated in their current activities, opening them to the FLUXMED aims and topics.

Exploitable products	Innovative methods for evapotranspiration measurements; Impacts of vegetation and crop types on soil water balance, surface runoff, and water use under current and past climates; Methods to combine satellite observations, ecosystem monitoring and eco-hydrologic modeling; Predictions of the impact of future climate on soil water balance, runoff and water use effects of land use and climate change in the Mediterranean area; Land cover strategies planning for climate change scenarios to optimize the use of water resources
Exploitation activities during the Project	Scientific papers, Review state-of-the art
Exploitation activities after the end of the Project	Use of the FLUXMED model data product and scenarios by FLUXMED inverse modelers, and for management purposes; Scientific papers; Expand the approach developed in FLUXMED to different basins; Further developments, integration into other services
Consortium-wide/Joint Exploitation	Longer-term goal would be operationalization of FLUXMED strategies for climate change studies in the Mediterranean area; Definition of a stable hydrologic monitoring in the Mediterranean; Definition of a hydrological monitoring network within the Mediterranean

The exploitation activities of FLUXMED will be developed by a direct involvement of end-user representatives in the project consortium, both public and private stakeholders (listed in Table 1), and by networks established by the partners in the participating countries and beyond, using several communication and technical materials. WP7 will take care that all stakeholders will be regularly informed and updated. Databases, and research data published by the consortium will be public domain, allowing widest possible re-use of data. All specifics about ownership and access to key knowledge (IPR) will be included in the Consortium Agreement (CA). Details on open access rules, ownership and access to key knowledge will be specified in the CA. On the project web site monitored data will be collected as well as their elaborations providing a web-based database that will be available for website visitors. We will follow the Green Open Access (GOA) for scientific publications developing an electronic repository for scientific publications, ensuring open access. The data and scientific publications will be stored in the Common Project Server of FLUXMED, which will be set up by the first three months. Open access rules for each type of data, which could be subjected to property rights from external consortium members, will be defined in CA. Publications will be deposited in an open access repository for scientific publications (e.g., OpenAIRE), and will be disseminated following GOA.

Communication activities

The project members will organize communication actions such as stakeholder workshops, training sessions and materials, and will be actively involved on communication activities such as workshops and seminars, conference papers and presentations, and attending national and international conferences.

Target audience will be referred to the project web site. The web site will be updated weekly with the project activities and events, project results and its progresses. The main functionalities of the web site will be: 1) link to technical social media in order to be attractive; 2) overview of the concept, objectives, the partnership and the activities of the project; 3) a consortium member dedicated access, a collaborative space for sharing information and documents.

Communication to the public will be also reached by press-releases for journal articles, which will be promoted on the public information area of the website and social media. Useful gadgets and materials with the project name and logo, will be distributed at the FLUXMED events, and during congresses and meeting where the project members will be involved. Additional communication instruments, such us Facebook, Google, and Twitter will be used to promote the project events, and project progresses. A logo will be designed to provide a visual identity to FLUXMED. In addition, other important communication activities will be: Conferences and Workshops, Flyers, posters and brochures, peer-reviewed articles, participation to the main international meetings, final report of the activities.

2.4. Market knowledge and economic advantages/return of investment

FLUXMED does not aim primarily at strengthening the competitiveness of companies, but close collaboration with relevant stakeholders in the water resources management and agricultural sectors will ensure a direct link with the

relevant economic sectors. Institutional and market constrains of the proposed management options will be studied in collaboration with the stakeholders, and a diagnosis and possible solutions will be proposed.
Annually, European water services invest approximately € 45 billion in water infrastructure (e.g., € 2 billion in Italy, € 6.5 billion in France). ENAS is investing this year € 115 million for the Sardinian water resources system (with 50 main dams). Hence, the optimization and the improvement of water resources management systems, and the decrease of the costs for agricultural development and its sustainability are key objectives from the economic point of view. Results and tools developed within the project will improve the knowledge base, and data assimilation and water management tools will be made available, and will be used for improving water management and agricultural systems. Following an open source approach, the knowledge and tools generated in the project could be also packed and/or developed as local/regional services in Europe and worldwide encouraging the development of SMEs dealing with environmental issues. This should also allow water resource managers, agricultural bodies, hydroelectric power companies, among others, mitigate their impacts, improve the efficiency of their coping strategies and allow them introduce more effective work practices which should have cost and resource benefits and hence economic advantages. The research project may allow to strength the advice/consultation capacities of the project partners for water resource managers, agricultural bodies, environmental managers, etc. The interest and economy importance of the project is demonstrated by the high number of stakeholders from all the involved countries, mainly public but also private companies, like ACQUAVITANA that is a water management company of small cities in Sardinia, and TDS (Tunisia Development Systems) in Tunisia that is interested in environmental data acquisition and remote visualization via web interface.

3. IMPLEMENTATION

3.1. Overall coherence and effectiveness of the work plan

The 7 specific objectives described in section 1.3 will be achieved through 7 Workpackages (WPs), which concepts, rationale and methods are described in section 1.4.

WP Number	WP Title	Duration (months)	Starting Month	End Month	WP Description
WP 1	**Management and Coordination**	**30**	**1**	**30**	(Leader: UNICA) The WP is concerned with the overall financial, administrative and operational management of the project as well as coordinating activities across work packages. The project coordination of UNICA will be carried out through meetings for sharing partner results, and stakeholder observations and recommendations. For speeding the coordination activity all social and fast communication media will be used. For instance, monthly conference calls using "Skype" will be organized, a "whatsapp" chat will be added for fast exchange, and a "slack.com" site will be created and used for facilitating day to day collaboration. UNICA will control that database will be collected as well as their elaborations in a web-based database. WP1 is organized in two tasks. *Task 1.1 organization structure and supervision of the results (Leader UNICA)* The project management team will take measures to guarantee control, validation and verification of the project results, ensure that plans are fulfilled and implementing necessary corrective actions. Specific activities will include: monitoring of progress; coordinate the preparation of reports and implementation plan; organization of the 3 Project Meetings (Italy, Tunisia, and Cyprus); follow the organization and updating of the project website; collecting and quality assurance of deliverables; deliver the data management plan *Task 1.2 administrative management (Leader UNICA)* The main goals associated with this task are to ensure punctual provision of periodic management reports and financial statements, and to handle payment issues with National funding bodies. Specific activities will include: daily management of administrative consortium activities within the consortium; follow up of the imple-

					mentation and update of the Consortium Agreement; check the progress of administrative work; coordinate the administrative bodies of the different participant institutions and the preparation of financial reports. This task will also oversee and mitigate any management risks (see Section 3.3) *Deliverables:* D1.1: Kick-off meeting and its minutes (resp: UNICA) D1.2.1: Data management plan (resp:UNICA) D1.2.2: Mid term project meeting and its minutes (resp:UNICA) D1.2.3: Updated schedules of activities (resp:UNICA) D1.2.4: Final project meeting and its minutes (resp:UNICA) *Milestones:* MS1: Project kick-off
WP 2	**Experimental fields and watersheds: a new transnational Mediterranean watershed monitoring network.**	**30**	**1**	**30**	(Leader: INRGREF) WP2 includes 3 Tasks *Task 2.1: monitoring of experimental fields (Leader: INRGREF)* We will distinguish the sites that are already instrumented to the sites that will be instrumented using meteorological or micrometeorological and sm sensors (Table 1). In the sites already instrumented: historical data will be collected and uploaded to the online Common Project Server of FLUXMED; check and calibration test of the sensors will be made. In the sites that will be instrumented: instruments will be acquired, and all instruments and software will be first tested at the laboratory; instruments will be installed at the sites and the first month will be used for trial-period; data will be uploaded to the FLUXMED on line database; maintenance and calibration tests of sensors will be made yearly. In some test sites (Table 1) geophysics methods will be used. Sapflow sensors will be installed both in the stems and roots in some sites (Table 1). *Task 2.2: monitoring of hydrologic basins (Leader: INRGREF)* - Rain and streamflow will be monitored in 5 basins (gage stations are mostly already operative, Table 1). - data will be collected, and checked for the accuracy; then data will be uploaded to the FLUXMED on line database; - in the basins already monitored, historical hydrological data will be collected and uploaded to the online Common Project Server of FLUXMED. - historical data of precipitation and temperature will be also collected from European Centre for Medium-Range Weather Forecasts (ECMWF). - sm and vegetation will be also monitored at the watershed scale, and will be compared with remote sensing observations (see WP4). *Task 2.3: analysis of field observation data (Leader: CESBIO)* Analysis and data elaboration will be performed for: control and quality check of data; estimation of ET components in agricultural and natural environments; estimation of relationships between ET and soil moisture in different field sites; estimation of uptake of root in the rocks. *Deliverables* D2.1: database from Task 2.1 (all partners) D2.2: database from Task 2.2. (all partners) D2.3: two submitted publications about data analysis (all partners) *Milestones:* MS2: Database completion.
WP 3	**Ecohydrological modeling**	**24**	**1**	**24**	(Leader: UNICA). WP3 is divided in 4 tasks. *Task 3.1: LSM-VDM calibration and validation at field scale (Leader: UNICA)* LSM-VDM models (e.g. UNICA model, CESBIO model) will be implemented for predictions of energy balance terms, soil moisture and LAI evolution. The model will be calibrated and validated, comparing observed and simulated time series of the energy balance terms, sm, and LAI through a trial-and-error procedure. *Task 3.2: Distributed ecohydrologic model at basin scale (Leader: UNICA)* - development of a distributed version of LSM-VDM model. - inclusion of modules for runoff propagation by using a modified version of the Muskingum –Cunge method and base flow. The model will be also coupled with remote sensing observations (WP4) for computing surface energy balance terms and ET at the basin scale. *Task 3.3: LSM-VDM calibration and validation at basin scale (Leader: CyI)*

					Model calibration and validation by comparing the simulated runoff data with historical runoff through a trial-and-error procedure. *Task 3.4: model intercomparison and optimazion (Leader: UNICA)* - models both at field and basin scales will be compared at the case studies. - model sensitivity to time scale and parameterization for the different climate and environmental conditions of the case studies *Deliverables* D3.1: report with calibration and validation of LSM-VDM models at field scale for the experimental sites (all partners) D3.2: developed distributed LSM-VDM models at basin scale (resp. UNICA) D3.3: 2 submitted publications about modeling at basin scale (all partners) D3.4: submitted publication on model intercomparison and optimization (UNICA) *Milestones:* MS3: Full version of operational models
WP 4	**Remote sensing and data assimilation**	**27**	**1**	**27**	(Leader: CESBIO) WP4 includes 3 tasks. *Task 4.1: acquisition of satellite images (Leader: CESBIO)* The aim of this task will be the acquisition of the satellite multispectral images for Ts and LAI estimates: Landsat (spatial resolution 30 m, temporal resolution 16 days), ASTER (spat. res. 15 m, time res. 16 d), Quickbird (spat. res. 1-3 m, time res. 3 d), SENTINEL 2 (spat. res. 10 m, time res. 3 d), NOAA AVHRR (spat. res. 1 km, time res. 1 d), SEVIRI (spat. res. 1 km, time res. 15 min). *Task 4.2: estimation and validation of Ts and LAI (Leader: CESBIO)* - LAI estimated from NDVI using satellite near-infrared and vis. bands - Ts obtained from satellite thermal infrared bands - Ts and LAI estimates tested with the observations at the fields (WP2). *Task 4.3: development of a data assimilation system (Leader: CESBIO)* - the Enkf will be implemented in the VDM LSM for assimilating Ts and LAI. - sensitivity analysis of the data assimilation system to frequency of assimilation and to spatial resolution of satellite images. *Deliverables:* D4.1: remote sensing images database. (resp. CESBIO) D4.2.1: LAI and Ts estimates from satellite images. (resp. CESBIO) D4.2.2: 1 submitted publication about estimates from satellite images. (all partners) D4.3.1: data assimilation system. (resp. CESBIO) D4.3.2: 1 submitted publication about data assimilation system. (all partners) *Milestones:* MS4: Database completion.
WP 5	**Analysis of land cover change strategies and climate change scenarios**	**24**	**4**	**27**	(Leader: UNIAS) WP5 includes 3 tasks. *Task 5.1: analysis of historical hydrologic data (Leader: UNIAS)* - computation of annual, seasonal, monthly and daily statistical series for precipitation, runoff, and temperature for case studies at basin scale. - Statistical tests for detecting trend and change on the historical hydrologic data across the Mediterranean gradient; *Task 5.2: generation of the future climate change scenarios (Leader: UNIAS)* - acquisition of future climate scenarios of IPCC - selection of IPCC climate models for future scenarios through comparison of historical climate model outputs with observed actual data. - generation of future climate scenarios from historical climate data perturbed with IPCC future climate scenarios through a stochastic generator. *Task 5.3: effects of land cover changes strategies and climate change scenarios (Leader: UNIAS)* - evaluation of land cover changes and spatial distribution changes of competing vegetation on water resources and uses under current climates; - evaluation of future climate change scenarios on water resources; - development of land cover strategies for optimizing the water resources use *Deliverables* D5.1: submitted publication on historical data analysis (all partners) D5.2: multiple future climate scenarios in the project database (resp. UNIAS) D5.3: 2 submitted publications about the effect of land cover strategies and climate change scenarios (all partners)

					Milestones: MS5: Inclusion of scenarios in the project database.
WP 6	**Development of water management and planning systems**	**20**	**11**	**30**	(Leader: CyI) WP6 includes 2 tasks. *Task 6.1: water management models for case studies (Leader: CyI)* - testing and improvement of water management models - use of the outputs of WP5 in the water management models for application of the models for case studies. *Task 6.2: strategies for water resources optimization (Leader: CyI)* - development of strategies for the optimization of water infrastructure and uses for current and future climate conditions *Deliverables* D6.1: scientific manuscript on water management model application in 6 Mediterranean case study sites. (resp: CyI) D6.2: submitted publication about strategies for water management optimization (resp: CyI) *Milestones:* MS6: Database update with water management optimization strategies. MS7: availaibility of improved versions for integrated modeling schemes
WP 7	**Quantifying benefits and sharing methodologies with stakeholders, dissemination and communication**	**30**	**1**	**30**	(Leader: UNICA) WP7 includes 2 tasks. *Task 7.1: project web site and other online communication systems (L. UNICA)* Development and maintenance of FLUXMED web site, a “Google” research page, a “Researchgate” page, a “Facebook” page, and a “Twitter” page *Task 7.2: engagement with scientific community and stakeholders (L. UNICA)* - a communication and dissemination plan will be developed. - organize introductory participatory workshops in all 5 countries to engage the multiple actors involved in the making up of water governance territory - organize participatory workshops in all 5 countries to identify water management scenarios with stakeholders - organize a final workshop to share project results with stakeholders - share methodological developments, by setting a common toolbox where academic partners exchange former and newly developed approaches; - deliver monitoring results and disseminate outcomes. - Project results will be made available to the stakeholders (Table 1) with training courses in all 5 countries *Deliverables* D7.1.1: dissemination and communication plan (DCP) (resp: UNICA) D7.1.2: reports from participatory workshops (UNICA) D7.2.1: Project web site (UNICA) D7.2.2: reports from training sessions (UNICA) *Milestones:* MS8: Web site.

3.2. Appropriateness of the management structure and procedures, including quality management

3.2.1 Management Structure

The role of the FLUXMED management structure is to ensure an easy cooperation between all the partners, and ensure the progress of the activities within the project lifetime. The communication will be guaranteed by exchanges of emails and documents trough internet, the “slack.com” site for day to day collaboration, videoconferences and workshops, and general assemblies. The organizational structure of the consortium will include the following bodies: *i) General Assembly* (GA): the decision body of the consortium, and it shall consist of one representative of each partner, the project coordinator and the Assistant Project Manager. The coordinator shall chair all meetings of the GA. The GA shall be free to act on its own initiative to formulate proposals and take decisions in accordance with the procedures set out in the Consortium Agreement (CA). The GA will be the decision body for any issue concerning the Consortium and will resolve any disputes between partners. Approvals by the GA shall be ensured by email vote (simple majority required). The decision and problem resolving process will be defined in detail in the CA.

GANTT CHART

Work Package \ Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
WP 1																														
WP 2																														
WP 3																														
WP 4																														
WP 5																														
WP 6																														
WP 7																														
Deliverable	D1.1		D7.2.1			D1.2.1, D7.1.1	D7.1.2					D4.3.1	D7.1.2		D1.2.2, D2.1, D4.1,	D3.1, D3.2	D5.1	D4.2.1	D1.2.3	D2.2, D6.1	D5.2			D3.3, D3.4		D4.3.2	D4.2.2, D5.3	D7.1.2		D1.2.4, D2.3, D6.2, D7.2.2
Milestone			MS1	MS8																	MS4	MS2	MS3	MS5	MS6		MS7			
Risk management			R9	R6		R4, R5	R2	R6	R9	R1		R9,R10		R4, R5	R2, R3, R6	R7		R9		R1, R8	R4, R5	R2	R7	R6, R9, R10			R9		R4	R1

ii) Coordinator is the responsible entity for administrative and managerial aspects. The scientific coordinator will monitor the progress of the project, and will also verify the quality of participant contributions, and ensure that deadlines will be met. The coordinator is responsible for maintaining contacts with WATER JPI and the General Assembly, and ensuring a transparent development of the project.
iii) Technical Management Team (TMT) will assist the coordinator in the day-to-day management of the Project including both legal and economic aspects. The TMT will support the Coordinator in executing the decisions of the GA. Head of the TMT will be the Coordinator. The TMT will also include an Assistant Project Manager (APM) and a designated financial administration. The APM will assist the Coordinator with executive management tasks (e.g., organization of meetings and workshops, follow-up of planning schedule). The financial relationships with each National funding bodies will be carried out by each partner, and TMT will support the partners. The responsibilities of the TMT will be to: reviewing and submitting reports; submit the mid-term and final reports; day to day coordination of the project and monitoring project planning and progress; communication within the project to both users, and public, organization of meetings and internal reviews.
iv) Work package leaders. the leader of each WP will ensure good communication within the WP. Main activities of the WP leader are: coordination of tasks and activities of the WP; manage and reaching the deliverables and milestones of the WP; ensure communication, coordination and interrelation with other WPs, including dissemination of the results generated within their WP; report to TMT of any possible deviations, unsuitability or risks affecting the quality of project results and/or objectives. The communications with partners and stakeholders will be ensured by WP Leaders through web-based tools (Skype, "slack.com" site, etc.), phone, email, video conferences and meetings.
v) Expert Advisory Committee: The Expert Advisory Committee (EAC) is composed of external scientific international experts and professional users, which will be actively involved for an external evaluation and validation of project. EAC members will be constantly informed of the project progress. The members of EAC will be: Professor Gaby Katul (Duke University, USA), Professor Amilcare Porporato (Princeton University, USA), a Water Authority representative, and a Water Industry representative that will be selected during the first project meeting.
3.2.2. Procedures
FLUXMED partners shall cooperate and focus their capacities on the common goal: ensure the progress of the project and reach the objectives. The Coordinator shall guarantee that each partner and player within the consortium have all the necessary tools needed to contribute to the project. Moreover, the coordinator ensures a high level of communication within the consortium as to avoid lack of communication or problems in the project management. The internal organization of the project shall be included in the CA. In particular, the CA will contain the specifics on: internal organization of the Consortium, its governance structure, and decision-making processes; measures for the distribution of the Community Financial Contributions among Partners and among activities type; provisions for the settlement of disputes within the partnership; definition of specific measures concerning intellectual property rights to be applied among the Partners and their affiliates, in compliance with the general arrangements stipulated in the contract; procedures for changes in the consortium composition; rights, rules for joint ownership, access rights to project results for participants and 3rd parties; rules on dissemination and use; rules for managing confidentiality and approving public presentations and publications. The CA also includes details on the organization of project meetings (e.g. General Assemblies), meeting minutes, and voting rules.

3.3. Risk management

The identification of risks is a constant process within the project life, begin during the proposal phase and it is regularly updated when the project starts. Through the risk analyses, the risk attributes are evaluated and prioritized. Hence it is possible to evaluate the probability of risk occurrence (Likelihood of Occurrence) and its impact on the project, and determine risk responsibility and best actions to eliminate or mitigate them. The coordinator is responsible for the risk analysis and mitigation process and establishes the risk management procedures. Each WP leader is requested to provide for the work package in which is included a risk evaluation plan of where the risk identification, risk analysis, risk responsibility and a mitigation purpose. The preliminaries risk evaluation plans provided by the WP leaders, and will be distributed to the consortium members. A preliminary risk assessment table with critical risks identified and mitigating actions is in Table 4. The timing of the critical risks is in the Gantt Chart.

Table 4: Critical risks for implementation

Description of risk (indicate level of likelihood: Low/Medium/High)	*WP*	*Proposed risk-mitigation measures*
R1: Coordination and/or management of FLUXMED fails (Low/Medium)	1	The project coordinators and the consortium members have exhaustive experience in managing research projects, and the assistant project manager will plan and pro-actively avoid deviations and failures.

R2: Disputes between partners (Low/Medium)	All	All the partners agree to try to resolve in the best friendly manner any dispute arising among them in relation to the implementation of the project. Failing to reach an amicable settlement, the dispute shall be handled according to the dispute resolution rules provided in the CA
R3: A partner decides to drop out of the project (Low)	All	The issue will be discussed in the GA, which will decide if it is necessary to re-allocate work to other partners or suppress work without reducing the scientific quality of the project.
R4: Not suitable quality of deliverables (Low/ High)	All	Revision and reorganization of each deliverable, and, for specific cases, reinforce partners participating in the deliverable
R5: Deliverables not delivered on time – delays in project (Low/medium)	All	Day-to-day communication between coordinator, WP leaders, and TMT will ensure the reduction of potential delays in the project by the definition of clear protocols of internal communication.
R6: Quality of monitored data is not satisfactory (Low/medium)	WP 2, 4	Quality control on observed data will be implemented. In case of relevant quality problems, remedial actions will be defined and executed
R7: Uncertainty in model scenarios for climate change (Low/medium)	WP 5,6	To minimize the risk of model result inconsistency, uncertainty will be assessed by sensitivity analyses, both for current and future climate
R8: Uncertainty in the deployed strategies for optimizing the water infrastructure (Low/medium)	WP 6	To minimize the risk of the planned strategies, sensitivity analyses will be carried out both for current climate conditions and for future climate scenarios
R9: Dissemination of the project results is not sufficient to create impact (Low/medium)	WP 6	The consortium is strongly determined to create sustaining impact. In addition, a dedicated tasks for dissemination, and communication will plan and execute this goal and prevent this risk
R10: Political instability in study sites countries (Medium)	All	The consortium will verify the existence of potential problems and will decide alternative or other potential most stable study sites.

3.4. Potential and commitment of the consortium to realize the project

The consortium of FLUXMED is well organized and balanced, so that a number of strengths guarantee the FLUXMED success. Indeed, the consortium is characterized by a strong international cooperation, and includes experts of a wide range of complimentary fields, hydrology, hydraulic, ecology, forestry, agronomy, micrometeorology, geophysics, and economy providing an excellent opportunity to advance water resources science of semi-arid and arid Mediterranean regions. FLUXMED offers a unique opportunity of exchanges of research and knowledge, which is the base for increasing the research development in water resources.
The composition of the consortium is well balanced, including female (2 of 5 PIs are female) and junior researchers, and covers all the aspects of FLUXMED. The inclusion of the Universities and National research institutes offers a unique opportunity of exchanges of research and knowledge, and ensures involvement and training of PhD students and postdoc scientists. The Table 2 describes the expertise of each partner, while the role of each partner in the project is described in the Table of section 5 (pag. 18-19). Participant teams will enrich each other on the topics they are not expert (as outlined on Table 2), but also on the overlapping topics they will benefit from sharing and comparing their respective technical approaches.
This international cooperation will enhance the dissemination of project results and will help to make developed tools and methodologies truly international. The FLUXMED consortium contains all the needed expertise to ensure the achievement of the objectives, and ensures a multidisciplinary cooperation between the experts of water system management, policymakers and the public society. Stakeholders are totally involved, and expect FLUXMED outcomes for applying models and tools in the management of their water, agricultural and environmental systems.
The consortium organizations are leading RDI institutions within their countries and beyond. The institutes to which the members of the consortium belong are devoted to water, environmental and agricultural sciences. Therefore, the research topic of FLUXMED will have the maximum consideration by these organizations. They will make available all the necessary resources with a high commitment in the project, including experimental facilities and laboratories, computing services and technicians. In addition, they will provide the necessary administrative services for a suitable management of the project, including outreach activities.

4. DESCRIPTION OF THE PARTICIPATING RESEARCHERS

Partner Number, according to Part A	Research Team Members (for personnel include name, position and affiliation)	General Description
Coordinator (UNICA)/Nicola Montaldo (M)	Andrea Saba, assistant professor in water resources, UNICA	Design and optimation of hydraulic infrastructures, economy implications
	Giulio Vignoli, Associate professor in geophysics, UNICA	Near-surface characterization especially with airborne electromagnetic and seismic surface wave methods
	Giovanni M. Sechi, Associate professor in water resources management, UNICA	Water resources management and planning, socio-economy
	Francesco Viola, Assistant professor in hydrology, UNICA	Surface hydrology, ecohydrology
	John D. Albertson, Professor hydrology, Cornell Univ. (USA)	Hydrology, land surface fluxes, micrometeorology, water resources
	Ram Oren, Professor ecology, Duke University (USA)	Global change ecology, terrestrial ecosystems, biogeochemistry, ecophysiology
	Alessandro Seoni, hydrology engineer, UNICA	Hydrology, water resources management
	Antonio Mascia, technical staff, UNICA	Field experiments, sensor building and management
Partner 1 (CyI)/Adriana Bruggeman (F)	Hakan Djuma, Postdoc, CyI Affiliation	Hydrology, erosion, soil carbon, land and water management, modeling
	Marinos Eliades, PhD student, CyI	Ecohydrology, sapflow, environmental monitoring, modeling
	Christos Zoumides, Assoc. Research Scientist, CyI	Ecological economics, stakeholder facilitation
Partner 2 (UNIAS)/Ashraf M. Elmoustafa (M)	Ahmed Hassan, Prof. of Environmental Hydrology, Faculty of Engineering, Ain Shams University.	Hydrology, Water Quality, groundwater studies, and flood management.
	Ahmed Lotfy, researcher at the Water Resources Research Institute.	Hydrological data analysis, GIS application ins water resources.
	Ahmed Raslan, Researcher Assistant, Faculty of Engineering, Ain Shams University.	Hydrological modeling, GIS application ins water resources.
Partner 3 (CESBIO)/Gilles Boulet (M)	Olivier MERLIN, CNRS researcher, CESBIO	Multi-sensor remote sensing data for multi-scale monitoring of surface water
	Aurore BRUT, assistant professor in micrometeorology	Water and CO2 fluxes through EC, scintillometry, surface renewal
	Lionel JARLAN, IRD senior researcher, CESBIO	Remote sensing data assimilation into land surface models in semi-arid areas
	Valérie LE DANTEC, assistant professor in ecology	Remote sensing; modelling of the plant functional response to water stress
	Vincent Simonneaux, remote sensing specialist, CESBIO	Support: operational approaches for the management of irrigated areas using satellite images
	Vincent RIVALLAND, modelling specialist, CESBIO	Support: SVAT modelling, thermal remote sensing, data assimilation
	Pascal FANISE, flux tower specialist, engineer, CESBIO	Support: acquisition and processing of flux tower data

Partner 4 (INRGREF)/Rim Zitouna Chebbi (F)	Hechmi Chehab, Assistant Professor, Olive Institute, Tunisia	Irrigation, antioxidant
	Dalenda Boujnah, Professor, Affiliation	Ecophysiology, irrigation management
	Mekki Insaf, Associate Professor, INRGREF, Tunisia	Agronomy, hydrology, agricultural water management
	Zairi Abdelaziz, Professor, INRGREF, Tunisia	Irrigation, water management, crop productivity

5. CAPACITY OF THE CONSORTIUM ORGANISATIONS

Partner Number (Organisation Name)		General Description
Coordinator (UNICA)	Role and main responsibilities in the project	Scientific coordinator, leader of WP1, WP3, and WP7, cooperate in all WPs.
	Key research facilities, infrastructure, equipment	Three EC towers, sapflow and soil moisture sensors, flow meters, Accupar ceptometer, soil physics lab., chemical analysis, hydraulic laboratory. Ground penetrating radar antennas, frequency and time – domain electromagnetic devices, electrical resistivity tomography
	Relevant publications and/or research/innovation products	Montaldo N, Albertson J. D, M. Mancini, Dynamic Calibration with an Ensemble Kalman Filter based data assimilation approach for root zone moisture predictions. J. Hydromet., 8, 910-921, 2007 Montaldo, N., & Oren, R. Changing seasonal rainfall distribution with climate directs contrasting impacts at evapotranspiration and water yield in the western Mediterranean region. Earth's Future, 6. https://doi.org/10.1029/2018EF000843, 2018.
Partner 1 (CyI)	Role and main responsibilities in the project	Leader of WP6, cooperate in all WPs with Peristerona Watershed case study, and leader of the Task 3.3 on the LSM-VDM calibration and validation at basin scale
	Key research facilities, infrastructure, equipment	Sapflow and soil moisture sensors, leaf water potential meter, flow meters, soil physics amd chemistry lab, High Performance Computing facility, forestry research site, fields of cooperative farmers
	Relevant publications and/or research/innovation products	Eliades, M., A. Bruggeman, M. et al.. The water balance components of Mediterranean pine trees on a steep mountain slope during two hydrologically contrasting years. J. Hydrol., 562, 712-724, 2018. Djuma, H., C. Camera, A. Bruggeman, M. Eliades, K. Kostarelos. The impact of a check dam on groundwater recharge and sedimentation in an ephemeral stream. Water 9 (10), 813, 2017
Partner 2 (UNIAS)	Role and main responsibilities in the project	Leader of WP5, cooperate in all WPs
	Key research facilities, infrastructure, equipment	Water Quality lab. GIS lab; including high performance computing facility and Softwares (i.e. GIS, HECs, MIKE SHE). Hydraulic laboratory, flow meters, soil moisture sensors, and sediment traps.
	Relevant publications and/or research/innovation products	Omar H. Zohny, Ashraf M. El Moustafa, Mohamed A. Gad, A GIS Automated Hydrologic Model for Engineering Applications. Journal of Al-Azhar University Engin. Sector, ISSN: 1110-6409, 2018 Ahmed Hassan, Sherine S. Ismail, Ashraf Elmoustafa, Shaimaa Khalaf. Evaluating Evaporation Rates Using Numerical Model (Delft3D). Current Science International, ISSN: 2077-4435, 6 (2), 20, 2017
Partner 3 (CESBIO)	Role and main responsibilities in the project	Leader of WP4, cooperate in all WPs and leader of the Task 2.3 on analysis of field observation data.
	Key research facilities, infrastructure, equipment	The Taous site Olive EC tower, remote sensing sensors, soil moisture, sapflow, leaf turgescence; The CESBIO lab RS data processing facilities, esp. the Sentinel 2 and 1 biophysical variable retrieval algorithms; the various opensource SVAT model platforms
	Relevant publications and/or research/innovation products	Boulet, G., Mougenot, B., Lhomme, J.-P., et al., The SPARSE model for the prediction of water stress and evapotranspiration components from thermal infra-red data and its evaluation over irrigated and rainfed wheat, Hydrol Earth Syst Sc, 19, 4653-4672, 2015. Merlin, O., Olivera-Guerra, L., Hssaine, B. A., et al., A phenomenological model of soil evaporative efficiency using surface soil moisture and temperature data, Agric For Meteorol., 256, 501-515, 2018.

Partner 4 (INRGREF)	Role and main responsibilities in the project	Leader of WP2, cooperate in all WPs
	Key research facilities, infrastructure, equipment	The team has a long experience: 1) on field observations: soil moisture, water plant status, leaf area index, and surface energy. 2) in irrigation management and in water resources management and 3) in collaboration with the water management stockholders, Citrus orchards belonging to the technical citrus center are made available for experiments, with an Eddy covariance tower.
	Relevant publications and/or research/innovation products	Zitouna-Chebbi R., Prévot L., Chakhar A., Marniche-Ben Abdallah M., Jacob F. Observing actual evapotranspiration flux tower Eddy covariance measurements within a hilly watershed: case study of the Kamech site, Cap Bon peninsula, Tunisia. Atmosphere, 9(2),68, 2018 Ferchichi, I. Marlet, S. Zairi A., How farmers deal with water scarcity in community– Managed irrigation systems: A case study in northern Tunisia. Irrigation and Drainage, DOI: 10.1002/ird.2135, 2017.