ISOMED ERANETMED3-147

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German Aerospace Center (DLR)
Project Management Agency
European and International Cooperation

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Project Acronym
ISOMED

Full Project Title
Environmental Isotope Techniques for Water Flow Accounting

Type of Activity
Innovation Project
Mobility

Cross cutting Issues
Governance
ICT
Gender

Main Keyword
Climate, Environment, Sustainability -> Coastal Research, Marine Research, Polar Research, Geosciences -> Hydrology [FB16]

Keyword 2
Climate, Environment, Sustainability -> Ecology, Nature Conservation, sustainable use -> Regional/urban water resources management [FD10]

Keyword 3
Climate, Environment, Sustainability -> Ecology, Nature Conservation, sustainable use -> Improved water infrastructures in terms of energy and consumption [FD04]

Keyword
groundwater recharge, isotopes

Start Date
31-03-2018

End Date
30-03-2021

Duration
36

Participating Countries
Cyprus

ISOMED ERANETMED3-147

Germany
Jordan

Project Summary

The project ISOMED aims at developing innovative methods for estimating environmental flows with the ultimate objective of increasing water use efficiency and reaching sustainability. Sustainability is defined as resilient balance of water resources renewal and uses within hydrological systems under anthropogenic pressure at various scales.

The project ISOMED promotes collaborative research on a highly innovative method of quantifying environmental flows with stable isotopes. Environmental isotopes of water are also used as indicators for water use efficiency and for stability and resilience of hydrological systems. The project will stimulate mobility of researchers and result in an SME-led innovative action on affordable recharge monitoring, that can be scaled and multiplied.

The approach and methodology of the project ISOMED is specifically well-suited for semi-arid and arid environmental and hydrological systems of the Mediterranean. Environmental flows in a Mediterranean climate are characterized by a pronounced seasonal variability creating a pulse-inertia pattern. Due to the very specific isotope hydrology of the Mediterranean, these water flows carry seasonal and regional fingerprints. The collaborative research focuses on developing and advancing methods for quantitative recharge assessment in agricultural, environmental and groundwater systems, using environmental isotopes. These indicators can be used in environmental flow accounting and integrated into modern water assessment frameworks. Results will expedite the detection of changes in environmental flows and balances and allow for an annual accounting of recharge, evaporation losses, origin of water sources and overall system performance.

The project team, consisting of partners from Cyprus, Jordan and Germany, involves a research institute (CYI, Cyprus), a ministerial institution involved in the management of groundwater resources (GSD, Cyprus), a university (GJU), a university of applied sciences (FHL) and a highly innovative SME. The project consortium has the necessary resources and infrastructure to develop the methodology: FHL runs a modern innovative stable isotope laboratory of the newest analytical standard and has actively contributed to the development of new technologies in environmental isotope hydrology over the past years. CYI is a highly recognized research institute addressing climate change, environmental science and information and computation technologies for monitoring environmental systems. GSD is a government institution responsible for groundwater and has initiated and supported innovative research projects on groundwater resources. GJU is a modern institute of higher education with a strong focus on environmental science and technology. The SME TRUEBNER GmbH is a researcher-led company focusing on innovative and affordable soil moisture and environmental monitoring devices.

The project team integrates well-established and well-connected experts with complementary skills in surface hydrology (CYI, FHL), groundwater (GJU, GSD, FHL), isotopes (GJU, CYI, GSD, FHL) and environmental flow assessment (FHL, GSD).

A key component of ISOMED, in addition to collaborative research, will be to improve mobility and improve training, education and research on the use of environmental isotopes in the Mediterranean. Mobility includes staff exchange and an annual management and science meeting as well as exchange of teaching staff, graduate and post-graduate students and experts.

The project deliverables are a new and readily applicable framework for environmental flow assessment based on isotope methods, an improved estimation of groundwater recharge providing ex-post quaterly recharge beneath agricultural production systems and natural recharge zones and quantitative indicators for sustainability and system performance. The project will provide a web-based toolbox and database on environmental methods and georeferenced data.

project consortium

If A: Summarize briefly
This proposal has not been submitted in another funding programme.

Financial resources
No

If yes, please specify

confirm
I confirm that the information given in this proposal is correct.

confirm
I confirm that the proposal is endorsed by all project partners.

Background, Questions and Objectives
Research issues, questions, actions

The project ISOMED aims at improving water use efficiency of economic activities to ultimately secure sustainable supply of drinking water, to optimize water-related production and to maintain or restore environmental flows in Mediterranean environments. Sustainability is defined as a stable and resilient balance of water resources renewal and uses within hydrological systems at various time and space scales. ISOMED is a collaborative research and capacity building project proposing to develop and apply innovative techniques for deriving measurable key indicators for water use efficiency and for the sustainable use of water resources. ISOMED will result in an integrated monitoring and ICT scheme to measure water use efficiency and sustainability of agricultural production schemes and of the natural environment providing these water resources. The monitoring and improved assessment of flows will help to secure and protect or restore ecosystem services. ISOMED proposes a system of environmental isotope techniques to monitor the dynamics of environmental flows in a quantitative way and to cast these into measurable indicators such as recharge rate, evaporation to transpiration ratio and residence time. The approach is suited for Mediterranean Environments and offers a number of advantages over common water balance monitoring, especially in semi-arid and arid environments with pronounced seasonal variation.

Scientific basis and state of the art

Water consumption and use in irrigated agriculture plays a key role in the hydrological balance of Mediterranean countries (Külls et al., 2000). Since antiquity, agricultural systems have had significant impact on hydrological balance and processes (Al-Qudah et al., 2016), at least since the early 1960s there is an imbalance of hydrological systems under intensive agricultural use in the Mediterranean. The first response to the modern water crisis has been to explore and develop water resources by drilling ground water boreholes, lowering them to greater depth and by constructing storage schemes (Luijendijk & Bruggeman, 2008). While the first activity has solved these problems only temporarily, leading to a gradual depletion of groundwater resources, also of deep aquifers, the second measure has had major impacts on the environment by reducing environmental flows to ecosystems (Abu-Jaber et al., 2003). The next generation of measures, including the use of treated wastewater and the attempt of reducing water losses and increasing the efficiency of irrigation systems has reduced water scarcity problems. These actions often were at the expense of water quality, due to introduction of residual fractions of inorganic and organic chemical compounds to agricultural production systems and eventually to the groundwater and connected ecosystems (Baram et al., 2013 and Christophi et al., 2011). This phase has also caused increasing salinization that is in proportion to water use efficiency. The third generation of measures aimed at improving the evaluation and quantitative assessment of recharge and environmental flows juxtaposing them to water demands from

agriculture (Al-Qudah et al., 2015). The third phase of water management from 1990 to about 2000 has clarified that there is a serious structural deficit and that, as a consequence a transformation of the water sector including a sound re-evaluation of water-related economic activities is needed to adapt to the now-known limits of sustainable production in the Mediterranean (Zagana et al., 2007). In this phase of water management social and economic variables were introduced into the equation of water management: Integrated Water Resources Management represents a rather qualitative approach defining the relationship of society, environment and economy as the essential components of water management. While IWRM was still lacking a procedural approach, the European Water Framework Directive (EWFD) introduced a normative legal framework, requiring a clear definition of system boundaries, environmental flows, mass and economic balance, also introducing good water quality as an objective. However, as a legal framework, it lacks a methodology of deriving indicators for these objective functions, especially with respect to groundwater. The methodological side of groundwater recharge assessment has been explored and investigated since the 1990s and is now well established, also and especially in Mediterranean climate and various pedological and geological environments found therein. Current approaches of water management also include socio-economic and environmental accounting of water represented as stock and flow system for water from the environment to the economy (fresh surface and groundwater, rainfall for rain-fed agriculture) and from the economy to the environment (return flows, sewage, pollutants and nutrients) including the economic valuation of water (Zoumides et al., 2014). Although this approach is a systematic and consistent approach, it lacks, again the methodological tools for assessing stocks and flows as well as adequate ICT tools for applying this approach. Hence, the major gap in all approaches can be identified as a lack of operational methods and tools to estimate flows and stocks, hydrological processes and in a manner that can be included and integrated into current management frameworks. Furthermore, all approaches having been derived for mid-latitude (and often humid and therefore quite regular flows) all lack a specific methodology for assessing stocks and flows under conditions of extreme variability, drought and highly intermittent flow dynamics. In summary, three distinct research needs can be derived for new phase of water management in the Mediterranean: 1.) Integrated approaches combining social, economic and environmental aspects require, as basis and prerequisite adequate and efficient methods for quantifiying environmental processes, stocks and flows. 2) Methods and tools need to be adapted to the Mediterranean environment and to its semi-arid to arid conditions with extreme events, droughts and intermittent flows; a modern and comprehensive approach for water assessment and management needs to include temporal and spatial integration at the right scales. 3) Empirical and applicable monitoring and evaluation tools need to provide indicators that integrate over the spatial and timescale of the management unit and that require affordable additional processing.

In conclusion, the potential for further development of new natural water resources by drilling or civil engineering is often exhausted or requires investments that are not in a reasonable proportion to the benefits they provide. To address the overall structural deficit, water saving technologies still offer some potential for optimization and reduction of water stress, but these technologies need to be combined with water quality indicators. The hydrological boundaries and limits, recharge rates for specific hydrological and hydrogeological systems in the Mediterranean are still not well known, there is considerable lack of knowledge on specific recharge rates at various scales of basins and aquifers at relevant timescale. Recharge and demand data are not available at sufficient temporal and spatial resolution to establish dynamic and adapted management schemes. A high potential for solving the water crisis in the Mediterranean is currently seen in water management approaches that include strategic and structural changes of economic activities, substitution and transformation of water intensive sectors to economically more rewarding but less water intensive activities. However, this approach also requires - as a prerequisite - the estimation of environmental stocks and flows that need to be scaled to basins and given at annual intervals.

It is therefore a major importance to develop a modern approach to water resources management, that includes the hydrological balance as an indicator of environmental sustainability as well as socio-economic data on the value produced by water for the economy and the society such as the SEEAW (System of Environmental-Economic Accounting for Water) approach. The strategic socio-economic and environmental assessment of water resources allows to explore options for economic transformation based on accounting

of flows from the environment to the economy and vice versa. Still, the SEEAW approach lacks a feasible and readily applicable monitoring tool to provide data on environmental flows and ICT tools. ISOMED offers such an approach based on environmental isotopes. Environmental isotope methods are based on the natural variation of isotope ratios in water, dissolved or particulate matter (Leibundgut et al., 2009) serving as an input function to track the origin, flow velocity, dispersion, phase changes and transformation of water. Isotopes have proven extremely useful to explore movement of water in semi-arid and arid environments (Klaus et al., 2013). Recent developments in analytical methods have opened new possibilities for using isotopes in hydrological and water resources studies (Mueller et al., 2014), especially when combined with other modern monitoring methods for hydrological processes (Cataldo et al., 2017).

Novelty, capacity building, mobility

The approach is novel and innovative in three main aspects: 1). The approach combines environmental isotopes as an operational assessment tool for environmental flows in the Mediterranean. Instead of monitoring for moisture content, water levels and discharge for many years and then calculating environmental flows, the ISOMED method is based on a sampling of soil moisture profiles and of aquifers every few years and provides the history of environmental flows of the last past years in response to management changes or land use changes immediately. The method gives direct evidence of environmental flow rates at relatively high precision and of changes to these flows in response to actions or environmental changes. 2) Environmental isotopes in soil water and in groundwater are used in an integrated way to characterize all aspects of using hydrological systems under irrigation. The approach combines stable isotopes of soil and groundwater to assess recharge rates as well as the evaporation / transpiration ratio as an indicator of unproductive water loss and also uses environmental isotopes for residence time analysis of associated groundwater systems in one integrated approach. Soil coring, direct push methods and subsequent groundwater sampling are combined into one approach covering all aspects of the recharge process. Environmental isotopes can be coupled with in situ soil water monitoring to underpin the results and improve the methodology. Finally, the approach is novel in proposing an associated ICT system to integrate, evaluate and analyze all data. The ICT system combines analysis of environmental isotopes and calculation of recharge rates, the derivation of unproductive losses, the analysis of residence times and the integration of these results into a digital and user-friendly system for environmental and economic flow accounting. The project provides essential data and an applicable tool for all frameworks of water management, environmental flow accounting and assessment methods.

Scientific added value and contribution of European-Mediterranean research networks

There will be significant scientific value added to European-Mediterranean research networks: The consortium combines modern laboratory facilities, offering new analytical methods with experts in environmental sciences of the Mediterranean and resource managers. The cooperation between GSD and FHL will help develop and apply this methodology in on-going efforts to characterize and manage groundwater water resources of Cyprus in a sustainable manner. The cooperation between GJU and FHL will offer new possibilities in applying this method to groundwater management in arid regions and will improve mobility and capacity building of young researchers in Jordan and will promote a new efficient technology for groundwater resources estimation to the Jordanian Water Sector.

Relevance and importance of the research

It is of vital importance for Cyprus and Jordan and in fact for all semi-arid and arid countries in the Mediterranean to develop an efficient and adapted monitoring and management instrument for groundwater resources, especially for basins with intensive irrigation. Current monitoring approaches require year-long, hardware-intensive and vulnerable monitoring at high spatial and temporal resolution. Due to the high variability of meteorological and hydrological variables, results emerge only after years and decades of monitoring at, in fact hourly intervals. The past has shown that this approach is not feasible and does not match the human resources and the means available for managing resources and that this approach is slow and provides results only with considerable delay. The scientific significance and major advantage of the

novel approach of ISOMED is, that results are obtained much faster and offer a retrospection into recharge rates and environmental flows of the last years. Once developed and operationalized, the method provides a time series of recharge rates of the last years to decade with annual resolution at least and allows to adapt management and to react swiftly to changes in hydrological conditions. The method will help to detect improvements or deterioration of groundwater recharge as a function of measures taken and will therefore facilitate scientific research on adaptation and remediation measures.

Stakeholder Engagement

The project is collaborative research, a mobility and an educational scheme which reaches out, in the first place, to stakeholders during the entire implementation/execution period. The approach will be applied to groundwater intake areas of water suppliers and cooperation with local farms will be offered to bring this new method into practice and application. An initial stakeholder meeting and a final public event will be organized, project brochures will be disseminated and press releases sent out to inform all interested parties. In Cyprus, the GSD as a government institution is a stakeholder itself and has a pivotal role in the allocation and distribution of water resources through drilling and abstraction permits.

Project Description

ISOMED fosters collaborative research on a highly innovative method of quantifying environmental flows with stable isotopes. Environmental isotopes of water are also used as indicators for water use efficiency and for the stability and resilience of hydrological systems. The approach and methodology of the project ISOMED is specifically and well suited for semi-arid and arid environmental and hydrological systems of the Mediterranean. Environmental flows in a Mediterranean climate are characterized by a pronounced seasonal variability creating a pulse-inertia pattern of water flows. Due to the very specific isotope hydrology of the Mediterranean these water flows carry seasonal and regional fingerprints. The collaborative research focuses on developing and advancing methods for quantitative recharge assessment in agricultural, environmental and groundwater systems using environmental isotopes.

The main objective of the collaborative research are:

1) To introduce and advance a new fast-track method for the reconstruction of recharge rates for the last years and seasons in natural and anthropogenically modified hydrological systems based on a one time sampling

2) To integrate this method into a comprehensive approach for the quantitative estimation of three key indicators for water management with environmental isotopes: a) groundwater recharge, b) water use efficiency and c) resilience and vulnerability of hydrological systems based on residence time distribution

3) To provide training on new and innovative environmental isotope methods for water resources assessment to stakeholders, experts and scientists in the Mediterranean Research community by developing a web-based toolbox, a database and training material and facilities

A general research objective will be to provide better data on water stocks and flows for IWRM and other management frameworks faster, in order to facilitate adaptation and learning by identifying impacts of land use and water management practices or environmental changes on water resources.

Description and the general approach and methodology chosen to achieve the project objectives

The project is organized in five work packages: coordination (WP1), stakeholder engagement (WP2), environmental isotope methods for water assessment (WP3) and mobility (WP4) and an innovative action (WP5). Each partner will coordinate one work package: FHL will be responsible for project coordination and cooperation (WP1), CYI will coordinate stakeholder engagement (WP2), GSD will coordinate sampling, data analysis and evaluation of environmental isotope data and pilot their use in water management by a government institution (WP3) and mobility of young scientists, experts and staff among the project partners

during the project will be coordinated by GJU (WP4). The SME will coordinate the innovative action (WP5).

WP 1 Coordination and cooperation (FHL, Prof. Dr. C. Külls)

Task 1.1 Project coordination, administration & communication with funding agencies

The project ISOMED will be coordinated by FHL. FHL will install a project office at the Laboratory of Hydrology and International Water Management. Project controlling will be run through the administration of FHL. The project will be managed by a team of Prof. C. Külls and a project scientist working for ISOMED. Decisions will be taken by the project steering committee consisting of one member of FHL, GSD, CYI and GJU each. The steering comittee will have at least a 3-monthly telephone-conference and will meet four times during the project. The first kick-off meeting will be held shortly after the beginning of the project in Cyprus. A collaborative web-platform and web-page will be developed for the project (deliverable 1, D1). After the first year, a status and management meeting will be held in Jordan. After the second year a science workshop and associated steering comittee meeting will be held in Lübeck. The final conference will be held at the end of the third year during the EGU (European Geophysical Union) annual meeting in Vienna, during this meeting, an open workshop will be help in the Hydrology Division with a focus on environmental isotope techniques. Results will be published in a peer-reviewed journal as open access article.

Task 1.2 Networking with the ERANET research network

The coordinator will liaise with and establish, develop and strengthen cooperation with CIHEAM, IAEA and the research community in the Mediterranean. Each partner will establish and maintain cooperation with stakeholders in their respective countries. The demonstration sites in Cyprus and in Jordan and the pilot laboratory and site in Lübeck Germany will be open to young scientists to learn the methodology and work on their own research projects using the ISOMED methodology. GJU, GSD and CYI will exchange staff, experts and students to strengthen cooperation. Experts and staff from ministries and stakeholders will be invited to the demonstration sites to learn about the method and its application in water management.

WP 2 Dissemination and stakeholder engagement (CYI, Dr. Adriana Bruggeman)

The main objective of WP 2 is to establish a good working relationship with stakeholders at the study sites and stakeholders that will use our data. This work package includes contacting and informing the key stakeholders in the study areas in Cyprus and in Jordan.

Task 2.1 Stakeholder meetings (at start and end of project).

One stakeholder meeting will take place at the beginning of the project and one stakeholder meeting (public event) at the end of the project. Stakeholders from the water sector in Cyprus and in Jordan will be invited through GSD and GJU and in cooperation with local community leaders. Stakeholders that have stakes in the study basin and aquifer will be invited as well as potential users of the methodology. Project brochures and a press release will be prepared and disseminated widely. During the stakeholder meeting the interests and needs of stakeholders will be addressed in terms of information, methodology and tools.

Task 2.2 Scientific dissemination (conference presentations, publications)

The project group will organize a workshop during the third year of the project at the European Geophysical Union meeting in spring 2020. During this meeting the ISOMED group will connect to the European Research Community with interest in Mediterranean Hydrology and Water Resources Management or environmental isotope methodology. The workshop will feature selected presentations and talks of project group members and be open to other researchers working on similar approaches and in the region. A special floor will be given to young researchers.

WP 3 Environmental Flow Assessment with Isotopes (GSD, Christos Christofi, co-lead by CYI)

Task 3.1 Selection and set-up of monitoring site

Potential pilot monitoring sites have been identified in the gabbro formations (Agros area) in the Troodos Mountains of Cyprus and in Wadi Araba, Jordan. Sites will be surveyed and the final site selection will be agreed with the expertise of all project partners. An environmental hydrology & isotope station will be set up for monitoring isotopes in rainfall, soil, spring, river and/or groundwater. Operational maintenance of the site, at a reduced rate and scale, should be feasible after the project. The site will have a rain gauge, robust automatic climate station, monitoring borehole or spring. A site and station characterization report will be prepared (deliverable 2, D2). Rainfall data will serve as input function for recharge estimation (see Task 3.2). Isotope data from springs, river flow and groundwater will be used for detection of unproductive evaporation losses (Leibundgut et al., 2009) and residence time analysis (Davila et al., 2013). All samples will be sent to FHL for isotope analysis.

Task 3.2 Data collection for assessment of recharge, indicators for water use efficiency and system resilience

Collection of environmental isotope data from rainfall (gauge, monthly), spring or river with an automatic collector or by sampling, possibly with the help of local stakeholders. A database will be prepared to hold all monitoring data (Task 3.3). At each site two sampling campaigns will be carried out. One campaign will be done by FHL to demonstrate the method and to analyze the isotope profile for recharge assessment. A soil profile of 1 to 3 m depth will be drilled with an engine driven-auger (available at FHL) and sampled at small depth intervals (5 cm). Samples will be equilibrated and measured for soil water isotopes with a method proposed by the leading partner (Garvelmann et al., 2012; Mueller et al., 2014). Seasonal patterns, their depth and associated water fluxes or recharge rates will be derived from this isotope profile. The second campaign will be done by young scientists themselves who have learned the sampling procedure during the first campaign. They will bring samples to the summer school in Lübeck and learn the application of the method in the laboratory with their own samples. A report on sampling results will be prepared as a deliverable 3 (D3).

Task 3.3 Web-database and toolbox for field environmental isotope

Although isotope methods are available since many years, there is only a relatively small community of researchers using them. In addition, environmental isotope methods are often used for singular and isolated applications only, instead of being integrated into a comprehensive approach. In recent years, significant progress has been made and in some areas new laser-based adsorption spectrometry has caused a breakthrough in terms of sampling rates, spatial resolution, samples size and precision. As a result, environmental isotope methods can provide in situ online monitoring and the results obtained can be cast into very useful indicators for water management. Environmental isotope methods are very well suited for Mediterranean environments and water management therein because they require clear and sharp input functions: In the Mediterranean the seasonal climate and rainfall pattern provide these inputs. The alternation of vapour sources from the Atlantic and from the Mediterranean adds further variations to the input function. And finally, in irrigated systems the combined use of irrigation water and rainfall creates a discernable pattern that can be used for the quantification of flows. The major gap is a lack of training, capacity building and common resources for the community of researchers and stakeholders in the Mediterranean. Therefore, the project will provide a web-based toolbox with online scripts, visualization tools and data from the ISOMED network. Data collected from the three partner research sites will be made available as case studies and for demonstration. The procedure of analyzing, checking and transforming data into indicators for groundwater recharge, water use efficiency and residence time will be disseminated. During the project an expert database and system will be developed for ISOMED partners. This online tool will be opened to stakeholders and experts on demand during the project: They are invited to add their isotope data and will get access to evaluation software in exchange. During the final phase of the project and after thorough internal evaluation and review, the toolbox will go public to publish and disseminate the methods that have been developed. Information will also be provided to IAEA (International Atomic Energy

Agency). The online tool will also contain coordinates of labs and experts offering analyses in order to promote further use.

WP 4 Mobility and Training of young scientists and Expert Staff (GJU, Prof. Dr. Nizar Abu-Jaber)

Task 4.1 Summer school 'Field Environmental Isotope Techniques' (FHL)

During the first year of the project an international summer school 'Environmental Isotope Field Techniques' will be carried out. This summer school will involve young scientists, staff of the participating institutions and give in-depth methodological training on recharge assessment with environmental isotopes, the soil isotope profile method, water use efficiency assessment and residence and vulnerability assessment of hydrological systems with isotopes. The summer school will be offered to a group of 12-15. The participants from the ISOMED project group will disseminate the methodology to their institutions and laboratories. The teaching material of the summer school will be provided as deliverable 4 (D4) online and as a report.

Task 4.2 Mobility of post-graduate students (GJU, CYI)

There will be staff and student exchange between GSD, CI, GJU and FHL. FHL offers participation in English post-graduate classes in a one week block mode offered by Prof. Dr. C. Külls at FHL. GJU and FHL universities already have a close cooperation and student, staff and expert exchange through ERASMUS and as partners. These exchange mechanisms will be promoted and used to invite and send master students to participate in a master course on environmental engineering at FHL and GJU. GSD will send staff members for studies, research and internship at FHL for capacity building in environmental isotope application, practical laboratory procedures and operation of laser spectrometry. GJU and FHL are already cooperating by staff, student and scientific exchange. It is planned to support the ISOMED project by additional student exchange and scientific visits for teaching and research through ERASMUS. FHL and CyI are planning to cooperate in the field of water research and environmental hydrology. Additional exchange between professors, scientists and young researchers is planned through ERASMUS cooperation.

Task 4.3 Mobility for professionals, experts (GSD, CYI, GJU, FHL)

Short-term visits will be organized for professionals and experts from participating institutions. Visits will be dedicated to studies in the respective study areas and study sites or to methodological developments and data analysis.

WP 5: Innovative Action: Client-oriented Affordable Recharge Estimation (CARE) (TRUEBNER)

The highly innovative SME TRUEBNER GmbH will lead a work package that features innovative action. The aims is to develop a client-oriented and affordable recharge monitoring and estimation system. The proposed project relies on reference measurements. Therefore it is of eminent importance to understand the soil water content dynamics and to break down rainfall into evaporated moisture and water drainage into deeper layers. In order to better investigate this in detail, selected sites will be equipped with modern moisture measurement technology for fine grained resolution. Both point sensors and a recently developed sensor for integral water content measurement over a larger measurement volume will be used. The so-called AquaFlex sensor with a typical length of 3 m provides more reliable mean values of water content than typical point sensors. The AquaFlex will be adopted to the measurement tasks of the project and optimized. In order to facilitate long-term autonomous operation of the sensing systems, logging devices with very low power consumption will be developed which withstand harsh environmental conditions at the selected field sites. At each site, one station will be installed on a natural recharge site and one on an irrigated site. The natural recharge site will be operated by the national counterpart (CYI, Cyprus and GJU, Jordan), the monitoring station on the irrigated site will be operated by a stakeholder (farmer, water supplier). In addition to environmental isotope methods, ISOMED aims at improving the self-monitoring of water resources for stakeholders, farmers, water suppliers. We start from the premise that all stakeholders in the water sector want to know about availability of resources and that providing this knowledge will actually alter water use

patterns and lead to adaptation to climate variability and climate change. TRUEBNER will, with the support of FHL, develop a software that these site measurements are visualized and transformed into information that is relevant for management, important for stakeholders and client-friendly: Farmers are interested in percolation rates of soil water as it also controls the loss of fertilizer. The monitoring system will provide this information in a user-friendly manner. It will also calculate recharge flux and provide this in a manner and format that is relevant and clear for stakeholders. The juxtaposition of natural and irrigated sites provides direct data on the natural recharge to water use ratio and is a direct, localized and dynamic indicator of water use efficiency. The software for recharge estimation forms deliverable 5 (D5).

Advantages of the methodology

The methodology offers a significant and game-changing advantage: Soil water isotope profiles provide fast, site, specific and direct empirical data on groundwater recharge at annual to seasonal resolution for the past several years. The method gives insight to and reveals the impact of land use practice, climate variability and land use change on groundwater recharge rates. Environmental isotopes can be used to distinguish between transpiration (by plants in production system) and evaporation (as a physical non-productive and plant-related or mediated process). The ratio of evaporation to transpiration is a direct indicator of how efficiently water is used and applied. Finally, residence time, as an integrated system property, indicates how fast a system reacts to changes, repeated measurements of residence times for systems with a high turn-over rate indicate changes in storage to through-flow ratios. These indicators can be obtained relatively fast and in a straightforward manner, only requiring sampling. The methodology can be made operational for a regular monitoring of recharge areas and irrigated areas. A further advantage of the method is that it can easily and readily be combined with studies of nitrate, pesticide and other solute or pollutant transport. The methodology provides direct indicators of when these substances have been released, when they will reach the groundwater and how fast they will be transferred through the system. The methodology does not require permanent installation except for the development infrastructure during the project phase and a national station for collecting rainfall reference data in Cyprus and Jordan. The method can be scaled and exported or applied to other sites.

Expected project results (in quantitative terms).

The combined approach of environmental flow accounting based on stable isotopes in the water cycle of Mediterranean environment will improve water management techniques significantly, will expedit the detection of changes in environmental flows and balances and allow for an annual accounting of recharge, evaporation losses, origin of water sources and overall system performance. In quantitative terms, it is expected that the uncertainty of estimating environmental flows and groundwater recharge will be reduced from more than 30% to about 10-15% of the recharge rate. The ISOMED methodology will shorten the time to obtain empirical data on recharge rates from at least 10 years (water balance method) or several years (water level fluctuation) to an analysis time of a few weeks from sampling to having a recharge time series of the last 2 to 5 years. The determination of residence times of hydrological systems will give direct information on how vulnerable systems are and how fast they will react to drought, pollution or deterioration and this will in turn help developing and improving protection and remediation strategies. High evaporation losses in natural or irrigated systems can be detected. Evaporation accounts for about 80% of the water balance in Cyprus, and about 10% of the rainfall becomes groundwater recharge. Reducing evaporation bears a large potential for saving water resources. A reduction of 5% in evaporation of a total rainfall of 400 mm per year corresponds to 20 mm per year, which could increase groundwater recharge from 40 to 60 mm per year or 50%. Environmental isotopes as a tool therefore offer an important potential to detect and reduce unproductive losses.

Potential for synergy between different tasks of the project and exploitation.

The installation of pilot sites will provide reference data for experts and scientists. The pilot sites can also be used for the engagement of stakeholders, demonstrating the methodology. Sites will also be used for research projects of young scientists and experts from all participating countries, for inter-comparison and for

exploring the limits and uncertainties of these methods along a climatic and hydrological gradient.

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Davila, P. F., Külls, C., & Weiler, M. (2013). A toolkit for groundwater mean residence time interpretation with gaseous tracers. Computers & Geosciences, 61, 116–125.
Garvelmann, J., Külls, C., & Weiler, M. (2012). A porewater-based stable isotope approach for the investigation of subsurface hydrological processes. Hydrology and Earth System Sciences, 16(2), 631–640.
Hübner, Christof; Kaatze, Udo, Electromagnetic moisture measurement, Universitätsverlag Göttingen, 2016, online available at https://www.univerlag.uni-goettingen.de/handle/3/isbn-978-3-86395-260-0?locale-attribute=en
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Külls, C., Salameh, E., & Udluft, P. (2000). Assessing water supplies for irrigation-availability of natural resources and sustainability indices. Deutscher Tropentag 2000. Ecosystem Functions., 1–7.
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Luijendijk, E. and A. Bruggeman. 2008. Groundwater resources in the Jabal Al Hass region, northwest Syria: An assessment of past use and future potential. Hydrogeology J. 16: 511-530.
Mueller, M. H., Alaoui, A., Kuells, C., Leistert, H., Meusburger, K., Stumpp, C., et al. (2014). Tracking water pathways in steep hillslopes by d 18 O depth profiles of soil water. Journal of Hydrology, 519, 340–352.
Zagana, E., Obeidat, M., Külls, C., & Udluft, P. (2007). Chloride, hydrochemical and isotope methods of groundwater recharge estimation in eastern Mediterranean areas: a case study in Jordan. Hydrological Processes, 21(16), 2112–2123.
Zoumides, C., A. Bruggeman, M. Hadjikakou, T. Zachariadis. 2014. Policy-relevant indicators for semi-arid nations: the water footprint of crop production and supply utilization of Cyprus. Ecological Indicators 43: 205-214.

Gender, young researchers, ethics

Gender and Diversity

Partners implement gender and diversity policies in their institutions related to recruitment, capacity development. Partners apply these principles for project related staff selection. Partners will also apply these principles in stakeholder involvement and take special care to have fair gender participation.

Support to young researchers through project activities

ISOMED ERANETMED3-147

A key component of ISOMED in addition to collaborative research will be to improve mobility and improve training, education and research on the use of environmental isotopes in environmental flow accounting. Mobility includes staff exchange and an annual management and science meeting, as well as exchange of teaching staff, graduate and post-graduate students and experts. CYI will recruit a PhD student especially for the project. Young researchers will be part of the project team in all meetings. Based on excellent experience from former projects, we will help initiate a network of young researchers through social media and help create direct communication channels between them through these means. ERASMUS student and staff mobility grants at FHL and CYI will be used to expand and sustain the research collaboration and remain on top of new research advances during and after the project.

Project management

Overall coordination and monitoring of the project

The project will be coordinated by FHL. A project manager will work on the project and take care of communication, implementation of work packages and timely submission of scientific and financial reports. The project manager will also monitor the overall progress of the project and report on progress, deliverables, delays or problems to the coordinator. Decision will be taken by a project steering committee. Every project partner delegates one member to the steering committee. The steering committee meets at the four planned meetings. The coordinator reports on the overall progress of the project and the steering comittee decides with majority vote about changes, adjustments, actions taken as a group and budget modifications. Communication between the project meetings will take place through regular tele-conferences (Skype meetings) organized and initiated by the coordinator. The interval for these meetings is at least once every three months. The coordinator will keep regular contact with the work package managers on progress of work package tasks, deliverables and milestones. The work package managers will monitor the progress of their work packages in terms of task completion, deliverables and milestones. They will report deliverables, milestones and any changes or deviations from the planned project progress to the coordinator.

Project progress and performance will be monitored through regular communication and monitoring of work packages through timed project deliverables and milestones. In total there are five work packages, four for collaborative research and one for innovative action led by an SME.

There are seven deliverables associated with identified work packages and assigned to work package managers and seven milestones to monitor the development and timing of critical components of the project ISOMED.

D1: Web-page for internal and external communication (webpage) (FHL): Within the first three months after the beginning of the project a web-page will be setup by FHL for the project. The web-page will include an open part for communication of project idea, activities and results. The page will include components for interaction and involvement of researchers and of stakeholders and provide material and information specifically for these user groups. The web-page will also include an internal section for communication and collaborative work. It will also include a section for the interactive management, uploading and review of deliverables. This first deliverable will be completed at the end of the third month.

D2: Site selection characterization (report) (CYI, GJU): Sites in Cyprus and in Jordan will be selected at which the soil sampling and the innovative action will take place. These sites will be characterized and described and referred to at the webpage. The site description and selection process will be documented and delivered as a report within the first 6 months. The report will consist of two components authored by CYI and GJU.

D3: Initial results from Cyprus and Jordan (Recharge rate and profile) (FHL). Samples for isotope analysis will be taken at the selected research demo sites in Cyprus and Jordan and analysed at FHL. The results will provide a detailed recharge profile as a demonstration of the methodology. Isotope data and recharge values for the last years will be reported as a deliverable. The deliverable will be supported by field data from CYI and GJU and will be available at the end of month 18.

D4: Summer school Training material (FHL). A summer school on environmental field isotope methods will be organized by FHL at the end of the second year. This summer school directed at young researchers will also be open for GSD, GJU and CYI staff for training. The training material will be provided as a deliverable at the end of the second year (month 24).

D5: Soil monitoring system user manual/description and user software (Truebner). The innovative action will provide as deliverable a client-friendly and affordable recharge estimation system (CARE) and a software that can read monitoring data and transform them to user-friendly and stakeholder relevant information on percolation rates, nutrient loss, water use efficiency and recharge rates. The system description and the software will be delivered at the end of month 36.

Young researchers will be invited to present their work at the meetings in Cyprus and Jordan. The EGU workshop organized by the ISOMED team will also provide a special opportunity to young researchers to present their research and work. Young researchers will be invited to and attend the meetings in Cyprus and Jordan. Mobility of young researchers will further be facilitated through parallel ERASMUS programs between FHL, GJU and CYI.

Risk management of not achieving the objectives and fallback positions.

In case of deviations from the original work schedule within a work package, the work package leader will inform the project manager and project coordinator. The project manager informs the coordinator and the coordinator initiates communication with the work package leader. The work package leader will identify problems and causes for the delay and suggest a solution. The coordinator will verify if other work packages are affected and in that case informs the steering committee to develop an overall solution. Actions on getting the project on track will be monitored and verified by the project manager and project coordinator.

The critical path of the project will be monitored through milestones.

M1: Sites selected and stakeholders involved (month 6). The site selection, initial contact and involvement of stakeholders will be completed until month 6. This milestones makes sure that the project is connected with local stakeholders and that data collection can start. The risk of not having this milestone completed is small as stakeholder contacts exist, interest is there and GSD is an institutional partner.

M2: Innovative action monitoring sites installed (month 12). The innovation action monitoring system will be installed during the first year. The system is available and the technology proven. The innovative action consists in developing a software of making the system user-friendly, stakeholder-oriented. The risk is low because the SME has developed this for operational and massive use, cost for single station are small, so losses or damage can be compensated for more easily.

M3: Profiles sampled and measured, recharge estimated (month 18). The third milestone is the sampling of isotope profiles. The sampling is combined with project meetings and involves partners and young scientists. The analysis or recharge values is expected to be robust. In case profile selection is delayed, no other work packages are at risk until month 18-24 (summer school).

M4: Staff trained (summer school) (FHL) and GSD lab capacitated to run profile method (month 24). The workshop is the milestone four and will be held in Lübeck (M4.1). As the team of FHL is very experienced, the risk of non-completion is low. Capacitating the GSD in carrying out the methodology on site is part of M4 (M4.2). This milestone involves a higher risk, if the infrastructure is not suited or additional parts need to be purchased. This is a research and innovation and involves risk. However, all partners are highly experienced, motivated and the development of laboratory capacity for this purpose has already been done by Prof. Dr. C. Külls in Lübeck. In case of delays, analyses can be carried out in Lübeck.

M5: Final results published and disseminated (month 36). The final milestone is the publication of results and

dissemination through a workshop at the EGU in Vienna. All partners are well connected and have the reputation and capacity to carry out such a workshop. The proposed way of holding an open workshop during an international conference is the most efficient way of disseminating results to a large audience.

Impact of Project results

Expected results of the project

The project deliverables are a new and readily applicable framework for environmental flow assessment based on isotope methods, an improved assessment of groundwater recharge providing ex-post quaterly recharge and nutrient flow rates beneath agricultural production systems and natural recharge zones and quantitative indicators for sustainability and system performance.

Impact of the project on the societal challenges addressed in the project and on cross-cutting issues.

The project will improve the self-monitoring and access to information and data on annual recharge rates to farmers, water-suppliers and other stakeholders. Building on the genuine interest of stakeholders depending on water resources, the collaborative research and the innovation action will provide better data on recharge in semi-arid and arid environments in the Mediterranean on an annual basis. Stakeholders will have their own access to data on water fluxes, associated nutrient fluxes through a user-friendly and customer-oriented and affordable monitoring system (CARE). This system is calibrated with modern methods.

The SME will provide a fast track and scalable soil moisture probe with datalogger and ftp data transfer. The soil moisture monitoring station will provide data on percolation velocity and movement of nutrients or solutes. This device will be calibrated and verified with the modern isotope method. The SME partner will develop a software to process soil moisture data and to provide applicable information to stakeholders on the variability of recharge (very high, high, medium, low, very low recharge per year) and on the observed velocity of soil moisture and nutrient fronts) giving direct information on whether water supply needs to be controlled and on the surplus water needed. This information will help stakeholders adapt to the conditions of the specific year.

Expected impact of the project on the scientific disciplines involved in the project.

The project will introduce a modern method of water flow monitoring from soil water isotope profiles to the Eastern Mediterranean and will transfer knowledge and build capacity among researchers at CYI, GSD and GJU on using and implementing these methods. The research method will provide a more dynamic picture of research fluxes at selected sites and help understanding impact of land use changes, climate variability and management practice at a much higher rate and thereby support adaptation, learning processes and scientific research of environmental hydrology in the Mediterranean. The method can be applied to far more fields of research: Environmental isotopes provide data on suitability for desert restoration, reintroduction of plants based on a precise description of eco-hydrological conditions, monitoring of pollutant and nutrient transport and climate change impacts.

Expected impact of the project results in terms of economic and societal needs of the Euro-Mediterranean Region.

Society, water, environment and agriculture are intrinsically linked in the Mediterranean since Millenia. Changes in climatic conditions and in land-use or management practice have, already in the past, resulted in adaptation and change processes of historic dimensions (Al-Qudah et al., 2016). The key to managing these processes is knowledge of environmental processes and adequate response to these processes. The proposed methodology improves knowledge of environmental flow and proposes a) to accelerate the rate at which data are generated, b) the quality and precision of environmental flows, c) the efficiency of obtaining these with modern methods. The most important aspect, however, is that ISOMED proposes to give stakeholders (farmers, water-suppliers) direct access to information and to integrate them into the data collection process. Team partners have made the experience in past projects in Jordan, Syria, Cyprus and

other Mediterranean countries that stakeholders have their own interest in knowing about recharge rates for several reasons: First, recharge also affects nutrient loss and farmers have a genuine interest in limiting the loss of fertilizer because this is an economic loss; hence, they are interested in knowing and monitoring the speed of percolation from year to year. Second, farmers and water-suppliers have a genuine interest in knowing the actual and current conditions of soil water status, percolation and recharge, because this affects their operation. We therefore suggest combining scientific research and methodology (environmental isotopes) for a precise estimation of water flows with a directly observable and affordable method for monitoring soil moisture and percolation (CARE). The key element is user-friendliness and customer-oriented presentation of data. The proposed system will provide such information and will be offered to customers after the project.

Result exploitation plan

Results will be used by all partners as a base for further research. Since the project results in a new applicable method various spin-offs and applications in different areas of environmental research, agriculture, ecology, hydrology and hydrogeology are envisaged. Results will be published in peer-review journals. The final conference will prepare peer-review publishing and help identifying key innovations through participation scientists in an open work-shop.

Knowledge exploitation

The ISOMED team will prepare a database of project data and provide these data. Standards for state of the art documentation of data sets will be followed. The innovation action will be accompanied by a software development to make the CARE system user-friendly and customer-oriented. The software will be used by TRUEBNER (SME) and offered with their products and by project partners.

Measures for the dissemination and exploitation of transnational projects results, implementation plan

Results of collaborative research will be published. All project partners share ownership of the intellectual property according to their institutional regulations and agree jointly on publication and use of data according to good scientific practice. FHL and CYI have access to support for patent suggestions through their institutions.

Team information

Participating teams and the institutions

The project team, consisting of partners from Cyprus, Jordan and Germany, involves a ministerial institution responsible for the management of water resources (GSD, Cyprus), a research and higher educational institute (CYI), a university (GJU) and a university of applied sciences (FHL). The project consortium has the necessary resources and infrastructure to evelop the methodology: FHL runs a modern innovative stable isotope laboratory of the newest analytical standard and has actively contributed to the development of new technologies in environmental isotope hydrology during the last couple of years. GSD is a government institution responsible for groundwater management and for the implementation of the EWFD and has initiated and supported innovative research projects. CYI is a research and higher educational institute, emphasizing international collaborations and cross-disciplinary research and education. GJU is a modern institute of higher education with a strong focus on environmental science and technology. The project team consists of well-established and well-connected experts with complementary skills in surface hydrology (GJU, CYI, FHL), groundwater (GJU, GSD, CYI, FHL), isotopes (GJU, GSD, FHL) and environmental flow accounting (FHL, GSD).

Lübeck University of Applied Sciences (FHL)

FHL is a university of applied sciences with an international profile in all technical disciplines offering English master programmes in environmental and civil engineering with a focus on sustainable water resources

management. Prof. Dr. C. Külls is a hydrologist with more than 20 years of experience in water resources assessment, recharge estimation studies in the Eastern Mediterranean and in arid and semi-arid regions in general. He has coordinated research projects on groundwater recharge in the Eastern Mediterranean (GREM) and in Cyprus and Jordan (GRC, GREM, INCO-DC) and participated in European Research Projects on recharge assessment and isotope methods (WADE, ITER). He is university professor at FHL operating an isotope laboratory and offering English courses and summer schools for international study programmes. The project team consists of him, the project manager Sebastian Schlauss, engivironmental engineer (M.Sc.) with 5 years' experience in project management of national and national international projects.

FHL publications

Davila, P. F., Külls, C., & Weiler, M. (2013). A toolkit for groundwater mean residence time interpretation with gaseous tracers. Computers & Geosciences, 61, 116–125.
Garvelmann, J., Külls, C., & Weiler, M. (2012). A porewater-based stable isotope approach for the investigation of subsurface hydrological processes. Hydrology and Earth System Sciences, 16(2), 631–640.
Mueller, M. H., Alaoui, A., Kuells, C., Leistert, H., Meusburger, K., Stumpp, C., et al. (2014). Tracking water pathways in steep hillslopes by d 18 O depth profiles of soil water. Journal of Hydrology, 519, 340–352.

Geological Survey Department (GSD)

The Geological Survey Department is the national agency and state councilor for geological matters. The mission of the Department is the safeguard of the public interest thought the identification, the exploitation and protection of mineral and groundwater resources, the investigation and assessment of the geological environment and geo-hazards, the monitoring and assessment of seismicity, the investigation of the foundation conditions, the protection and promotion of sites of geological and mining heritage and the production and dissemination of unbiased geo-information to society. The Hydrogeology Section is responsible for groundwater drilling and prospecting, aquifer research and groundwater monitoring under Water Framework Directive, Groundwater Directive and Nitro-pollution.
Mr. Christos Christofi is a Senior Geological Officer, at the Geological Survey Department since 2001 and he is currently the head of the Hydrogeology Section. Prior to that, he worked as a Mine and Environmental Geologist at the Hellenic Copper Mines in Cyprus. He received his Bachelors in Geology Rutgers State University (USA) in 1996 and an MSc from New Jersey Institute of Technology (USA) in 1999 where he also worked as a teaching assistant and as a research assistant in the geo-environmental laboratory. His research interest focuses on hydrogeology and hydrochemistry. He is a member of several national committees and a national delegate in a number of EU committees, including the one on Working Group E, Groundwater. Mrs Theodosia Heracleous is a Geological Officer, Hydrogeology, at the Geological Survey Department since 2005. She received her bachelor in Geology from Aristotle University of Thessaloniki, Greece, in 2003. She then worked for two years to a Geotechnical laboratory and to a quarry where she focused on product quality control. After joining the Survey in 2005, she is involved in groundwater prospecting and protection. Her research interest focuses on hydrogeology and hydrochemistry.

GSD Publications

Constantinou. C.A., M. Rigas and C. Christophi (2014). Concentration and distribution of arsenic, cadmium, lead and mercury in the groundwater bodies of Cyprus. In K. Voudouris, G (Eds.), Advances in the Research of Aquatic Environment, Vol. 1: 978-960-88816-62-2.
Christophi, C. and C.A. Constantinou (2011). Nitrogen sources and denitrification potential of Cyprus aquifers, through isotopic investigation on nitrates. In: N. Lambrakis et al. (Eds.), Advances in the Research of Aquatic Environment, Vol. 2: DOI 10.1007/978-3-642-24076-8.
Constantinou, C.A., Kalergis, G and Christophi, Ch. (2005). Study of groundwater flow regime in fractured formations with data from dataloggers: The Troodos Ophiolite Complex. In G. Stournaras et al. (Eds.), Proceedings of 7th Panhellenic Hydrogeological Conference, Athens 2005

The Cyprus Institute (CYI)

ISOMED ERANETMED3-147

The Cyprus Institute (CYI) is research and technology institution, carrying out pioneering research programs to address problems of regional as well as international significance. The CYI comprises three specialized multidisciplinary research centers, developed in partnership with leading international institutions in their respective thematic areas. The ISOMED project will be carried out in close cooperation with the Energy, Environment and Water Research Center (EEWRC). The Center has a PhD program in Energy, Environmental and Atmospheric Sciences. CYI is involved in various European and national funded projects related to water and natural resource management, environmental observations and climate change modelling, impact assessments and adaptation. The CYI Water Group conducts hydrologic field and modelling investigations as well as transdisciplinary research in cooperation with government organizations, rural communities and local enterprises.

Dr. Adriana Bruggeman's main research interests are the monitoring and modeling of hydrologic and environmental processes. Her research work with interdisciplinary research and stakeholder teams focuses on the development and evaluation of technologies and policies for natural resource management and climate change adaptation. She has worked as an agricultural hydrologist at the International Center for Agricultural Research in the Dry Areas, based in Aleppo, Syria from 1998 to 2009. In that capacity, she has coordinated and cooperated in integrated natural resource management projects with research and development stakeholders throughout the West Asia and North Africa region. Prior to that she worked as a research assistant and associate on non-point source pollution research projects to assess the effect of best management practices on surface water and groundwater quality in Virginia. She has an MSc in Hydrology and Water Management from Wageningen University, The Netherlands (1988) and a PhD in Biological Systems Engineering from Virginia Polytechnic Institute and State University (Virginia Tech), USA (1997).

Dr. Christos Zoumides is a Post-doctoral Fellow in CYI's Water Group. His research focusses on facilitating communications between science and society as well as on analysing and mapping costs, benefits and trade-offs of water and land management practices. He has an MSc in Ecological Economics from the University of Edinburgh (2008) and a PhD from the Cyprus University of Technology. His thesis focused on quantitative methods and tools for sustainable agricultural water management. He has been working on FP7 and H2020 research projects (BEWATER, RECARE, BINGO), as well as on projects funded by the Cyprus Research Promotion Foundation (AGWATER).

CYI Publications

Aw-Hassan, A., F. Rida, R. Telleria, A. Bruggeman (2014). The impact of food and agricultural policies on groundwater use in Syria. Journal of Hydrology 513: 204-215.
Luijendijk, E. & A. Bruggeman. (2008). Groundwater resources in the Jabal Al Hass region, northwest Syria: An assessment of past use and future potential. Hydrogeology J. 16: 511-530.
LeCoz, M., A. Bruggeman, C. Camera, M.A. Lange (2016). Impact of precipitation variability on the performance of a rainfall-runoff model in Mediterranean mountain catchments. Hydrological Sciences Journal 61(3): 507-518.
Zoumides, C., A. Bruggeman, M. Hadjikakou, T. Zachariadis (2014). Policy-relevant indicators for semi-arid nations: the water footprint of crop production and supply utilization of Cyprus. Ecological Indicators 43: 205-214.
Zoumides, C., A. Bruggeman, E. Giannakis, C. Camera, H. Djuma, M. Eliades and K. Charalambous (2017). Community-based rehabilitation of mountain terraces in Cyprus. Land Degradation and Development 28(1): 95–105.

German-Jordanian University (GJU)

Professor Abu-Jaber is a geologist and geochemist who has been working on issues of isotopes and groundwater recharge in Jordan for 20 years. This included an extensive project in the Tulul al Ashaqif area of northeastern Jordan. The area was an ideal area to study recharge due to the presence of shallow perched aquifers which are regularly recharged by the scarce precipitation in this arid area (Abu-Jaber et al., 2003). An important component of this study was a detailed isotopic and geochemical study of the shallow groundwater and it's response to recharge events using geochemical tracers. Deeper groundwater recharge

was studied in various regions of Jordan using isotopic, chemical and thermal tracers. More recently, he and his colleagues have been investigating recharge through soil cover in the more humid areas of western Jordan (Al Qudah et al., 2015). This included the study of ancient engineering practices on surface water and groundwater infiltration in the Petra area in southwestern Jordan (Al Qudah et al., 2016). The team of GJU consists of Carteena Hamarneh (geologist and archaeologist with much experience on traditional dry land use management through terracing), Mohammad Smadi (hydraulic engineer with experience in surface water modeling in arid regions) and Qasem Abdelal (civil engineer with experience in surface water modeling).

GJU Publictions

Abu-Jaber, N., Abderahman, N., Azaizeh, W., Omari, H., Haddadin, G., Al Sokhny, K., Hamzeh, M., and Al Qudah, K. (2003). Investigation of shallow ground water in the Tulul al Ashaqif highlands, Jordan. Abhath Al Yarmouk, Basic Science and Engineering Series 12 (2A): 381-400.
Al Qudah, K., Abdelal, Q., Hamarneh, C. and Abu-Jaber, N. (2016). Taming the torrents: The hydrological impacts of ancient terracing practices in Jordan, J. Hydrol. 542: 913-922.
Al Qudah, K., Abu-Jaber, N., Jaradat, R. and Awawdeh, M. (2015). Artificial rainfall tests, soil moisture profiles and geoelectrical investigations for the estimation of recharge rates in a semi-arid area (Jordanian Yarmouk River Basin). Environmental Earth Sciences 73:6677-6689.

TRUEBNER (SME)

TRUEBNER GmbH develops, produces and distributes measurement and communication systems especially for agricultural applications and hydrological research. Its products are used in irrigation systems for farms, greenhouses and municipal areas. TRUEBNER has also a substantial customer base at scientific institutions, e.g. it is the soil moisture sensor supplier for the large-scale TERENO (terrestrial environmental observatories) project which spans across Germany. TRUEBNER has a strong focus on R&D within its team of engineers. Furthermore both owners hold positions as professors at the Mannheim University of Applied Sciences. Therefore attractive apprentice opportunities for students will be offered within the project. CEO Prof. Dr. C. Huebner is working in the field of moisture measurement for 25 years. His research interests include dielectric measurement methods and their application in industry, civil engineering and agriculture. CEO Prof. Dr. D. Trebbels research focuses on advanced time domain reflectometry methods. He is a recognized expert in electronic design for measurement and instrumentation. An engineer/technician will support the research within the project by lab work, building prototypes and performing experiments. TRUEBNER has strong relations both to industry and the science community worldwide, e.g. as a sponsor of the leading international conference on moisture measurement (www.isema2016.org). Prof. Huebner published an internationally recognized book on electromagnetic moisture measurement methods which covers extensively soil water content determination [1]. A paper of both CEOs on moisture measurement for agricultural applications appeared recently [2]. TRUEBNER has also proven experience in conducting research projects (2014-2017, KMU-innovativ Verbundprojekt SENKON: Wireless sensor and control system for efficient and quality optimizing irrigation in viticulture). TRUEBNER has an intrinsic motivation to contribute to the project by introducing advanced measurement technology into hydrological applications, performing cutting-edge research in the field of moisture determination, networking with other researchers/institutions and exploring new market opportunities worldwide. TRUEBNER is interested in a long-term collaboration which fosters knowledge transfer and demonstrates the advantages of innovative measurement strategies in hydrology.

TRUEBNER Publications

Cataldo, A, Benedetto, E. D., Huebner C. & Trebbels D. (2017). TDR application for moisture content estimation in agri-food materials. In IEEE Instrumentation & Measurement Magazine, 20(3): 26-31.
Hübner, Christof; Kaatze, Udo (2016) Electromagnetic moisture measurement, Universitätsverlag Göttingen, 2016, online available at https://www.univerlag.uni-goettingen.de/handle/3/isbn-978-3-86395-260-0?locale-attribute=en

ISOMED ERANETMED3-147

Project Coordinator

Academic Title	Prof. Dr.
First name	Christoph
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Total Cost of the consortium partner	129,380
Requested Funding	129,380

ISOMED ERANETMED3-147

Project Partner 1

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Website	www.moa.gov.cy
Total Cost of the consortium partner	12,660
Requested Funding	12,660

ISOMED ERANETMED3-147

Project Partner 2

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Family name	Abu-Jaber
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Total Cost of the consortium partner	64,600
Requested Funding	58,140

ISOMED ERANETMED3-147

Project Partner 3

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Website	https://www.cyi.ac.cy
Total Cost of the consortium partner	57,334
Requested Funding	57,334

ISOMED ERANETMED3-147

Project Partner 4

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Total Cost of the consortium partner	41,200
Requested Funding	20,600

Financial plan

	Name	Name of organisation (short)	Country	Requested funds (EUR)	Total costs (EUR)
Project coordinator	Christoph Külls		Germany	129,380	129,380
Total				**129,380**	**129,380**

	Name	Name of organisation (short)	Country	Requested funds (EUR)	Total costs (EUR)
Project partner 1	Christos Christofi		Cyprus	12,660	12,660
Project partner 2	Nizar Abu-Jaber		Jordan	58,140	64,600
Project partner 3	Adriana Bruggeman		Cyprus	57,334	57,334
Project partner 4	Dennis Trebbels		Germany	20,600	41,200
Total				**148,734**	**175,794**

Overall	**278,114**	**305,174**