Call	Nexus Theme 2023
Topic	1.4.1-2023 Accelerate adaptation and mitigation to climate change in the Mediterranean region by deploying WEFE nexus solutions
Type of action	(IA) Innovation and Action
Duration in months	36

Project name: "Mediterranean Advocacy for Low-carbon Innovative Green Nexus solutions to speed-up climate change adaptation" – MED-ALIGN

Description of the Italian case study, geographical location.

The case study is the North Sardinia Land Reclamation Consortium (thereafter Consortium) including the irrigation districts of Chilivani, Perfugas, and Valledoria plains (94000 hectares, Figure 1). As typical semiarid Mediterranean climate, the irrigation season at the Consortium starts approximately at the beginning of April and ends at the end of September. Agriculture consists mainly of forage cropping system, including maize or sorghum for silage, Italian ryegrass and alfalfa for hay, and winter cereals. The crop production is mainly aimed for satisfying the internal request of fiber and protein for livestock. Horticulture prevails in the Valledoria plain. The hydraulic system was designed in the 1960 years. The Monte Lerno lake feeds by gravity the collective distribution network of the Chilivani plain. The Valledoria and Perfugas plains are irrigated by the Coghinas river, pressurized networks served by pumping stations and storage tanks convey water from the river to the end-users. The irrigation districts operate according to an on-demand delivery schedule, where all farmers are served at their convenience. The service-oriented operation of the distribution network being conducted by the Consortium ensures a fixed pressure head at each hydrant, which is suitable for operating the high-pressure sprinkler systems (fixed systems, hose reel irrigators) for the forage crops, and trickle and micro-irrigation for horticulture. Water consumption is recorded by automatic flow meters located at the inlet of the fields and activated by magnetic cards. At the end of 2022 a project of the Recovery plan of the Italian Government will fund the installation of new water counters for remote data transmission. In addition, ultrasound flow meters are to be installed at the upstream end and in various parts of the network in aims of communicating discharge and mapping water losses and/or illegal water abstractions.

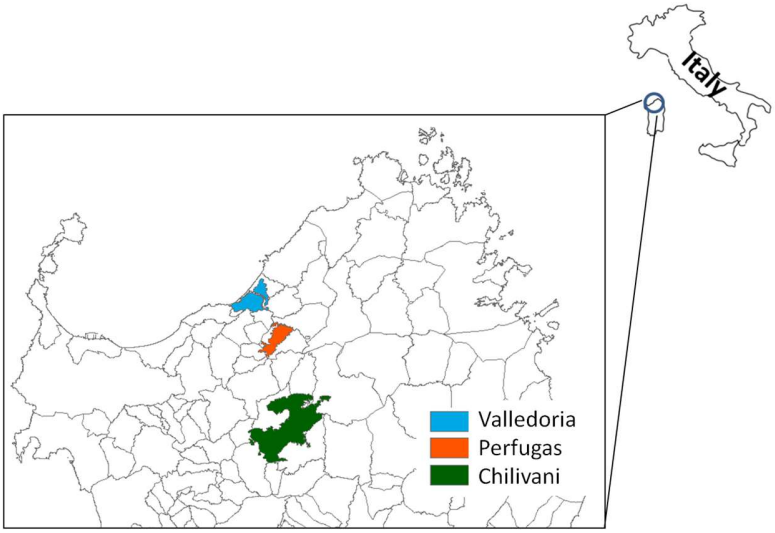

Figure 1: geographical location of the irrigation districts of the North Sardinia Land Reclamation Consortium

Problem: drivers and impacts

The foreseen modernization of the pressurized distribution network in North Sardinia Consortium mainly concerns the physical aspects of the infrastructure for improving the performance of water conveyance and on-farm delivery systems. This modernization is a key factor to a better water use and allocation efficiency. However, the interaction between the water use efficiency and the energy consumption was not adequately considered. The extraction and pumping water for distribution in pressurized irrigation networks significantly increases the energy cost for running the system. Criticisms linked to the inefficient water use and high energy costs are aggravated in the current context of climate changes and energy crisis. Niedda et al. (2014) indicated in the North Sardinia a reduction of 40% of precipitation respect to the 1960 years, when the hydraulic infrastructure of the Land Reclamation Consortium was designed. In summer 2017, unprecedent restricted water rationing was applied due to a persistent drought, which hardly impacted local farming economy. Higher pressure on water resources is expected in near future. A modeling analysis of Masia et al. (2021) foresees a relevant increase of crop evapotranspiration in the next decades in the Mediterranean area.

The dramatic increases of the energy unitary cost in the Covid-19 period is adding unattended running costs of the consortium and consequently will increases the service fee on the farmers. These additional costs may put farmers under pressure to sustain their farms. Farmers are struggling due to direct and indirect effects of increased costs of fuel and other goods necessary for the agricultural production (animal feed, fertilizers, seeds etc.). Several farms are at high risk of economic failure, and this is creating general protest and social unrest.

Representativeness

Seven Land reclamation Consortia are present in Sardinia (900000 ha), which have common traits of hydraulic infrastructures and present similar criticisms for inefficient water use and high energy running costs. At the farm level the most common irrigation system is high-pressure sprinklers for irrigating forage crops, while low-pressure systems are only used in horticulture. Irrigation decisions are mainly driven by the experience of the farmer, while the potentiality of Decision Supporting Systems (DSS) and Automation for water and energy saving remains largely unexploited.

Innovation of NEXUS demonstration cases to Water, Energy, Food and Ecosystems resources context

An integrated approach helps in achieving a balance between food production and water and energy consumption, and to promote the designing as well as the management practices with minimum impact on the farmers. The project aims to develop and test innovative IoT technologies and approaches for saving water and energy in the cropping systems of North Sardinia traditionally irrigated with high pressure-low efficient irrigation systems. This approach seeks to improve and adopt reliable and effective measures able to manage trade-offs and build synergies between water, energy, food production and the ecosystem, in order to increase the resilience of the agriculture towards the water scarcity and energy crisis. In brief our project proposes an integrated approach for saving energy by saving water, under a Nexus vision of resources. Our approach toward energy starts at the farm, a bottom-up approach that aims to encourage the diffusion of the best practice for increase water efficiency reducing water consumption and pressure requirement in the downstream hydrants, for saving energy upstream and generate opportunity of energy recovery in the distribution network managed by the Consortium.

Ambition

This pilot proposal aims to exploit IoT for increasing the resilience of agriculture towards the pressing problems of water scarcity and energy in the Mediterranean area. The tight nexus between water and energy is very much expressed in the pressurized irrigation distribution networks of North Sardinia Land Reclamation Consortium, and effectively maximizing the efficiency of irrigation at the farm level and thus saving water means saving energy. To this end, a range of technologies is available (e.g. micro-irrigation, DSS, etc.), however, their adoption is still hindered by several barriers directly linked to the farmers and farming systems. A friendly to use Smartphone App, will enable to raise the farmer awareness about the significant value of efficiently using water, positioning their behavior within the general context water scarcity challenge. In particular, advanced low-cost IoT field-solutions for bringing farmers from awareness to action will be provided while, energy self-sufficiency of the collective irrigation infrastructure will be promoted, with what it entails as economic advantage for farmers. Energy self-sufficiency will integrate water saving low-pressure irrigation systems to decrease pumping costs and producing/recovering renewable energy in the distribution network. The proposed energy plan will be the instrument through which both approaches will be explicitly translated in strategies and policies in view of future technological investments for the self-sufficiency of the Consortium.

Foreseen activities and demonstrative cases

The action will implement the following activities:

- *Smartphone App for measuring farmer irrigation performance and promoting efficiency in irrigation (TRL-6-8)*. A smartphone App will be released to the farmers for comparing the effective water volumes used for irrigation with optimal water crop requirements (i.e. that maximize crop productivity) and supporting them in the irrigation piloting. The App will interface with the database of the Consortium to retrieve the effective water consumption periodically transmitted by the automatic flow meters (figure 2). The optimal water crop requirement will be evaluated by specific analyses of farm infrastructure, management, crops, soil type and climate. An innovative integrated approach will be used for estimating the optimal crop water requirements and then the crop irrigation requirements. The algorithm uses multispectral satellite imagines and remote sensing-based modelling (e.g., Land Surface Energy Balance Models) integrated with soil water information provided by field sensors (described below). The App will be also an interface to share knowledge and data between farmers and the App managers, it will automatically release friendly textual and graphical warning to the farmer notifying his performance level. Low-performant irrigation managers are encouraged to improve their performance, and the App managers could suggest a variety of technical solutions for saving water (e.g. low-pressure irrigation system, DSS, etc.). Moreover, in all the demonstration cases a set of IoT sensors for determining the current soil water status will be installed in field, for supporting the irrigation scheduling of the farmers in order to improve their performance. The proposed IoT device will integrate a tensiometer, a pressure sensor, a microcontroller and a radio module to transmit the data using LoRaWAN protocol through LoRa gateways to the network server while the results will be mapped using ArcGIS Pro. The IoT system will interface with the App, providing to the farmer the advice for starting and ending irrigation.

Good irrigation managers are encouraged in maintaining their ability in saving water. It will be evaluated together with the Administrative Authority of the Consortium approaches for rewarding good irrigation practices (e.g., through discounts in the service fees of the Consortium).

The full functional App will be released for testing in 5 representative farms of the Chilivani and Perfugas irrigation districts (demonstrative cases). A demo of the APP will be released for a larger number of farms. Questionnaires will be supplied for evaluating the capacity of the App of influencing behaviors and habits of the farmers, and for evaluating the effectiveness of the functionalities, graphical user interface and warnings of the App. Finally, suggestions of the farmers will be yielded by the questionnaires.

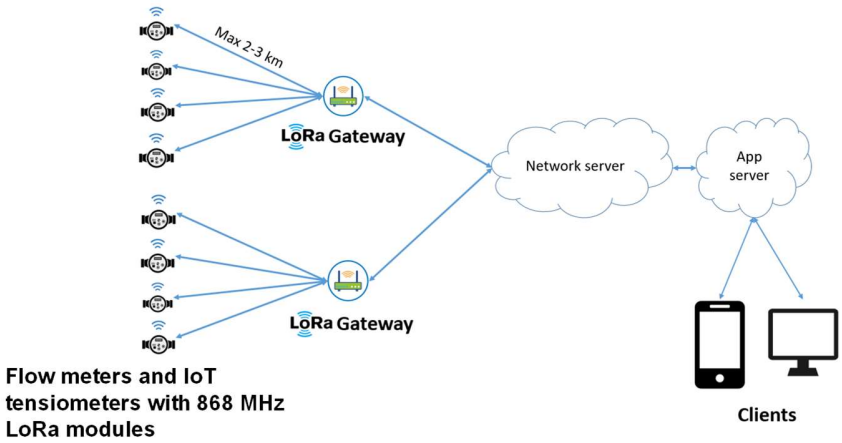

Figure 2 network architecture for smart LoRa metering system for remote data transmission and integration with the App.

- *low-pressure irrigation system for forage or silage crops (TRL 6-8)*. A field demonstrator will be set in a farm of the Perfugas plain, consisting in an innovative and high-performant low-pressure irrigation and fertigation system for Maize or Sorghum crops. The scope of this demonstrator is to show to the community the potentiality, in term of energy and water saving, automation and crop productivity, of the low-pressure systems applied for silage crops traditionally irrigated by high-pressure sprinkler systems. The irrigation system will be designed and managed with innovative integration of ICT and automation following the "4.0 irrigation" principles. The site will be instrumented for automatic monitoring of soil-water, vegetation status and climate. Advanced protocols will be tested for the remote piloting of the irrigation system and integration with DSS driven by the monitoring instrumentation in field.

-*Energy plan*. A study will be performed for supporting future energy policies of the North Sardinia Consortium. We believe that producing this general plan is a necessary pre-requisite for realizing effective investments in production/recovery of energy at the Consortium level. The study, starting from the current spatial and temporal distribution of water uses and of pressure heads, will reconstruct the hydraulic model of the distribution network (e.g. using Epanet model). Then it will individuate opportunities for modernization, rehabilitation or even the partial re-design of the distribution system, for saving energy but also for producing renewable energy (solar or hydro-electric). The design of the pressurized irrigation distribution network of the Consortium was based on the on-farm pressure head satisfaction of the high-pressure requiring irrigation method (high-pressure sprinklers or guns) in the most unfavorable hydrant, while the rest of the hydrants will have an excess of pressure. The study will evaluate the technical feasibility and the economical convenience of the application of new energy recovery technologies (e.g. crossflow turbine) that use the excess of pressure head in pipes to produce energy, and will evaluate the impact of the insertion of these devices in the pressure head available in the downstream hydrants. The objective is generating new energy which could be made available "on-site" for alleviating the energy costs of the farms. The energy plan will operate at the large distribution network scale, but also will consider pipelines serving single farms or clusters of farms with hydrants with similar excess of pressure head.

The widespread application of low-pressure high-efficiency irrigation systems (trickle, micro and sub irrigation, or pivot and rangers with high-efficiency micro-sprinkler) for irrigating forage crops is a desirable long-term result of the project, which we aim to reach by the App diffusion and the field demonstrators. Reducing the irrigation water volumes used by the farms will also minimize the energy consumption at the consortium level, by reducing the starting cycles of the pumps. As part of the energy plan, we will evaluate how much energy can be saved for scenarios of increasing water saving. Moreover, the diffusion of low-pressure irrigation systems will reduce pressure requirement at the farms and will increase the pressure-excess in the distribution network. Through the hydraulic model of the network, we will evaluate where the increased pressure-excess could produce additional opportunities of energy recovery in pipes.

-*Stakeholder engagement.* In all phases, participatory approach, exchange of information and collaboration between different actors (participated SWOT Analysis and Living Labs) will be used to lead to radical innovations that concretely face-up the observed criticisms. When facing challenges in an evolving real-life context, it becomes very difficult for an individual actor to find the right solution. Only by collaborating and co-creating solutions with end users and the actors involved, complexity and uncertainty is reduced and the possibility of finding a sustainable solution increases.

By implementing a *participatory action research* methodology, we aim at generating *hybrid knowledge* (scientific and technical) in order to act to change reality. Action research consists of an attempt to modify reality, but it also aims to produce scientific knowledge concerning these modifications, through stakeholders' participation. The main idea is to involve the stakeholders in the research processes to identify possible solutions, designing them in collaboration with them.

The approach will include as follow: 1) semi-structured interviews and focus groups finalized to collect stakeholders' perceptions and experience, roles and responsibilities, access to resources, problems and strategies in relation to water scarcity and energy cost problems; 2) participated analysis of strengths, weaknesses, opportunities and threats (SWOT) about water scarcity and energy costs; 3) living Labs for generating social learning spaces and participatory social intervention. The main goal concerns the possibility of changing conditions deemed the dissatisfaction of the stakeholders.

Contribute of CIHEAM Bari

1- Contributing to designing, developing and validating the IoT ground sensors mapping system.
2- Contributing in the interface of the sensor's transmission protocol with the developed App.
3- Participating in the app algorithm development "Smartphone App for measuring farmer irrigation performance and promoting efficiency in irrigation".
4- participating and commitment to the living labs approach during all the activities mentioned above.

Stakeholder

The main stakeholders are the farmers, who are experts in the use of the natural resources of the area: they know how interdependent natural and socio-economic cycles work in terms of their farm life from their personal experience and they also have a problem-solving attitude.

Administrators and technicians of the North Sardinia Land Reclamation Consortium, in charge of the irrigation water for the whole district, managing the pressurized distribution network, the pumping stations and the drainage network.

Policy makers and researchers, whose frameworks and theories support the evolution of policy and the design and implementation of research about water and energy use, and agricultural development in general. Among the decision makers and implementers, the Regional Agency of Agricultural Policies Application and Rural Development (LAORE) plays a relevant role in the implementation of water saving strategies in agriculture.

Enel distribution, the Italian society in charge of the energy network, which can share solutions and strategies for re-thinking and co-designing the energy system of the Consortium with a view to energy saving.

Considering that the water scarcity and energy costs are very complex interconnected issues, it is clear to all stakeholders that only a range of solutions could contribute, together, to solve it and that a unique solution doesn't exist. Innovative approaches will be developed, tested, and shared within a real-word test environment (Living-Lab) where all stakeholders could evaluate the impacts. This mitigation strategy completely meets the environmental policies of the Regional and National Government, where water and energy saving strategies have a key role.