Water reuse and NbS for a resilient water management in the Mediterranean: NATMed project

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ABSTRACT

Water is extremely scarce across the Mediterranean Region, containing only 3% of global water resources (1). Furthermore, current patterns of water management have been shifting from a supply-oriented approach to one based on demand causing seasonal mismatch between water sources and demand. Consequently, supply of natural water no longer meets the growing demand, in particular, the agriculture sector accounts for more than 80% of the withdrawal of water in Southern and Eastern Mediterranean countries. This situation is compounded by increasing climate change impacts affecting fresh water resources and intensifying seasonal variability, increasing problems in already water-stress areas and potentially generating water-stress in new places (1,2).

To address this challenge, along with the adoption of wastewater treatment, reuse and water-use efficiency, the proper management of the water cycle has to be improved, from water catchments, storage to distribution system; both in natural and artificial water bodies.

Natural ecosystems play a fundamental role in regulating different features of the water cycle, providing ecosystem services (ES) to regulate, clean and supply water. Therefore, maintaining healthy ecosystems have a direct effect on improving water availability. In this way, Natured-based Solutions (NbS) can provide water-related services, regarding water storage and purification, erosion control, and moderate extreme events, as well as other environmental, social and economic water-dependent ES, addressing water security, water resources management challenges, in addition to the Sustainable Development Goals and their targets (3,4).

NATMed project (PRIMA RIA & IA) will foster this new approach of integrated water management developing Full Water-Cycle – NbS (FWC-NbS), focused on improving water storage and distribution infrastructures through ES provision to impact in the entire hydrological process, following circular economy perspectives.

Keywords: Water reuse, Nature-based Solutions, Full Water-Cycle – NbS, Ecosystem Services, Water management

PROJECT DESIGN

NATMed is focused on creating, implementing, and validating a set of 12 Nature-based Solutions (NbS), collectively known as Full Water-Cycle NbS (FWC-NbS). These solutions will be integrated with existing grey and natural water infrastructures, addressing different phases of the water cycle to enhance ecosystem services related to water quality and quantity. Additionally, the project aims to improve water-dependent services, such as social, economic, and environmental benefits, while empowering local communities and stakeholders across the Mediterranean. By fostering resilient societies, NATMed seeks to generate green jobs, promote local economic growth, and develop integrated water management plans. The solutions will be co-developed with transdisciplinary teams, incorporating regional traditional knowledge and a strong gender perspective to ensure sustainability and impact.

The effectiveness of these FWC-NbS will be demonstrated through five case studies across Spain, Greece, Italy, Turkey, and Algeria, each reflecting the Mediterranean's geographical, economic, and social diversity. All case study sites fall under the Csa (hot summer Mediterranean) under the Köppen-Geiger climate classification (5), except for Algeria, which is classified as BWh (hot-arid desert). The case studies focus on specific local water management challenges, addressing summer and winter water cycle issues in the region. Supported by the Mediterranean Community of Practice (MedCoP), the project will also develop decision-making tools for the implementation of FWC-NbS, ensuring maximum environmental, social, and economic impact.

Case Study 1 (CS1) is located at the Experimental Center of New Water Technologies (CENTA) in Carrión de los Céspedes in Andalusia, Spain. It functions as a living lab for developing, testing, and evaluating innovative water technologies, wastewater treatment, and recycling management practices. CS1 also operates as a wastewater treatment facility for the local community. The region faces several challenges related to droughts, water scarcity, stored water quality, water pollution, and the impact of climate change. The goal of CS1 is to reuse treated wastewater for agricultural irrigation and reduce evaporation rates of stored water. With that aim, we are evaluating and optimising the performance of seven types of constructed wetlands (CWs). The treated water from the CWs is stored in tanks, one equipped with floating gardens specifically designed to reduce the evaporation rate other equipped with an ultrasounds system to reduce the proliferation of microalgae and *Escherichia coli* (6) and improve the water quality. In a final step, we analyse the effects of the treated water on agricultural soils.

Case Study 2 (CS2) is based in the natural wetland complex of western Macedonia, Greece, around Lake Chimaditida. Along with Lakes Zazari, Petron, and Vegoritida, it forms part of a broader lake network. The lake is surrounded by two small hills and a large crop area created by extensive drainage work. Large seasonal

wetlands form in the areas where the lakes connect with the agricultural fields. The biodiversity of the area is very rich, and provides an important habitat for birds and rare plant species. Lake Chimaditida experiences eutrophic conditions and can range from mesotrophic to hypertrophic depending on hydrological, climatic and biological factors. It is part of the EU Natura 2000 area, a Special Protection Area and a Special Area of Conservation. The main challenges in this area are seasonal drought, declining groundwater levels, eutrophication, reed encroachment, water pollution and runoff, and siltation. The focus of this case study is to enhance the wetland's water storage and purification capacity through sustainable management and pollution control. We are developing a livestock management system in the area to support the conservation and restoration of the lake, with a specific focus on controlling reed beds. Riparian buffers are also being established along the lake's shores to improve water quality by reducing pollution from agricultural activities and pesticide runoff. Additionally, water distribution systems are being enhanced through the implementation of monitoring and the development of an irrigation plan, which will help reduce water consumption in the region and improve the lake's water levels.

Case Study 3 (CS3) is located in the agricultural district of Arborea, Sardinia, Italy. Arborea is characterised for its agricultural productivity, with agriculture and livestock farming being among the most important economic activities in the region. The agricultural district of Arborea is one of the most productive agricultural locations in Italy and has been designated as a Nitrate Vulnerable Zone (NVZ) due to nitrate contamination risks. It lies on a plain surrounded by wetlands protected under the EU Natura 2000 Directive and the Ramsar Convention, with interconnected sandy and alluvial aquifers. Key challenges in the area include managing water quality and preventing nitrate contamination in aquifers. The case study focuses on improving groundwater storage and quality by enhancing nature-based practices to reduce nitrate contamination. Specifically, the existing Forested Infiltration Area (FIA) system implemented in the area during the MENAWARA-ENI CBC MED project, will be upgraded to achieve these goals. The objective is to implement cost-effective and more efficient technical solutions that will enhance both groundwater quality and storage capacity.

Case Study 4 (CS4) takes place on Bozcaada, a small island in the northern Aegean Sea, Türkiye. Bozcaada suffers from limited water resources, with no major river and no rich vegetation, and small number of aquatic and paludal plants. Drinking water is supplied through a pipeline from the mainland and a small amount is used for agriculture. The population fluctuates significantly between winter and summer, straining water resources. The primary challenges in the area include the impacts of climate change, water quality degradation, unbalanced water demand driven by tourism, recurrent droughts and water scarcity, salinity intrusion, erosion risks, management of irrigation water usage, soil fertility depletion, and reduction in agricultural yields. The case study focuses on improving groundwater quantity and quality by promoting natural infiltration, reducing surface runoff, and enhancing agricultural practices. To achieve this goal, five NbS and two technologies are used in CS4. As part of the Managed Aquifer Recharge (MAR) techniques in CS4, we are developing NbS to promote natural infiltration in a declining sub-catchment that is particularly prone to surface runoff. The goal is to enhance aquifer recharge by infiltrating additional water. Additionally, we are monitoring and installing recharge wells to replenish aquifers with freshwater and prevent seawater intrusion into coastal areas. To further supplement existing aquifers, new groundwater storage systems, such as underground dams, are being developed to store and reuse water from riverbeds. In parallel, we are implementing conservation agriculture practices in a fig (*Ficus carica*) plantation to promote soil health, minimize environmental impact, and optimize water resource use. Moreover, we are developing climate-resilient agricultural practices to adapt Paulownia tree cultivation to changing climatic conditions, addressing risks such as droughts, floods, storms, and temperature shifts. To support decision-making, Bozcaada’s water distribution system is being analysed using a Supervisory Control and Data Acquisition (SCADA) system, which gathers data on water consumption and pipe system losses. Lastly, an intelligent irrigation system based on soil moisture monitoring is being developed on the island to reduce water use for irrigation.

Case Study 5 (CS5) is located in Touggourt, within the Oued Righ valley in southeastern Algeria. The Oued Righ Canal, which spans 150 km, runs through palm groves and oases, forming a vital ecosystem for local communities of the area. The canal flows into Chott Merouane, one of the most important Algerian wetlands. The southern part of the canal was dug, while the northern part is of natural origin. The canal collects water from the few annual storms and wastewater from agricultural irrigation. The primary challenges in this area revolve around drought and water scarcity, water quality deterioration, stagnant water accumulation, air pollution, siltation, excessive evaporation, soil degradation, loss of biodiversity and erosion. The goal of this case study is to improve water quality by reducing the discharge of wastewater and agricultural runoff into the Oued Righ Canal. Two NbS are implemented in CS5. On one hand, a CW pilot system will be implemented to improve the quality of water discharged into the Oued Righ canal, increase the functionality of the existing wastewater treatment plant and reduce maintenance costs. On the other, riparian buffers with macrophyte species on the banks of the canal will be implemented to act as a natural purification system and protect against agricultural runoff and erosion.

Figure 1. Overview of the 5 Case Studies (demonstration areas) of the NATMed project

In these 5 case studies, continuous data collection helps track the performance of the implemented technologies and ecosystem services, allowing for necessary adjustments to improve water quality, biodiversity, and the sustainable use of water resources. Ecosystem services, such as water cycle regulation, natural purification through wetlands, and biodiversity protection, are central to these projects. By using NbS, such as the ones implemented in NATMed, we expect not only to address local challenges, but also to improve essential ecosystem services for communities and their environment, ensuring solutions that lead to long-term sustainable improvements in water management and ecological health, adapting to changing conditions as needed.

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