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System-Dynamic models for groundwater management in SW Messinia, under different climatic scenarios

KASTANIDI Erasmia[1], MANEAS Giorgos [2,3] , PANAGOPOULOS Yiannis [4], VIAENE Peter [5], DE KOK Jean-Luc [5], BERG Håkan[2], MANZONI Stefano [2], VELAORAS Dimitris[1] KARAGEORGIS[1] Aristomenis P.

[1.] Institute of Oceanography, Hellenic Centre of Marine Research
[2.] Stockholm University
[3.] Navarino Environmental Observatory
[4.] Institute of Marine Biological Resources and Inland Waters, Hellenic Centre of Marine Research
[5.] Environmental Modelling Unit (RMA), VITO NV, Belgium

*corresponding author:
e-mail: e.kastanidi@hcmr.gr

Abstract SW Messinia, Greece, is an interlinked coastal-inland area in the Eastern Mediterranean region. Extensive olive tree plantations and tourism are the main human activities in the area, both of which depend on groundwater resources to cover their irrigation and supply needs. The same groundwater sources are also the main freshwater sources for the Gialova lagoon, a coastal wetland with high ecological and commercial value. The combined effect of human interventions and climatic conditions over a period of 60 years has led to increased saline conditions in the wetland since the 1960s, and unless freshwater inputs are enhanced by restoring hydrologic connectivity between the wetland and the surrounding freshwater bodies, salinity in the lagoon is expected to increase even more under drier and warmer conditions predicted to occur in the future (Manzoni et al., 2020). However, surrounding fresh water bodies have high nutrient inputs and unless these are reduced, any increased connectivity could further degrade the sensitive ecosystem of the wetland (Bray et al., submitted). Under the COASTAL EU project, we have developed a System Dynamics model that combines tangible (e.g. runoff, water demand, salinity, population, tourist arrivals) and intangible (such as awareness and willingness to cooperate) attributes of the local social ecological system. This model is used as a basis for discussions with local stakeholders and for promoting social learning by connecting local concerns with lagoon management. These connections are considered essential for achieving the transition towards collaborative integrated agricultural practices that will enable the restoration of lagoon connectivity accounting for changing climatic conditions (increased temperature, reduced precipitation).

Keywords: Land-Sea Interactions, Social Ecological System, Climate scenarios, System Dynamics

1. Introduction

In SW Messinia, Greece, all human activities depend on groundwater resources to support their livelihoods for irrigation as well as domestic consumption. These resources also serve as the main freshwater sources for Gialova Lagoon, a coastal wetland with high ecological, cultural and commercial value. During the previous century, the wetland has been gradually transformed from brackish to saline (Maneas et al., 2019) with Mean Annual Salinity (MAS) at 33 g/lt, a value that is expected to increase even more under future drier and warmer conditions (Manzoni et al., 2020). These values have already profound implications on species and habitats, which impacts the local fishing economy as well as deteriorating a habitat that is of international importance for migratory birds (Maneas, 2019), hence affecting the international recognition of the area (COASTAL workshops, 2018). All of which would be greatly impacted if the status of the lagoon deteriorates further. Improving the connection to the sea by opening of additional canals with the Navarino Bay has been suggested as a way to improve water circulation, which would be beneficial for fishing (Arvanitidis et al., 1999), but not for the migratory birds, which would benefit from increased freshwater inputs. A challenge for the region is how to balance societal and conservation needs, and suggest salinity restoration solutions with a broader acceptance by the society, taking into account future climatic conditions and identifying local population and businesses' adaptation potential.

COASTAL project follows a problem-driven approach involving the interaction of different stakeholders, for identifying local problems as well as opportunities and proposing solutions, through the creation of Multi-Actor Labs (MALs). The MAL of SW Messinia, like all other MALs (COASTAL Image), has been active in brainstorming sessions which have resulted in system dynamic models using a well-balanced combination of qualitative and quantitative tools for identifying mid- and long-term impacts as well as solutions. The System Dynamic models for SW Messinia connect agricultural and tourist activities with the status of Gialova Lagoon, and have been used for fostering analytic-deliberation and promoting social learning about the system among participants, driving the co-creation of a vision for a Sustainable Messinia, which expands across major economic sectors (agriculture, tourism and olive oil

making) by joining forces and connecting rural and coastal activities to build a Brand Name based on the local identity of olive oil making in close connection to highly valued natural environments.

System Dynamic Models for SW Messinia

Stakeholders Vision for a Sustainable Messinia has been the focal point of the System Dynamic Models developed which focus on land-sea interactions and climate-resilient land and water management, as the most important challenges in achieving this and for maintaining the highly valued ecosystem services of the lagoon under a changing climate (Figure 1).

The SD model developed for the area has focuses on addressing three important challenges:

a) shifting to integrated farming practices,

b) the restoration and enhancement of ecosystem services in the Gialova Lagoon wetland

c) shifting to sustainable forms of tourism, including thematic tourism activities,

The model suggests that restoration and enhancement of the ecosystems services in the Gialova Lagoon is dependent upon the increase of freshwater inputs, as these are vital for regulating lagoon salinity. Expected future climatic conditions, with increased temperatures and a reduction in precipitation rates coupled with an increase in evaporation will further deteriorate the status of the lagoon, which is an area of international importance for migratory birds, but is also important for the local fishing communities. Through the use of System Dynamic models we have been able to demonstrate that by saving water from irrigation and domestic use, wetland salinity would be kept to current values, when considering the expected increase in evaporation rates, due to climate change. Still, these values are below optimum for fish (Figure 2), resulting in the need for additional, freshwater inputs, which these can only achieved by restoring the natural flows with the two nearby streams, Xerolagados and Tyflomitis. However, the water quality of both streams depends on agricultural activities, and data collected as part of the project show that both rivers have high nutrient concentration, hence this restoration can only be made possible if agricultural activities become more sustainable, by using less agrochemicals (Bray, et al, submitted). Reducing the amount of fertilizers applied is also in line with the Farm to Fork Strategy of the European Green Deal, which could help the transition by providing incentives to farmers for adopting sustainable practices, taking into issues such as the small farm land size the ability and willingness to cooperate within and among sectors, which have also been described as very important parameters for achieving this transition.

Conclusion

The co-creation of a system dynamics model, following participatory modeling strategies (Voinov et al, 2018) as part of the stakeholders workshops organized within the framework of the COASTAL project (Akinsete et al, 2021) has promoted social learning about the system among the participants. Including stakeholders in the process increases understanding about system's behavior and helps connect local concerns with lagoon management, whilst also demonstrating how a maintaining a good environmental status for the lagoon will be beneficial for the local economy, both through the fishing activities and as a focal point for the Brand Name identified in the stakeholders' vision. The ideal vision described by the stakeholders, is currently being tested against the conditions described as part of the Shared Socioeconomic Pathways – SSPs- (O'Neil, 2014) and their effect on the on its successful implementation, which relies greatly on increasing environmental awareness and the adoption of nature based solutions as well as technological advancements that will reduce water demand. However the SSPs describe alternative future scenarios that are being identified with reduced willingness to adopt more environmental friendly practices and rely more on the use of new technologies, which will pave very different futures for the area.

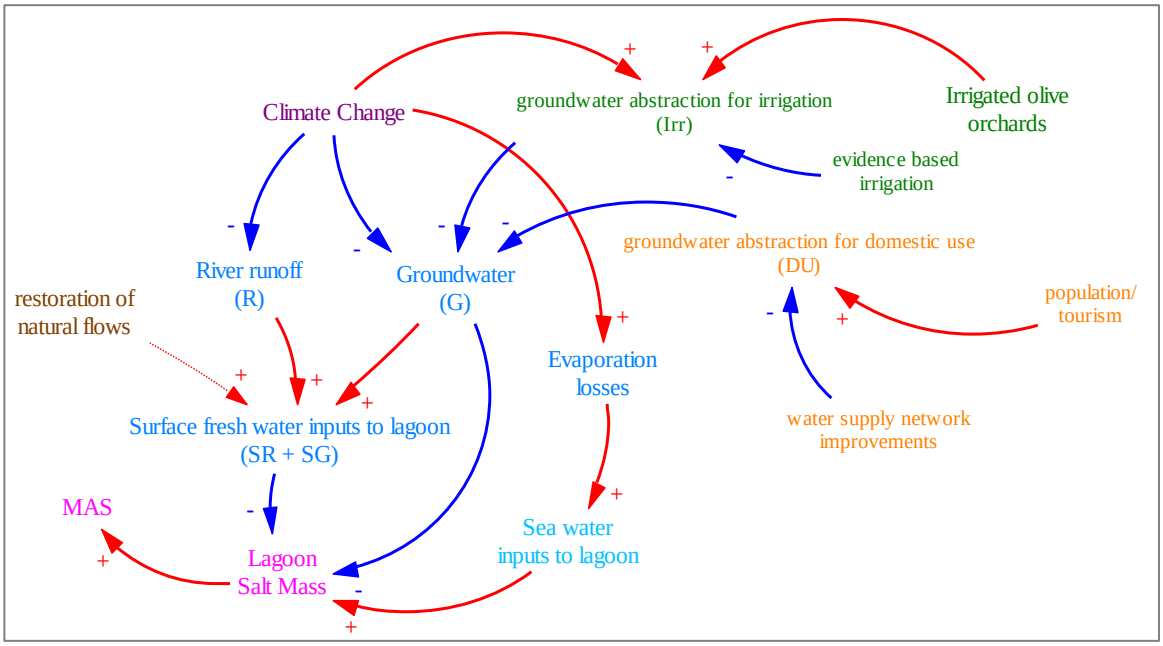

Figure 1. The Conceptual SD model of the SW Messinia land – sea interactions system

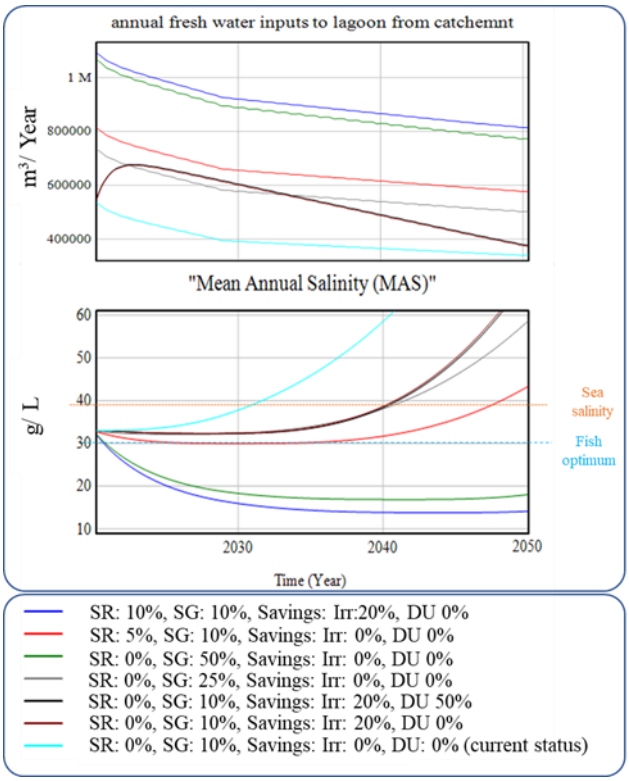

Figure 2. MAS trends under different fresh water restoration approaches

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