Mapping ecosystem services in a Mediterranean watershed in the context of socio-ecological restoration actions, adaptation and mitigation to Climate Change

Itxaso Ruiz[1], João Pompeu[1] and María J. Sanz[1,2]

[1] Basque Centre for Climate Change (BC3), Leioa, Spain
[2] Ikerbasque Foundation - Basque Foundation for Science, Bilbao, Spain
itxaso.ruiz@bc3research.org

Abstract. Human prosperity and well-being of Mediterranean watersheds are underpinned by their natural capital, which among others, provide clean water and multi-functional landscapes, today jeopardized. Historically, water demand for irrigation and industrial use, along with increased population density and land-use changes, has altered the landscape of Mediterranean basins. Mapping Ecosystem Services (ES) there, is thus key to understanding how basins depend on biodiversity, the effects of shortcutting ES functions, and the consequences to its societies. Based on land use data and well-known relationships between ES, together with key spatial information for management purposes, we provide maps of a Mediterranean watershed placed in Eastern Spain and called El Mijares, aimed at raising awareness about areas of ecosystem goods and services to watershed stakeholders. These outputs will then be used as the point of departure from which to identify ES priorities and discuss potential actions to promote ES with watershed stakeholders, in a participatory way. Lastly and based on the previous steps, different socio-ecological models will be constructed for assisting local actions for sustainable use of El Mijares ES. The methodology developed for El Mijares may be replicated in other Mediterranean watersheds which face similar challenges in water management and desertification. The upscaling of this pilot study may promote nature conservation, climate protection, and disaster risk reduction in the Mediterranean by considering the scientific literature and the know-how of the local societies.

Keywords: Watershed, Mediterranean, Ecosystem services, Spatial information, Sustainable Land Management.

1 Introduction

The Mediterranean basin constitutes a climatic hotspot where the resilience of its ecosystems and societies is being affected. This region is witnessing, among others, more unstable weather patterns, a reduction in annual rainfall, and a rise in air temperature. Along with climate change, increased population density, water demand, and land-use changes have altogether altered the landscape and water cycle of the Mediterranean basin. Here, we present the case study of the Mijares watershed within the Mediterranean basin, which offers an ideal environment for studying the challenges posed by managing Mediterranean water resources. First, because of the landscape heterogeneity and water uses along the river (Pompeu et al., 2021). Second, because of the fragile balance between available water resources and water demands (CHJ, 2018). And last, because despite its fairly regular flow in the seasonal distribution, it registers both torrential floods and periodic droughts that challenge the planning and management of its resources. In this context, we propose Sustainable Land Management (SLM) actions at the watershed scale to achieve climate change adaptation and mitigation while promoting Ecosystem Services (ES) that hinder water scarcity, soil erosion, and biodiversity decline (Sanz et al., 2017). Thus, we seek the combination of several actions to achieve regional (watershed scale) more integrated approaches. With this study, we aim at proving that SLM is a successful tool for strengthening the functioning of ES in the rural Mediterranean areas.

2 Methods

El Mijares is a 4045 km² watershed located on the Eastern Spanish coast. In it, the river rises in Sierra de Gúdar at 2000 m altitude, and after 156 km it flows into the Mediterranean Sea through the coastal plain of Castellón, in Valencia. The upper and middle course of the river runs embedded between karstified limestones while in the lower course, the river accumulates quaternary materials from its great fluvial fan. Its average annual temperatures range between 14 and 16.5ºC and the average annual rainfall between 300 and 750 mm. For this watershed, we first generated a Land Use and Land Cover map (LULC) with 30 meters of spatial resolution (Fig. 1a), based on samples from CORINE maps (Pompeu et al., 2021). The samples were extracted from representative patches of no land cover changes in the five CORINE time-frames (1990, 2000, 2006, 2012 and 2018), and evaluated with field work data and high-resolution Google Earth imagery. We then used the Random Forest algorithm to classify all available Landsat-8/OLI imagery from 2018, whose variables were the spectro-temporal (summer/winter) radiometric indices and phenological metrics derived from cloud-masked (Fmask) dense EVI (Enhanced Vegetation Index) time series, as described in detail in Bendini et al. (2019).

Next, we used the LULC map as an input parameter in ARIES (Artificial Intelligence for Environment & Sustainability), an integrated modeling tool that combines expertise from specific disciplines and assesses trade-offs and scenarios for multiple ES (ARIES Homepage). Because it operates in a cloud-based environment where data and new models are continuously shared by experts on the field, the availability of ES models fit to El Mijares addresses varying systems within the watershed. The ARIES tool has the capacity to integrate scientific data and models that simulate and integrate environmental and socio-economic systems. In addition, ARIES uses artificial intelligence to choose the best parameters and data for the models currently available in the platform, considering the spatial resolution and the context (time and space) in which the models will be applied (ARIES homepage). In our context, we used our LULC map as the only manual input and the best data to feed the models were automatically selected by the ARIES engine.

For this presentation, we have selected two soil-related ES to the overall watershed: the amount of organic carbon stored from the topsoil up to 200 cm depth, and the soil retained due to vegetation cover. The Soil Organic Carbon (SOC) model includes the spatially explicit data by ISRIC (ISRIC Homepage). The soil retention due to the vegetation cover model is an implementation of the commonly used Revised Universal Soil Loss Equation (RUSLE) (Renard et al., 1997), which calculates the RULSE using the existing land cover and then changing all land to bare soil. The advantage of using ARIES in such a local context, is the ability of the platform to deal with the best available information to run the model at the landscape scale (ARIES homepage).

3 Results

The watershed land cover (%) is shown in Figure 1a, along with the amount of SOC (Figure 1b) and soil retained due to vegetation cover (tones/hectare /year) (Figure 1c). These outcomes show that the higher shares of land types within El Mijares are forests (41.3%) and herbaceous vegetation areas (38.4%). Additionally, these two land types, provide the highest SOC and the highest soil retention capacity, indicating that SLM in forests and herbaceous vegetation areas should be further explored to protect and promote ES related to carbon storage and soil protection in the watershed (Table 1).

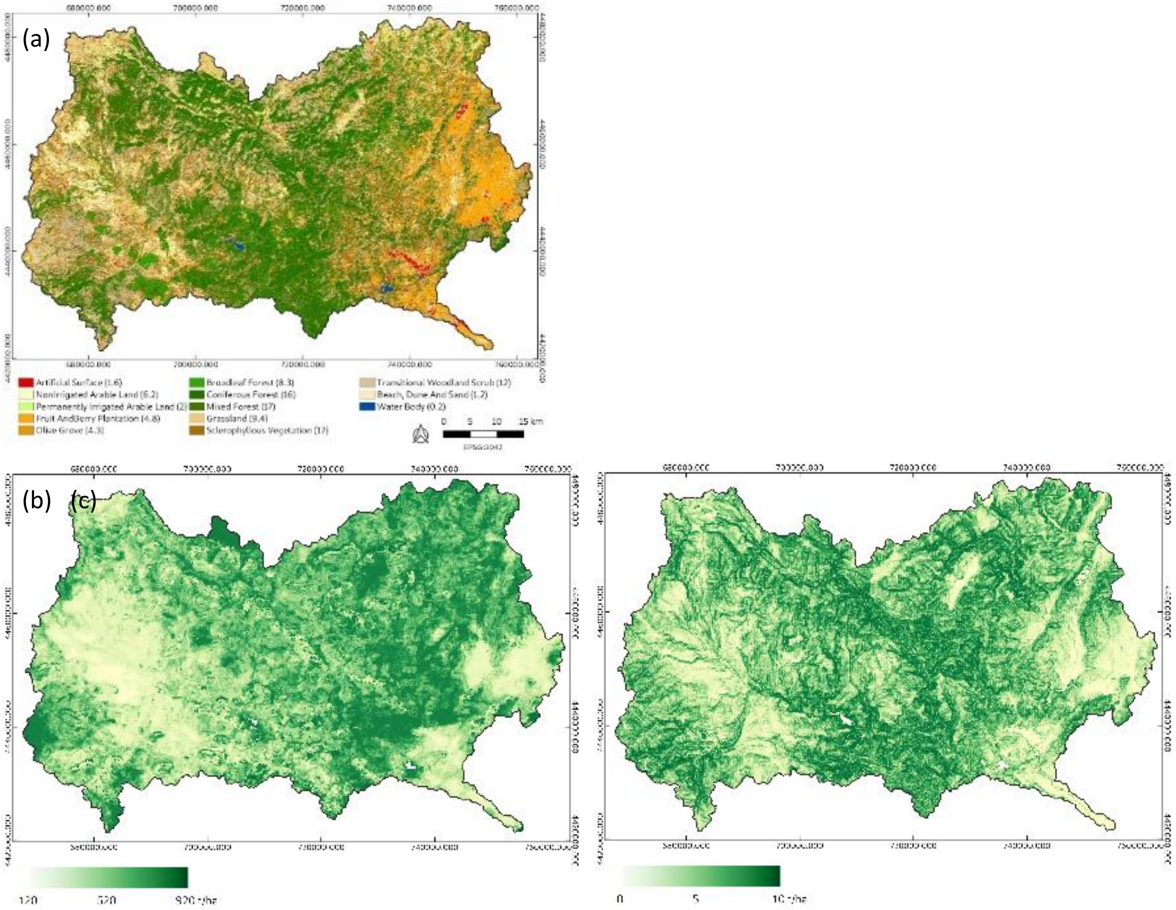

Fig. 1. (a) Landsat-based LULC from El Mijares (% of LU in the watershed), **(b)** Soil Organic Carbon storage model applied to El Mijares (tones/hectare/year), **(c)** Soil retention due to vegetation cover model applied to El Mijares (tones/ hectare/year).

Table 1. LULC (%), SOC (million tons per hectare per year), and soil retained due to vegetation cover (million tons per hectare per year), per land type.

Land type	LU (%)	SOC (Mton)	Soil retention (Mton)
Artificial surface	1.6	1.11	0.37
Non-irrigated arable land	6.2	6.78	7.2
Permanently irrigated arable land	2.0	2.34	3.2
Fruit and Berry Plantation	4.8	5.52	6.4
Olive Grove	4.3	4.79	3.62
Broadleaf forest	8.3	8.19	38.62
Coniferous forest	16	20.10	156.66
Mixed forest	17	21.53	127.48
Grassland	9.4	11.69	41.23
Sclerophyllous vegetation	17	21.77	78.77
Transitional woodland-scrub	12	15.76	67.78
Beach, dune and sand	1.2	1.31	0.45
Waterbody	0.2	0	0
Total	100	120,89	531,78

4 Discussion

These results, which highlight the potential of applying SLM measures that promote SOC storage and soil retention within the watershed, have been used as the point of departure from which to identify ES benchmarks and future scenarios and priorities for potential actions (SLM practices) to shortcut the effects of landscape degradation and water scarcity with a set of key watershed stakeholders. To do so, we will incorporate the knowledge and preferences on ES and SLM actions of relevant stakeholders from the watershed into the ES maps and model diverse socio-ecological scenarios. By integrating this bottom-up approach we aim at facilitating decision-making toward more integrated and sustainable land management in the Mijares. This process of public participation is possible as the regional government of Valencia ratified its interest and commitment to participate in the project. With this methodology, we further plan to cross our LULC map with other ES models available in the ARIES platform (e.g. net value for pollination), input better resolution data, and readjust parameters of the used models to better fit the context of the Mijares.

5 Conclusions

SLM actions that promote carbon storage and soil retention appear as the most effective tools for strengthening the functioning of several Ecosystem Services (ES) in the Mijares given the large extent of forests (41.3%) and herbaceous vegetation areas (38.4%) within the watershed. From these results, the selection of SLM actions to be put in place will be the result of an interdisciplinary engagement that includes scientific research, the use of artificial intelligence, and the collaboration with key stakeholders of the watershed.

References

1. ARIES Homepage, https://aries.integratedmodelling.org/, last accessed 2021/04/15.
2. Bendini, H.N., et al. Detailed agricultural land classification in the Brazilian cerrado based on phenological information from dense satellite image time series. International Journal of Applied Earth Observation and Geoinformation, 82, 101–872 (2019).
3. CHJ, Confederación Hidrográfica del Júcar. Plan Hidrológico de la Demarcación Hidrográfica del Júcar. Revisión de tercer ciclo, 2021–2027 (2018).
4. ISRIC Homepage, https://www.isric.org/explore/soilgrids, last accessed 2021/04/15.
5. Pompeu J., Ruiz I., Ruano A., Sanz MJ. Land use and land cover databases for Mediterranean landscape analysis at the watershed scale. BC3 Working Paper Series 2021 01. Basque Centre for Climate Change (BC3). Leioa, Spain (2021).
6. Renard, K. G., Foster, G. R., Weesies, G. A., McCool, D. K., Yoder, D.C. Predicting soil erosion by water: a guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE). Agriculture Handbook, 703, USDA-ARS (1997).
7. Sanz, M. J., Vente, J. de, Chotte, J.-L., Bernoux, M., Kust, G., Ruiz, I., Almagro, M., Alloza, J.-A., Vallejo, R., Castillo, V., Hebel, A., and Akhtar-Schuster., M. (2017). Sustainable Land Management contribution to successful land-based climate change adaptation and mitigation
8. WOCAT SLM database, https://qcat.wocat.net/en/wocat/list/?type=technologies, last accessed 2021/02/11.