Simulation of irrigation in the Ebro River basin: new meteorological and physiographical datasets to better describe agriculture.

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1. Introduction

Irrigation consumes roughly 70% of the world's freshwater. Even though its advantages are well known, it has disadvantages such as the alteration of local and regional hydrological regimes, affecting continental water and energy cycles of irrigated basins and of their downstream areas. Moreover, climate change and population growth can stimulate the expansion of the irrigated agricultural surface, and the change to more efficient irrigation practices, which increase evapotranspiration, potentially increasing its hydrological impacts. Thus, irrigation management is a vital task for sustainability in a changing climate. The scientific community can help address this issue by developing tools to improve irrigation planning and monitoring. For example, Land Surface Models (LSM) permit testing scenarios, which is essential for water resources management. Irrigation schemes have been implemented in LSMs (Druel et al., 2021), but LSMs need forcing and physiographic data adapted to irrigation processes.

This work presents a new dataset to simulate irrigation (LIAISE-Ebro-Irrig-Sim, LE-IS) using a LSM, at 1 km spatial resolution, over the Ebro basin (Spain). It consists of a meteorological forcing and a Land Cover Map (LCM), an Actual Irrigated areas Map (AIM), and an Irrigation Methods Map (IMM). The Ebro basin is Spain's largest basin and one of Europe's major Mediterranean basins. Its precipitation is unevenly distributed: wet in relief areas, where water resources are generated, and dry in the central valley, where agricultural areas are situated. To manage the basin's water resources, there is an extensive network of dams and canals. According to the Ebro Hydrographic Confederation, irrigated agriculture and farming represent 92% of the basin's total water use.

2. Data

SAFRAN (Système d'Analyse Fournissant des Renseignements Atmosphériques à la Neige) is a meteorological analysis system developed at Météo-France (Durand et al., 1999). Observations and first guess data are combined using an optimal interpolation algorithm to compute estimates of precipitation, 2 m temperature, 10 m wind speed, 2 m relative humidity, and cloudiness. Modelled downward visible and infrared radiation are also provided.

LDAS-Monde LAI (Leaf Area Index) Assimilation Increments, computed for two summer days (20/08/2017 and 10/08/2019) at a spatial resolution of 1 km, were used in this study. LDAS-Monde (Albergel et al. 2017) is a tool, based on the SURFEX (SURFace EXternalisée) LSM, that can assimilate satellite-derived LAI from the Copernicus Global Land service in SURFEX's natural land surface scheme, ISBA (Interaction Sol Bioshère Atmosphère; Boone et al., 1999). In irrigated areas, the LAI increments are mostly due to irrigation, which is not simulated by the model.

ECOCLIMAP (Faroux et al., 2013) is a database that offers a set of land surface parameters and an ecosystem classification for meteorological and climate modelling. The latest version, ECOCLIMAP-SG (Druel et al., 2021), provides LCM, irrigated areas map, tree heights, and climatology of LAI and soil and vegetation albedo. Its LCM is based on ESA-CCI's, has a 300 m spatial resolution and thirty-three classes divided into water, natural, and urban types. It is the default physiography of the SURFEX LSM (Masson et al., 2013).

SIGPAC (FEGA, 2019) is the Spanish acronym for the Agricultural Plot Geographic Information System from the Spanish Ministry of Agriculture, Fisheries and Food. It contains farming and livestock plots information yearly reported by farmers. The data used corresponds to 2019 and 2020 and refers to the crops grown per plot and if the plot is prepared for irrigation.

AEMET (Spanish acronym for the Spanish Meteorological State Agency) (AEMET, 2011) and SMC (Catalan acronym for the Catalan Meteorological Service) (www.meteo.cat) offer observed meteorological station data. In this study, precipitation observations have been employed.

3. Methods

The LCM has been developed using SIGPAC data informing the crop to be grown per plot and year. First, SIGPAC crops were classified into ECOCLIMAP-SG LCM's vegetation classes. Second, each SIGPAC plot was assigned its crop correspondent vegetation class. Next, the map was interpolated to a 1 km grid. Finally, those pixels within the Ebro basin that had been identified with a different ECOCLIMAP-SG class, were also reassigned in the original ECOCLIMAP-SG LCM to obtain a new LCM.

The AIM has been developed combining SIGPAC data identifying which crops are prepared to be irrigated with LDAS-Monde LAI Assimilation Increments corresponding to two Summer days. The latter allowed us to differentiate potentially from actual irrigated areas. Validation analyses were done to define a threshold at which a pixel was considered to be irrigated. For this, datasets of potentially irrigated areas were used, since, to our knowledge, there are no datasets that provide information about actual irrigated areas. The threshold was established at 0.2. We believe that this value enabled us to be more selective and better restrict simulations to irrigated areas.

For the IMM the LCM and the AIM have been combined. First, irrigated regions from the AIM were divided into traditional and modern irrigation districts. Second, the LCM was used to differentiate between herbaceous and tree crops. The flood method was assigned to traditional irrigated crops, while the sprinkler and drip methods were assigned to herbaceous and tree crops, respectively.

A new version of the SAFRAN forcing has been developed at 1 km spatial resolution over the Ebro basin. The system has ingested AEMET and SMC observations for all variables, and it has used ERA5 (Hersbach et al., 2017) data as first guess, for all variables except precipitation.

4. Results

The LE-IS dataset has been developed after performing a validation study of the ECOCLIMAP-SG LCM, with SIGPAC as a benchmark, that showed poor results over the Ebro basin. In addition, since the AIM provided by this database corresponds to potentially irrigated areas, this data is overestimated over this basin.

Fig. 1 shows ECOCLIMAP-SG's LCM and irrigated areas map (first column) and LE-IS' LCM, AIM, and IMM (second column). It should be noted that ECOCLIMAP-SG does not have an IMM. First, comparing both LCMs, variations in the spatial distribution of herbaceous and tree crops can be observed. There is an increase of Summer C3 and C4 crops in LE-IS' map. Second, LE-IS' AIM shows a reduction of the irrigated surface if compared to ECOCLIMAP-SG's. This is coherent since the latter refers to potentially irrigated areas instead of actual ones. In addition, the irrigated areas identified in LE-IS AIM receive water from the main irrigation systems' major canals identified in the Hydrological Plan from 2015-2021 (Spanish Ministry of Agriculture, Fisheries and Food).

To analyse LE-IS' sensitivity we compared two SURFEX simulations done over the Ebro basin (2008 - 2019). Both use SAFRAN's new version, but one employs the default (ECOCLIMAP-SG) maps (Fig. 1) and the other one employs LE-IS'. It has been seen that with LE-IS, there is 28% less irrigation water than with the default physiography. This is mainly due to the decrease in irrigated surface. Fig. 2 shows mean annual modelled evaporation using ECOCLIMAP-SG (panel a) and LE-IS (panel b). Their difference is shown as a percentage in panel c. These differences can be due to the LCMs' redistribution of herbaceous and tree crops and that the evaporation rate is higher for the former than for the latter. For example, modelled evaporation over the region identified by the red rectangle (panel b) is lower when LE-IS is used than when ECOCLIMAP-SG is used to simulate it. This can be explained by the fact that the LCMs show different classes over this region: ECOCLIMAP-SG shows C3 and C4 crops, while LE-IS' shows a temperate broadleaf deciduous class.

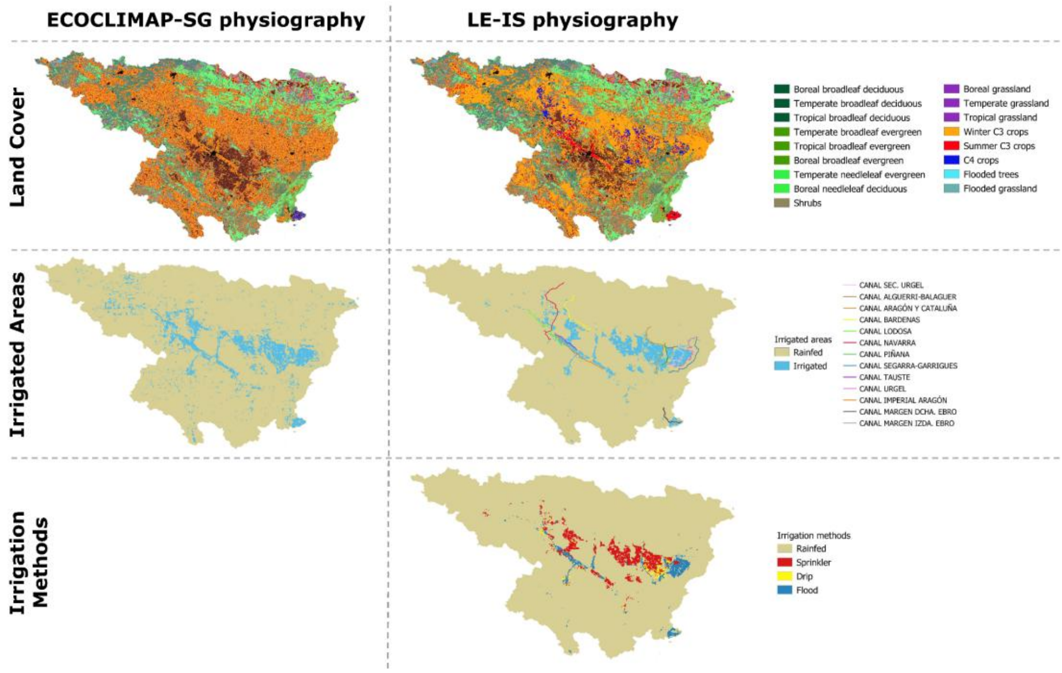

Figure 1. ECOCLIMAP-SG and LE-IS physiography: LCM, AIM, and IMM. Only the vegetation covers are provided in the LCM's legend. The main canals from the main irrigation systems identified in the Hydrological Plan from 2015-2021 have been included in LE-IS's AIM. It should be noted that ECOCLIMAP-SG does not provide an IMM.

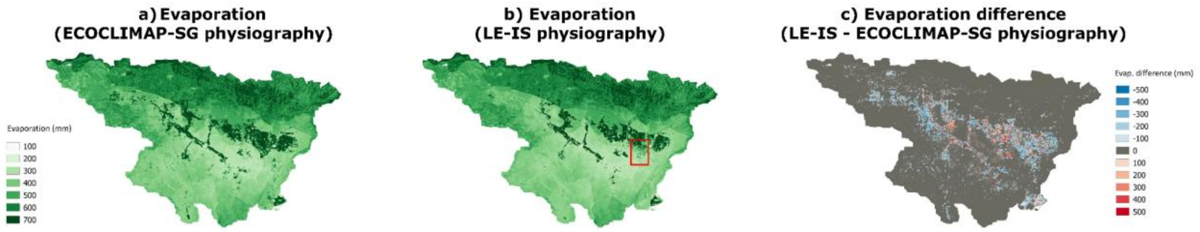

Figure 2. Mean annual (2008 to 2019) modelled evaporation using ECOCLIMAP-SG physiography (a), LE-IS data (b), and the difference as a percentage between them (c).

5. Conclusions

The LIAISE-Ebro-Irrig-Sim Data (LE-IS) is a dataset created to simulate irrigation using a LSM over the Ebro basin at 1 km spatial resolution. It consists of a meteorological forcing and the following maps: land cover, irrigated areas, and irrigation methods. The latter have been developed using annual information provided by farmers: crops grown per plot and if the plot is prepared for irrigation. Thus, LE-IS should favour a more realistic behaviour of modelled parameters affected by irrigated crops.

There are significant differences between ECOCLIMAP-SG and LE-IS LCM and AIM. For example, a redistribution of vegetation covers and a reduction of the irrigated surface. These affect modelled parameters. A comparison of two simulations using ECOCLIMAP-SG physiography and LE-IS' shows a reduction of irrigation with the latter physiography and different evaporation spatial patterns.

One of the main perspectives is to study the impact of different irrigation strategies on modelled parameters using LE-IS. It can also be used as a benchmark for comparison and validation studies.

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