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ON THE IMPORTANCE OF REMOTE SENSING DATA TO VALIDATE A DYNAMIC VEGETATION MODEL APPLIED TO A SEMI-ARID BASIN

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In Mediterranean ecosystems, the catchment water balance is directly affected by type, density and structure of vegetation. There are several dynamic vegetation models but most of them have large information requirements and this information is not always available on the field. On the other hand, nowadays satellite information can be used for this purpose. For this reason, in this work, we focused on the implementation of a parsimonious dynamic vegetation model, using both field measurements and satellite information. The results obtained suggest that a parsimonious model with simple equations can achieve good results in general terms and it is possible to assimilate satellite and field observations for the model implementation.

INTRODUCTION

The vegetation plays a key role in catchment's water balance particularly in semi-arid areas (Laio et al. [2]). In these water-controlled ecosystems, the vegetation structure controls the hydrological processes through its impact on the water cycle (Rodriguez-Iturbe et al. [8]). For this reason, the number of hydrological models which include vegetation development as a state variable has increased substantially (Quevedo and Francés [7]).

Most of these models are complex and they have normally high parameter requirements. However, in operational applications the available information is frequently quite limited. Therefore parsimonious models, together with available remote sensing information, can be valuable tools to predict vegetation dynamics (Medici et al. [3]). For this reason, we have focused on the use of the parsimonious and dynamic vegetation LUE-model proposed by Pasquato et al. [6].

The model was applied in a semi-arid catchment (La Hunde, East of Spain) covered predominantly by an Aleppo pine forest (by afforestation) and it was calibrated and validated using remote sensing data (in particular NDVI satellite products) and field observations (transpiration and soil moisture).

The main objectives of this work were: (1) to calibrate and validate the LUE model using both, satellite and field data; and (2) to check the capability of this parsimonious model to reproduce the vegetation dynamic and hydrological behavior in an experimental plot of this water-controlled basin.

FIELD MEASUREMENTS AND SATELLITE DATA

The Hunde experimental area is located in the southwest of Valencia Province in Spain. The climate is Mediterranean with a mean annual rainfall of 466 mm and a mean annual temperature of 13.7 ºC (1960-2007). The mean annual reference evapotranspiration is 749 mm. The vegetation in the study experimental plot is characterized by Aleppo pine plantations of high tree density with scant presence of other tree species either in forest gaps or as understory species (e.g., Quercus ilex sbsp. Ballota, Pinus pinaster) (Molina and del Campo, [4]).

Measurements of soil water content and transpiration were carried out in an experimental plot of 30x30 m. Soil water content was measured by 9 FDR sensors (EC-TM, Decagon Devices Inc., Pullman, WA), placed at 30 cm depth and considering either tree influence or not (under projected crown or not). Transpiration was measured in 4 trees. In each tree a HRM sap flow sensor was placed at 1.3 m height and at the north side (HRM sensor, ICT International, Australia). In this way, plant transpiration and soil moisture were obtained in the experimental plot during the period from 27/03/2009 to 31/05/2011.

The Leaf Area Index (LAI) of the experimental plot was measured only once at the beginning of the observation period (in March 2009) and its value was 2.6. More information about how this measure was done can be found in Molina and del Campo [4]. With this scarce data, the information provided by satellite was very useful. The satellite information used in this study was the Normalized Difference Vegetation Index (NDVI) included in the products MOD13Q1 and MYD13Q1 (NASA Land Processes Distributed Active Archive Center (LP DAAC)) and provided every 16 days at 250-meters spatial resolution.

CONCEPTUAL MODEL DESCRIPTION

The dynamic vegetation model was coupled with a hydrological model which follows a tank-based schema. This model was composed of three interconnected tanks. Briefly, the first tank corresponds with the amount of water retained by the canopy. The other two tanks correspond to the involved soil depth which is divided into two layers: a shallow layer that involves the processes of bare soil evaporation and superficial roots transpiration, and a second, underlying layer that provides soil moisture to deeper roots. A more detailed description of the hydrological model used can be found in Pasquato et al. [6].

The used dynamic vegetation model is based on the light use efficiency (LUE) concept as done by Montaldo et al. [5] and others. The LUE is the proportionality between plant biomass production by terrestrial vegetation and absorbed photosynthetically active radiation in optimal conditions. More specifically, the model simulates gross primary production (GPP) as a function of absorbed photosynthetically active radiation (APAR) and the LUE. Net primary production (NPP) is then calculated taking into account maintenance respiration. The modelling is focused particularly on simulating foliar biomass, which is obtained from NPP through an allocation equation based on the maximum LAI sustainable by the system, and considering turnover. Dawson et al. [1] showed that NDVI is influenced by leaf water content. For this reason, some authors (William and Albertson [9]; Pasquato et al. [6]) recommend the use of a water stress factor to make comparable the LAI with the NDVI (hereinafter, LAIr).

METHODOLOGY AND RESULTS

The calibration process was performed as follows: (1) the parameters involved in the hydrological model were automatically calibrated using plant transpiration and soil moisture as observed series and using recommended values for the parameters of the dynamic vegetation model taking into account that the LAI's values had to be around 2-4 as measured in field (some sources: Laio et al. [2]; Pasquato et al. [6]), (2) an automatic calibration of the parameters involved in the dynamic vegetation model using the NDVI data series provided by MODIS satellites (Aqua and Terra) and with the hydrological model previously calibrated and (3) an expert manual variation of some parameters to improve the combined results.

The results obtained in relation to transpiration and soil moisture are shown in figure 1. Taking into account that the proposed model is parsimonious and very simple, the obtained results are acceptable with a Pearson correlation coefficient of 0.717 and 0.859 for the calibration period and, 0.609 and 0.711 for the validation period for transpiration and soil moisture respectively.

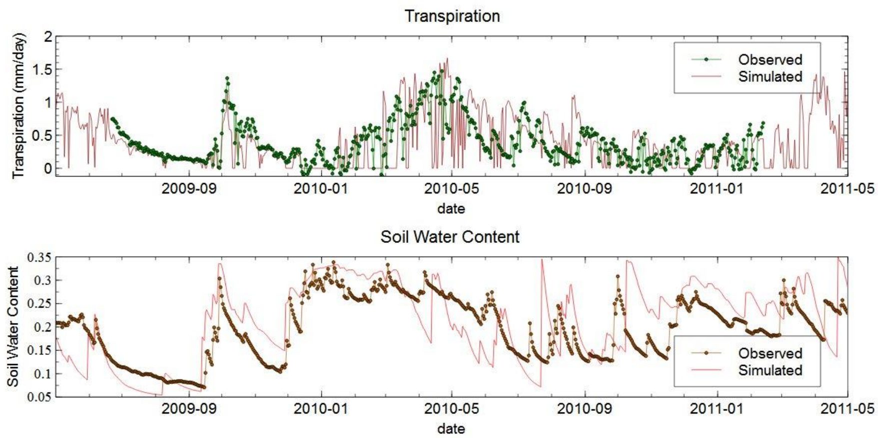

Fig.1. Results obtained in relation to transpiration and soil moisture for the whole simulation period

With regards to the vegetation dynamics, the periods with the worst results are shaded in Figure 2. The first and second ones correspond to very dry periods. In these two periods, the model underestimates the vegetation state. On the other hand, the third period corresponds to a very rainy period. In this case, the model overestimates the state of the vegetation. However, in general terms, there is a strong positive relationship between the LAIr simulated by the LUE-model and the NDVI provided by satellite in the whole period. In fact, the Pearson correlation coefficients between the LAIr and the NDVI from satellite are 0.635 and 0.499 for the calibration and validation period respectively.

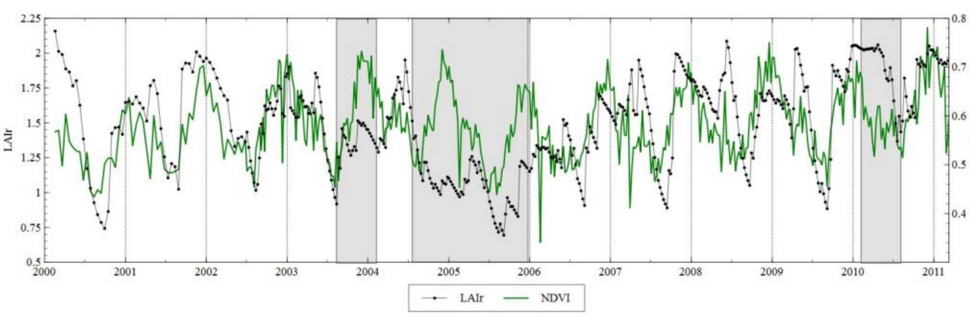

Fig.2. Comparison between LAIr simulated by the model and NDVI from satellite for the whole simulation period

CONCLUSIONS

The obtained results suggest that this parsimonious model is able to adequately reproduce the dynamics of vegetation (the correlation coefficient with the satellite and field transpiration data satisfactory) and also reproduces properly the soil moisture variations. In other words, it has been shown that a parsimonious model with simple equations can achieve good results in general terms and it is possible to assimilate satellite and field observations for the model implementation.

In this research, the satellite data played a key role in the implementation of the model. In fact, the measured transpiration data covered only less than two years with a high cost when the satellite NDVI observations were easily available from 2000 to now. Hence, the satellite data was a very useful complementary source of information.

To conclude, we want to emphasize the importance of satellite data in the future of hydrology modeling, especially in arid and semi-arid regions. In fact, nowadays, water scarce regions are often regions with a small amount of recollected information about vegetation state variables. In this information scenario, satellite data could be the best and single one source of information that can be used to implement hydrological models.

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