Recent advances in the interrelationship of vegetation and climate in Spain

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Introduction

The terrestrial biosphere is one of the most critical and complex components of the climate system, regulating fluxes of energy, water and aerosols between the earth surface and atmosphere. The terrestrial biosphere also is central to biogeochemistry of our planet, mostly with regard to the global carbon and nitrogen cycles. Particularly, vegetation plays an important role in the interaction between biosphere and atmosphere. Vegetation regulates energy exchange between the land biosphere and atmosphere, determines the hydrological processes and, through photosynthesis, fixes atmospheric carbon dioxide in the biomass. Thus, a better understanding of vegetation response to climate variability is crucial.

The purpose of this work is to synthesize the progress that has recently been made in understanding the atmosphere/vegetation interrelationships by the WCRP Spanish committee using remote sensing. Remote sensing technique plays a major role in the study of the biosphere processes by providing information on the spatial and temporal variations of many Earth processes at regional and global scale.

Studies in Spain

Regional Scale: Several studies are presented to quantitatively analyze changes in vegetation related to precipitation. The analysis is performed using different data sets (NOAA-AVHRR and MODIS-Terra) and along two different periods (1989-2002 and 2000-2009) (**Example A**). The vulnerability of natural ecosystems against the effects of climate fluctuations like drought is presented. Special attention is given to semiarid areas where vegetation is used as an indicator of landscape degradation (Martínez & Gilabert, 2009; Pérez-Hoyos et al., 2010).

Moreover, forest presently serves as a major net sink of atmospheric carbon being of great relevance to control the interchanges between vegetation and atmosphere. In this sense, an example of the modeling of regional carbon net fluxes of the Spanish forests from remote sensing is shown (**Example B**).

Local Scale: Different exercises have been carried out in order to get a deep insight in the relation between vegetation and atmosphere, particularly on land degraded areas. A local study is presented in Valencia region (**Example C**) (Estrela et al., 2009).

Examples

A. Vulnerability of Spain natural ecosystems to climate fluctuactions

The inter-annual changes on the NDVI NOAA-AVHRR database (MEDOKADS) was analyzed along the period 1989-2002 using a multi-resolution analysis (MRA) based on the wavelet transform (WT).

Results show that the MRA provides relevant information about vegetation dynamics at regional scale, such as the magnitude of the land-cover change. The latter, in combination with precipitation data, has been used to interpret the observed land-cover changes and identify those subtle changes associated to land degradation (Figure 2 left). Figure 2 (right) shows the Identification of land-cover changes associated with only negative trends. Red color depicts losses of vegetation cover associated to land degradation, which is affecting areas such as Almería and Murcia (A), Alicante (B) and Castilla-La Mancha (C).

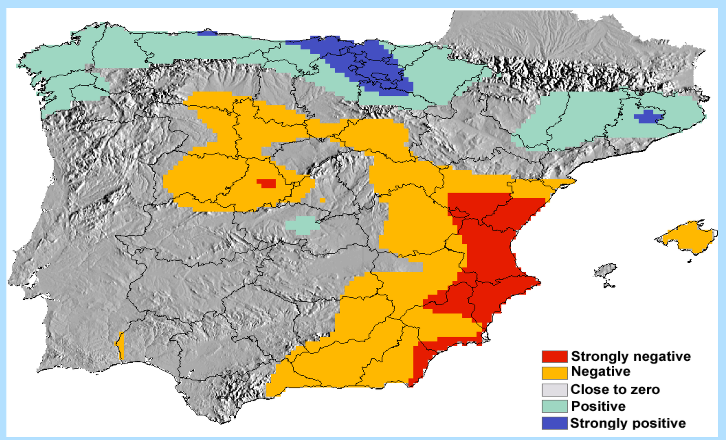


Figure 1. Trend of the SPI index computed from 59 SPI data by using the kriging method over the period 1989-2002

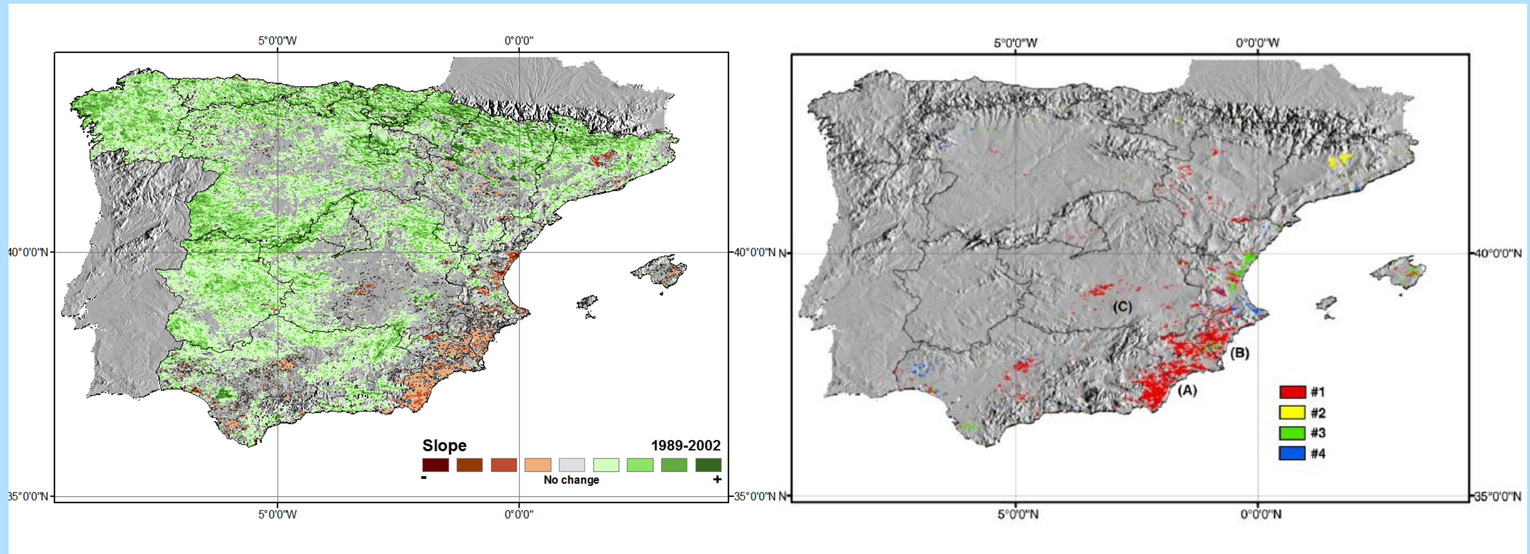


Figure 2. Magnitude of the land-cover change (left) and identification of negative trends along with climatic data (right)

Other example is the classification based on the Ecosystem Functional Types (EFTs) – i.e. units that group similarly functioning ecosystem based on functional attributes such as productivity or fluxes of matter and energy. EFTs were derived based on different satellite-based parameters from MODIS multitemporal data along the period 2000-2009 (Figure 3). Different metrics from fractional vegetation cover (FVC) which capture the phenological patterns are included. Other variables considered are the moisture index which is an indicator of the supply of water relative to the demand.

An algorithm based on self-organizative (SOM) combined with k-means was used to derive the functional diversity of the main and most representative ecosystems in the Iberian Peninsula (Figure 3).

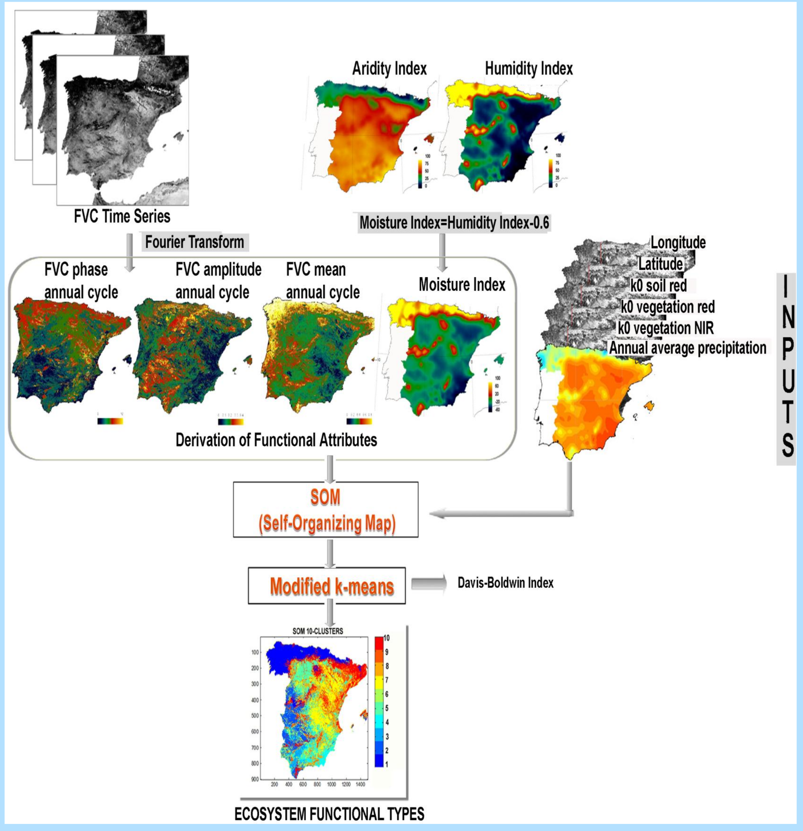


Figure 3. Flowchart of the methodology used for derived the EFTs.

EFTS show a decreasing biomass gradient from northwest to southeast in the Iberian Peninsula (Figure 4). Northern areas occupied by broadleaf forests, ecosystems with high biomass and low intra-annual variability (cluster 4). Southwest areas present functional ecosystems with low biomass and high intra-annual variability (cluster 8), usually sparse vegetation. The dominant EFTs, cluster 5 (9.4%) and cluster 1 (7.5%) occupy the central area of the Peninsula, and are closely related to crop areas with low biomass, high intra-annual variability and peaks in late spring.

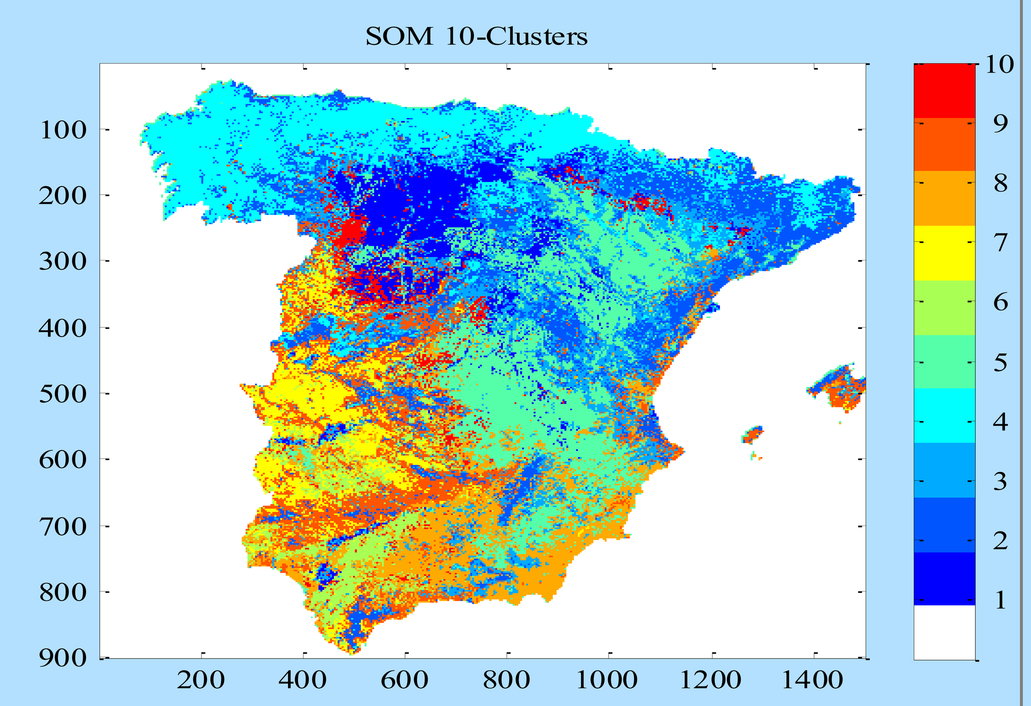


Figure 4. Distribution of ecosystem functional types (EFTs).

B. Carbon net fluxes of the Spanish forests

Forests have an important role in regulating both water and carbon cycles. The necessity for monitoring and quantifying the amount of carbon accumulated within forests has increased in the last decade.

This example shows an optimized remote sensing-based procedures to estimate monthly CO_2 fluxes in Spanish forests based on (1) Estimation of daily global radiation and *PAR*, (2) estimation of daily filtered *fAPAR* (3) estimation of the RUE coefficient (Figure 5), and (4) incorporation of optimized forest land cover information.

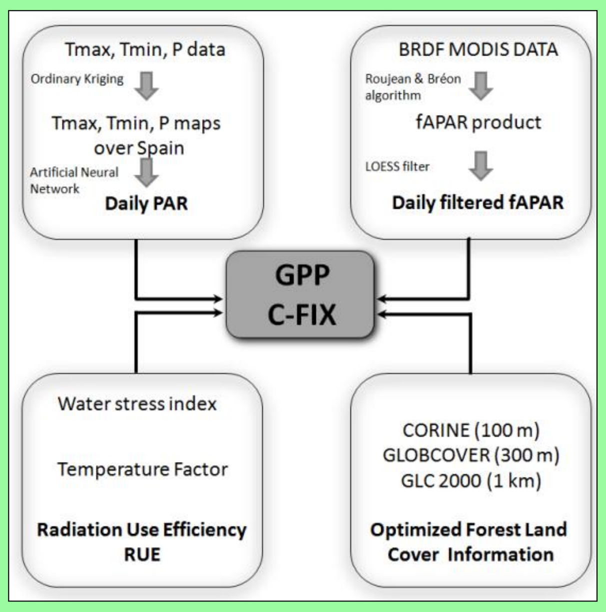


Figure 5. Methodology proposed to derive monthly *GPP* at 1 km for the Spanish forests.

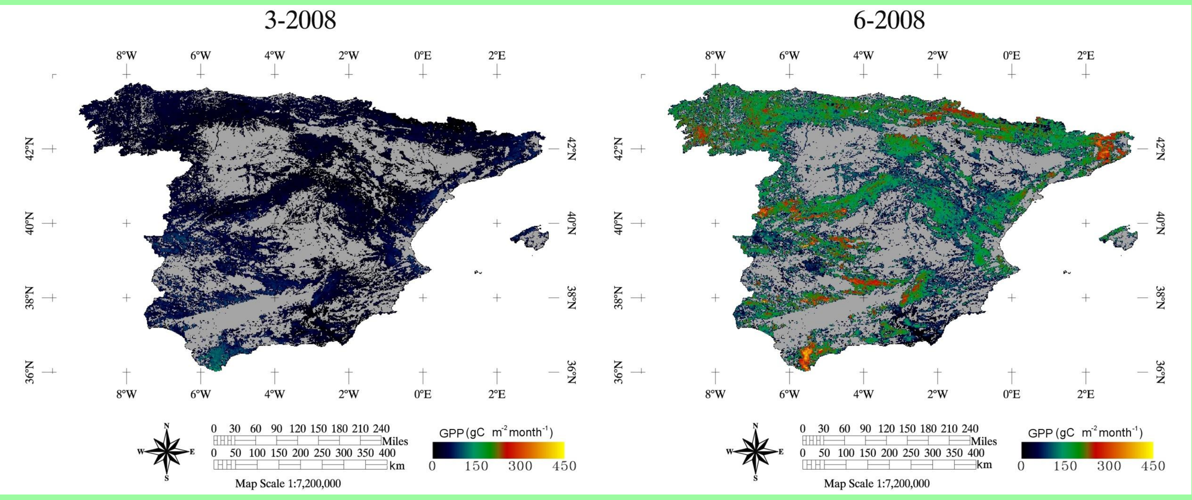
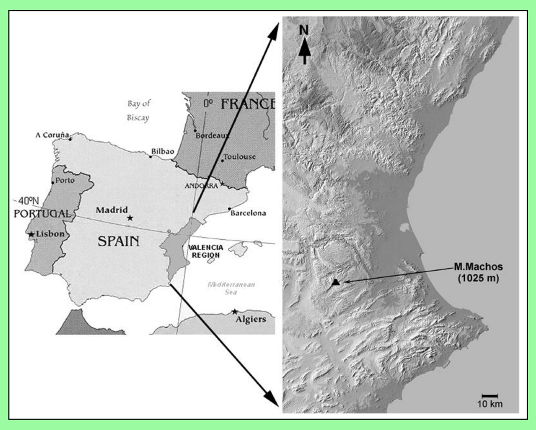


Figure 6. Examples of monthly *GPP* estimated for two different seasons. Grey: non-forestal areas.

C. Interrelation between vegetation and atmosphere at a local scale

The good potential for fog water collection at certain mountainous locations has lead to considered this new and easily available water as a resource for the reforestation of remote areas where land degradation has occurred after the long-term effects of fire.



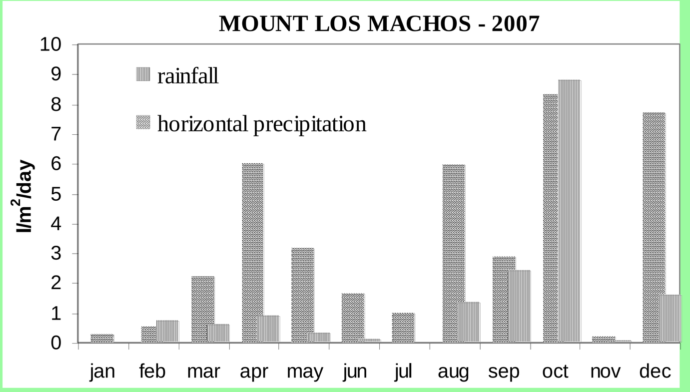


Figure 7. Rates (L/m2/day) of rainfall and fog (horizontal precipitation) for 2007.

The experimental plot, located in an inland mountainous area of the Valencia region, covers an area of about 2500 m². In 1979 a great wildfire burned around 30000 ha of mixed mature pine forest mainly dominated by maritime pine (*Pinus pinaster*) and, in a lesser extent, Aleppo pine (*P. halepensis*). Vegetation recovered after the wildfire with an abrupt change in species dominance and community structure.

Seedling survival rate of both species was high in relation to other field experiments conducted on in the same area. Holm oak responded to water pulses increasing seedling survival both with and without biosolid application. Maritime pine showed a trend to increase seedling survival with the water pulses only in the fertilized seedlings.

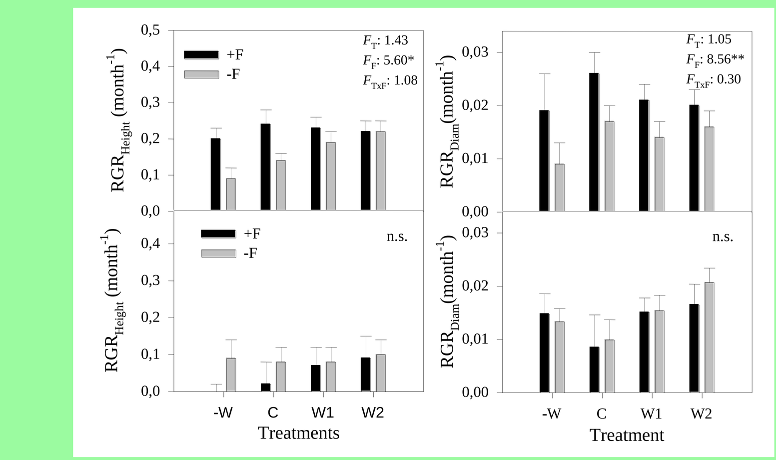


Figure 8. Relative growth rate (mean and standard error of all surviving individuals) of *Pinus pinaster* (top) and *Quercus ilex* (bottom) seedlings from late spring to winter in relation to Fertilization (F) and Water pulses (W) treatments.

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