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Vegetation dynamics and soil water balance in a water-limited Mediterranean ecosystem on Sardinia, Italy

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Semi-arid regions, such as around the Mediterranean, suffer from broad desertification processes produced by both natural (climate variations, fires, etc.) and human (deforestation, overgrazing, urbanization, pollution, fires, etc.) influences. Mediterranean ecosystems are commonly heterogeneous savanna-like ecosystems, with contrasting plant functional types (PFTs, e.g., grass and woody vegetation) competing for the water use. At the same time the structure and function of the vegetation regulates the exchange of mass, energy and momentum across the biosphere-atmosphere interface, influencing strongly the soil water budget. Vegetation dynamics are usually neglected, other than seasonal phenology, in land surface models (LSMs). However, changes in vegetation densities, influencing the partitioning of incoming solar energy into sensible and latent heat fluxes, can result in long-term changes in both local and global climates (e.g., precipitation and temperature), which in turn will feedback to affect the vegetation growth. In semi-arid regions, this may result in persistent drought and desertification, with substantial impacts on the human populations of these regions through reduction in agricultural productivity and reduction in quantity and quality of water supply.

With the objective to investigate vegetation dynamics, soil water budget and land-surface fluxes interactions in a water-limited ecosystem, an extensive field campaign in a Mediterranean water-limited field is performed, and a parsimonious and robust vegetation dynamic model (VDM) is coupled to a 3-component (bare soil, grass and woody vegetation) LSM.

The case study is in Orroli, situated in the mid-west of Sardegna within the Flumendosa river watershed. Sardinia is a region that suffers from water scarcity, and the Flumendosa basin plays a primary role in the water supply for much of southern Sardinia, including the island's biggest city, Cagliari. The site landscape is a mixture of Mediterranean patchy vegetation types: trees, including wild olives and cork oaks, different shrubs and herbaceous species. An extensive field campaign started in April 2003. More than three years of data are available now. Interestingly, hydrometeorological conditions of the monitored years strongly differ, with dry and wet years in turn, and a wide range of hydrometeorological conditions can be analyzed. Land-surface fluxes and CO_2 fluxes are estimated by an eddy correlation technique based micrometeorological tower. Soil moisture profiles were also continuously estimated using water content reflectometers and gravimetric method, and periodically leaf area index (LAI) estimates of both plant types are made using the Accupar LP-80 by Decagon Devices Inc. Furthermore, two high spatial resolution (2.8 m) Quickbird satellite images were acquired in August of 2003 and March 2004 for defining the spatial organization of the main land cover types around the tower for two contrasting seasons of the year (Summer and Spring).

A parsimonious ecohydrologic model is developed. The VDM computes the change in biomass over time as difference between the rate of production (e.g., photosynthesis) and the rate of destruction (e.g., respiration and senescence). VDM incorporates two PFTs using basic rules regarding competition for a limiting resource. The VDM is then coupled to a 3-component LSM, with the VDM providing the green biomass and the LAI evolution through time, and the LSM using this information in the computation of the land surface fluxes and updating the soil water content in the root-zone.

The coupled VDM-LSM model is successfully tested for the case study, demonstrating model high performance for the wide range of eco-hydrologic conditions included in the observation period. Results demonstrate that vegetation dynamics influence strongly water balance and resources of this Mediterranean ecosystem, and the inclusion of the VDM in the LSM is demonstrated to be essential when studying the climate-soil-vegetation interactions.