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Actual evapotranspiration estimation in a Mediterranean mountain region by means of Landsat-5 TM and TERRA/AQUA MODIS imagery and Sap Flow measurements in Pinus sylvestris forest stands.

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Evapotranspiration monitoring has important implications on global and regional climate modelling, as well as in the knowledge of the hydrological cycle and in the assessment of environmental stress that affects forest and agricultural ecosystems. An increase of evapotranspiration while precipitation remains constant, or is reduced, could decrease water availability for natural and agricultural systems and human needs. Consequently, water balance methods, as the evapotranspiration modelling, have been widely used to estimate crop and forest water needs, as well as the global change effects. Nowadays, radiometric measurements provided by Remote Sensing and GIS analysis are the technologies used to compute evapotranspiration at regional scales in a feasible way. Currently, the 38% of Catalonia (NE of the Iberian Peninsula) is covered by forests, and one of the most important forest species is Scots Pine (Pinus sylvestris) which represents the 18.4% of the area occupied by forests. The aim of this work is to model actual evapotranspiration in Pinus sylvestris forest stands, in a Mediterranean mountain region, using remote sensing data, and compare it with stand-scale sap flow measurements measured in the Vallcebre research area (42º 12' N, 1º 49' E), in the Eastern Pyrenees.

To perform this study a set of 30 cloud-free TERRA-MODIS images and 10 Landsat-5 TM images of path 198 and rows 31 and 32 from June 2003 to January 2005 have been selected to perform evapotranspiration modelling in Pinus sylvestris forest stands. TERRA/AQUA MODIS images have been downloaded by means of the EOS Gateway. We have selected two different types of products which contain the remote sensing data we have used to model daily evapotranspiration, daily LST product and daily calibrated reflectances product. Landsat-5 TM images have been corrected by means of conventional techniques based on first order polynomials taking into account the effect of land surface relief using a Digital Elevation Model, obtaining an RMS less than 30 m. Radiometric correction of Landsat non-thermal bands has been done following the methodology proposed by Pons and Solé (1994) which allows to reduce the number of undesired artifacts that are due to the effects of the atmosphere or to the differential illumination which is, in turn, due to the time of the day, the location in the Earth and the relief (zones being more illuminated than others, shadows, etc). Atmospheric correction of Landsat thermal band has been carried out by means of a single-channel algorithm improvement developed by Cristóbal et al. (2009).

To compute actual evapotranspiration (AET) we have used the B-Method proposed by Jakson et al. (1977) and modified by Carlson et al. (1995) and Caselles et al. (1998), based on the energy budget, that needs as an input variables net radiation (Rn) and the difference between land surface temperature (LST) and air temperature (Ta). Air temperature has been modelled by means of multiple regression analysis and GIS interpolation using ground meteorological stations. Net radiation have been computed following two approaches based on the energy balance equation using albedo, land surface temperature, air temperature and solar radiation. Both air temperature and net radiation have been modelled at a regional scale.

We have compared remote sensing daily actual evapotranspiration estimates with measured canopy transpiration. Sap flux density was measured by means of Heat dissipation sensors in 12 trees per stand, sampled according to diametric distribution, corrected to account for radial patter of sap flow using the Heat Field Deformation method and then scaled-up to stand level transpiration using tree sapwood areas. Sap flow measurements are comparable with AETd as in the Scots pine stand understorey evaporation is not significant. Measurements with sap flow technique show a mean, minimum and maximum values of AETd = 2.2, 0.6 and 3.6 mm day -1, respectively (Poyatos et al. 2005).

Results show, in the case of MODIS AETd modelling, a RMSE of 1.6 mm compared with sap flow measurements. These results show that computing AETd by means of MODIS data in a heterogeneous area do not offer good results due to its spatial resolution (1 km). In the case of Landsat-5 TM AETd modelling, we have obtained better results with a RMSE of 0.6 mm which are in agreement with other studies that present an estimated error of about $\pm$ 30%. Moreover, we have to take into account that Landsat-like spatial resolution seems to be the best option to estimate AETd in this kind of areas.

Keywords: Actual evapotranspiration modelling, Sap Flow, Remote Sensing, Pinus sylvestris, Mediterranian region.