Water Budget with Phenology derived from Optical Satellite Data

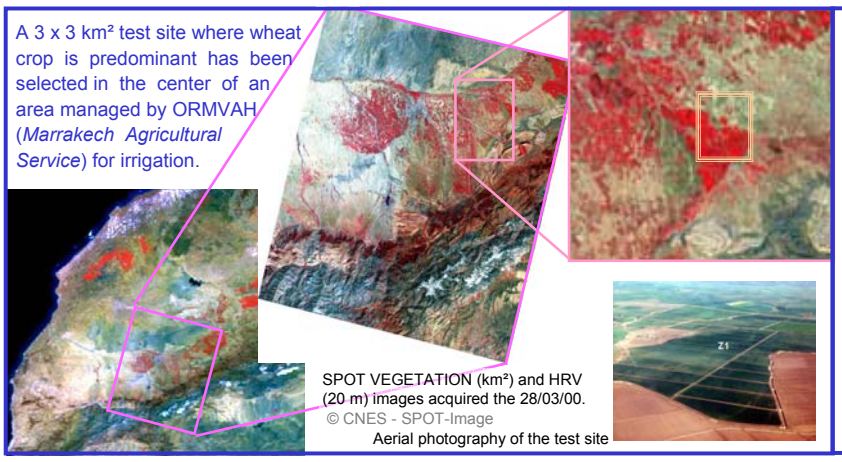
B. Duchemin, F. Frappart, M. Magnac ✗ G. Chehbouni, G. Dedieu, P. Maisongrande, B. Mougenot

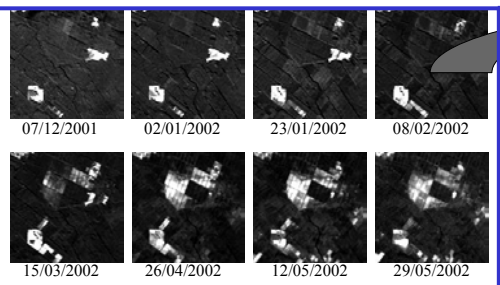
Summary: The SUD-MED project aims at the monitoring of water resources on semi-arid regions by coupling ground truth, process models and satellite measurements. The test area is the water catchment of Oued Tensift that covers about 30.000 km² around the Marrakech city. The climate is arid : the pluviometry is weak and irregular (~ 240 mm/year) while the potential evapotranspiration is very high (ETP=2,400 mm/year). Hydrological processes are dominant on mountains (Atlas at South and Jbilet at North of the Catchment), while the vertical water budget - Rainfall, Irrigation, Drainage and Evapotranspiration – is the major term to be known for irrigated crops in the plain. Dominant irrigated crops are cereals, olive and orange trees. Here we attempted to estimate the latent heat flux of cereals over a 3 x 3 km² site where. Spatial results were obtained using a time series of 8 SPOT-HRVIR data at high spatial resolution (20 m) acquired during the 2001-2002 agricultural season.

Two methods were compared. The first one was developed by the FAO (Allen, 1998) to assess crop water requirements. The second one is based on the STICS agrometeorogical model (Brisson et al. 1998) for the estimation of actual latent heat fluxes of wheat. In both cases, we present maps where evapotranpirations were cumulated during the 2001-2002 agricultural season. These maps were established through remote sensing data, either by estimating phenological stages and crop coefficients (case of FAO method), or by calibrating the time course of Leaf Area Index (case of STICS model). The difference between the two maps allows to caracterise the water deficit, but data was not available to validate the results. Efforts will first be addressed to collect ground truth. The perspective is also to provide water budget map at a regional scale through the used of both high and coarse spatial resolution satellite data.

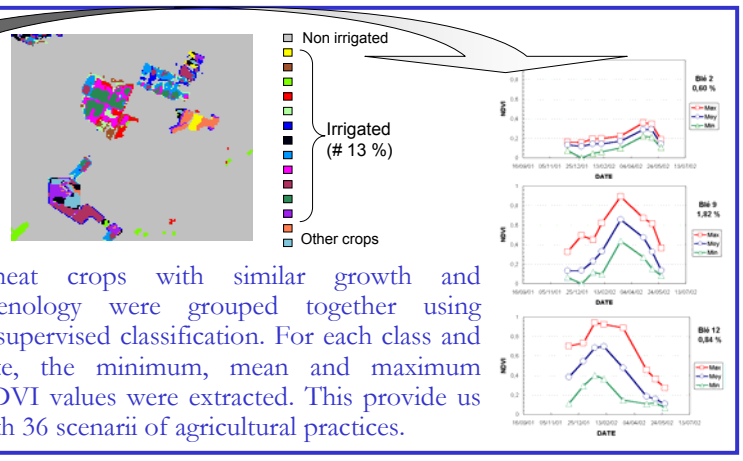
Test Area and Satellite Data

A 3 x 3 km² test site where wheat crop is predominant has been selected in the center of an area managed by ORMVAH (*Marrakech Agricultural Service*) for irrigation.





Time series of NDVI derived from 8 SPOT HRV data were analysed. Due to a severe drought year 01/02, irrigation was partially done. Crop development was generally weak and delayed because of late rainfall.



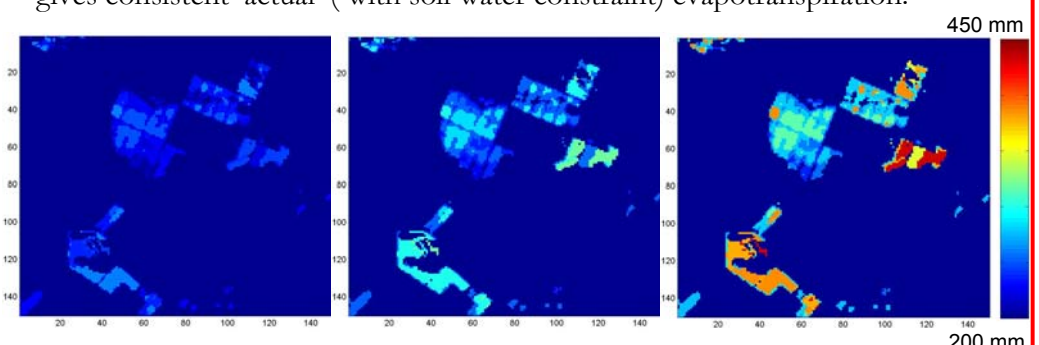
Wheat crops with similar growth and phenology were grouped together using unsupervised classification. For each class and date, the minimum, mean and maximum NDVI values were extracted. This provide us with 36 scenarii of agricultural practices.

Estimating Evapotranspiration…

…using the STICS model

STICS (Simulateur mulTIdisciplinaire pour les Cultures Standards, Brisson et al. 1998) is a crop model constructed as a simulation tool able to work under agricultural conditions. The latent heat flux was calculated through the resistive scheme. A sensitivity analysis gave us the major parameters that drive evapotranspiration : humidity at field capacity and at wilting point, apparent soil density, day of maximum Leaf Area Index (LAI) and maximum rate of the setting up of LAI.

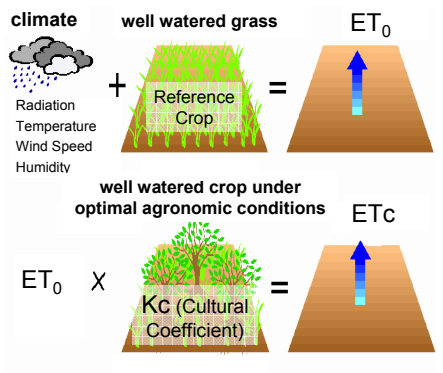
Soils properties were determined through the analysis of soil maps and pedo-transfert rules. The day of maximum LAI was determined by analysing NDVI time series for each scenario. NDVI also provide us with LAI through the equations of Baret et al, 1989. The maximum rate of the setting up of LAI was optimised against the LAI derived from the SPOT-HRV time series in the STICS model through a Simplex Algorithm. After optimisation, the model gives consistent 'actual' (with soil water constraint) evapotranspiration.



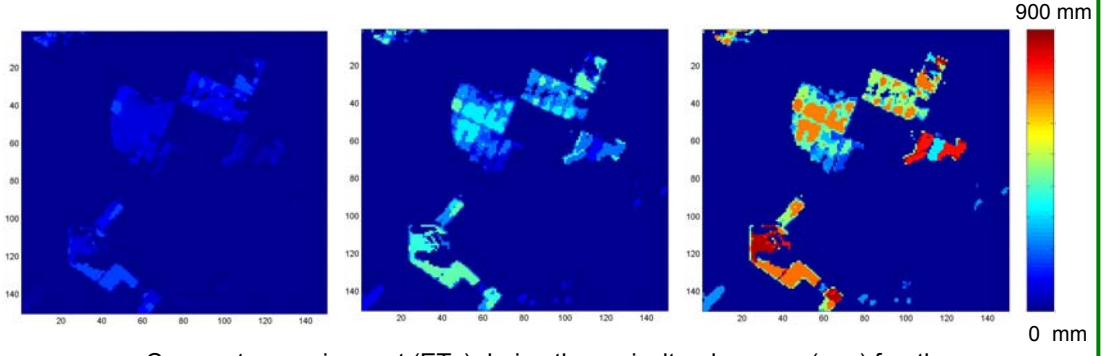
Cumulated 'actual' evapotranspiration (ETr) during the agricultural season (mm) for the minimum (left), the mean (center) and the maximum (right) scenario of crop growth

… using the FAO method

In the FAO method, the concept of the reference evapotranspiration (ET_0) was introduced to study the evaporative demand of atmosphere independently of crop type, crop development and agricultural practices. The crop evapotranspiration **ETc** under standard conditions (disease-free, well-fertilized crops, grown in large fields, under optimum soil water conditions and achieving full production) is obtained through a cultural coefficient (**Kc**).

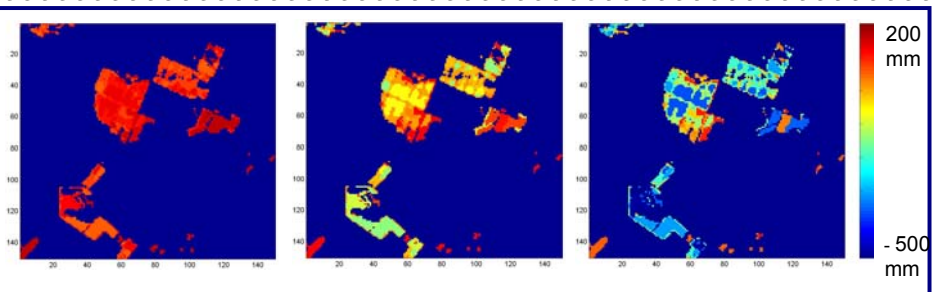


Here the Kc was driven through an exponential relationship with NDVI (as for LAI) assuming it reaches its minimum value (0.4) at planting and yield (NDVI = 0.13) and its maximum value (1.15) when the canopy is totally covering the soil (NDVI ≥ 0.5). This approach predicts evapotranspiration in 'standard' conditions.



Crop water requirement (ETc) during the agricultural season (mm) for the minimum (left), the mean (center) and the maximum (right) scenario of crop growth

Finally, the difference between the two maps (Etc/FAO – Etr/STICS) can be interpreted as a water stress index. These results need now to be validated using experimental data that we planned to acquire during the 2002/2003 agricultural season. After the validation phase, a second perspective will be offered by using additional coarse spatial resolution satellite data and deconvolution algorithm to provide results inside mixed pixels at a regional scale.



Sums of Etr ('actual' evapotranspiration) – ETC (crop water requirement) difference during crop growing for the minimum (left), the mean (center) and the maximum (right) scenario. When highly negative, this difference measures water stress on well-developed crops.

Corresponding author :
benoit.duchemin@cesbio.cnes.fr
http://www.cesbio.ups-tlse.fr

References :

Allen R.G., 1998. Crop evapotranspiration – Guidelines for computing crop water requirements – FAO Irrigation and drainage paper 56. *Food and Agriculture Organization of the United Nations, Rome, 1998* (ISBN 92-5-104219-5, see http://www.fao.org/docrep/X0490E/X0490E00.htm)

Brisson et al. 1998. STICS : a generic model for the simulation of crops and their water and nitrogen balances. I Theory and parametrization applied to wheat ant corn. *Agronomie* 18: 311-346