SAMIR, "Satellite Monitoring of Irrigation"

A tool for irrigation monitoring using remote sensing for landcover mapping and evapotranspiration estimation

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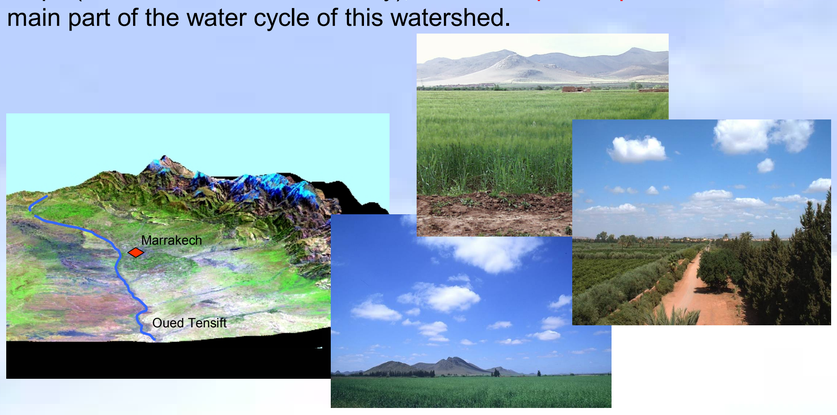
***ABSTRACT** : The sudmed project, carried out by CESBIO (Toulouse, France) and University Cadi Ayyad (Marrakech, Morocco), is studying the hydrological functioning of the Tensift semi-arid Watershed (Marrakech, Morocco), to help monitoring its hydrological resources. The evapotranspiration (ET) of the irrigated crops of the plain is one of the major fluxes of this watershed, which consumes 85% of the water used. To assess the evapotranspiration at the plain level (10000 km2), we built the SAMIR software based on the «FAO» model (Allen et Al. 1998). FAO method was chosen because of the good trade off it achieves between data requirements and results accuracy. ET estimation requires 3 types of data : (1) climate to compute reference ET0, (2) land cover and (3) vegetation development (= Kc). SAMIR includes also a simple soil module allowing to compute the water budget of the crop and thus the irrigation requirements. An example of pumpings estimates at the Haouz plain level is given.*

Introduction

Irrigation is the world major water consumer, using about 65% of the resources. As more and more arid areas are facing water shortage problems, the design of tools providing with spatialized estimates of crop water balance is useful to ensure for a sparing water management. Evapotranspiration (ET) of the irrigated crops is one of the major fluxes conditioning the water budget. ET assessment basically requires information about climate, vegetation state and soil water content. Remote sensing is a major data source for vegetation study, including crop identification and development monitoring. High resolution remote sensing time series are now or will be soon available (SPOT, FORMOSAT-2, Venus (2009)). This type of data allow the monitoring of vegetation stages over large areas, giving access to development stage of vegetation, which are usually the critical point in estimating ET.

Study area

The Haouz plain has a semi-arid climate : 240 mm annual rainfall, 1400 mm potential evapotranspiration (ET). Covered with about 150000 ha of irrigated crops (wheat and olive trees mainly), whose evapotranspiration is one of the main part of the water cycle of this watershed.



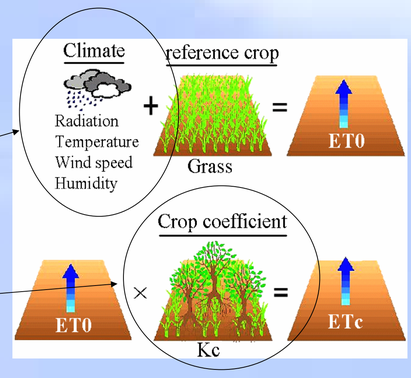
Objectives of the SAMIR tool

- Estimation of evapotranspiration and water balance of the crops
- Estimation of the water needs, from daily to annual forecast
- Spatialization of water balance

The FAO method (Allen et Al. 1998) was chosen here because data available is not enough to run complex physical based models

FAO method is based on the multiplication of :

- **a climatic component** (ET0)
- **a crop coefficient** (Kc) obtained from **satellite data**



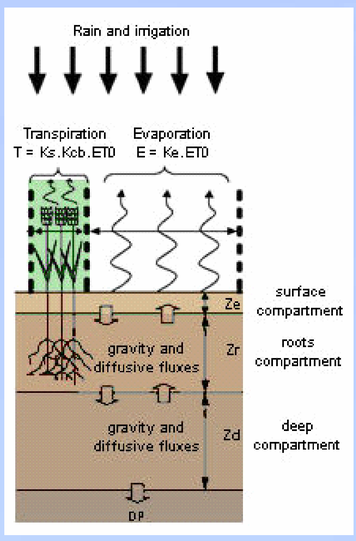
Climatic data is obtained from ground measurements or from meteorological model outputs, and is used to compute the reference evapotranspiration ET0.

The land cover in the area is complex, including trees plantations and annual crops, trees often including understories of trees. Thus, only 4 main crop types were discriminated based on NDVI time profile analysis and very high resolution images texture analysis to identify trees.

The crop development coefficients (Kc) are derived from NDVI using calibrated relations, and considering the land cover class of each pixel.

A three compartments soil model is linked to the evaporation calculation allowing the computation of the full water budget of the crop, according to the following equation :

Rainfall + Irrigation
=
Evaporation + Transpiration
+ Deep Percolation + Δ Soil Water Content



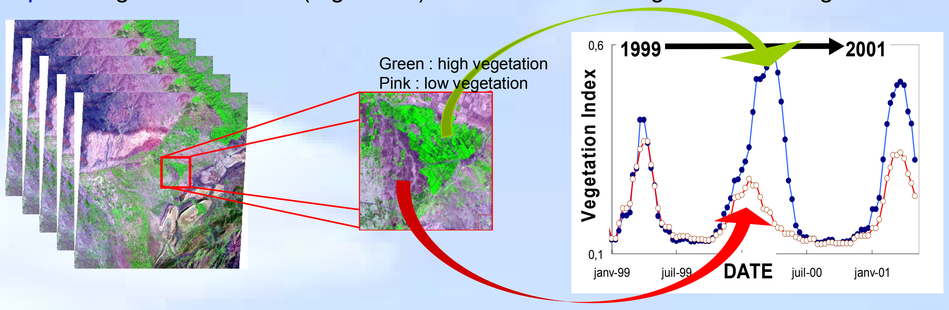
=> Irrigation is either input or estimated by SAMIR

- surface compartment for soil evaporation only
- root compartment for crop transpiration only
- deep compartment standing for deep storage.

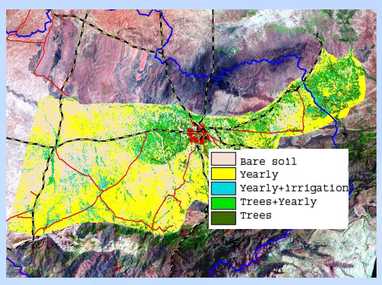
Excess water pouring from deep compartment is considered as lost for the crop

Satellite images provides with a regular synoptic view of the vegetation.

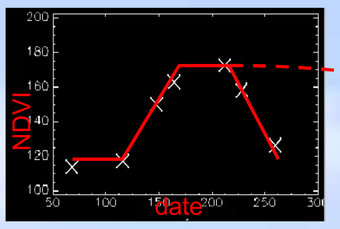
Step 1- Vegetation indexes (e.g. NDVI) can be related to vegetation coverage



Step 2- Classification of NDVI time profiles allows identification of 4 broad land cover classes



Step 3- Knowing landcover type, the NDVI time profile from satellite can be related to the time evolution of the crop coefficient of the FAO method



Example of **wheat**

Kc = 1.7 (NDVI – NDVImin)

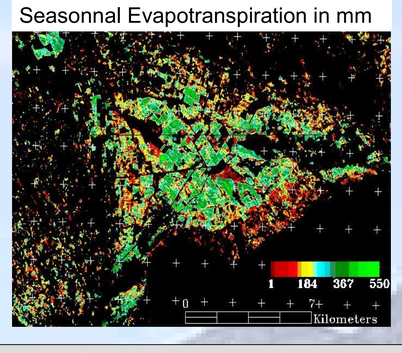
Profile fitted using trapeze forms or spline interpolation when enough points available

Output

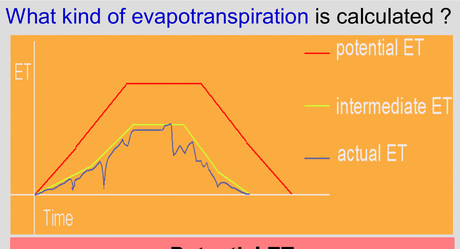
→ at the plain and plot scale

Evapotranspiration maps

Seasonnal Evapotranspiration in mm



What kind of evapotranspiration is calculated ?



Potential ET
Evapotranspiration in non-limitant condition (without water stress) = **by the book theory**

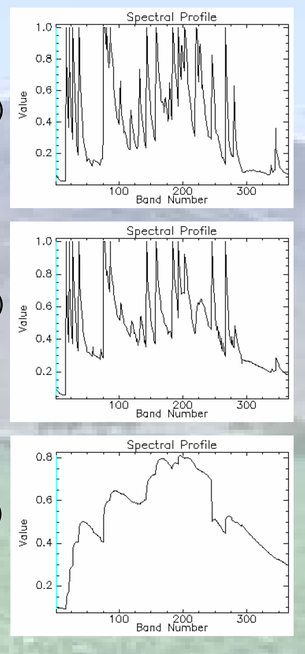
Intermediate ET
Intermediate level between potential and actual ET
=> available with **remote sensing single crop approach without soil modelling.**

Actual ET
Actual Evapotranspiration (water stress and soil evaporation considered => **SAMIR** using dual crop approach and soil modelling

Soil water temporal profiles

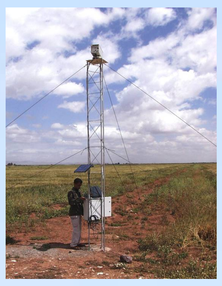
→ Decomposition of the processes at the pixel scale

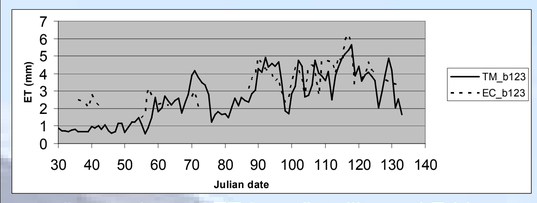
Example of a annual crop : (a) surface, (b) roots and (c) deep soil compartments.



Validation of ET

using ground measurements of the water fluxes (scintillometers and Eddy correlation systems)



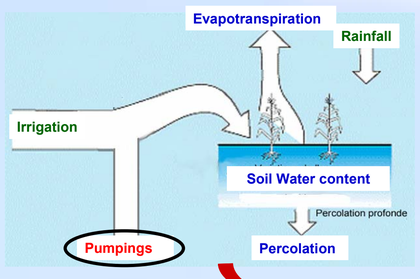


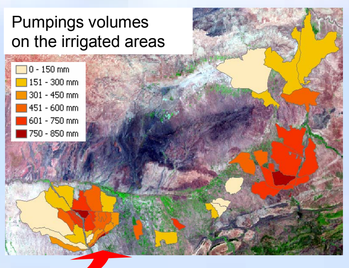
Comparison of ET from Satellite and Eddy correlation measurements in 3 wheat fields (the plot illustrates one of them)

Average difference is 27% at the daily scale but decrease to 18% at the weekly scale. The overall difference was 5% for the whole set of measurements (including 3 plots, total of 160 days).

Application to pumpings estimation

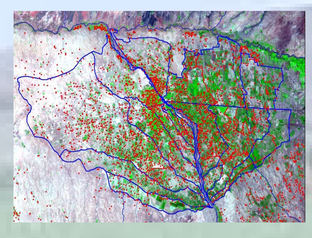
The overexploitation of the aquifer in irrigated areas makes it a key information for the water managers



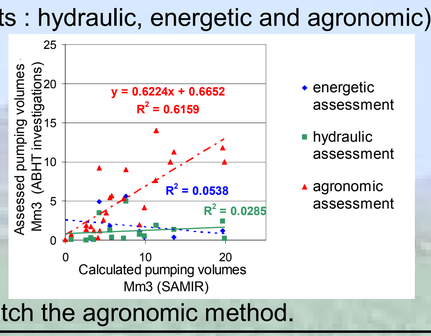


ET + Percolation + Δ Soil = Rainfall + Irrigation + Pumpings

→ **Validation** using punctual pumping assessments from the Tensift Basin Hydraulic Agency (ABHT) (3 assessments : hydraulic, energetic and agronomic).



Sum of pumpings per irrigation sector →



=> The SAMIR estimations match the agronomic method.

Ongoing Developments

=> Developing the irrigation rules in order to well reproduce the actual conditions.

=> Developing forecasting capabilities : phenology extrapolation, based on statistical or model based extrapolation of crop development.

IRD Institut de recherche pour le développement

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