Using satellite-based remote sensing data and field measurements to validate a dynamic vegetation model implemented in a water-controlled catchement

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GLOBAL VEGETATION MONITORING AND MODELING

INTRODUCTION

It is well known that the vegetation plays a key role in the catchment's water balance particularly for semi-arid areas. For this reason, the number of hydrological models which include vegetation as a state variable has increased in the last decade. However, frequently, the available information to implement those dynamic vegetation models is quite limited. Therefore, satellites are a valuable source of information.

In this work, the authors focused on the use of a parsimonious model called LUE-model[3]. The main advantages of this simple conceptualization are: (1) the low number of parameters, (2) it could be easily coupled with a hydrological model and, (3) it is directly connected with satellite data. The main objectives of this work were: (1) calibrate and validate the LUE model using both, satellite and field data; and (2) check the capability of the model to reproduce the vegetation dynamic and hydrological behavior (soil moisture and transpiration).

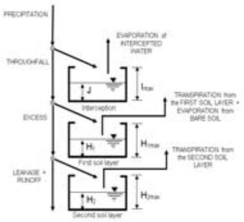
STUDY AREA

- La Hunde catchment
- East of Spain
- Area: 16.94 km^2
- Mediterranean climate
- Predominantly covered by Aleppo pine
- Water-controlled catchment

Experimental plot location

MODEL DESCRIPTION

CONCEPTUAL SCHEMA



HYDROLOGICAL MODEL

Water balance equation:

$$\frac{dH_1}{dt} = (P - I) - D - E - T_1$$

$$\frac{dH_2}{dt} = D - L - T_2$$

Interception storage:

$$\frac{dJ}{dt} = I - \min(ET_o \cdot f_t, J)$$

FAO: $T = ET_o \cdot \lambda_v \cdot \lambda_s$

Transpiration:

$$T_1 = ET_o \cdot f_t \cdot \min(LAI,1) \cdot \beta_t(H_1) \cdot r_1$$

$$T_2 = ET_o \cdot f_t \cdot \min(LAI,1) \cdot \beta_t(H_2) \cdot (1 - r_1)$$

Bare Soil Evaporation:

$$E = ET_o \cdot f_b \cdot \beta_b(H_1)$$

VEGETATION MODEL

LUE-Model

$$\frac{dB_l}{dt} = (LUE \cdot \varepsilon \cdot APAR - \mathrm{Re}) \cdot \varphi_l - \kappa_l \cdot B_l$$

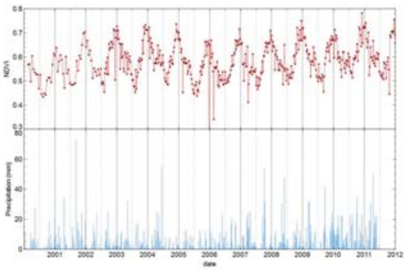
$$\varphi = 1 - \frac{LAI}{LAI_{max}}$$

ε depends on:
Water Stress: **connection with hydrological model**
Temperature

$$LAI = B \cdot SLA \cdot f_t \qquad LAI_r = LAI \cdot \left(1 - \overline{\zeta_{10}}\right)$$

B: leaf biomass [kg DM m^{-2} ground]
LUE: light use efficiency [kg DM MJ^{-1} m^{-2}]
APAR: absorbed photosynthetically active radiation [MJ m^{-2} d^{-1}]
Re: maintenance respiration [kg DM m^{-2} d^{-1}] [5]
φ: fractional leaf allocation
k: leaf turnover factor
ζ: water stress [4]; $\overline{\zeta_{10}}$: 10-days average water stress
LAI_{max}: maximum LAI supported by the system
f_t: fractional vegetation cover
SLA: specific leaf area [m^2 leaf kg^{-1} DM]

REMOTE SENSING DATA



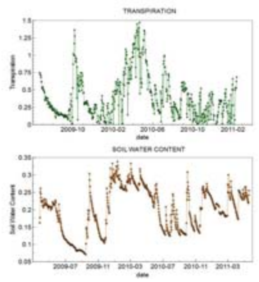
NDVI

- Maximum values → Winter
- Minimum values → Summer
- Related to chlorophyll content[2]
- To be compared with LAIr:

↓

Chlorophyll content is sensitive to water stress[1]

FIELD DATA



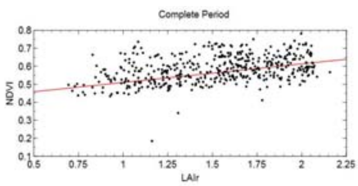
TRANSPIRATION

Sap flow sensors → Heat-Ratio Method
Three theoretical diameter classes:
- Big: 1 selected tree
- Medium: 2 selected tree
- Small: 1 selected tree

SOIL WATER CONTENT

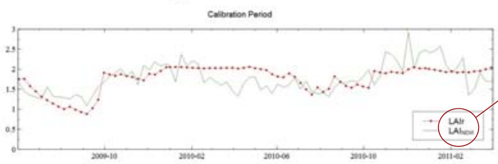
Soil Moisture sensors
30cm depth
9 sensors
- With tree's direct influence: 6
- Without tree's direct influence: 3

RESULTS



SATELLITE DATA RESULTS

- Complete Period: 01/01/2000 – 30/06/2011
- Calibration Period: 01/06/2009 – 31/03/2011
- Temporal interval:
  - Model → daily
  - Satellite data → weekly
- Correlation coefficient between LAIr and NDVI:
  - Complete Period → 0.499
  - Calibration Period → 0.635



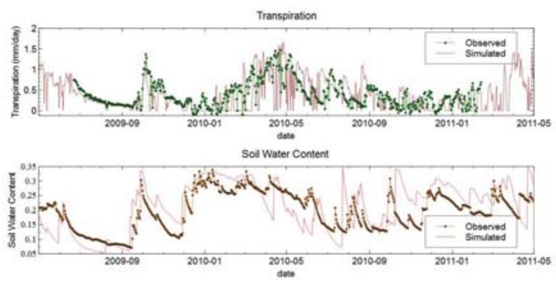
$$LAI_r = LAI \cdot \left(1 - \overline{\zeta_{10}}\right)$$

$$LAI_{NDVI} = -\frac{1}{k} \ln \frac{NDVI_{can} - NDVI}{NDVI_{can} - NDVI_{back}}$$

- RMSE between LAIr and LAI_{NDVI}:
  - Complete Period → 0.1418
  - Calibration Period → 0.1121

FIELD DATA RESULTS

- Correlation coefficient between observed and simulated:
  - Transpiration: 0.717
  - Soil Water content: 0.859



CONCLUSIONS

Field
- The tested dynamic vegetation model managed to reproduce observed transpiration evolution.
- The model is also capable to reproduce soil moisture dynamics.

Satellite
- NDVI is related to chlorophyll content, which is sensitive to water stress in the analyzed vegetation, resulting in minimum values during summer.
- Taking into account water stress dynamics, the model output LAIr satisfactorily reproduces NDVI behaviour.

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