Irrigation Requirement Estimation Using MODIS Vegetation Indices and Inverse Biophysical Modeling

Lahouari Bounoua[1], Marc L. Imhoff[1], Ping Zhang[1,2] , Arnon Karnieli[3], Mohammed Messouli[4]
Email: Lahouari.Bounoua-1@nasa.gov
1. NASA Goddard Space Flight Center, Greenbelt, MD 20771 2. Earth Resources Technology Inc. , Laurel, MD 3. Ben-Gurion University of the Negev 4. Univeristy of Cadi Ayyad, Marrakech

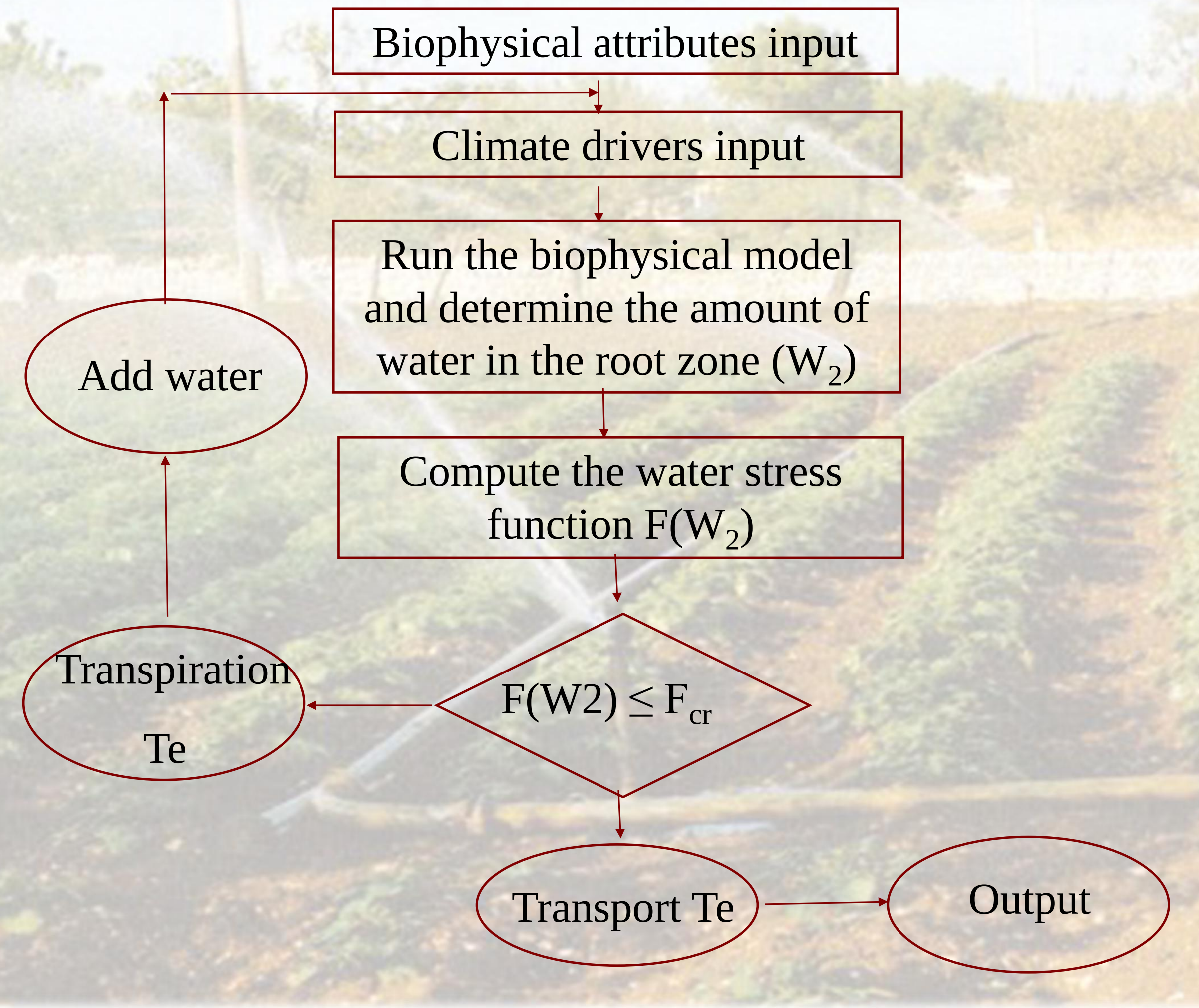
Introduction

We combine remote sensing data from Landsat and MODIS and an inverse biophysical modeling methodology to detect irrigated agricultural lands in arid and semi arid regions and to quantify the amount of irrigation water required for agricultural production as influenced by climate, crop type, soil characteristics and irrigation efficiencies. This satellite-supported inverse modeling approach will provide unique information on the minimum physiological water requirement for each crop type and climate conditions and may be used for an priori planning of cropping as function of soil characteristics and water supply. Furthermore, the methodology also applies different irrigation efficiencies and takes into account soil salinity to estimate the total water allocated to irrigation.

Algorithm

MODIS data are used to estimate the seasonal cycle of LAI, FPAR and other biophysical parameters of a crop canopy. The inverse modeling approach consists of comparing the carbon and water flux modeled under both equilibrium (in balance with prevailing climate) and non-equilibrium (irrigated) conditions.

We postulate that the degree to which irrigated lands vary from equilibrium conditions is related to the amount of irrigation water used**.**



Biophysical attributes input

Climate drivers input

Run the biophysical model and determine the amount of water in the root zone (W_2)

Compute the water stress function F(W_2)

F(W2) ≤ F_{cr}

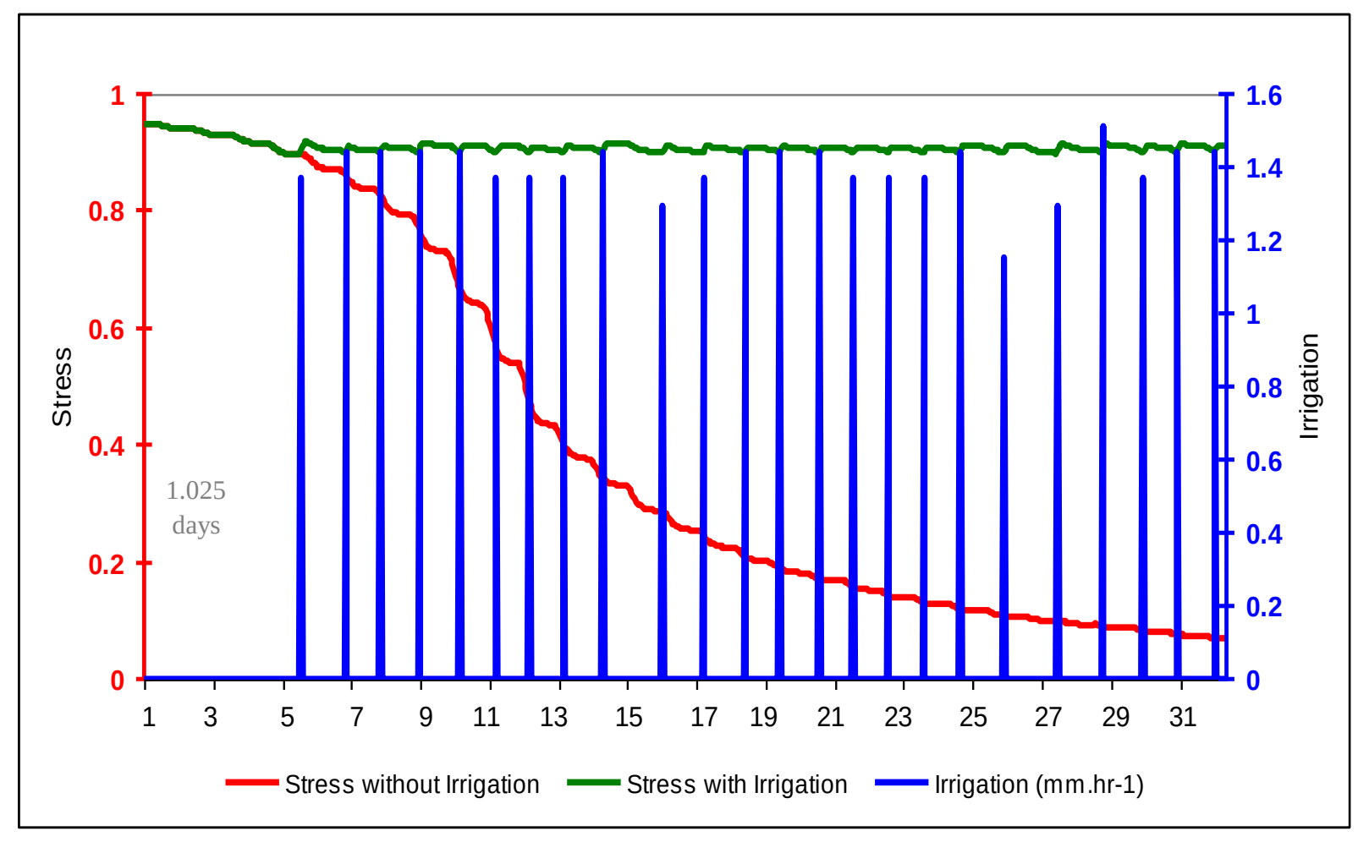
Add water

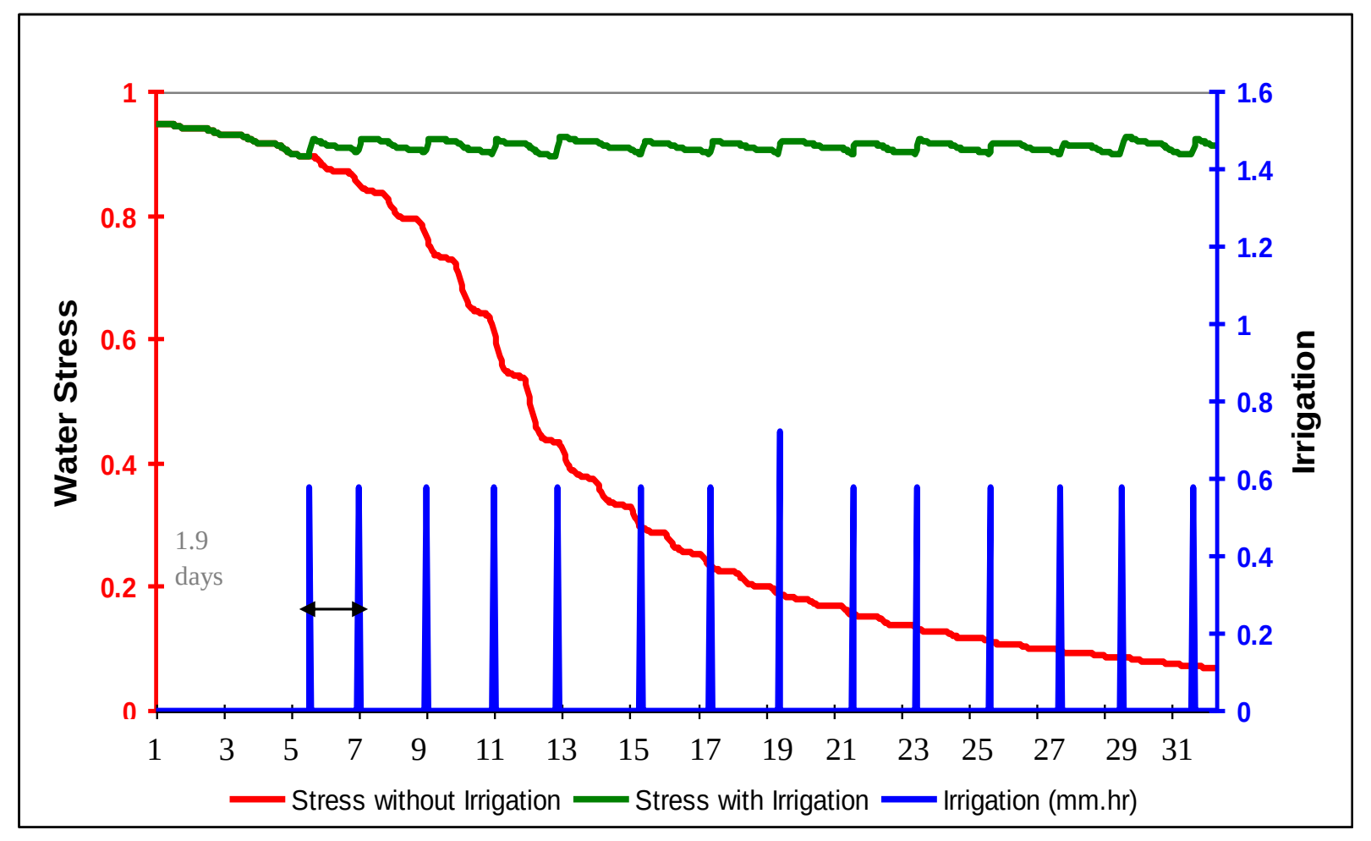
Transpiration Te

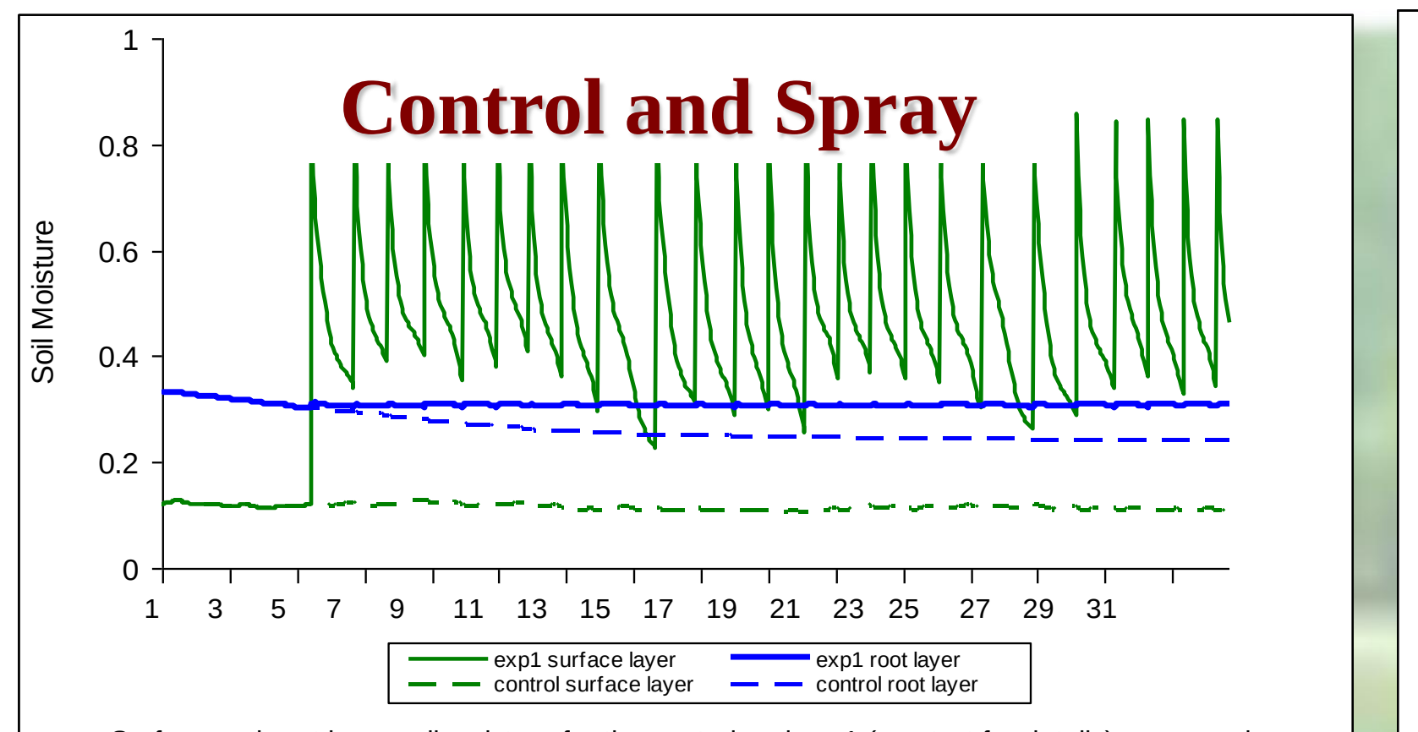
Transport Te

Output

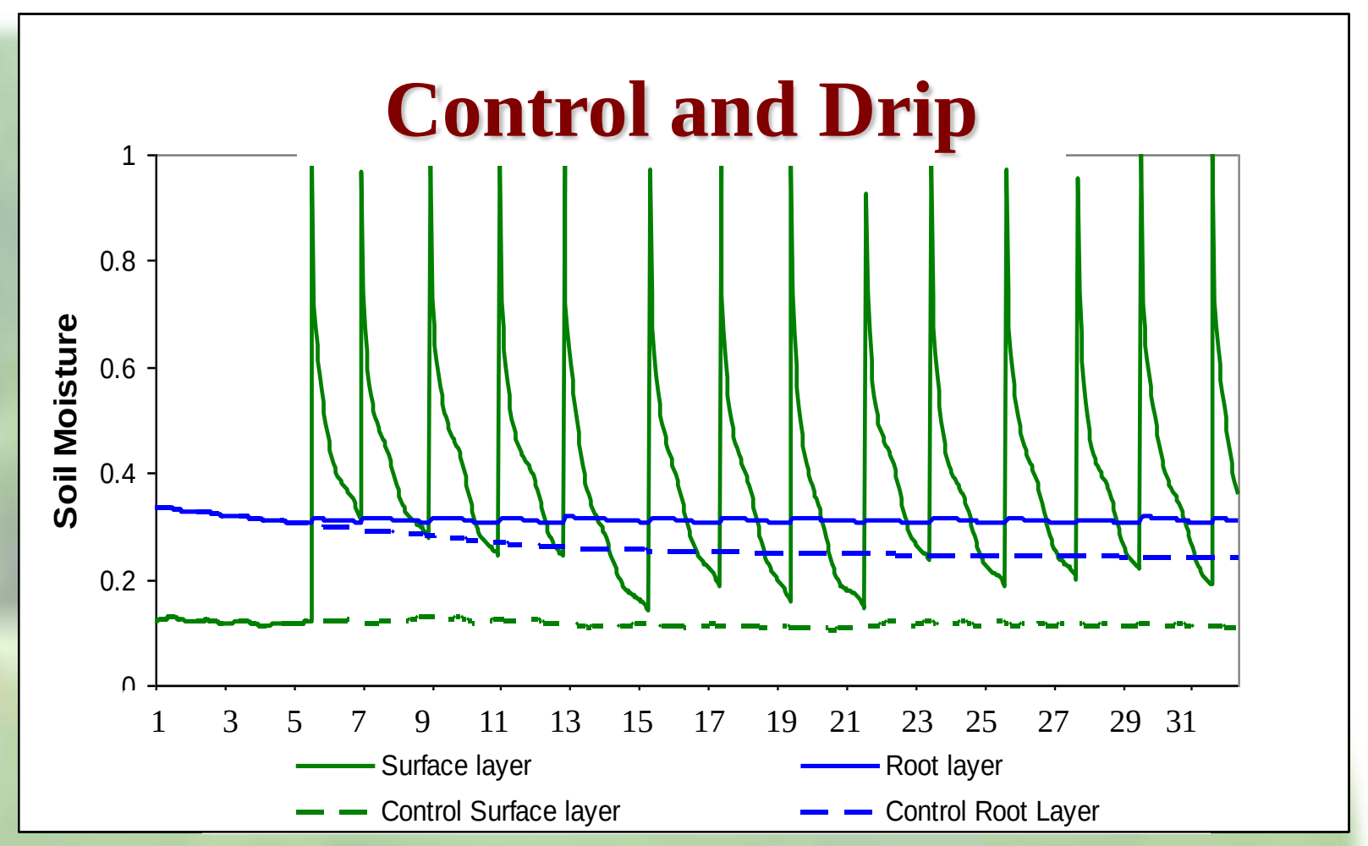
Results







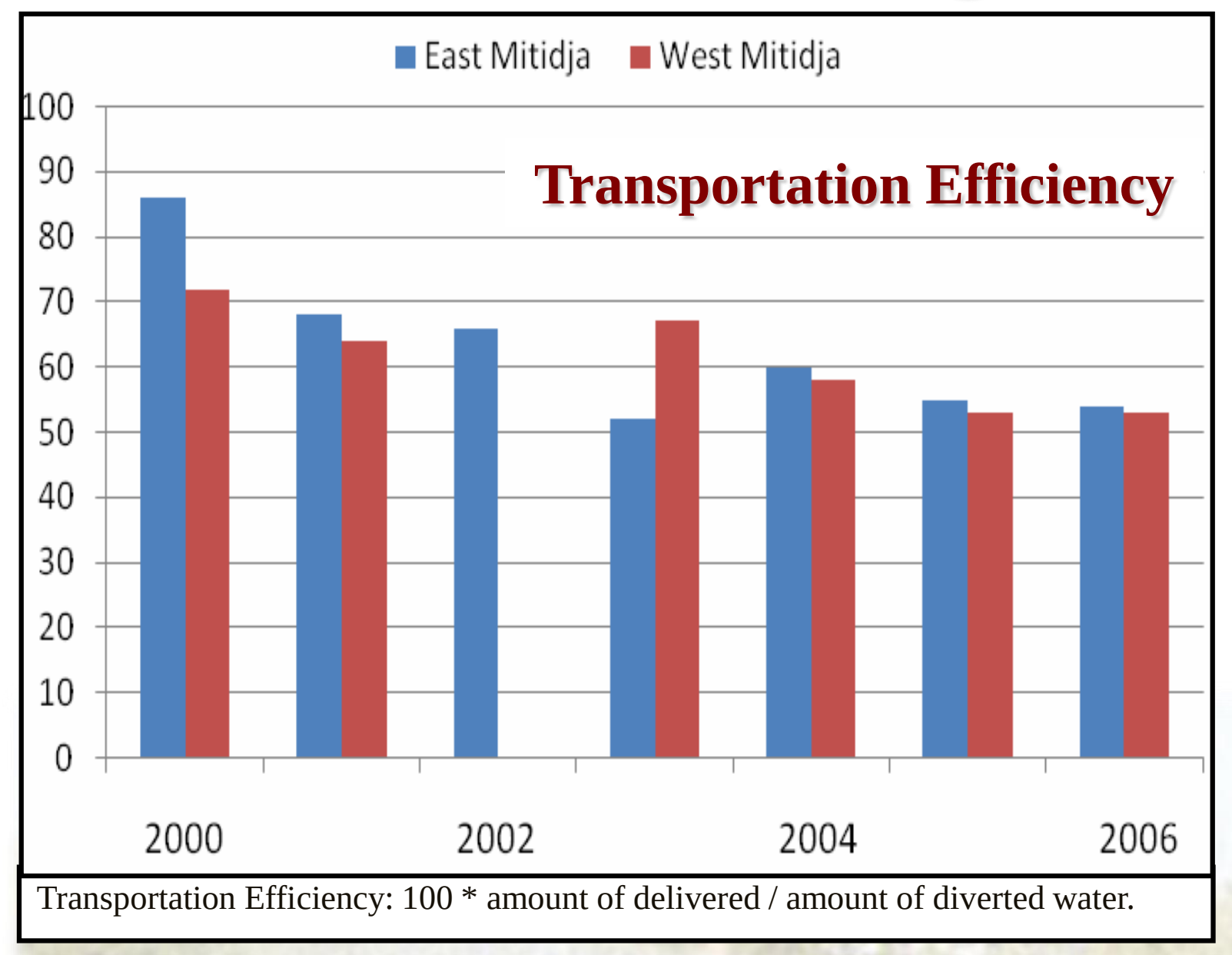
Surface and root layer soil moisture for the control and exp1 (see text for details) expressed as a fraction of saturation for July



Since water is added directly on top of the canopy, it first saturates the canopy interception store, fills the surface layer and then infiltrates into the root zone. The water content in the first layer almost mirrors the irrigation pattern. As water is added however, the moisture content in the root zone slowly builds up and maintains values significantly higher than those obtained during the control simulation.

The use of the drip irrigation method reduced both the canopy and ground interception compared to spray irrigation. This water delivery method results in less frequent irrigation events (about every 48 hours) with an average water requirement amount of about 0.6 mm per occurrence, that's about 43% of that simulated for spray irrigation.

Irrigation Efficiency



Transportation Efficiency: 100 * amount of delivered / amount of diverted water.

Along with the minimum physiological water requirement, several efficiencies apply when computing the total water use for irrigation.

- **Transport (Conveyance) Efficiency**
- **Transpiration Efficiency**

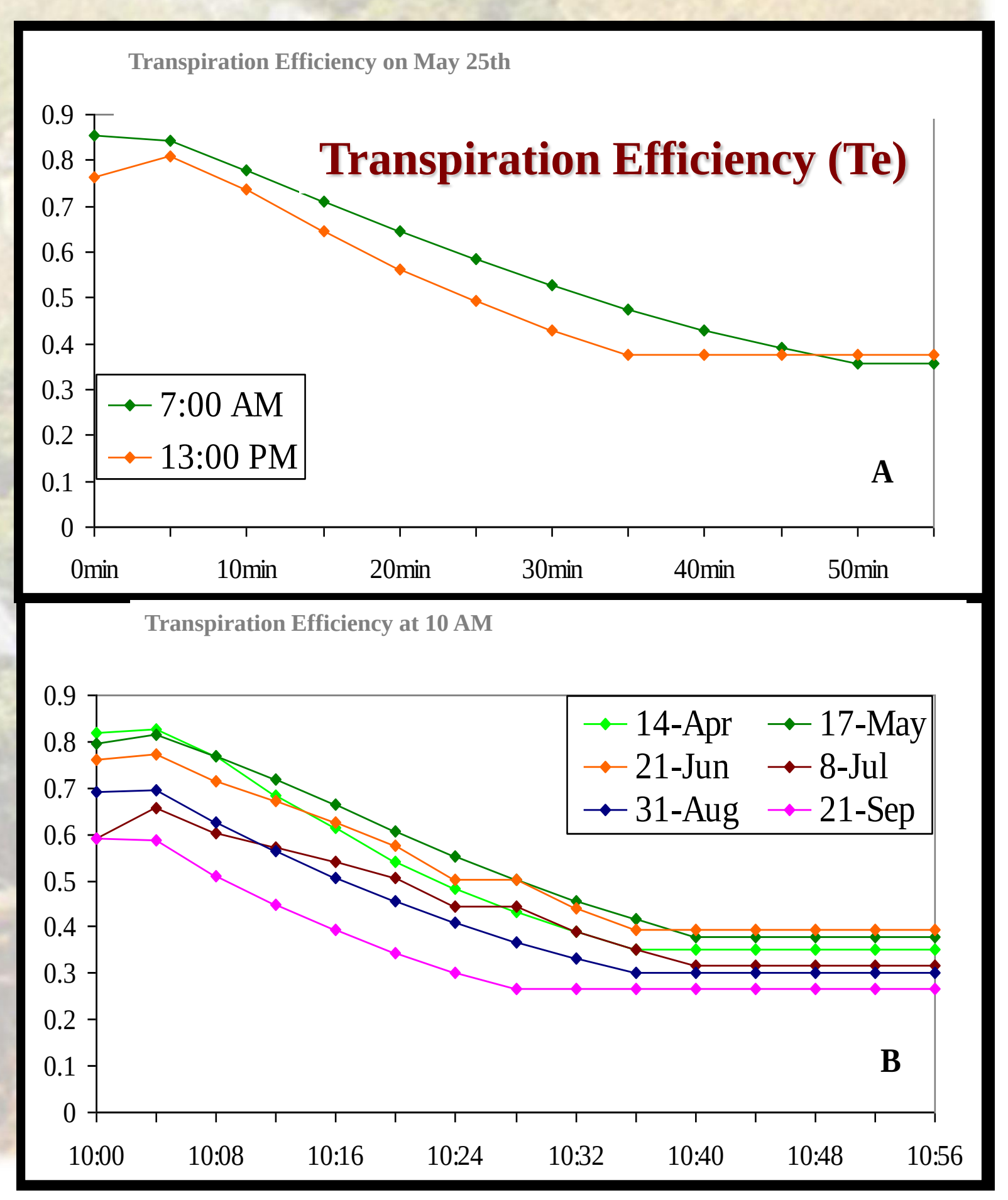
For this North African region, the conveyance efficiency for all transport types has degraded since 2000, due to the aging of the irrigation system, leading to transport efficiency values around 50% for 2006 .

Te = 100* Transpiration / evapotranspiration

Transpiration Efficiency is highly dependent on climate, soil and crop types. Because irrigation alters the thermal structure of the mixed layer by cooling the canopy air space, Transpiration Efficiency varies with time during the irrigation process.

- At any time of the day; irrigation is more efficient at the beginning of the irrigation process than at the end
- Irrigation is more efficient during morning rather than afternoon hours
- Furthermore, irrigation is more efficient during spring than summer when the evaporative demand is high .

This is an important result that can be used to optimize productivity and reduce water use.



Field data and Validation

We believe the methodology is a good first order algorithm to estimate the total water used for irrigation in dry lands. However, it still needs further refinements and validations. Most importantly it is amenable to satellite data and can be expanded to compute global estimates of irrigation water.

We will refine the model estimate of the minimum physiological water requirement for observed agricultures and further develop it to quantify the total amount of water used for irrigation, including losses to transport and transpiration efficiencies, soil salinity and delivery methods. The transport efficiencies vary with farming practices and regions and will be determined through field campaigns. We will validate the methodology over multiple local sites over the different regions and apply the validated algorithms over large scale agricultural areas in the arid and semi-arid regions.

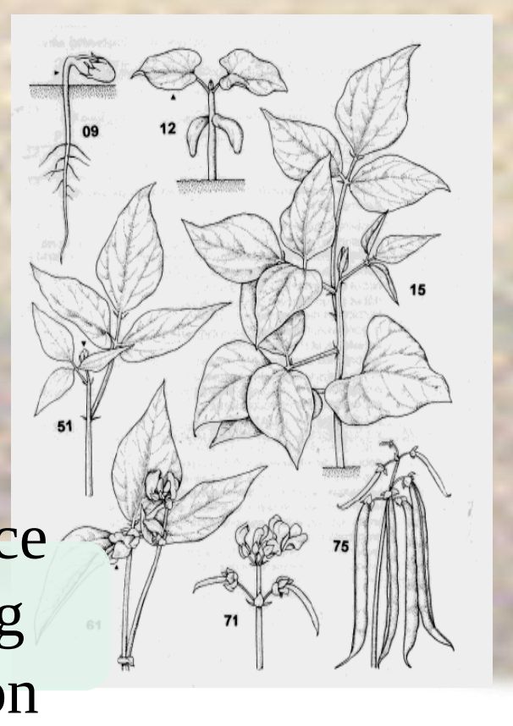
The following is a sample field campaign report collected from a country in North Africa (Algeria). This report can provide detailed information of crop types and density, soil salinity, crop phenology as well as irrigation type and amount.

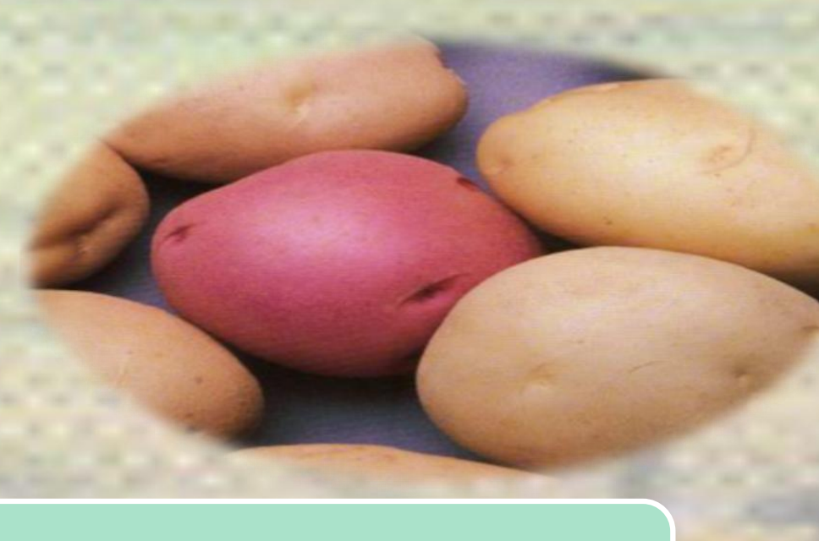
Temperature: 15C -25C

Soil salinity: 2-3 mmhos/cm

PH: 5.5-6.8

Phenology
- Emergence
- Flowering
- maturation





Temperature: 15-21C

Soil salinity: 3-5 mmhos/cm

PH: 5.8-6.5

Phenology
- Emergence
- Flowering
- maturation

Temperature: 18C -27C

Soil salinity: 3-5 mmhos/cm

PH: 5.6-6.9

Phenology
- Emergence
- Flowering
- Maturation