IRRIGATION REQUIREMENT ESTIMATION USING VEGETATION INDICES AND INVERSE BIOPHYSICAL MODELING

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1. INTRODUCTION.

The world's population is increasing rapidly and agricultural food production must increase to keep up with the continuously growing demand. Agriculture is the world's largest water-use sector and has strong influence on the water cycle, especially in arid and semi-arid regions, through the diversion of surface and extraction of underground fresh water.

Even though water seems abundant on our planet, less than 1% of the world's liquid freshwater is available for human use and about 70% of it is used for irrigation of agriculture. The amount of water withdrawn annually for agricultural use is over 1,500 m^3 per person in most of Central Asia while it is less than 20 m^3 per person in many African countries. In the Middle East and North Africa, the water withdrawal as percentage of the total renewable water resource is more than 50 % (FAO-Aquastat). The scarcity of fresh water availability is already the subject of conflicts around the world where political boundaries dissect natural watersheds, aquifers and river flow. This source of conflict is expected to be more acute in the near future as climate changes; and population and agricultural and water demand increase for the same or decreasing precipitation amounts. For these areas in particular, where the water supply and demand are out of balance, variations in regional climate can have potentially predictable environmental and socio-economic consequences.

We explore an inverse modeling method using a biophysical model forced by observed satellite and climate data to quantify the irrigation water demand in semi-arid areas. We constrain the carbon and water cycles modeled under both equilibrium, balance between vegetation and prevailing local climate, and non-equilibrium, water added through irrigation, conditions (Fig.1) . We postulate that the degree to which irrigated dry lands vary from equilibrium climate conditions is related to the amount of irrigation water used.

The amount of water required over and above precipitation is considered as a minimum physiological irrigation requirement. Several efficiency factors apply when computing the total water use in agriculture. These efficiencies relate to water transport, delivery method, evaporation, consumptive biomass and yield, itself depending on the carbon allocation.

2. THE MODEL.

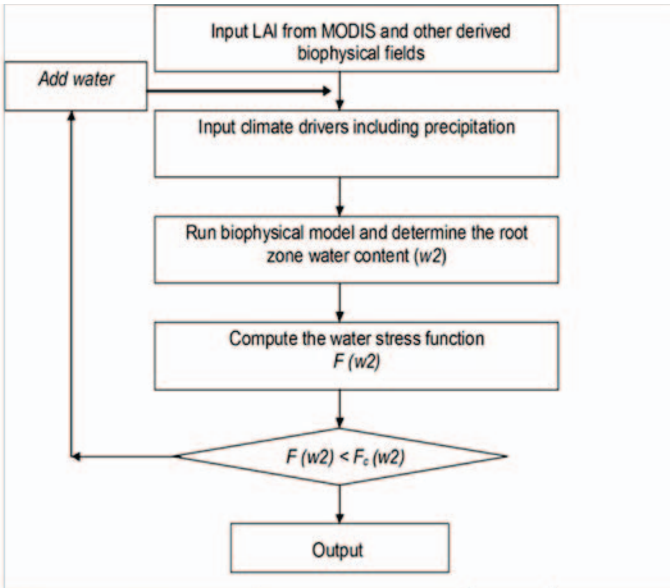

Figure 1: Iterative process for the determination of the minimum water required to sustain observed leaf density on the canopy.

We used the Simple Biosphere model-SiB2 of Sellers et al. (1996) for the inverse modeling component in this study. In SiB2, the vegetation distribution (Defries and Townshend 1994) as well as its spatial and temporal phenology is described using global satellite observations. Each vegetation class is assigned a set of parameters including: 1) time-invariant parameters such as physiological, morphological and optical properties and 2) time-varying phenological parameters describing the vegetation's seasonal evolution. In the version of SiB2 used in this study, we obtain LAI from the MODIS instrument (MOD15A2) to derive the biophysical fields such as the fraction of photosynthetically active radiation absorbed by the green leaves of the canopy (FPAR), the greenness fraction, the roughness length, the zero-plan displacement and the vegetation bulk aerodynamic resistance needed for the model. FPAR is used directly in an integrated photosynthesis-conductance model to calculate the photosynthesis and transpiration rates. LAI and FPAR are prescribed from satellite observations; they then affect the surface water and energy balance but do not respond to it. The LAI is used in the calculation of albedo as well as the transpiration and interception loss components of the evapotranspiration.

3. METHODOLOGY.

We test this method over semi arid areas in Northern Africa and South Central Asia, known agricultural area with no summer rainfall. Water is added using two distribution methods: The first method adds water on top of the canopy and simulates the spray irrigation. The second method allows water to be applied directly into the soil layer and serves as proxy for drip irrigation.

4. PRELIMINARY RESULTS.

Preliminary results indicate that the spray irrigation resulted in an additional amount of water of about 1.4 mm per occurrence with an average frequency of occurrence of 24.6 hours. In contrast, the drip irrigation resulted in less frequent irrigation events, about one every 48 hours, with an average minimum water requirement amount of 0.6 mm per occurrence or about 43% of that simulated during the spray irrigation case. The simulated monthly irrigation under this method for July is 8.8 mm; a remarkable 26.05 mm less than the spray irrigation. Our estimates for the physiological minimum water irrigation amounts are much lower than reported country-level total water requirements. The difference is due to the irrigation efficiencies. Over the two regions with different climates, soils and crops the minimum amount of physiologically required water represents about 50 to 60 % of the total reported irrigation (table 1).

Table 1: Modeled minimum physiological water requirements

	North African site Size = 1 ha Crop type: leguminous	South Asian site Size = 100 ha Crop type: Cotton
Data collection	2008	2008
Spray Irrigation (m^3 ha^{-1} yr^{-1})	1170.00	4095.00
Percent of total reported %	61.5	56.5
Drip Irrigation (m^3 ha^{-1} yr^{-1})	300.00	1365.00
Percent of total reported %	16	19
Reported irrigation (m^3 ha^{-1} yr^{-1})	1920.20	7000-7500

References

AQUASTAT database

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