Using remote sensing to assess crop water productivity

Xueliang Cai and Prasad Thenkabail

Crop consumptive water use, biophysical parameters, and water productivity values can be mapped to support ‘more crops per drop.’

Water productivity, which relates crop production to water use, is a key indicator for evaluating agricultural water management. Irrigation, the single biggest fresh water consumer in the world, is facing enormous pressures from rising food demand, competitive water uses from other sectors, and the uncertainties of climate change. Sustainable agriculture requires increasing water productivity by producing more food with less water. Remote sensing-aided water productivity assessment helps to pinpoint hot or bright spots and assess the potential for improvement.

Crop patterns, evapotranspiration, biomass, and yield accumulation all can be estimated using satellite sensor data. In our research, we used satellite map data to calculate crop water productivity. The International Water Management Institute (IWMI) made a pilot study in the Sry Darya river basin, central Asia[^2], which collected land use (or cover) and social-economic information. Intensive field measurements were made to monitor crop growth conditions and the water supply at sample study sites (see Figure 1). We extracted the cropping pattern information, including crop types, growth season, cultivating extent, and crop rotation, using multi-temporal Moderate Resolution Imaging Spectroradiometer (MODIS) and Indian Remote Sensing (IRS) satellite images, and a one-time QuickBird satellite image. We related the IRS and QuickBird wavebands to the field-measured crop-leaf-area index, biomass, and grain yields using statistical regression analysis. We also estimated crop actual evapotranspiration (ET) over growth period using the Simplified Surface Energy Balance model, which takes inputs from thermal bands of six Landsat Enhanced Thematic Mapper Plus (ETM+) images and daily weather data. We produced water productivity maps by dividing crop biomass and yields by seasonal ET maps.

We established the spectro-biophysical models for cotton, wheat, maize, rice, and alfalfa using IRS and QuickBird data. The best IRS and QuickBird spectro-biophysical models, mostly involving near IR and red bands, explained 65–90% of the crop variability. The IRS data showed about 10% greater variability than QuickBird. (This was because of the uncertainty in the precise location of a 2.44m resolution QuickBird pixel.)

We mapped the evolution of crop water use with remote sensing (see Figure 2). Rice and cotton used the most water of the five crops studied. The average seasonal water use of rice was 619mm compared to 512mm by cotton. However, portions of the cotton fields in the best growing conditions consumed more water (905mm) than the highest consumed by rice (769mm). This was because of the significantly longer growing season for cotton (about 6 months) than rice (about 4 months). However, the percentage of area in which cotton consumed more water than rice was very limited. The results indicated that at the best growing conditions, cotton can consume more water than rice due to its substantially longer growing period.

Figure 3 shows water productivity of cotton mapped with IRS and QuickBird. While the overall magnitude of water productivity can be mapped from both sensors, the spatial variability is captured to different degrees. The maps showed 55% of the total cotton area demonstrated low water productivity (<0.3 kg/m³), of which 21% was very low (<0.2kg/m³). We saw similar


Continued on next page
variability with other crops. These results imply there are significant opportunities for growing ‘more crop per drop’ using the existing cropland and water resources to re-enforce food security in the coming decades to support ballooning populations. Water productivity can be increased in three ways: increasing crop productivity, reducing water input, and a combination of the two.

Our research showed the inherent strength of remote sensing in water productivity studies. While the maps help show the spatial variability of water productivity within and between fields, they also help identify factors affecting water productivity. A survey revealed that, at a local scale, the significance of factors is: soil salinity (43%), water logging (31%), field leveling (13%), water deficit (7%), and other factors such as weeds, soil moisture, and crop density (6%).

The various analyses we conducted suggest possibilities for advanced applications of remote sensing in agricultural water management. Time series data will further ensure robust models to reveal temporal variability. In the future, the various biophysical parameters mapped using remote sensing can be integrated

Figure 2. The seasonal evolution of actual evapotranspiration estimated from Landsat Enhanced Thematic Mapper Plus images and weather data.

Figure 3. Water productivity maps of cotton using Indian Remote Sensing (IRS) satellite and QuickBird (QB) data.

Continued on next page
with eco-hydrological models to enhance their ability in spatial interpretation. IWMI has also advanced the method to map water productivity in the Indo-Gangetic basin in south Asia and Limpopo basin in southern Africa. Large-scale analysis of the magnitudes and variations of water productivity and the links to factors can help policymakers find appropriate ways for basin sustainable development.

Author Information

Xueliang Cai
International Water Management Institute
Colombo, Sri Lanka

Prasad Thenkabail
U.S. Geological Survey
Flagstaff, AZ

References