The role of Remote Sensing in Irrigation Monitoring and Management

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Outline

• Why do we care about irrigation?
• Remote sensing for irrigated agriculture
• What are the needs of irrigators?
• Future directions
• Conclusions
Importance of irrigation

- 70% global fresh water withdrawals
- 35% crop production (16-18% of area)
- 2-3 times more yield than non-irrigated
- Soil degradation
  - Salinization, water logging
- Hydrological impacts
  - increased ET, decreased runoff
- Atmospheric impacts
  - irrigation-precipitation feedback
- Climate change
  - reduced inflow, enhanced ET
In Central Asia

reduction in cultivated area [2000-2005]

irrigated area in 1999

future of irrigation

UNEP/GRID (2003)
Why remote sensing?

• Objective observations
• Systematic measurements across space and time
• Large area coverage
• Accessibility
• Multiple spatial scales from individual fields to river basins
• Reduced cost (economies of scale)
• Integration into models
• Integration with GIS
Variables of interest

- Land use*
- Irrigated area*
- Crop type*
- Water use (ET)
- Production/yield
- Performance indicators
- Water stress/need
- Soil moisture*
- Salinity*
- Precipitation*
- Snow pack*

*directly observable with remote sensing
Land use

• Describes the use of land for different purposes
• Irrigators want to know the use of land in districts/basins
• Remote sensing of land use is mature, 100s of examples in the literature
• Involves categorical classification of data
• Often interpreted from land cover
Irrigated area

• Need to know the area irrigated
  – Underreporting
  – Large area management
  – Water allocation
• Remote sensing of irrigated area
  – Easier in drylands
  – Not self-evident in humid climates
• Often requires time-series data
• Prior knowledge of moisture conditions maybe necessary
• Spatial resolution maybe a limiting factor
What about areas that are actually irrigated?
Irrigated area

- Temporal analysis
- Spectral analysis
- Interannual analysis
Criteria for irrigation:

1. Soil moisture level drops below a defined threshold
2. Vegetation (crops) must be in growing stage (indicated by positive values for the 1st derivative)
3. Additional criteria may include: a minimum value for the 1st derivative and a minimum number of consecutive time steps a pixel must fulfill criteria 1 and 2.

Green biomass (NDVI) under irrigation in Syria 2004; from 1km SPOT VEGETATION and modeled soil moisture

Geerken et al (2007)
Irrigated area

Annual, accumulated ‘NDVI under Irrigation’
Indicator for irrigation intensity

Geerken et al (2007)
Crop type

• Each crop has different water needs
• Production estimates depend on crop
• Remote sensing of crop type exclusively requires multi-date imagery
• Inverse relationship between categorical detail and accuracy
• Spatial resolution is an important factor
  – High resolution: need many-cost is an issue
  – Low resolution: cover fraction (experimental)
• One time/one place issue
Crop type

2006 Cuming County, Nebraska
Cropland Data Layer

Categories
- Corn
- Soybeans
- Other Crops
- Other Grains & Hay
- Alfalfa
- Winter Wheat
- Idle/Fallow/CRP
- Pasture, Non-ag Waste
- Grass/Herbaceous
- Mixed Forage
- Woods
- Water
- Dev Open Space
- Dev Low Intensity
- Dev Med Intensity
- Dev High Intensity
- Emer Herb Wetlands
- Woody Wetlands
Crop type

Application of machine learning tools

NASS summer crop fraction  
predicted summer crop fraction

Ozdogan (in prep.)
Water use (ET)

- Thermal remote sensing is key input
- Remote sensing as input to a model
  - As a state variable (SEBAL)
  - Parameterization (e.g. land cover or Kc)
- Requires coincident meteorological obs.
- Success highly variable
  - Method
  - Input data
  - Environmental conditions (e.g. topography)
- Aggregate estimates better than field scale
- Lack of high resolution operational thermal sensors
Water use (ET)

Application of SEBAL-METRIC to MODIS data over Afghanistan

Senay (2006)
Bausch (1995)

Fig. 1. Example of the basal crop coefficient ($K_{cb}$) curve for corn generated using the reflectance-based crop coefficient ($K_{cr}$) calculated from measured canopy reflectance in 1990.
Yield

- Empirical approach vs. modeling
- Results highly variable
- Time-series data maybe necessary
- Requires crop type identification
- Inverse estimates from ET/model
- Irrigated lands have higher yields
- Operation monitoring currently non-existing
- One-place/one-time issue
Crop yield

Kucharik (2003)

AGRO-IBIS model

Suggests that irrigated lands require special handling
Soil moisture

- Irrigation scheduling
- Water needs
- Microwave data key
  - Passive microwave
  - SAR
  - Scatterometer
- Spatial resolution (10s of km)
  - Applicable to basins
- Soil moisture vs. vegetation moisture
- Dedicated sensors forthcoming
- Specialized branch
Soil moisture

Data from FIFE

Evaporative fraction (-)

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1

Volumetric soil water content (cm³/cm³)

y = 0.4213Ln(x) + 1.2836
R² = 0.8549

Smith et al (1992)
Soil salinity

- Key soil degradation variable
- Especially important in drylands
- Multi-spectral bands with key locations are important
- Hyperspectral better
- Band combinations of visible and IR for index generation
- Categorical and continuous recovery
Soil Salinity

SI = \sqrt{b1 - b3}

NDSI = \frac{b3 - b4}{b3 + b4}

BI = \sqrt{b3^2 + b4^2}

LISS sensor
b1 = 450 - 520 nm
b3 = 620 - 680 nm
b4 = 770 - 860 nm

Khan et al. 2005
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Remote sensing is vastly underutilized in irrigation monitoring and management

- Resolution (spatial + temporal)
- Quality of results
- Disconnect between irrigators and remote sensors
- High cost of training/equipment
  - Shortsighted view of economies scale
- One-time/one-place syndrome
- Top-down approach
Summary

Bastiaanssen (2000)
Thank you

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