The role of Remote Sensing in Irrigation Monitoring and Management

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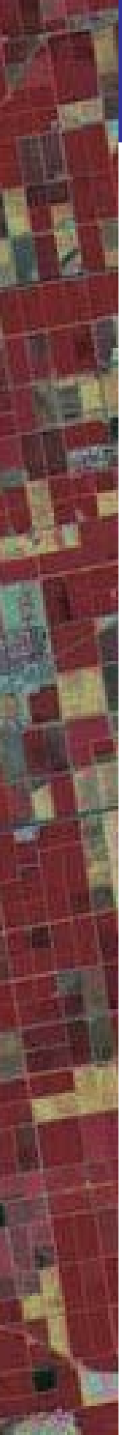
forward thinking for the planet
sage

Outline

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



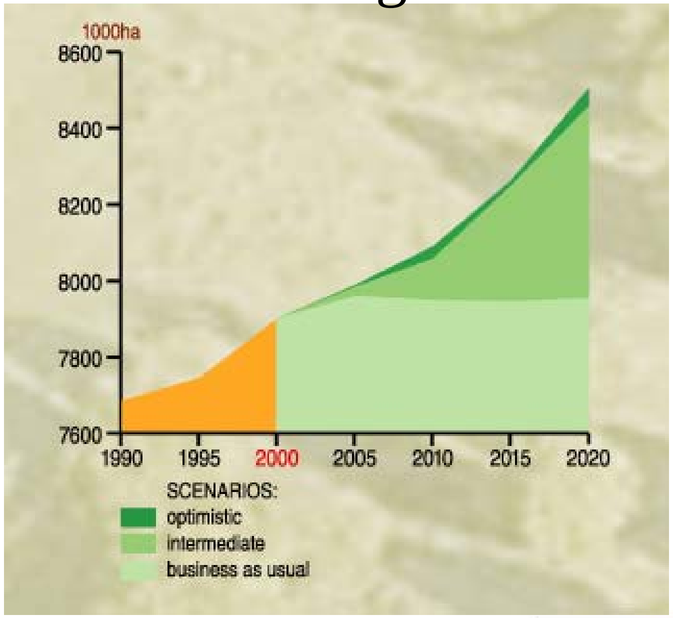
Importance of irrigation

- 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

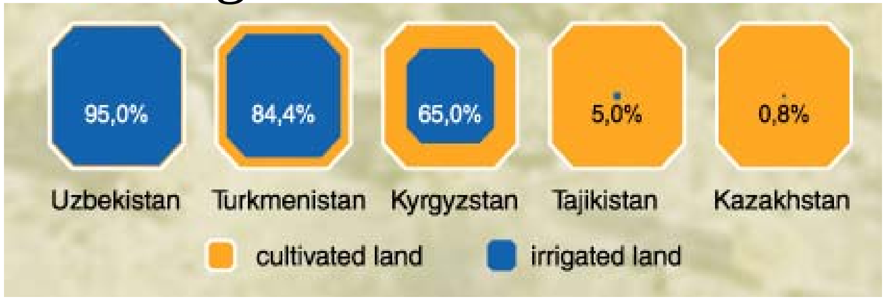
In Central Asia

reduction in cultivated area [2000-2005]

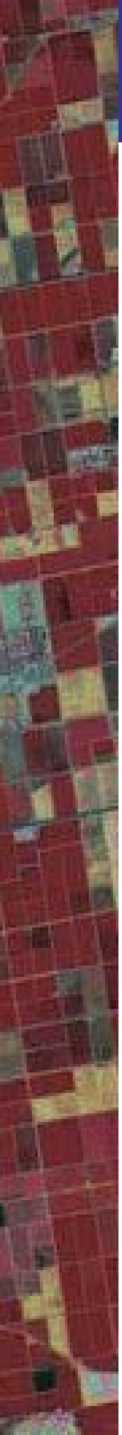
future of irrigation



irrigated area in 1999



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

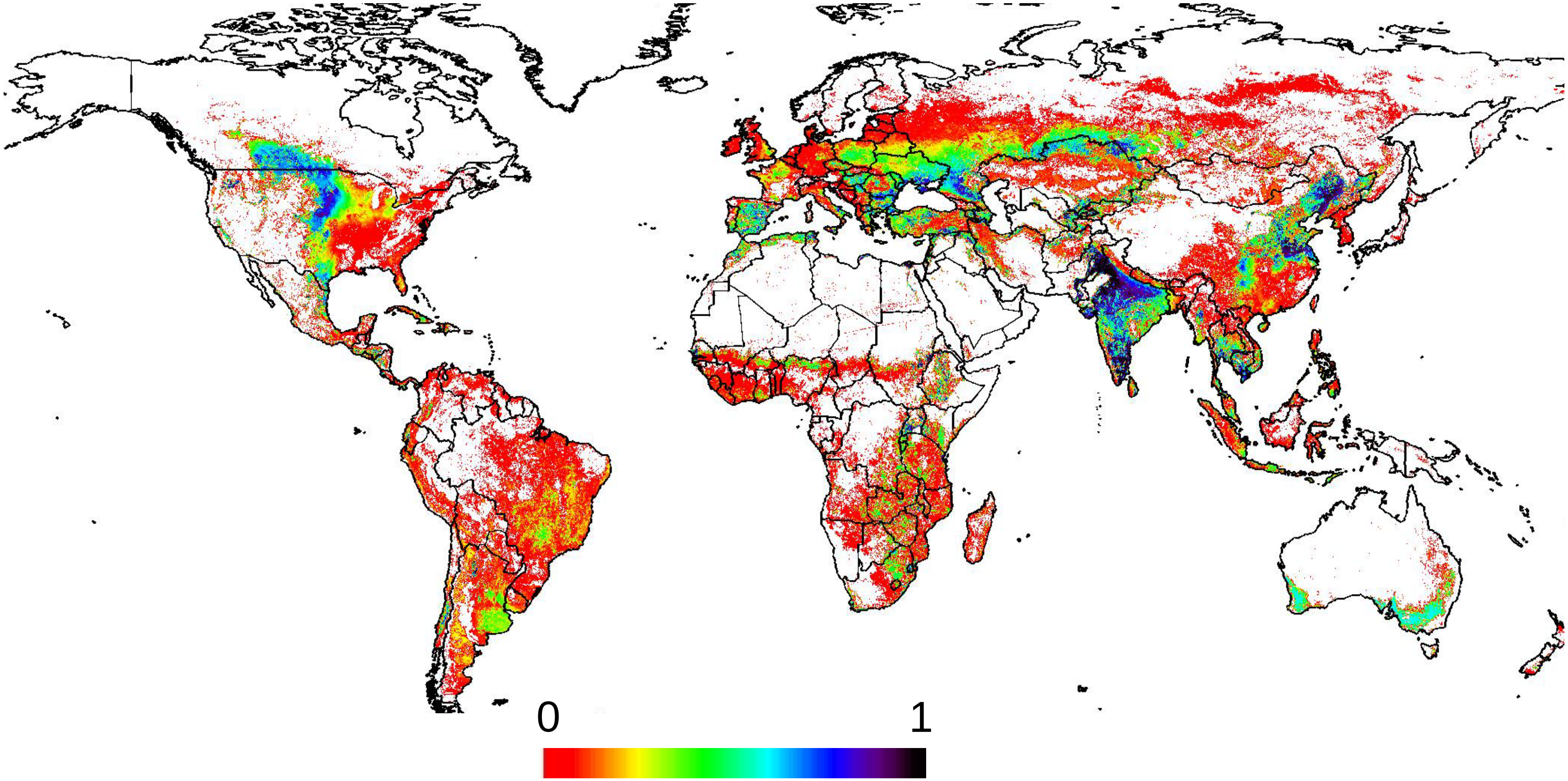
- Describes the use of land for different purposes
- Irrigators want to know the the use of land in districts/basins
- Remote sensing of land use is mature, 100s of examples in the literature
- Involves categorical classification of data
- Often interpreted from land cover

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

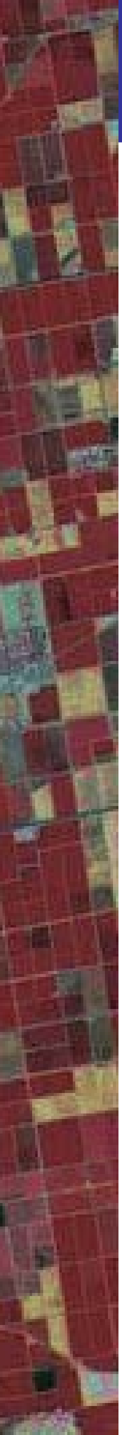
Irrigated area

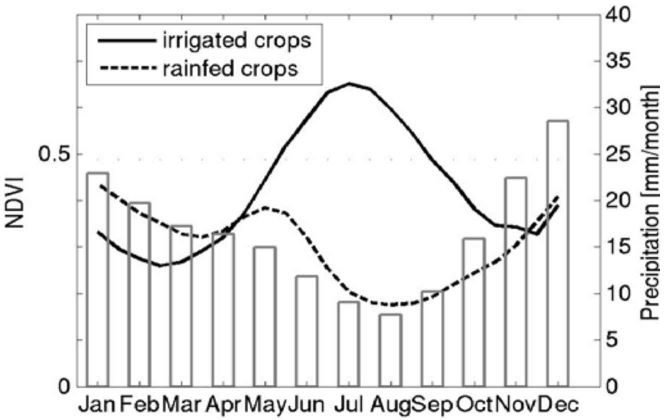
global irrigation potential



What about areas that are actually irrigated?

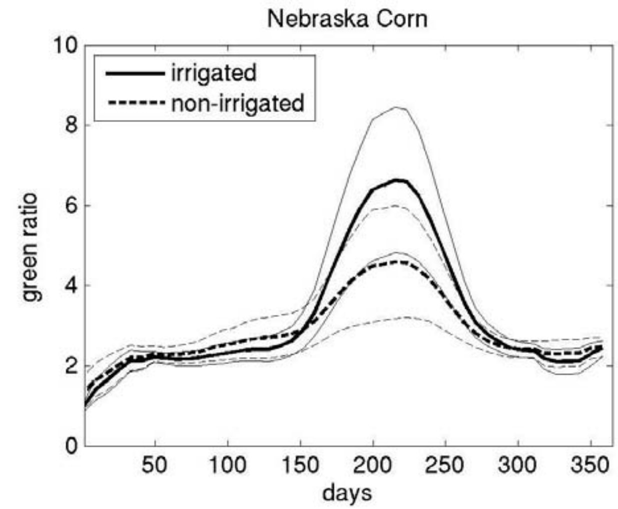
Irrigated area

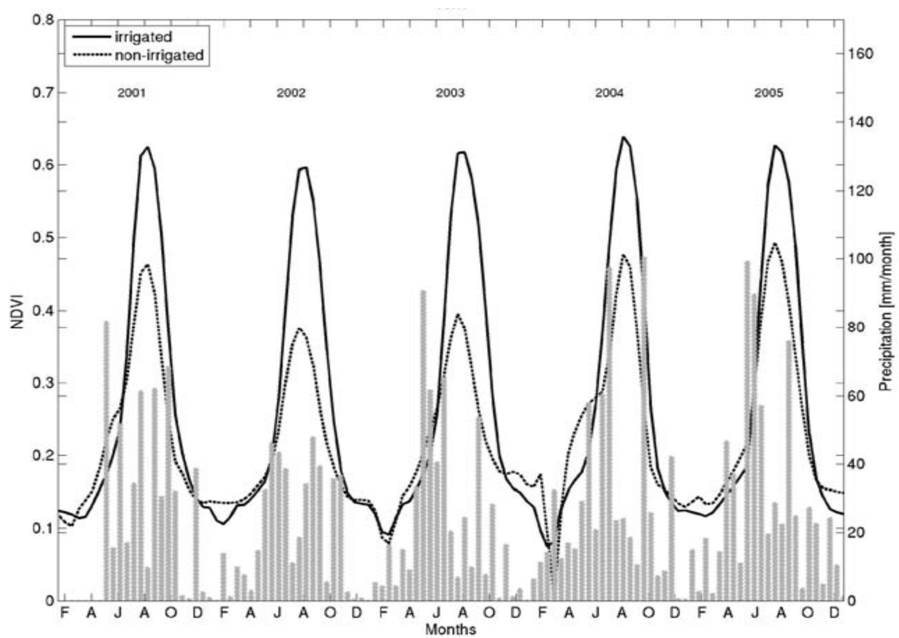




temporal analysis

spectral analysis



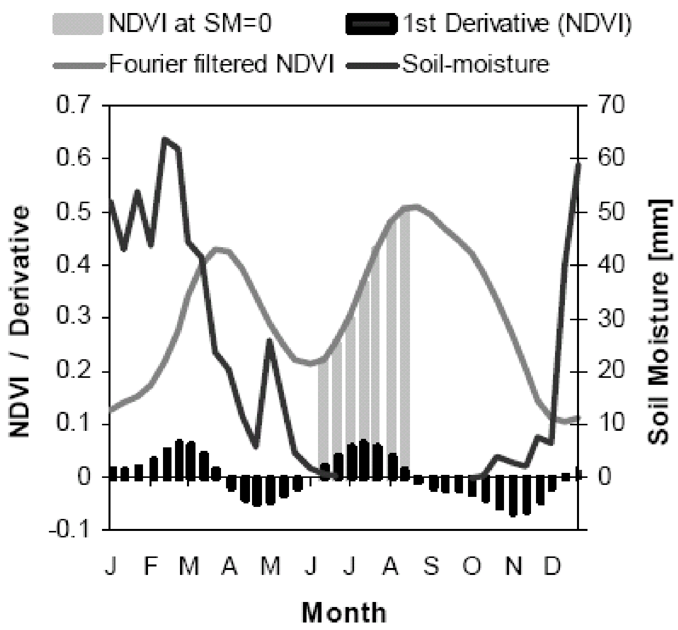


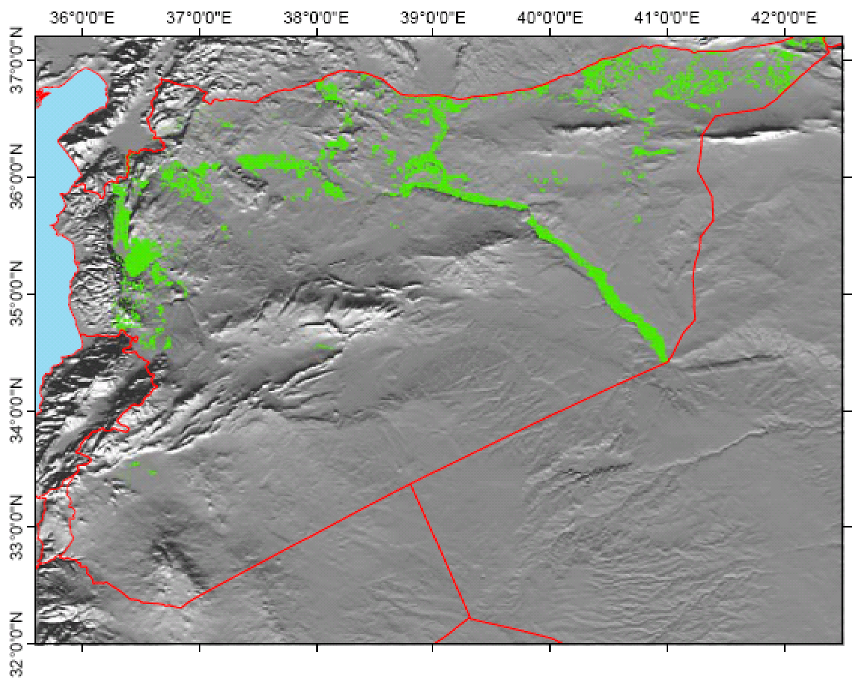
interannual analysis

Irrigated area

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.





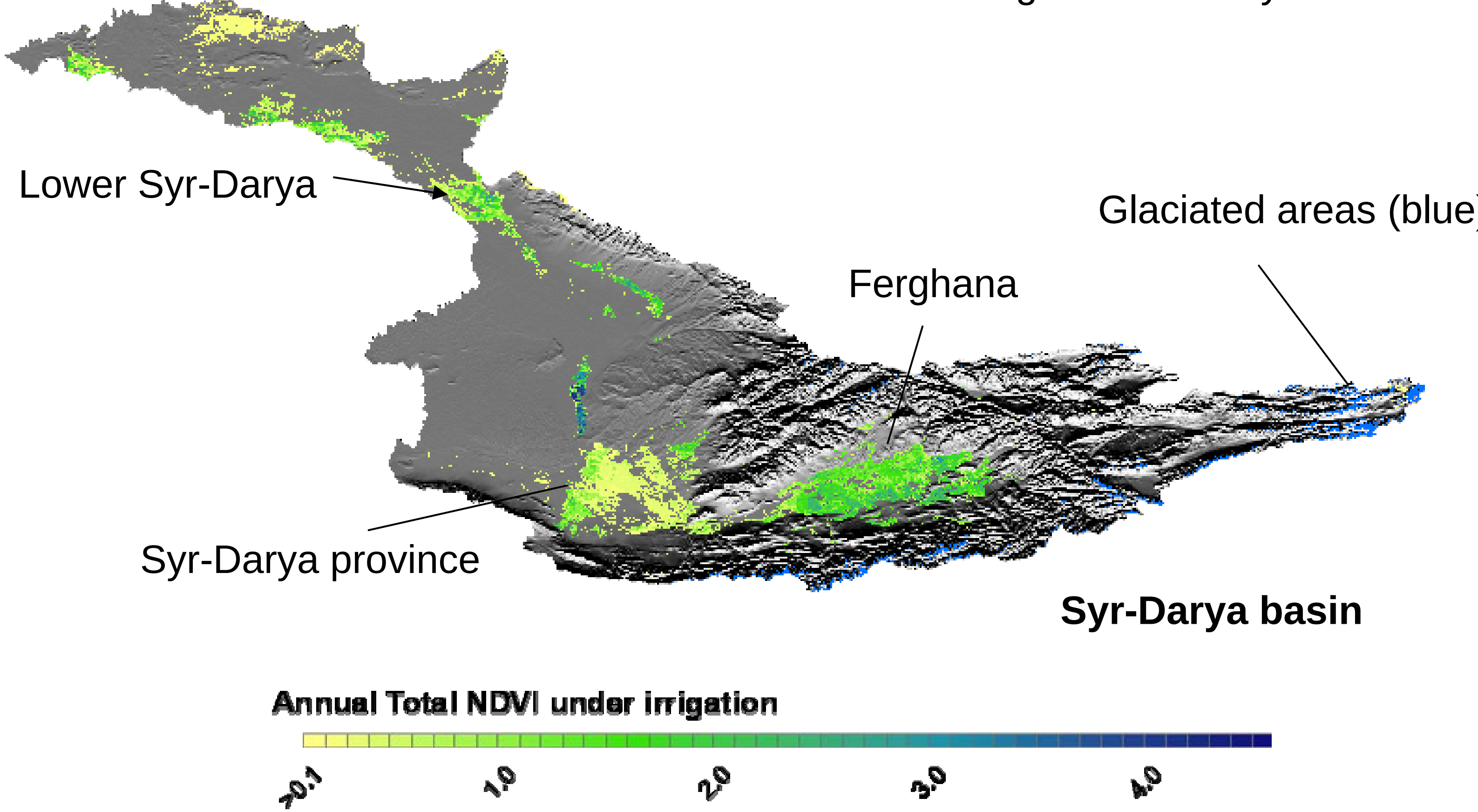
Green biomass (NDVI) under irrigation in Syria 2004; from 1km SPOT VEGETATION and modeled soil moisture

Geerken et al (2007)

Irrigated area

Annual, accumulated 'NDVI under Irrigation'

Indicator for irrigation intensity



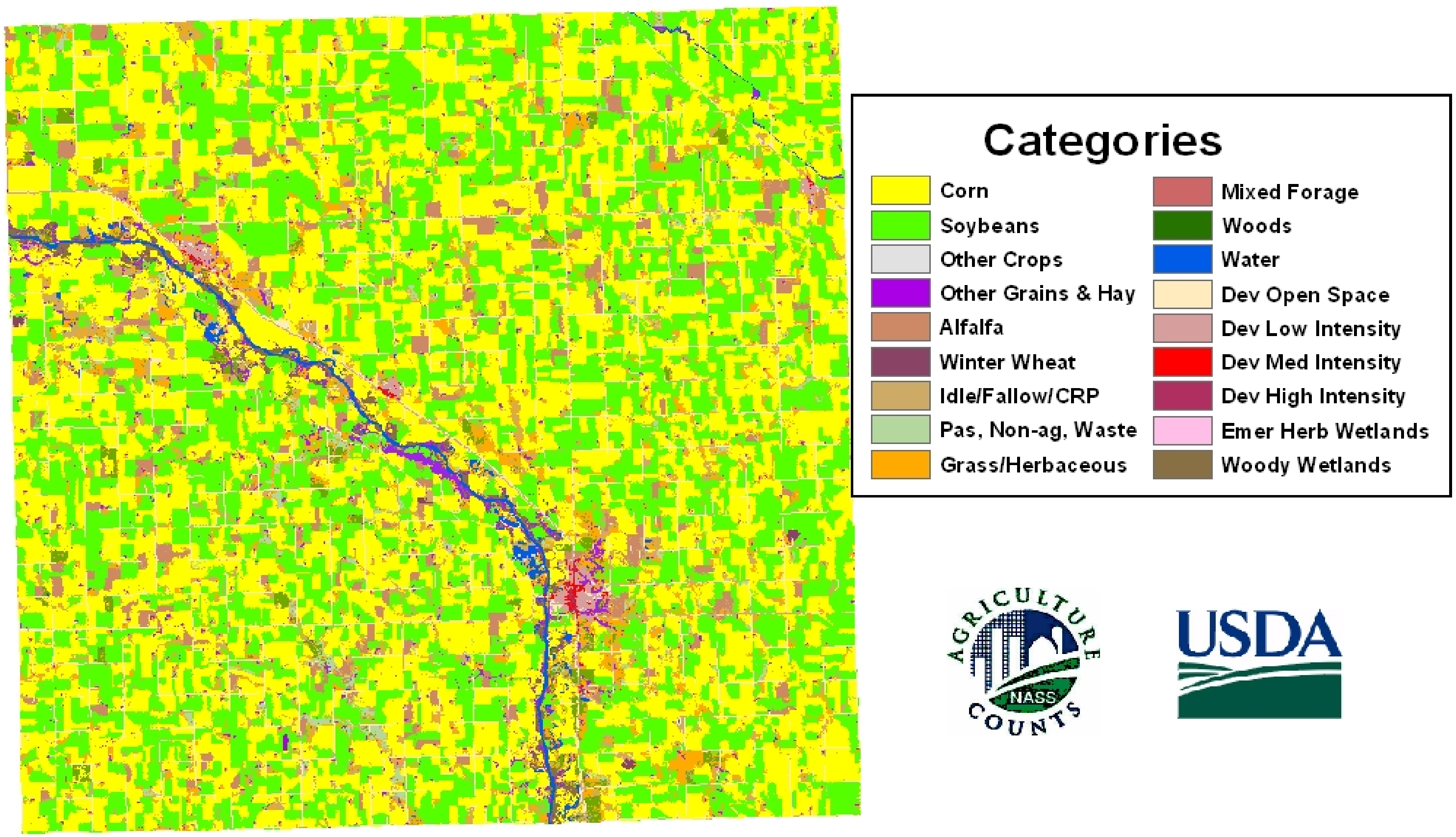
Geerken et al (2007)

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

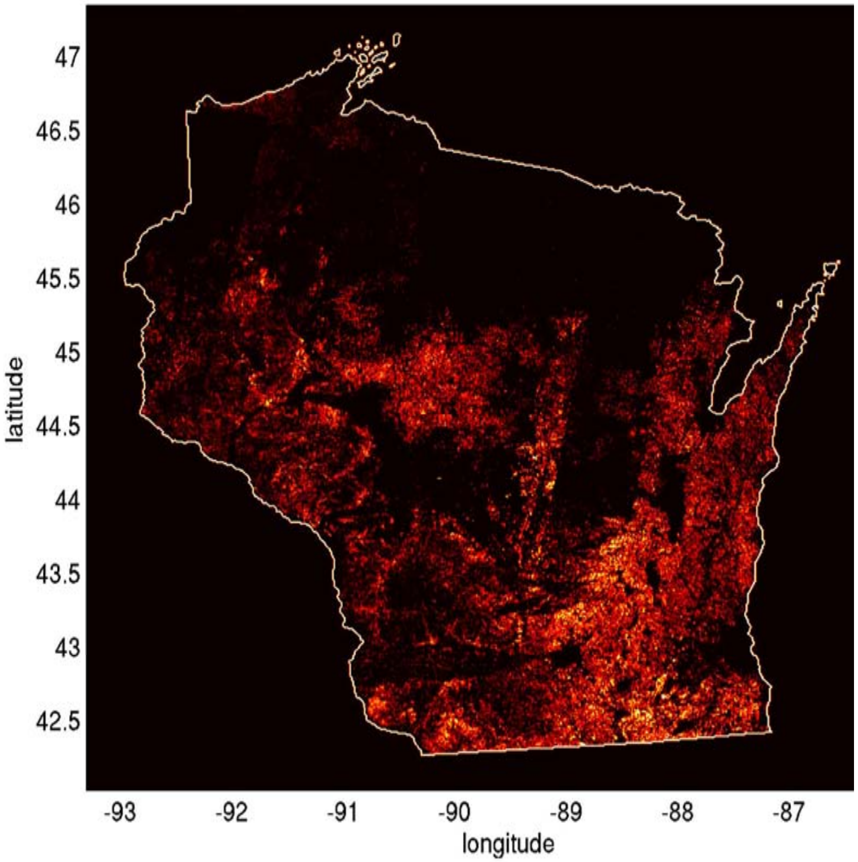
2006 Cuming County, Nebraska
Cropland Data Layer



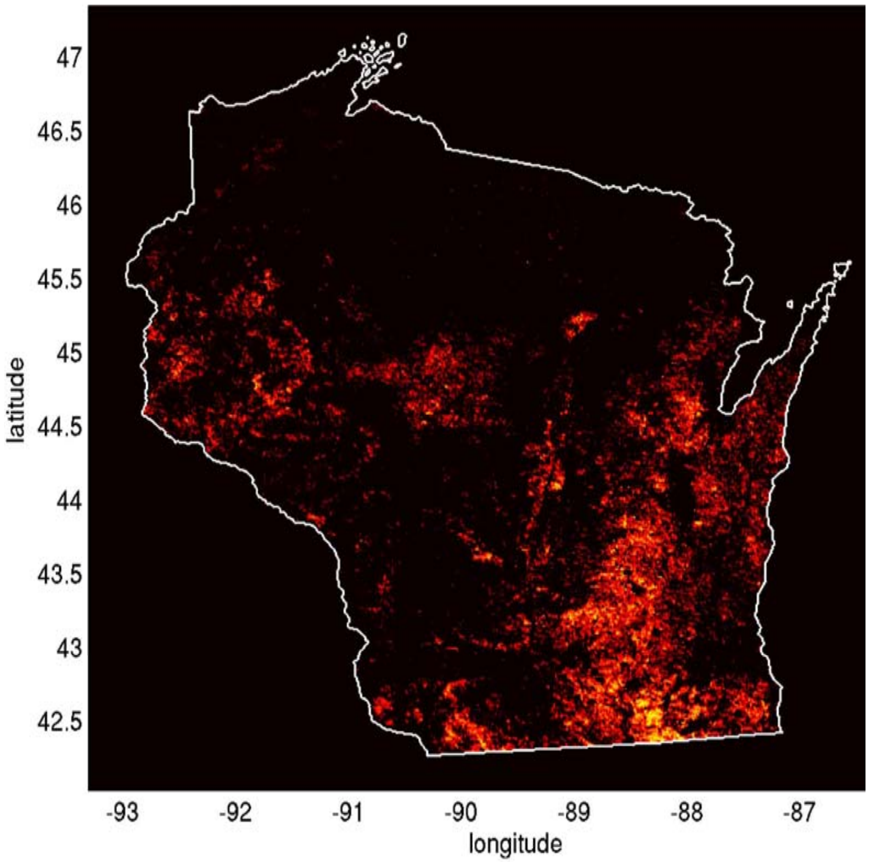
Crop type

Application of machine learning tools

NASS summer crop fraction



predicted summer crop fraction

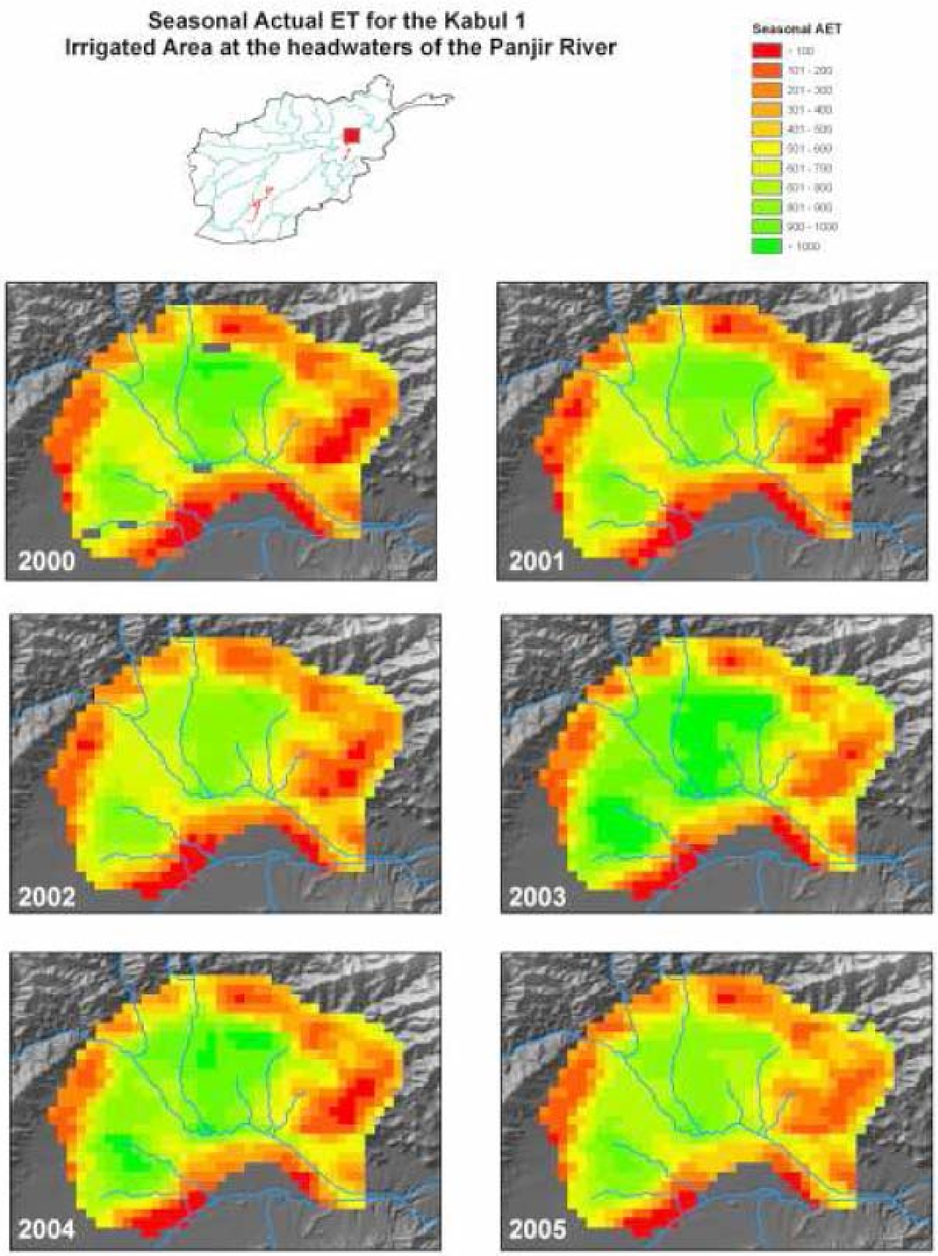


Ozdogan (in prep.)

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)

Water use (ET)

Reflectance-based Crop Coefficients (Kc)

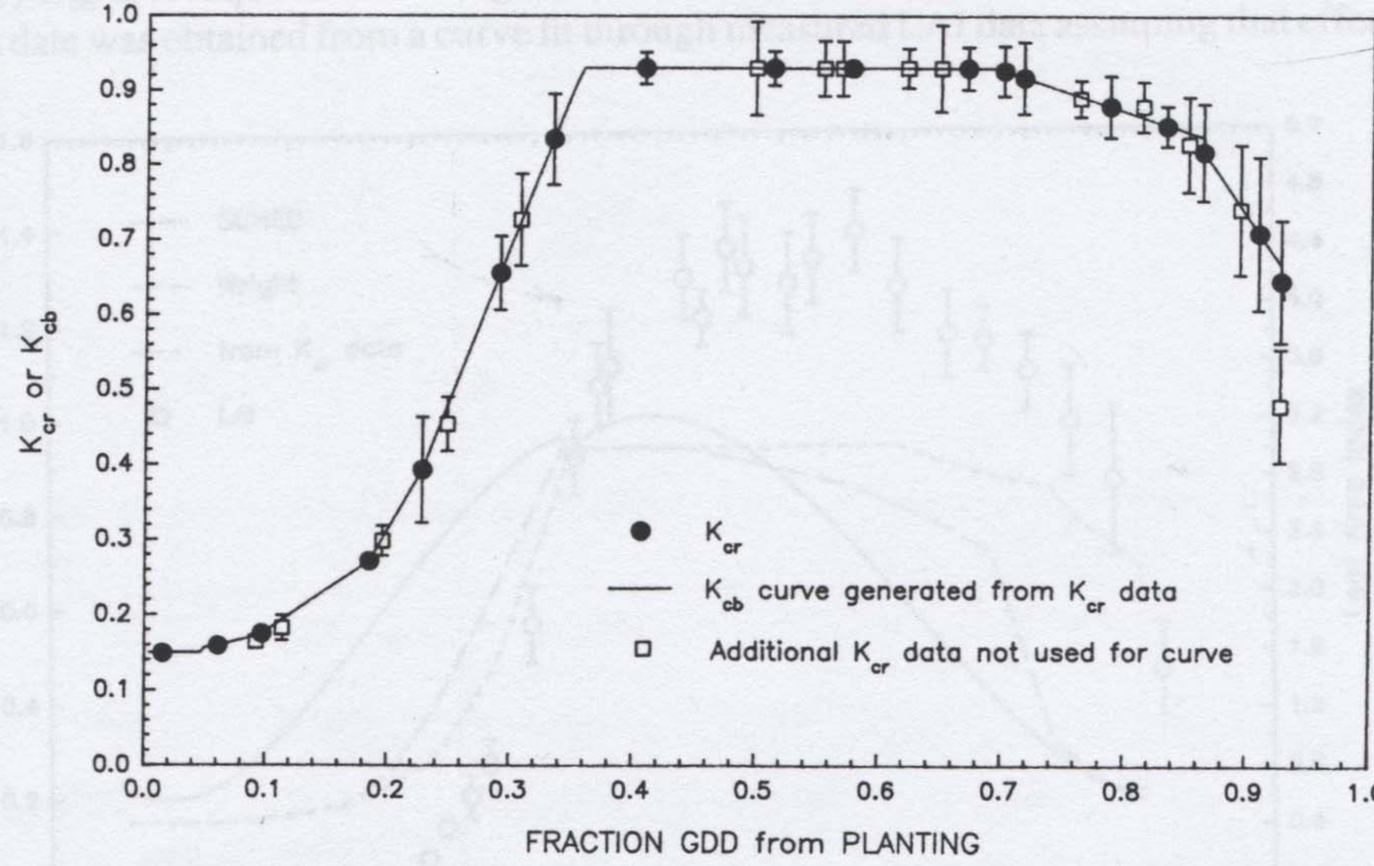


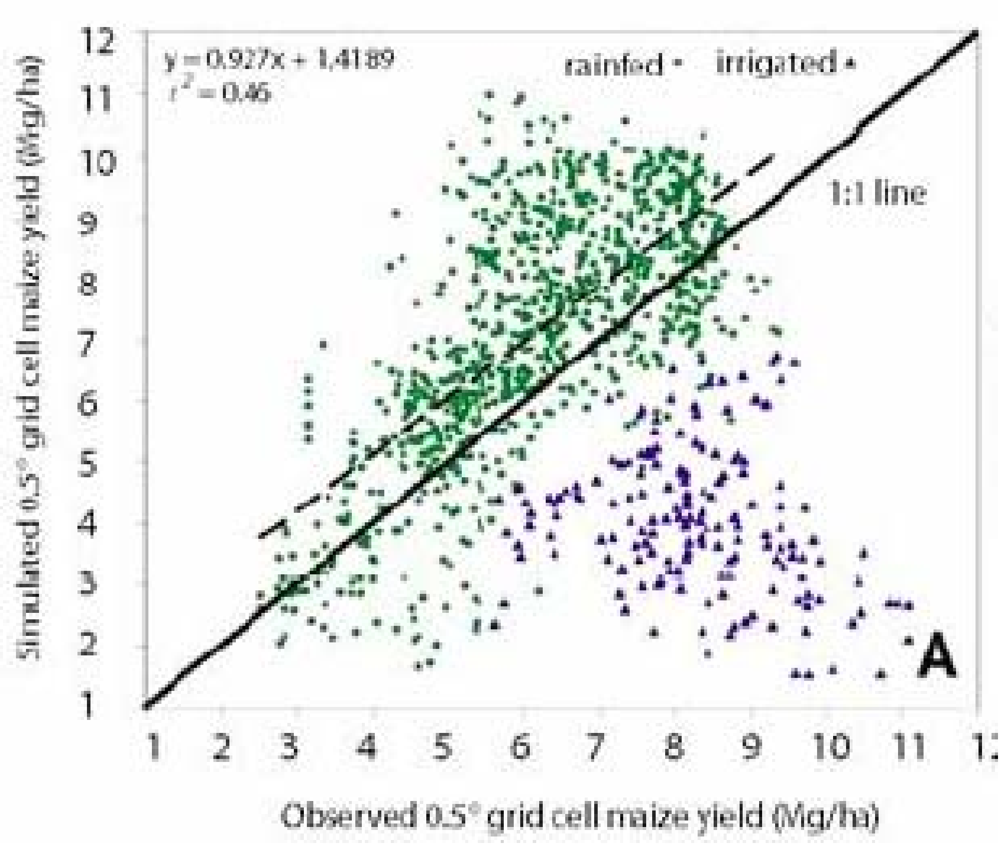
Fig. 1. Example of the basal crop coefficient (K_{cb}) curve for corn generated using the reflectance-based crop coefficient (K_{cr}) calculated from measured canopy reflectance in 1990.

Bausch (1995)

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



AGRO-IBIS model

Suggests that irrigated lands require special handling

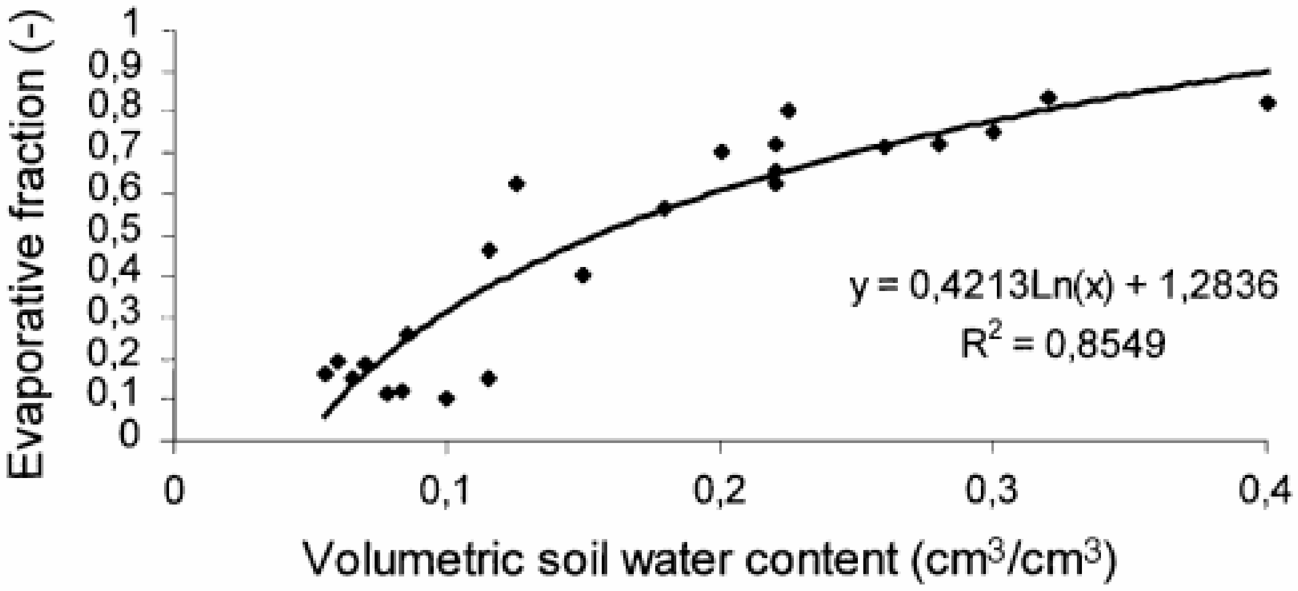
Kucharik (2003)

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



Smith et al (1992)

Soil salinity

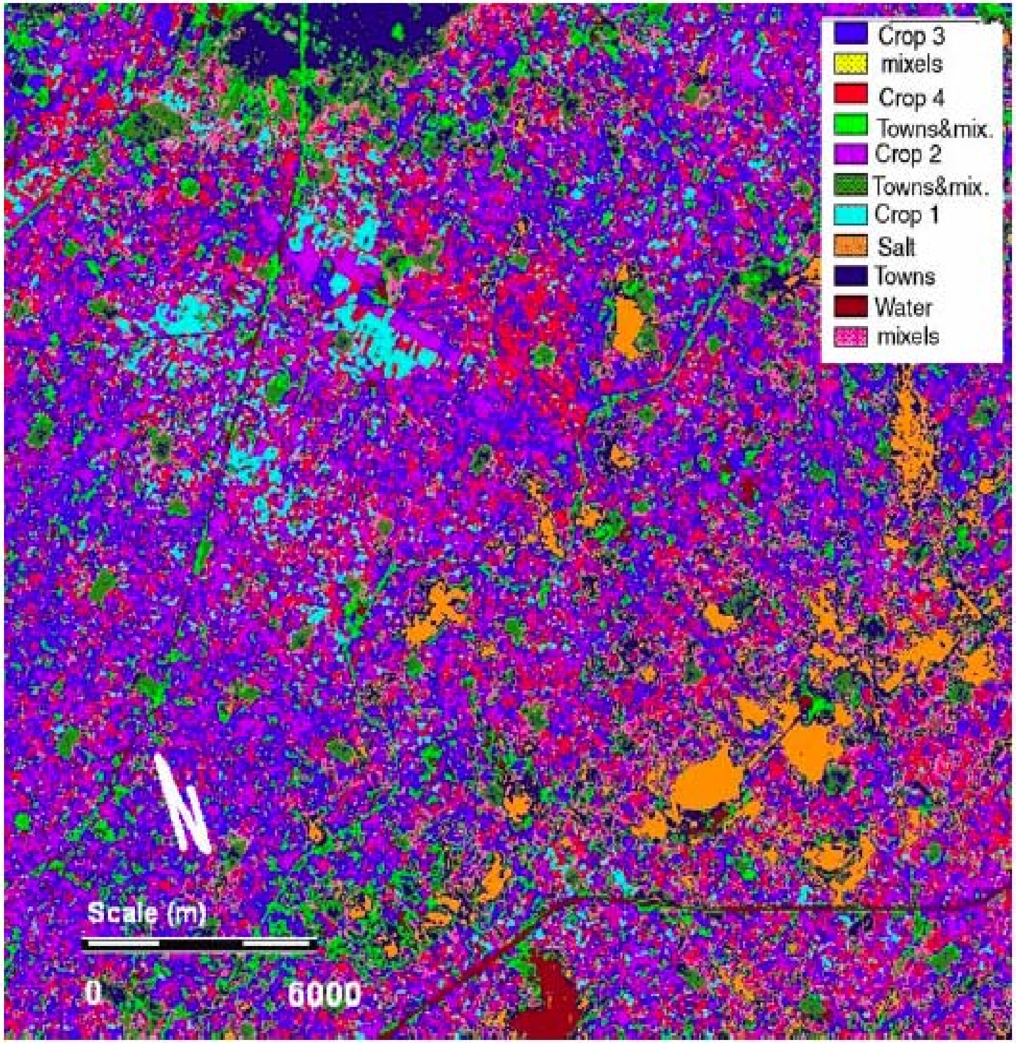
- Key soil degradation variable
- Especially important in drylands
- Multi-spectral bands with key locations are important
- Hyperspectral better
- Band combinations of visible and IR for index generation
- Categorical and continuous recovery

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

Summary

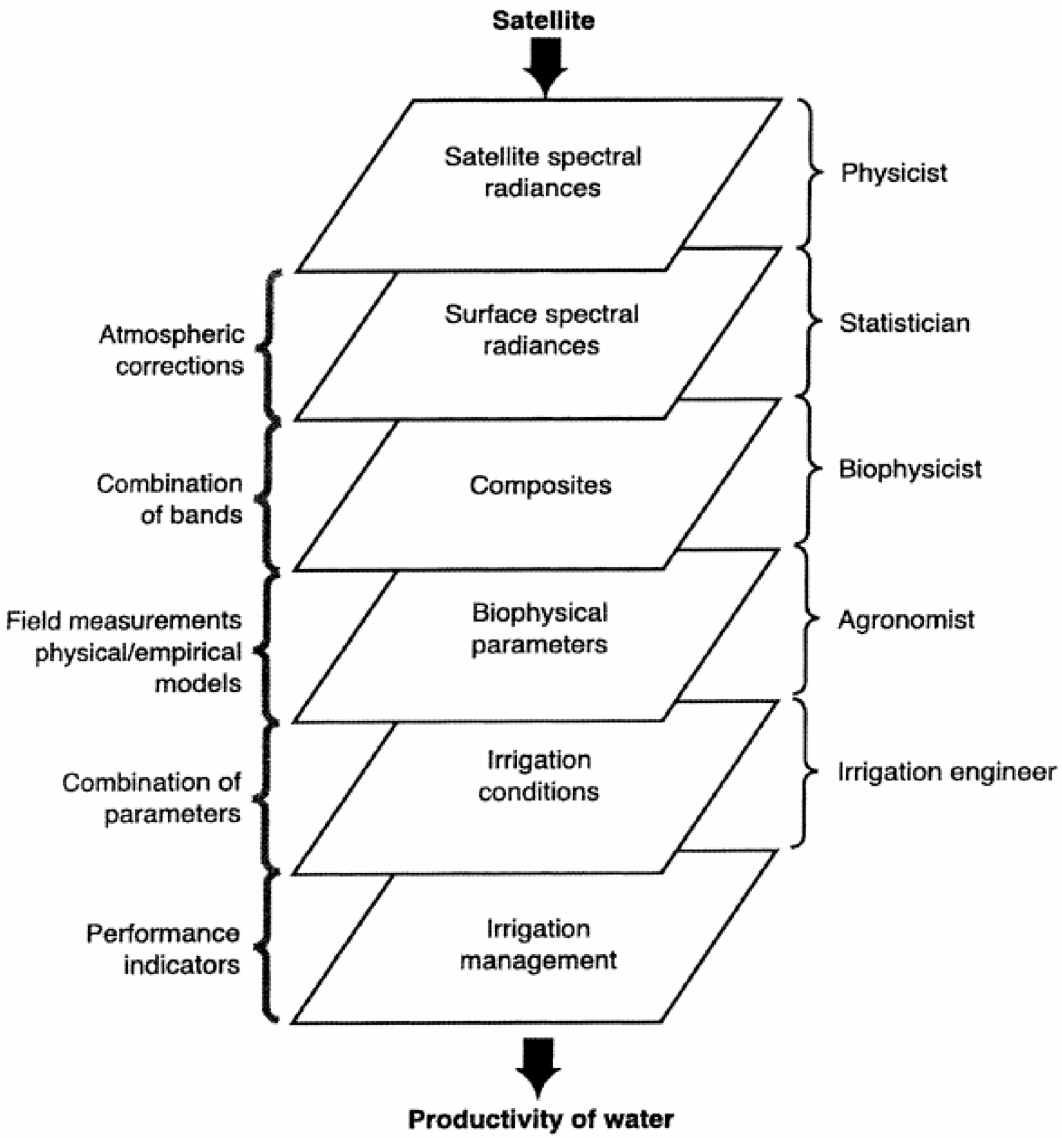
variable	**accuracy**	**operational**	**cost**
land use	high	yes	low
irrigated area	medium	emerging	low
crop type	medium	emerging	high
water use (ET)	medium	no	medium
yield	low	no	high
soil moisture	medium	no	low
soil salinity	medium	no	low

Summary

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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