
IWMI
International
Water Management
Institute
Comprehensive
assessment
of water management in agriculture
FAO
FIAT PANIS
Irrigation
How much is there really & what does it mean?

Contents

- This workshop and its objectives
- Mapping irrigated areas using remote sensing
  - Key Issues
  - Evolution of work at IWMI
  - Other work
- Challenges
- Spin-offs

Objectives of workshop

SHARE KNOWLEDGE

- Methods
- Results
- Data

UNDERSTAND RESULTS

- Implications for water use and food production strategies
- Accuracy, precision and scale
- Resolve RS approaches and statistical data.

IDENTIFY CHALLENGES & OPPORTUNITIES

- Further research
- Specific topics for collaboration
- Mapping irrigated areas in AFRICA

CREATE NEW PARTNERSHIPS FOR A REGIONALLY BASED RESEARCH AGENDA

- IWMI / FAO – national & regional
- Between national & regional
- Strengthen links to NASA, USGS, Universities etc.

Co-author a state of the art **book** on estimating irrigated area – global, regional and national scales

Programme

- Day 1 – International and global
- Day 2 – National perspectives
- Day 3 – Workshop on global and regional mapping from remote sensing (IWMI)

- RSCEWAS – Capacity building workshop – other methods and techniques

Improved global data on irrigated areas (actual and equipped, intensity of land use)

- What is the role of irrigation in providing food production and food security?
  - Input into water supply/demand/food & climate models for scenario exploration.
- How much water is used for irrigation?
  - Better assess environmental impact of irrigation.
- Investigate potential for intensification.
- How much informal irrigation is there? What is the breakdown between formal and informal irrigation?
- How much investment is actually used?

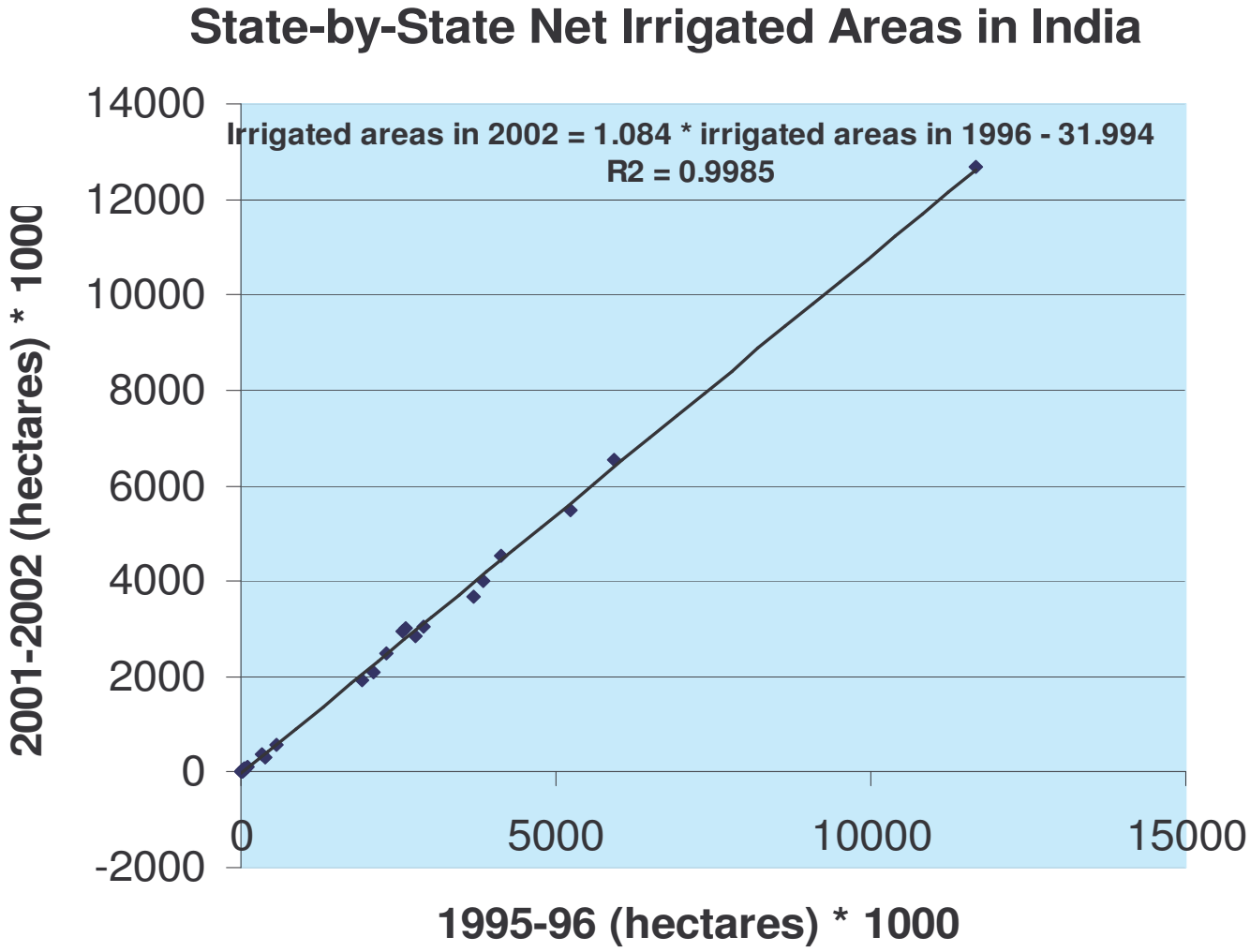
Mapping irrigated areas with RS

- Irrigated area mapping requires time series data that incorporate spatial and temporal heterogeneity of agriculture.
- Remote sensing data are available in time series with different spatial, spectral and temporal resolutions.
- Analysis of these various types of data requires different techniques – develop and evaluate.
- The techniques should ideally allow analysis of data at different scales and allow automation of processing for long-term repeatability.
- A tool for irrigation monitoring at country level.

Why estimate irrigated area better?

- What is the contribution of irrigation to global, regional, and national food security and production?
  - What is cropping intensity?
- What has happened with the groundwater boom, esp. in Asia?
- What is the impact of better estimates on calculated water resources use?
  - What is the impact of cropping intensity?
- Can we resolve RS estimates with statistical estimates and understand systematic reporting errors in local statistics?

National Statistics

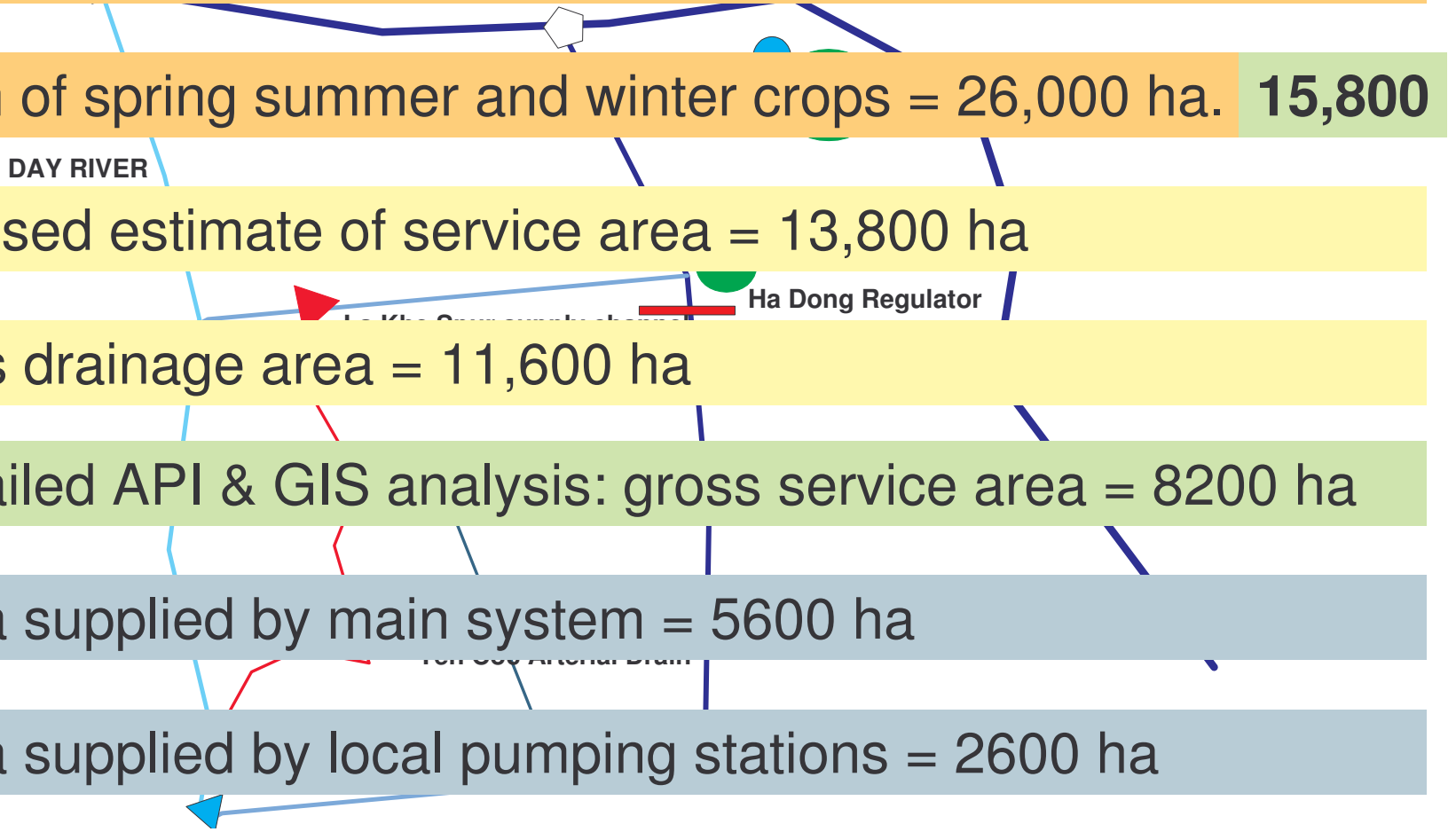


Irrigated areas in 1995-96 and 2001-2002 for the 29 Indian States are the same: Ministry of Agricultural Statistics.

La Khe – an irrigation system in Vietnam – different views!

First Official Statistic – Irrigated area of La Khe = 26,000 ha.

Sum of spring summer and winter crops = 26,000 ha. **15,800**



Revised estimate of service area = 13,800 ha

Less drainage area = 11,600 ha

Detailed API & GIS analysis: gross service area = 8200 ha

Area supplied by main system = 5600 ha

Area supplied by local pumping stations = 2600 ha

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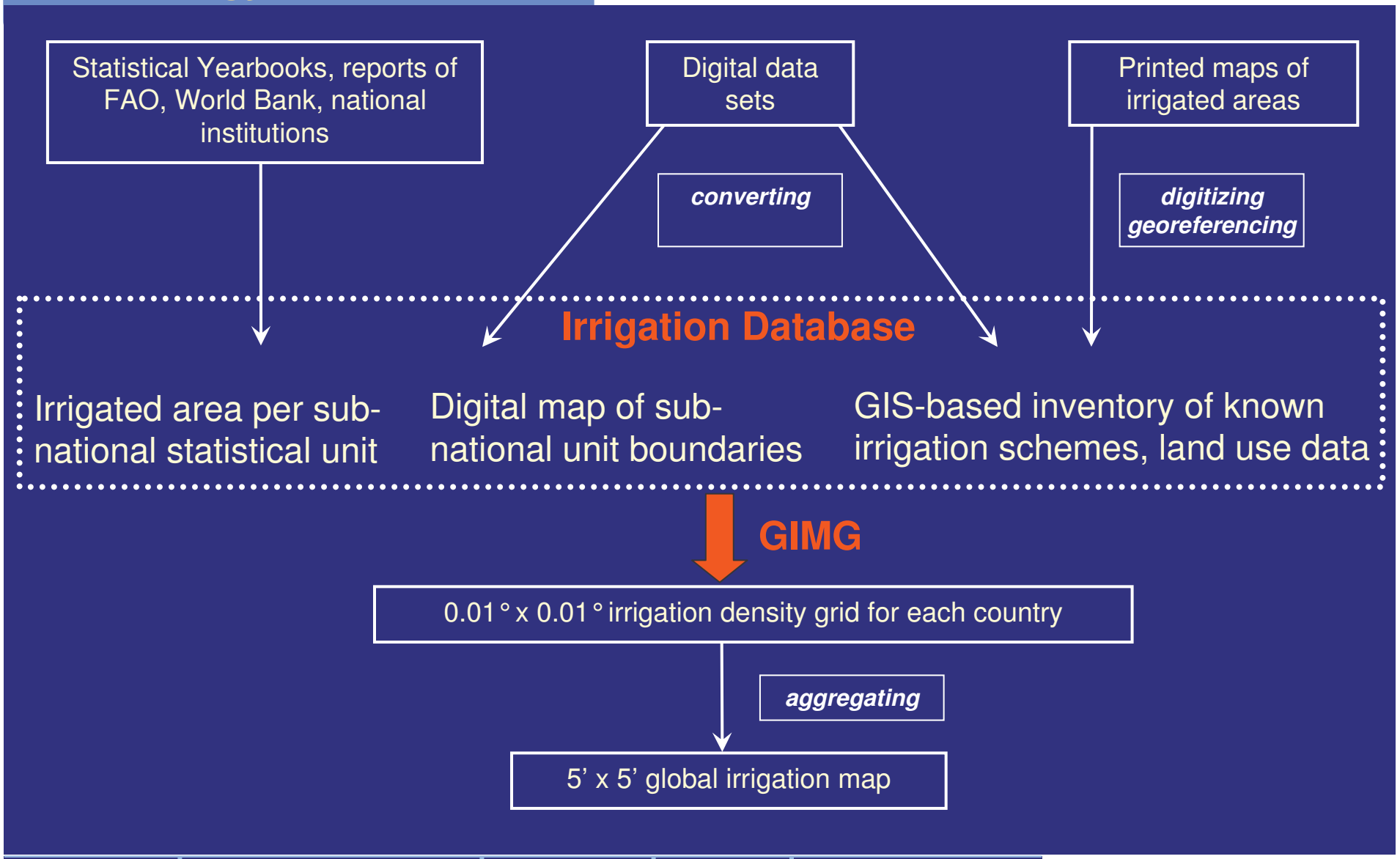
FRANKFURT AM MAIN

Scheme of mapping methodology



Map quality per country

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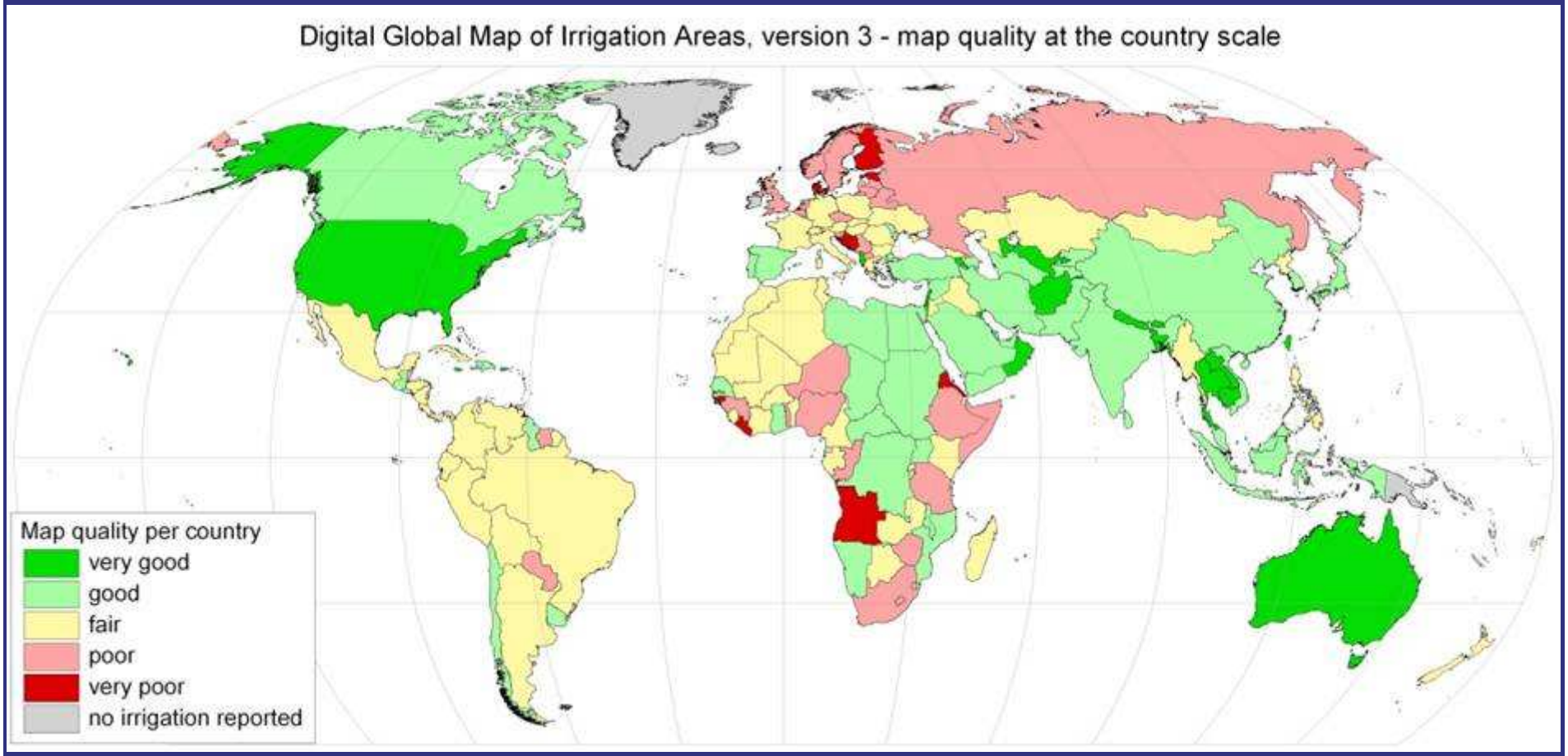
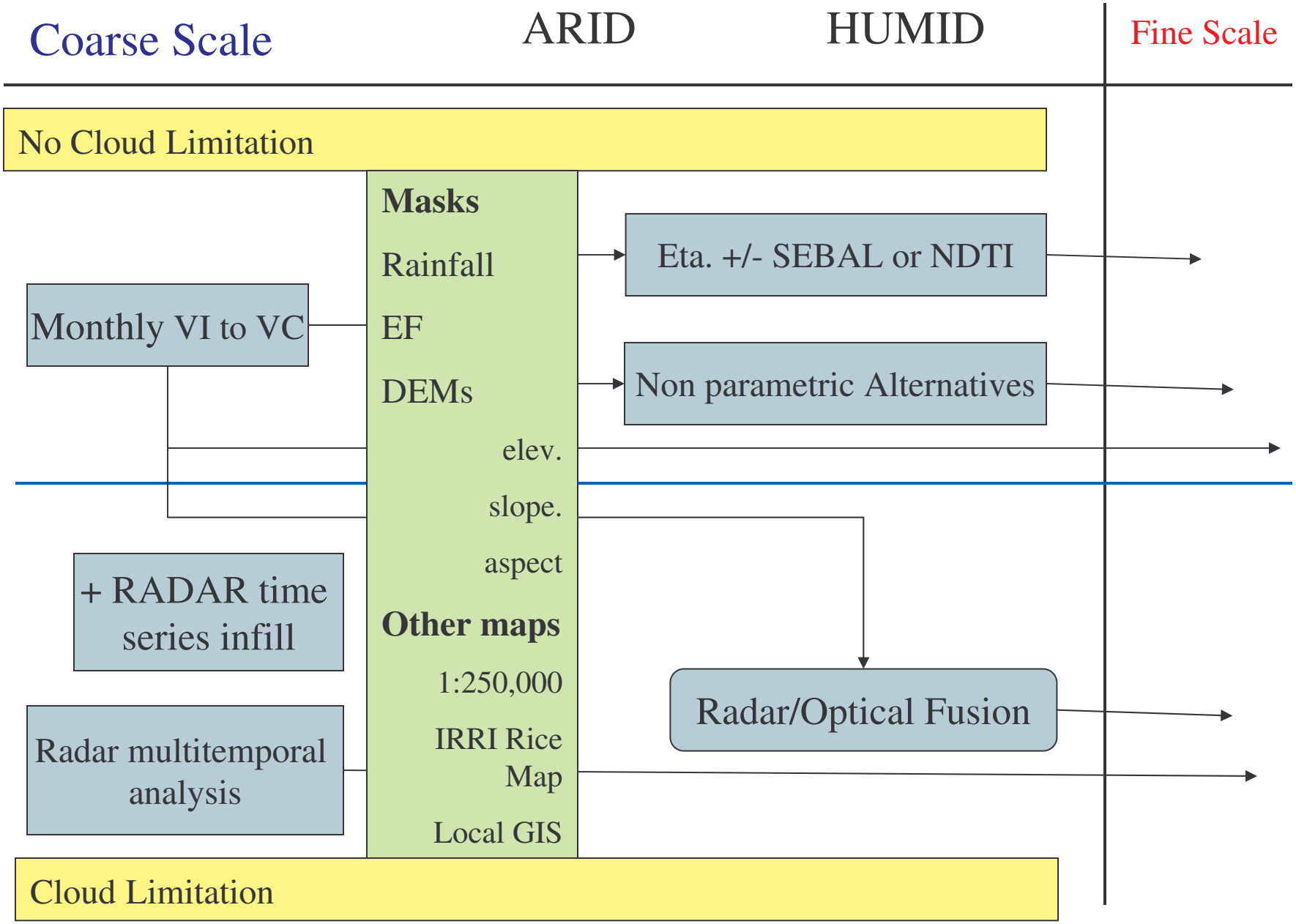
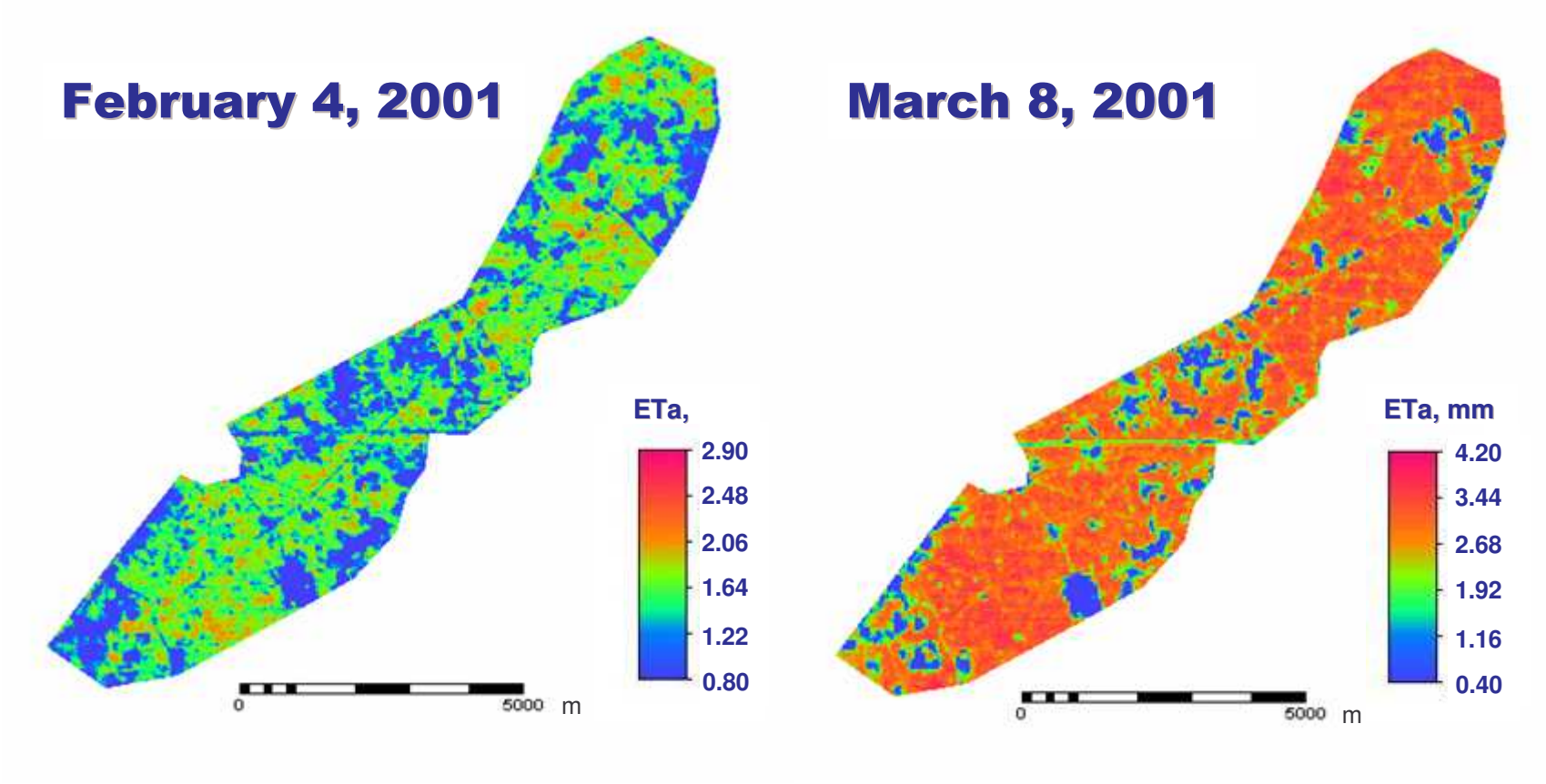


GIAM methodology "101", 2002: where we started

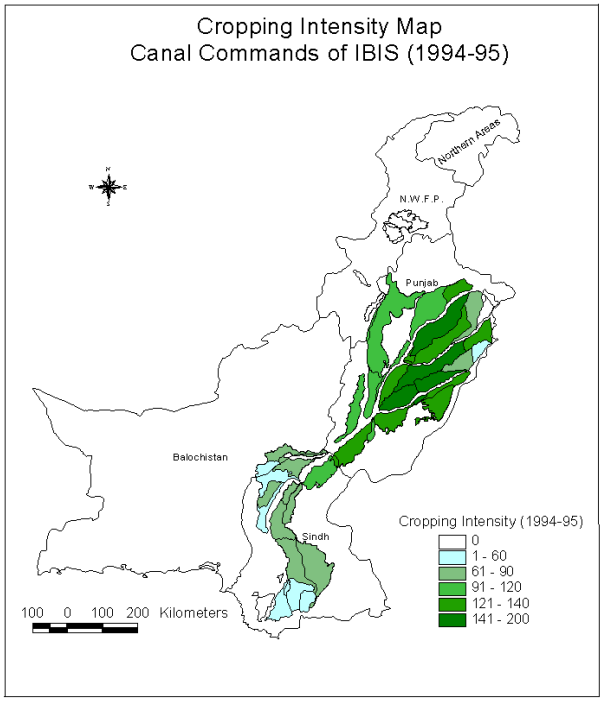


ET_a in Bata Minor, Kaithal, Haryana, India



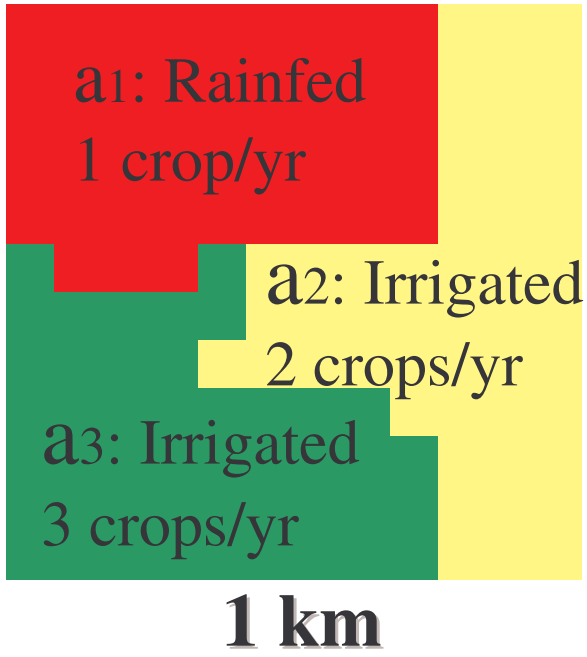
Results from SEBAL Analysis (Ines, 2001)

Scale examples



WORKSHOP | MAPPING | CHALLENGES | SPIN-OFF

Mixed Pixels, a challenge
1 crop/yr (rainfed), 2 crops/yr, 3 crops/yr



a_i : *proportion of each agriculture pattern*

i: Agricultural Pattern

$$a_1 + a_2 + a_3 = 1.0$$

$sd_{i,j}$: *sowing date*

j: sowing count

1 crop/yr : $sd_{1,1}$

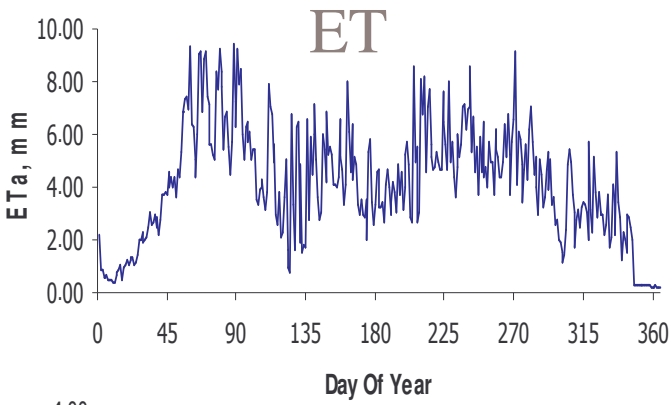
2 crops/yr : $sd_{2,1}$, $sd_{2,2}$

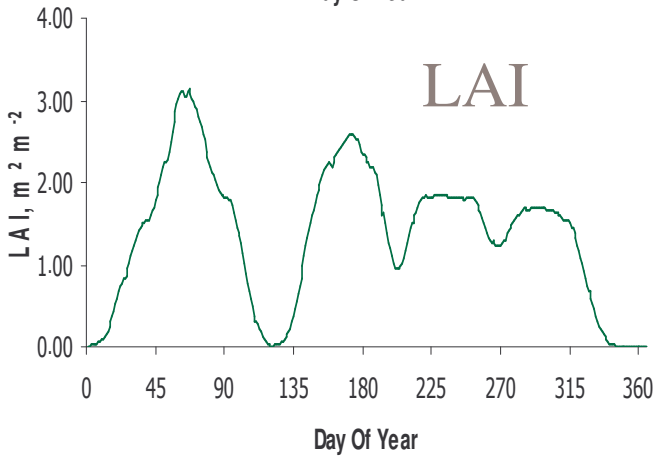
3 crops/yr : $sd_{3,1}$, $sd_{3,2}$, $sd_{3,3}$

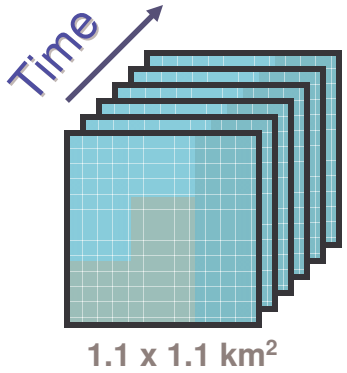
Source, Ines and Honda

Low resolution RS; Mixed-pixel
1 crop/yr (Rainfed), 2 & 3 Crops/yr (Irrigated)

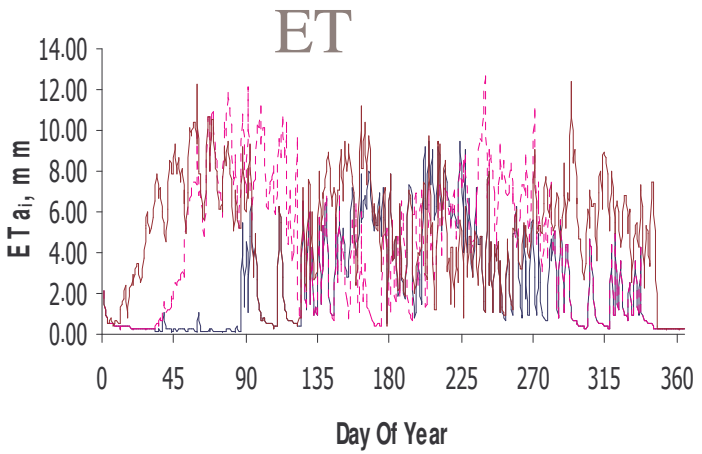
Observed Mixed Pixel

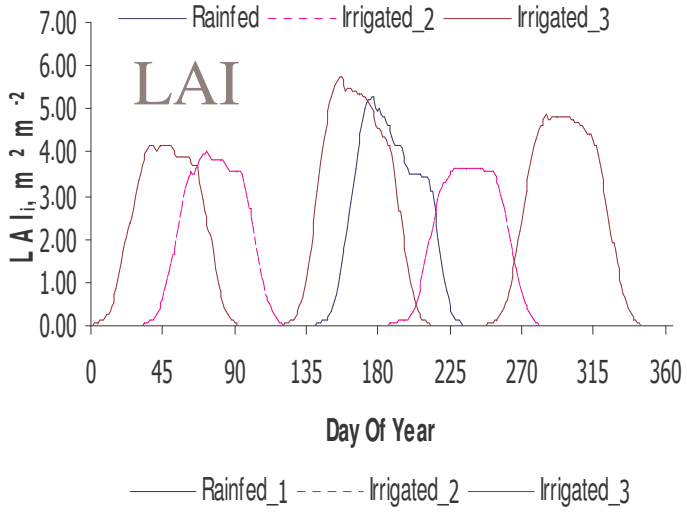






Reality





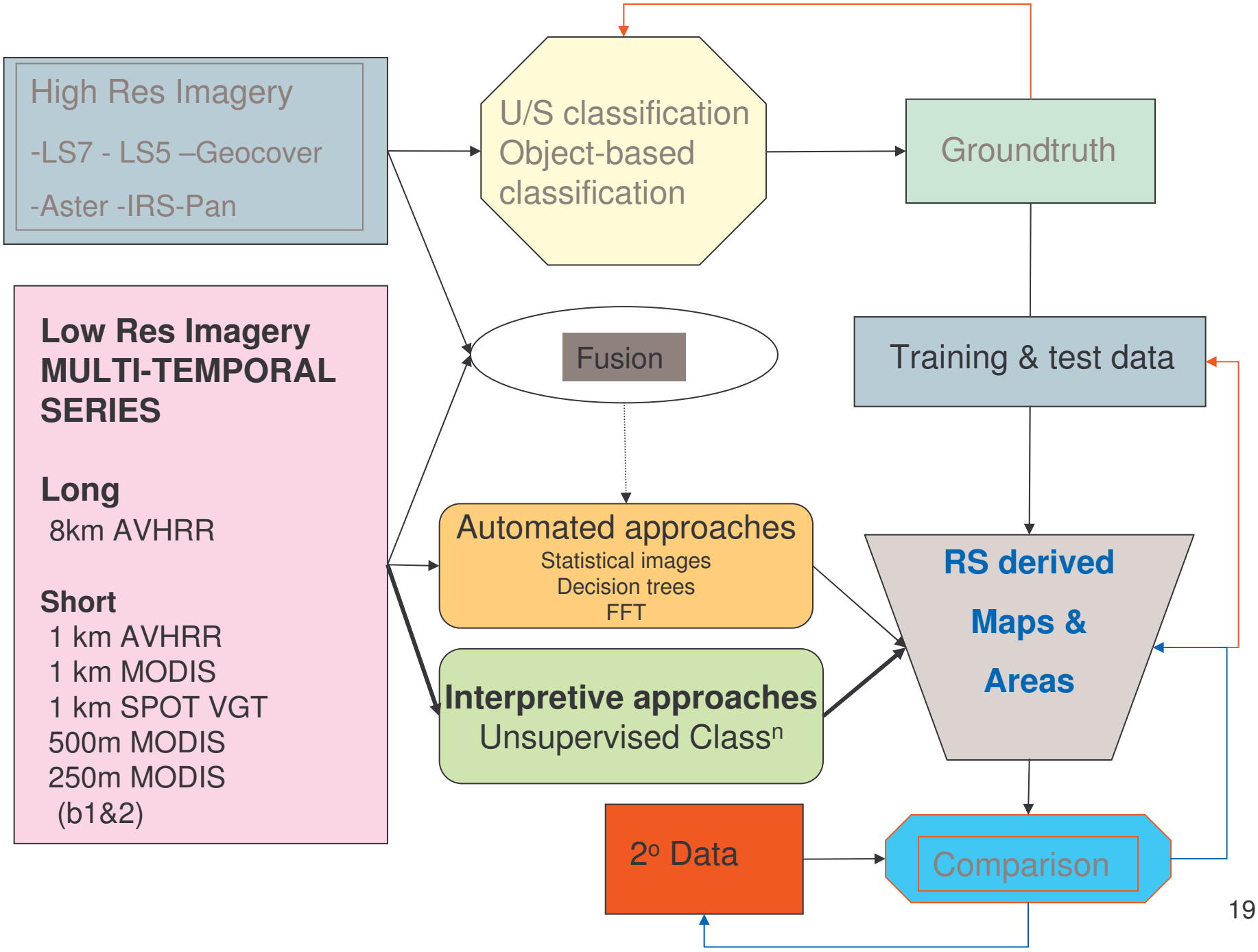
Depending on the proportions of rainfed1, irrigated2 and irrigated3 in the 1.1 km x 1.1 km pixel

Approaches

- Scale and precision versus cost – public domain preferred.
- Need for groundtruth – everywhere
- Therefore needed a collaborative model of research – FAO, AIT, Yale, across IWMI projects – India, Pakistan, RSA etc.
- Bottom up: from GIS and Landsat (15-30m) up to 500m (MODIS) – national & regional
- Global: top down – 10km to 500m

Multitude of Sources

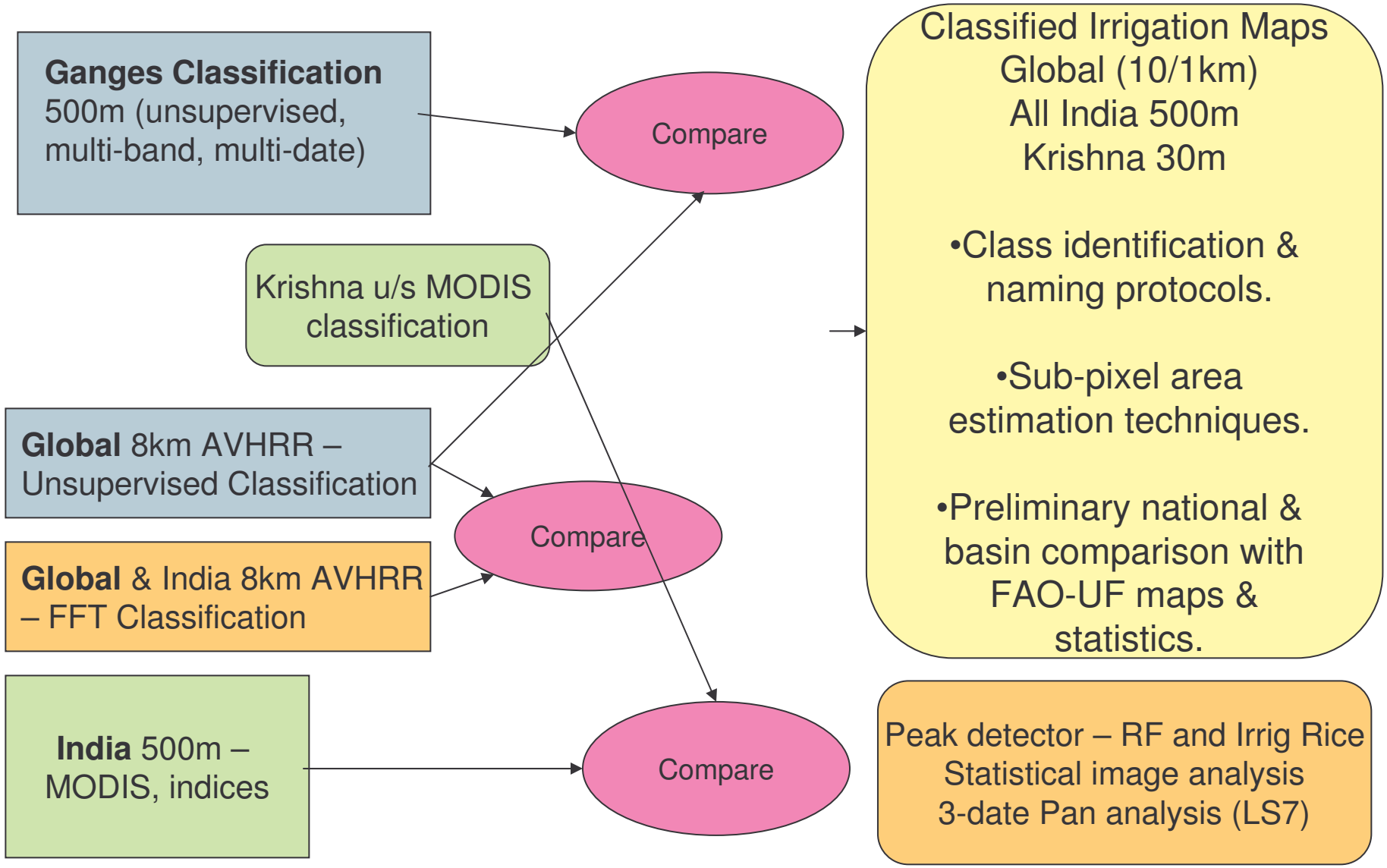
- Spectral properties / multi-spectral: Fusion of different spectral channels.
- Polarization properties / multi-polarization: Fusion of different polarization SAR data.
- Temporal properties / multi-temporal: Fusion of data acquired in different time.
- Spatial properties / multi-resolution: Fusion of data from different sensors.


High Res Imagery
-LS7 - LS5 –Geocover
-Aster -IRS-Pan
U/S classification
Object-based
classification
Groundtruth
Low Res Imagery
MULTI-TEMPORAL
SERIES
Long
8km AVHRR
Short
1 km AVHRR
1 km MODIS
1 km SPOT VGT
500m MODIS
250m MODIS
(b1&2)
Fusion
Training & test data
Automated approaches
Statistical images
Decision trees
FFT
RS derived
Maps &
Areas
Interpretive approaches
Unsupervised Class^n
2º Data
Comparison

We “ignored” **AFRICA**, reasoning that in most places, the scale of irrigation was very small, and needed hi-resolution image analysis

- Expensive – needs preliminary identification of areas: multi-temporal analysis in general would be difficult
- Well-established techniques at hi-res (?)

Where we ended up - September 2006



Other associated research

- AIT – discriminating rainfed and irrigated rice.
- AIT – advanced sub-pixel estimation
  - (inverse solution of SPW model - grid computing)
- Uni. New Hampshire: rice mapping in China for methane emissions estimation.
- Australia inventory in Goulburn Murray – GIS with Landsat.
- USA Olgallala Aquifer work with UND.
- Iran NSA – vegetation and irrigation mapping.
- USGS irrigated area mapping in US
- ++++++++++++

Advances in Groundtruth

- On-ground missions at 500m pixel scale based on classes identified from MODIS 500m Multi-temporal image analysis.
  - Ganges, Krishna, “All India” (not Punjab and Haryana)
- **Degree Confluence Project – volunteer network**
- Contributed data – eg ISIA, Vic. Irrig.
- **Google Earth – increasing 1-4m data coverage**.

Remote sensing estimates and statistics – where to next?

- Equipped area and distribution between IWMI global map V2 and FAO-UF map V3 similar.
  - Initial comparison between FAO and IWMI approaches at global scale done
- IWMI estimate of annualised area much higher than equipped area due to high cropping intensity in India and China.
- Absolute accuracy assessment hard at 10km – should be easier at 500m.
- Formal independent assessment of differences between FAO-UF version 4 and IWMI Global V2 after workshop.

Need to properly understand differences FAO-UF / IWMI RS

- Cross check spatial differences ☻
- Differences in disaggregated areas and intensities? ☻
- How to do some absolute accuracy assessment? Where? Method?
- Explain differences in detail
- Resolve differences and elaborate implications.

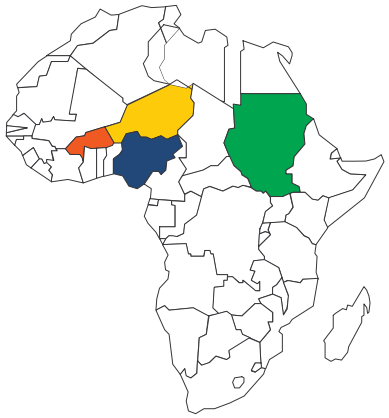
Implications of findings

- If total annual irrigated area is much bigger than previously estimated, what proportion of the world's food is sourced from irrigation (40/17)?
  - More? Less? How does this vary regionally and nationally?
- How are the contributions of irrigated and rainfed agriculture actually calculated / derived?
  - Stats, samples, trade, stocks, price behaviour?????

- What are implications for water use statistics? (presumably greater use)
  - Effect on water productivity
  - Room for manoevre in future in irrigated agriculture
    - Intensification?
    - Improvement of WP and LP?
    - Balance of RF and irrigated agriculture in different regions?

Challenges for RS & irrigation

Mapping



? Irrigation potential in Africa

- API ± RS,
- Soils / detailed land use.

Complement GIS

(FAO)

Understanding

Why can we identify groundwater (sometimes)?

Scale and accuracy – what is optimum?

Trends and inter-annual variation..

Common language –

What is irrigation?

Expand ground truth "library": refine classes

New Methods

Moving beyond NDVI ???

Discrimination

- single irrigated crops & multiple rainfed crops.
- Orchards & forest
- Pastures
- SSI / Spate irrig.

Accuracy & quality assessment

Spin-offs

Global wetland mapping and inventory

- Needs other contextual information in addition to RS
- Greater GIS focus

Other products

Global map of rainfed areas
Global LUCC
DSP & other data archives

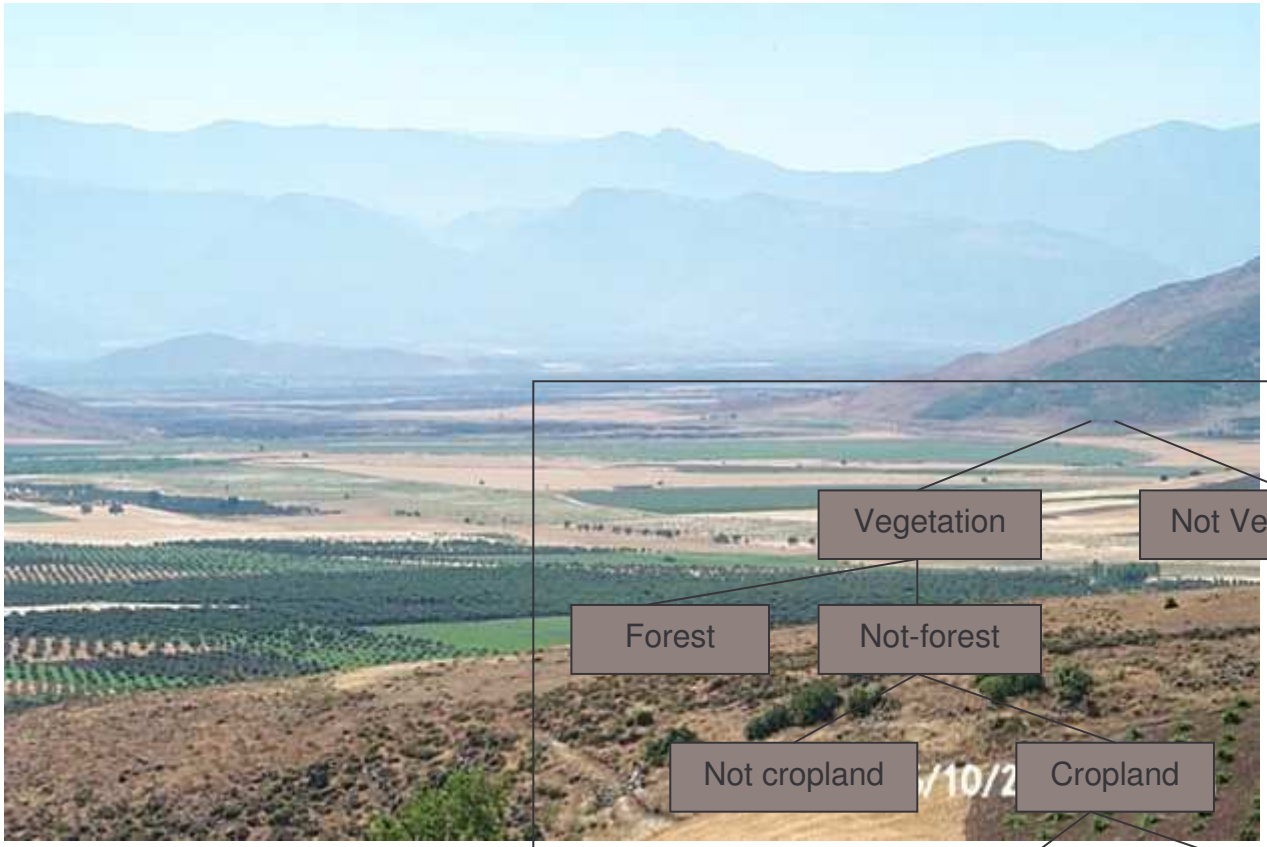
Crop Water Productivity Estimation

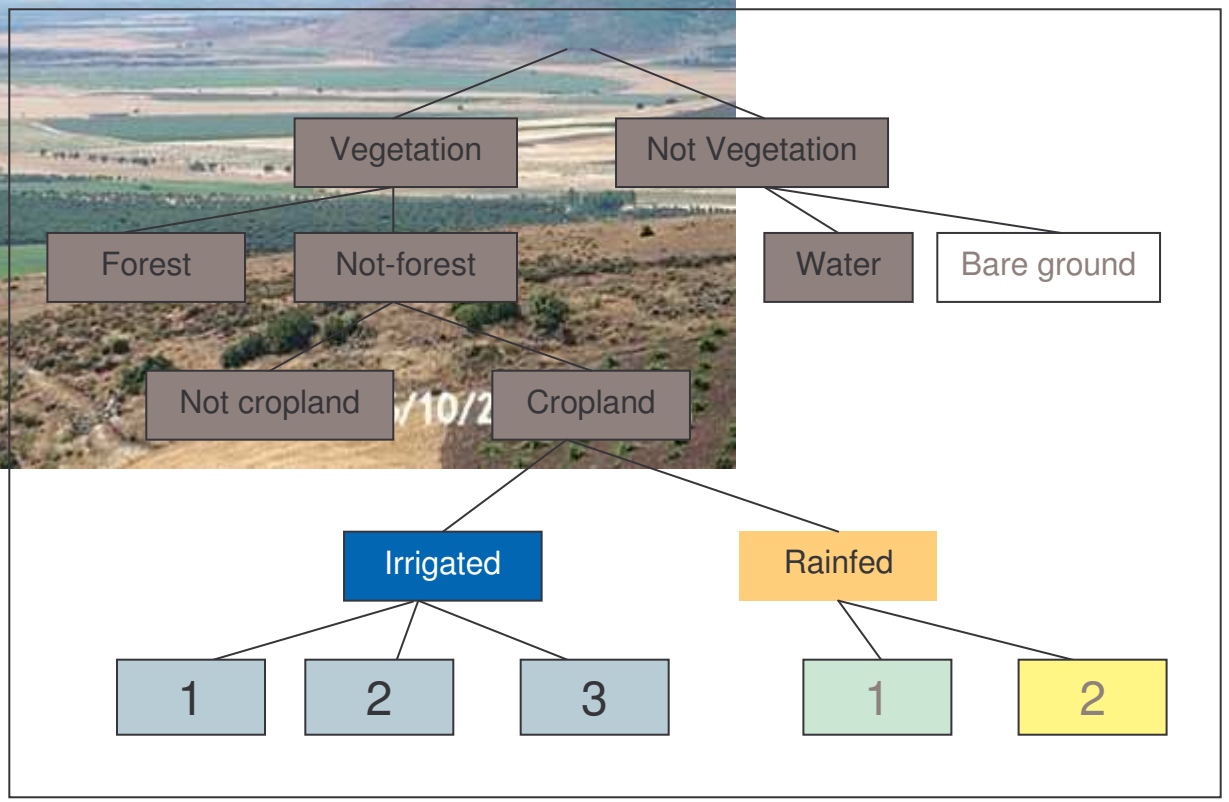
- RS-crop growth models –

  Total biomass, yield, HI,

- RS (SEBAL) / ground based water use
- Crop mapping

Thanks




Vegetation
Not Vegetation
Forest
Not-forest
Water
Bare ground
Not cropland
Cropland
Irrigated
Rainfed
1
2
3
1
2

Spares

System characteristics derived by GA

Derived System characteristics from IM_GA

Stochastic variables	Mean	Standard deviation
α (soil parameter)*	0.0212	0.0252
n (soil parameter)	1.4144	0.0381
Emergence date**	November 22	7 days
Depth to groundwater+	434.6 cm	33.5 cm
Irrigation scheduling***	0.72	0.28
Irrigation quality****	2.4 dS m^{-1}	0.74 dS m^{-1}

* Mualem-Van Genuchten (MVG) parameters.
** Sowing dates were represented by emergence dates in Extended SWAP.
***Irrigation scheduling criterion, T_a/T_p
**** Average value of surface water and groundwater, surface water has good quality for irrigation
+ Assumed spatially distributed but not significantly distributed in time

Mapping out some work paths…

- Pilot study at regional or national scale
  - What is a reliably documented country?
  - Task sharing – who does what?
- Components?
  - 2° Statistics (+- FAO/UF treatment), RS at multiple scales of area (Irrig and RF).
  - Estimates of production (Irrig and RF).
  - Stocks and trade
  - Water use / water balance (from stats and calculated)
- Models????

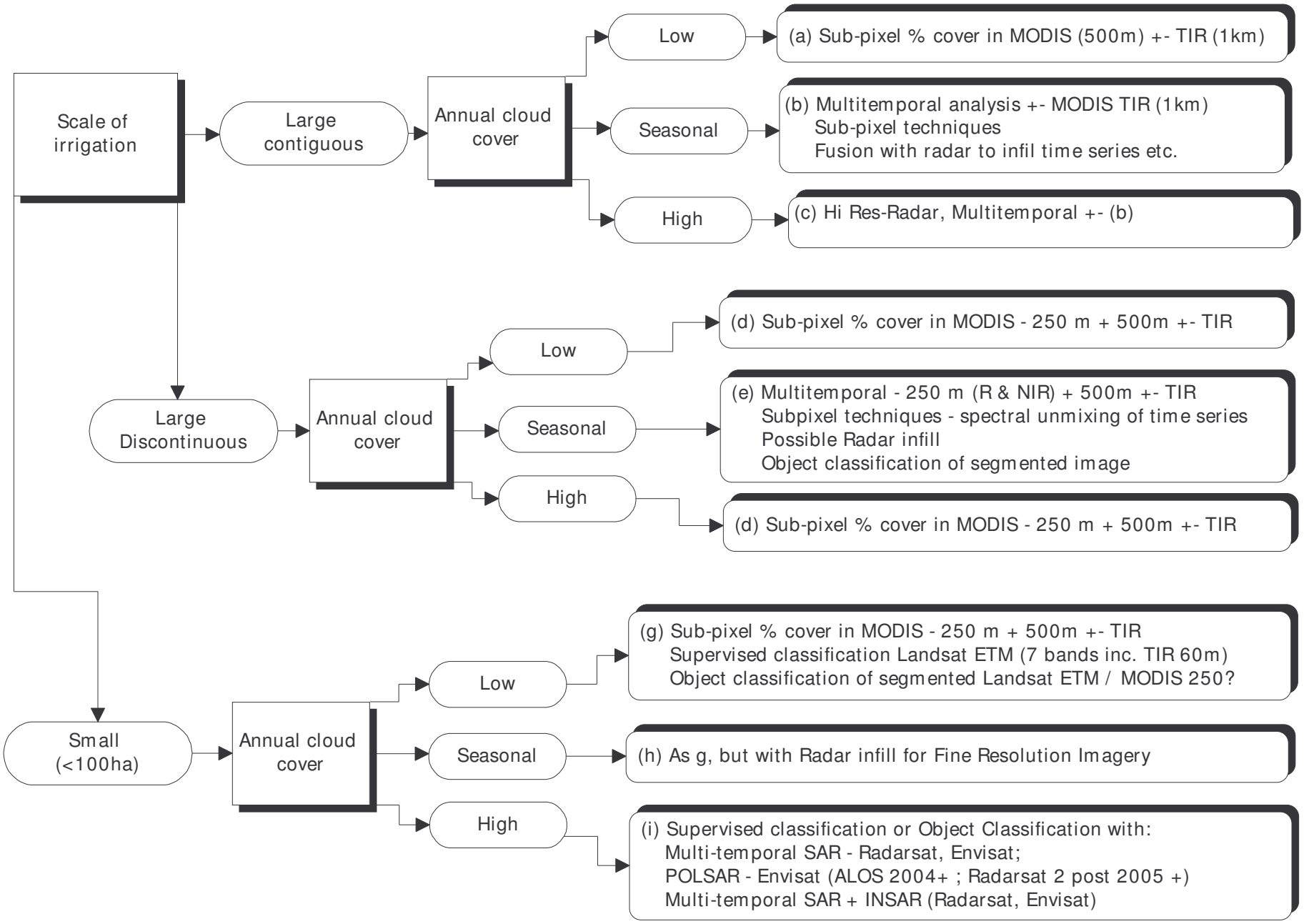
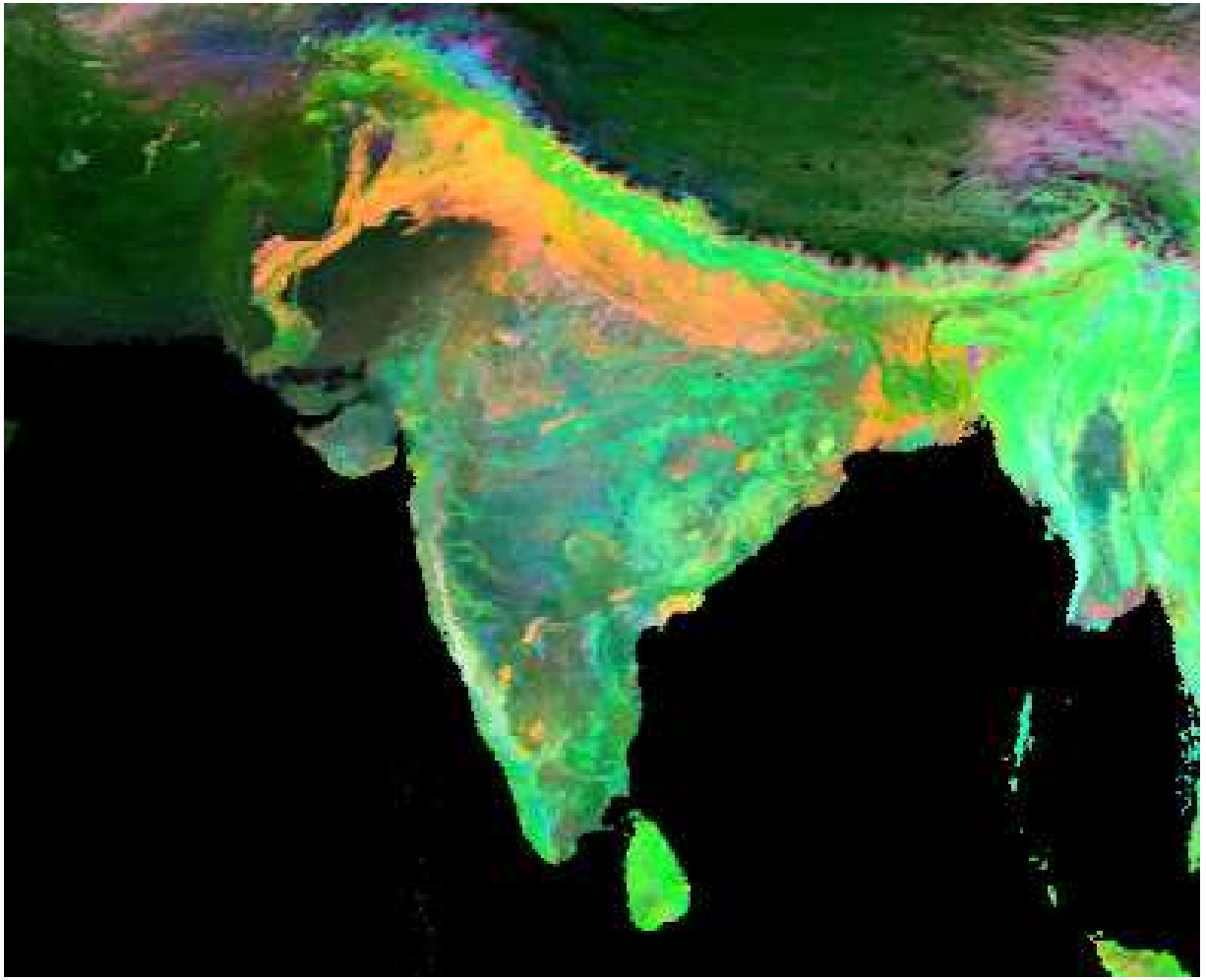


Figure 1 Mapping options for mapping subsets of global irrigated area

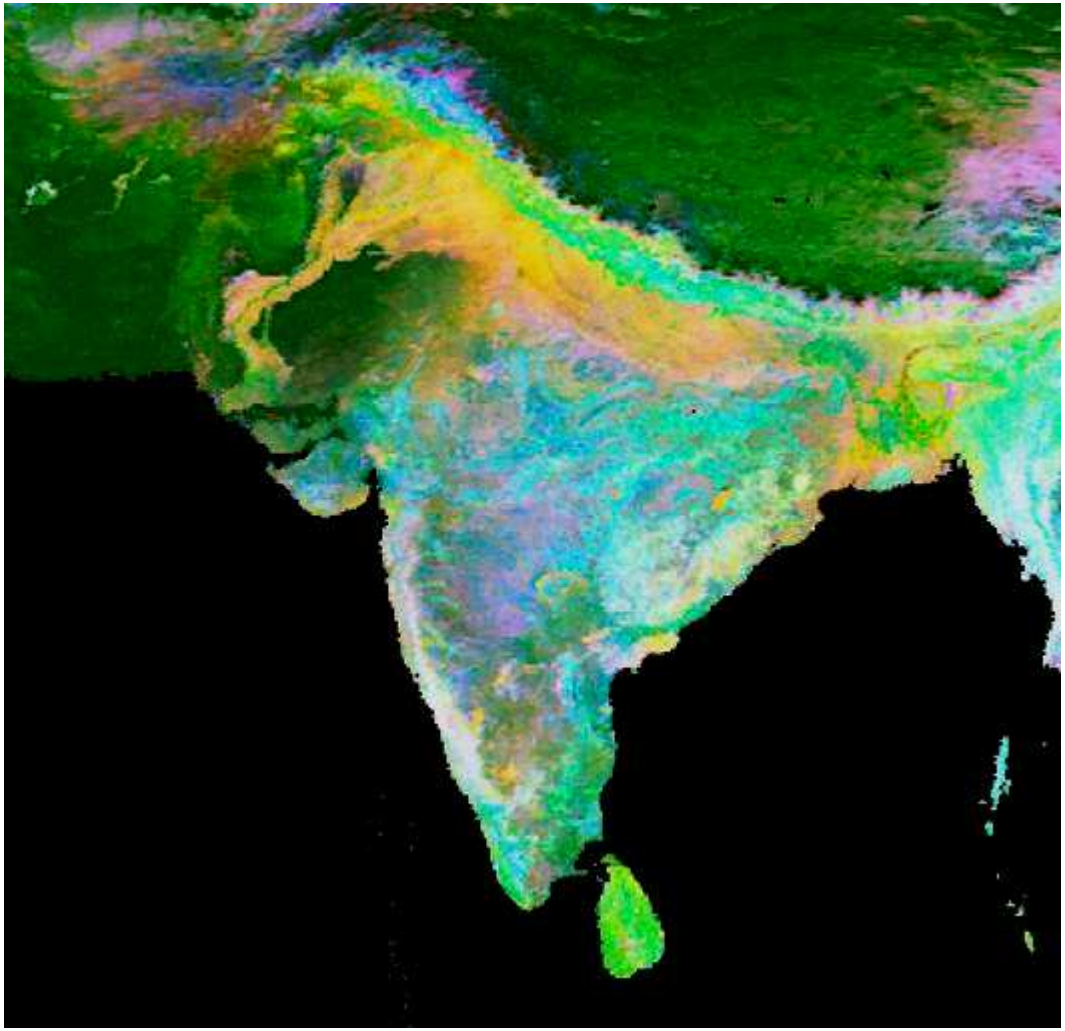
Background (2)

- **What are the shortcomings?**
  - Most figures present simply irrigated without time reference (seasonal and long-term variations in water supply, also impact the actual irrigated area observed in any one season)
  - Limit accuracy of low resolution imagery (the mixing land cover type within a pixel)
  - Lack of a generic methodology applicable on irrigated area mapping at global scale.

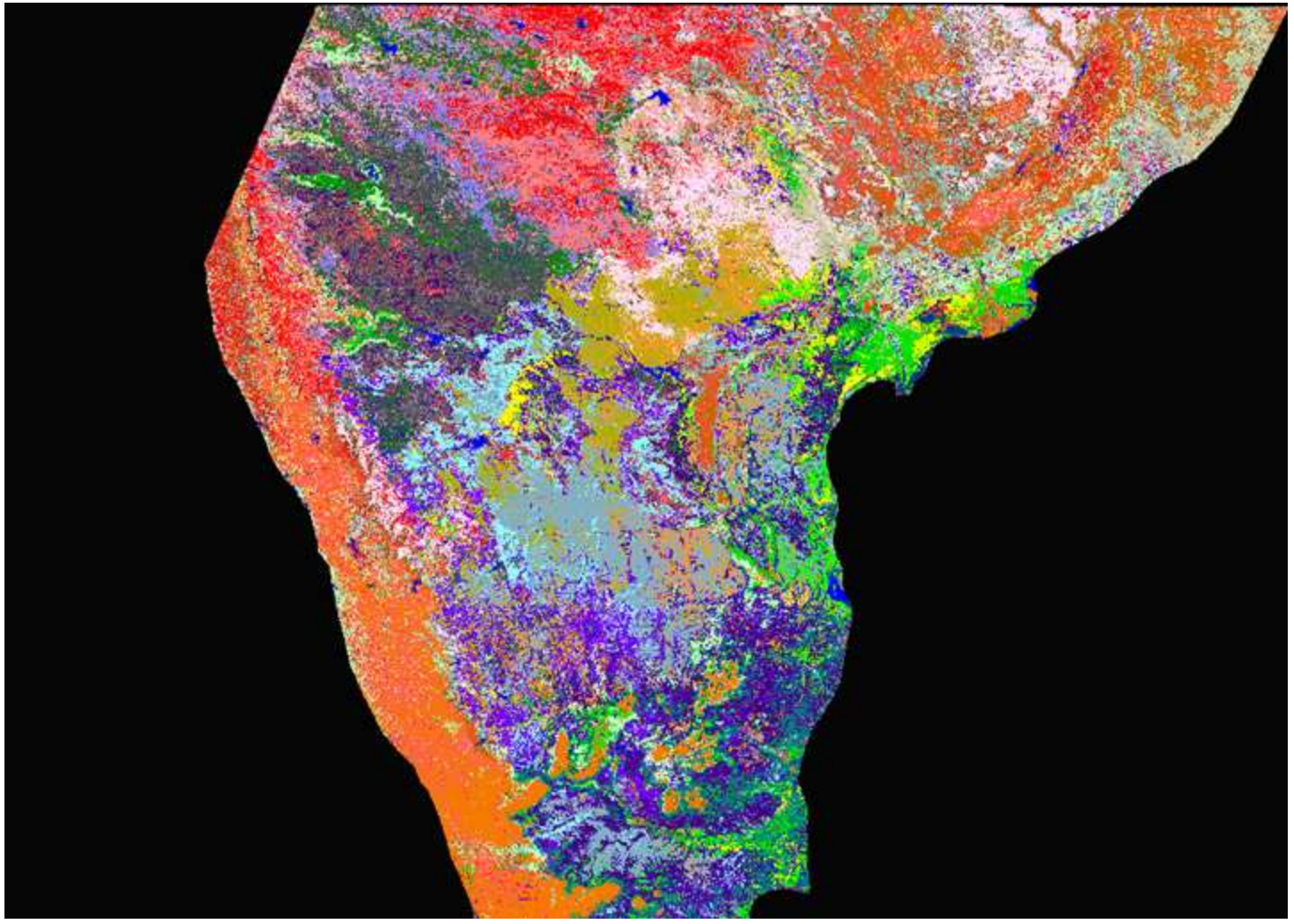
Two Season Cultivation Areas



Two Season Cultivation Areas Derived from 4 Years of Data

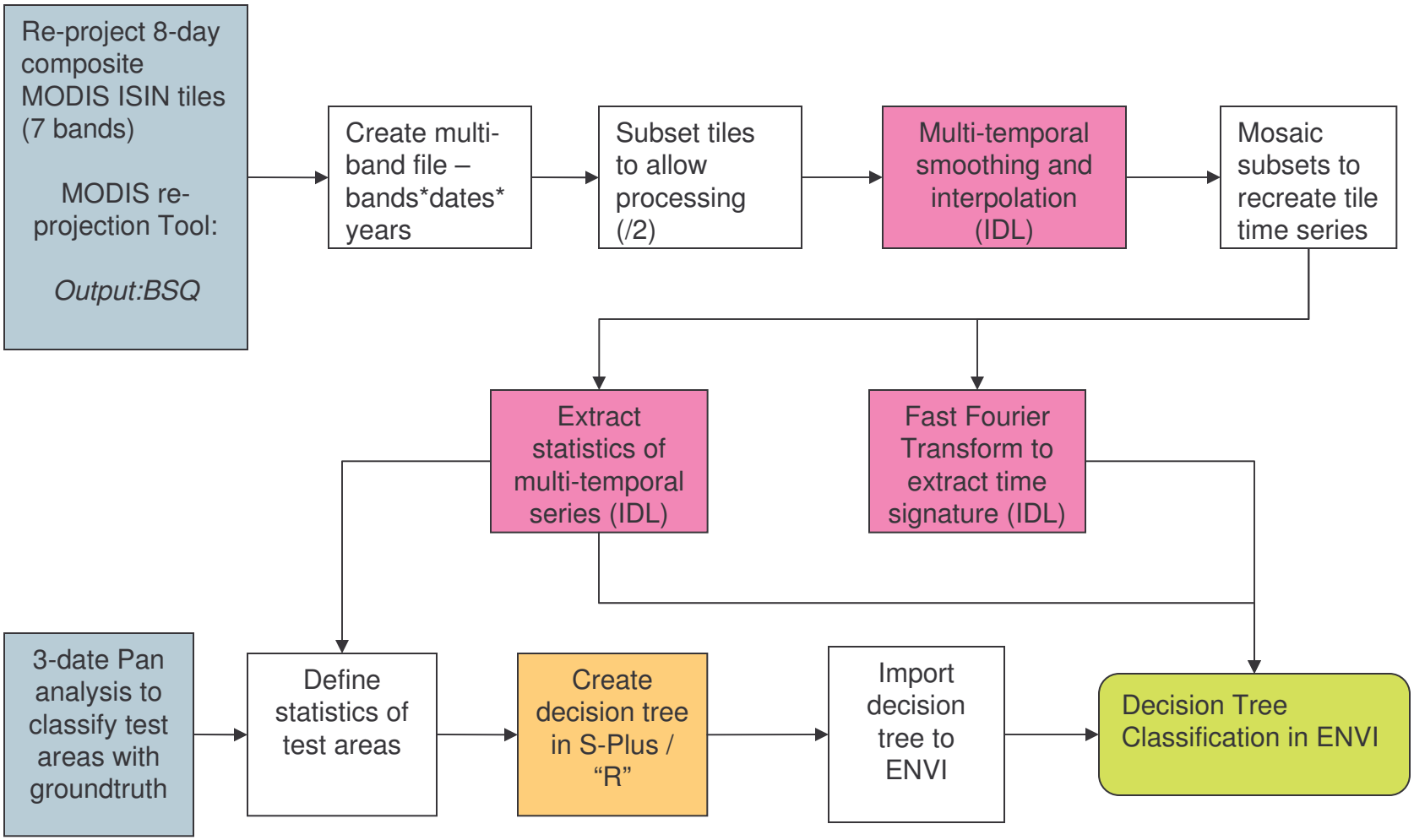


Classified map derived from statistics images

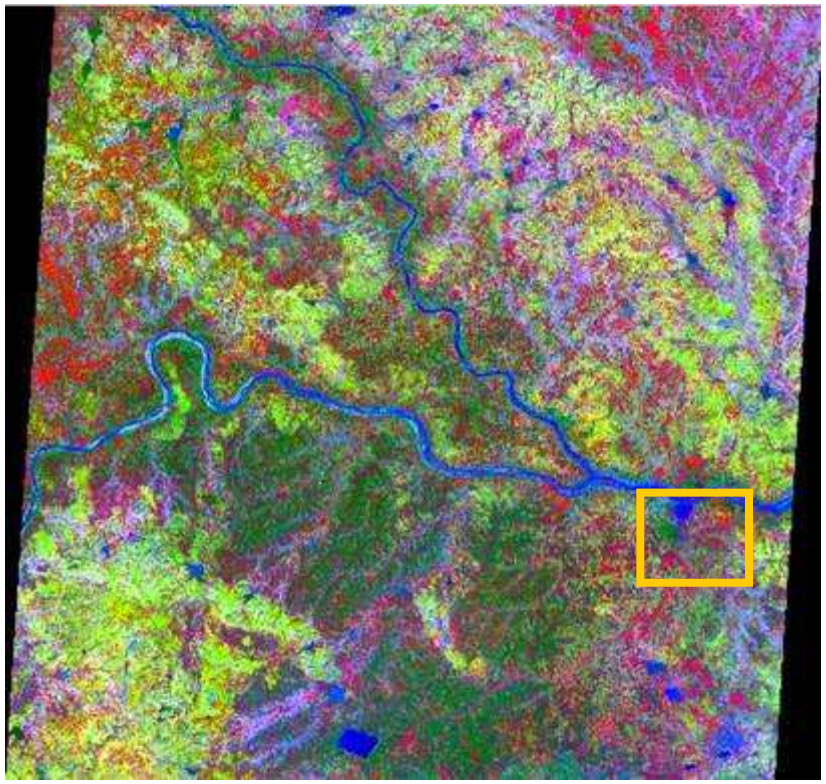


Irrigated areas are in yellow and green color

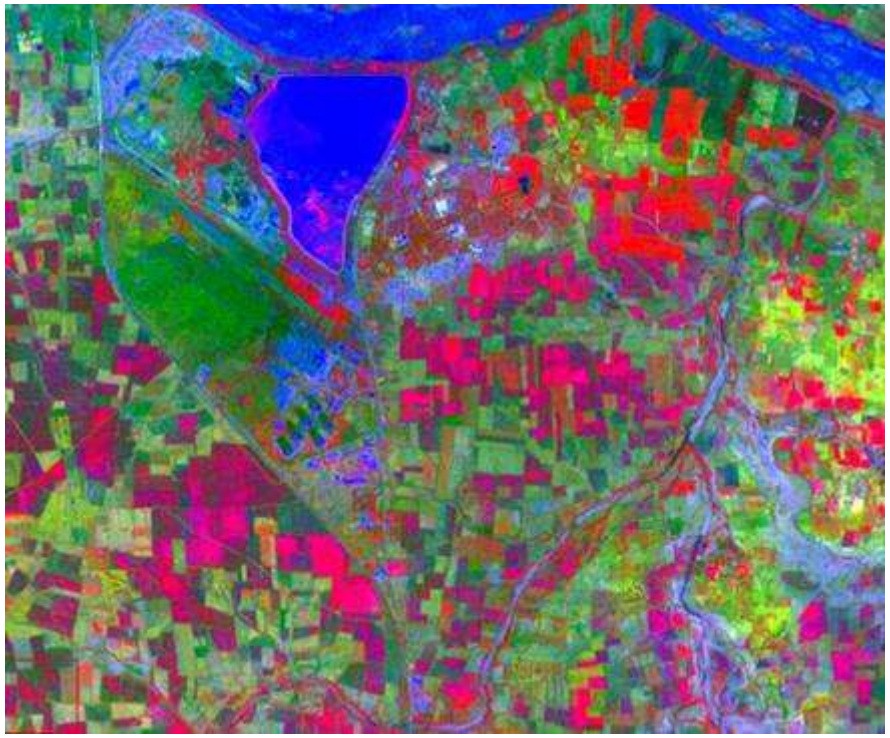
Processing chain for multi-temporal analysis of satellite data, using Fourier analysis and Decision Trees – by MODIS tile.



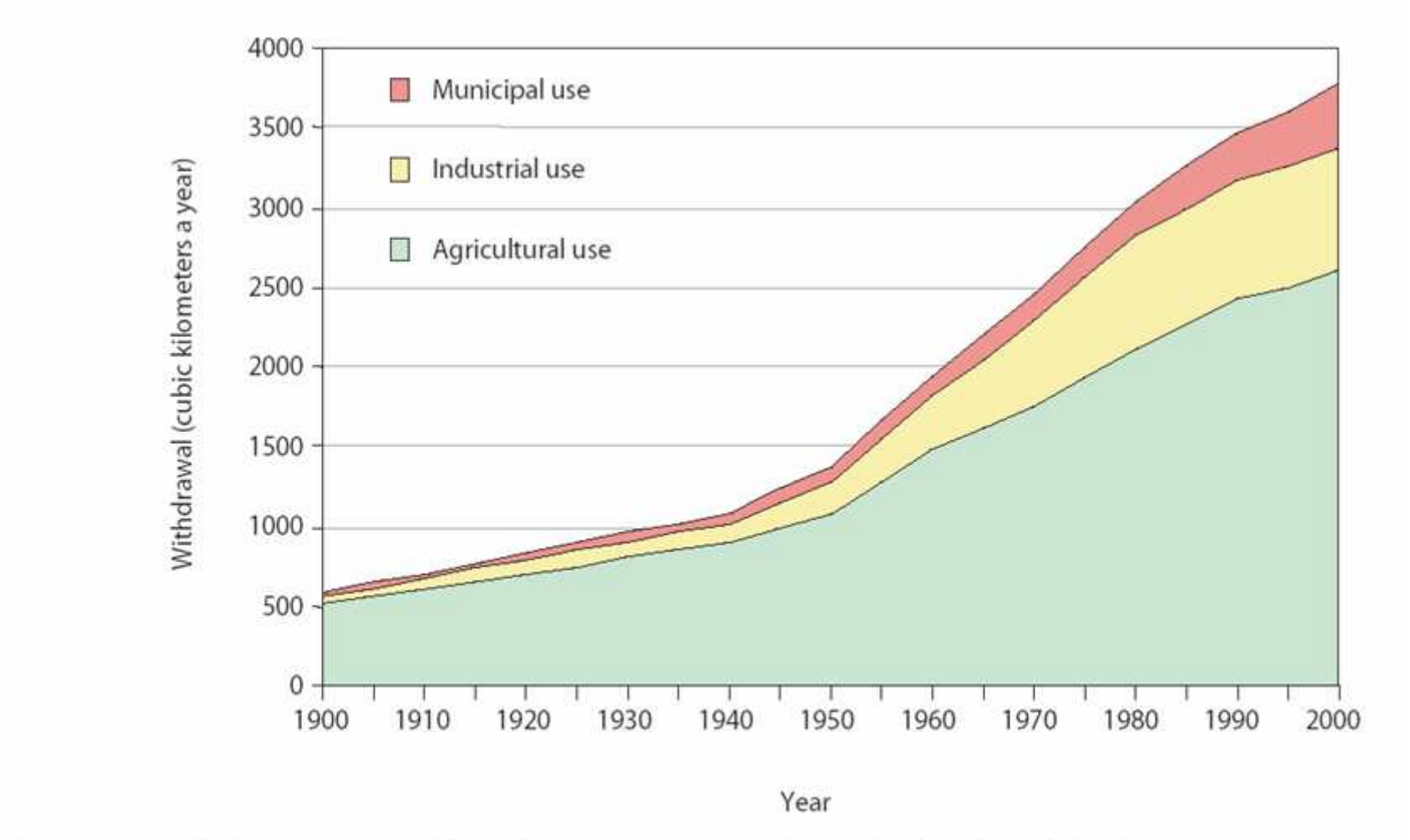
Sample of ASTER Image (South of India)



Detail of ASTER Image for a particular area

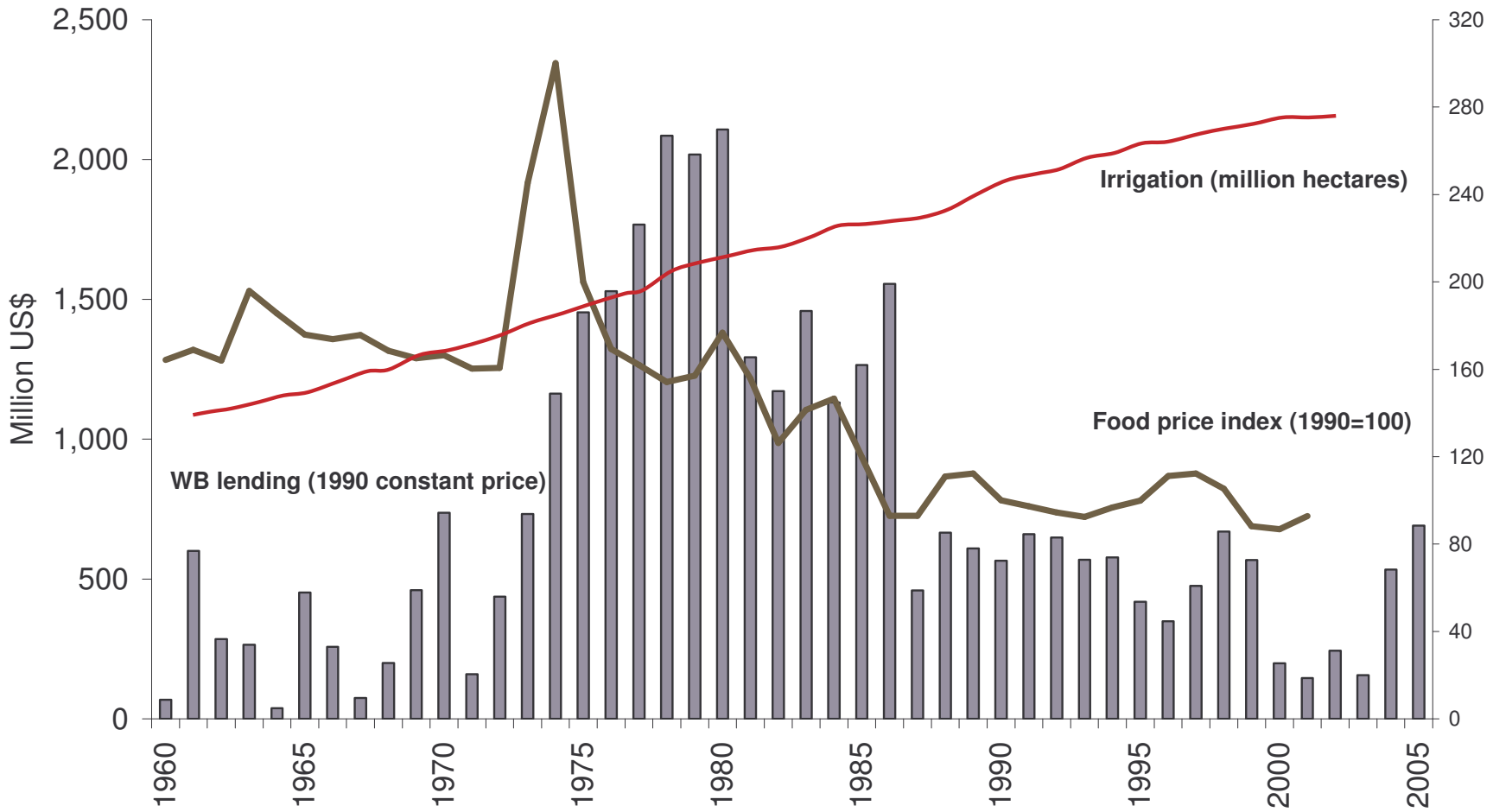


Global water use

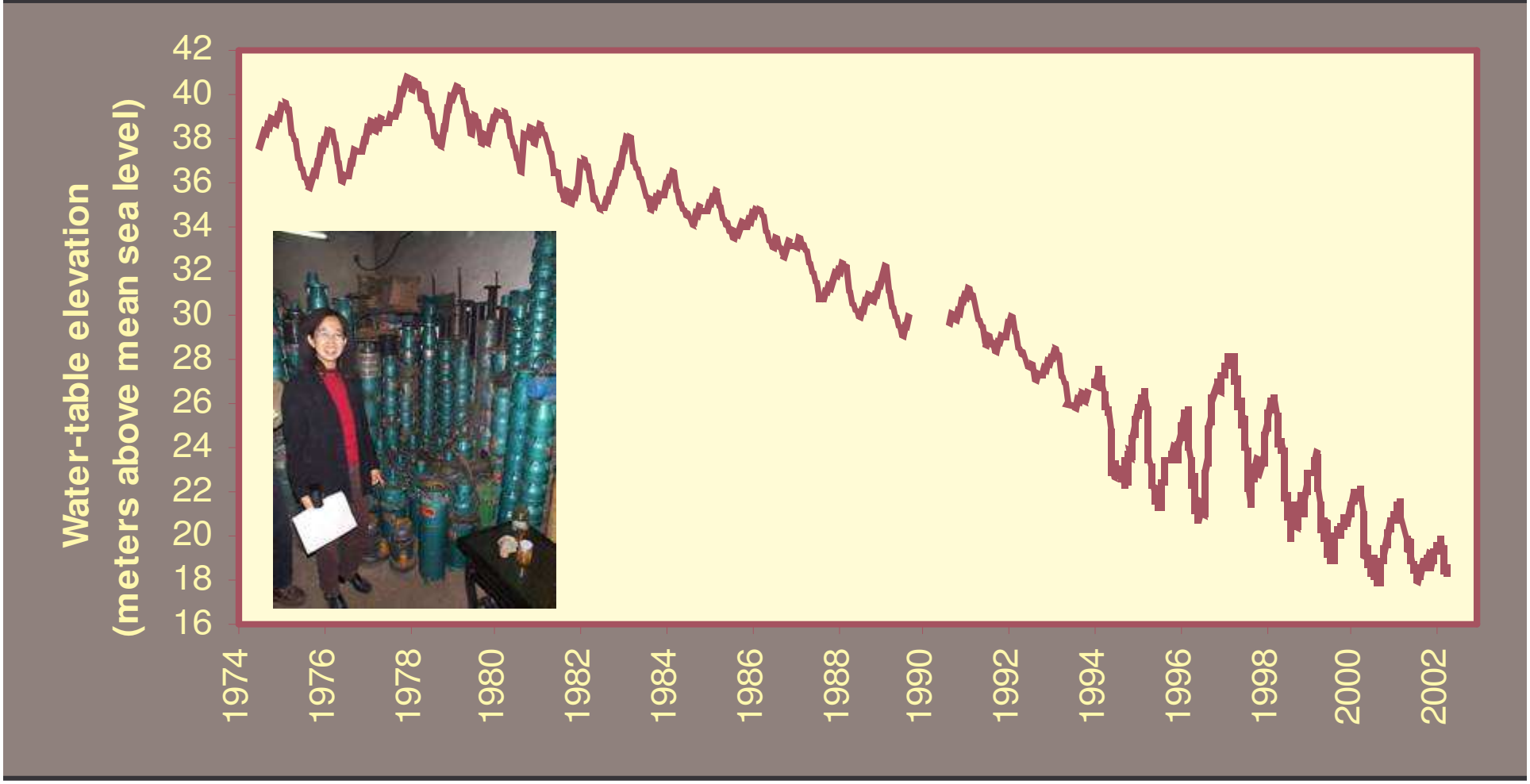


Based on Shiklomanov, I., IWRA Water International Vol 25 (1), March 2000

Public investment in Irrigation, irrigated area and food prices



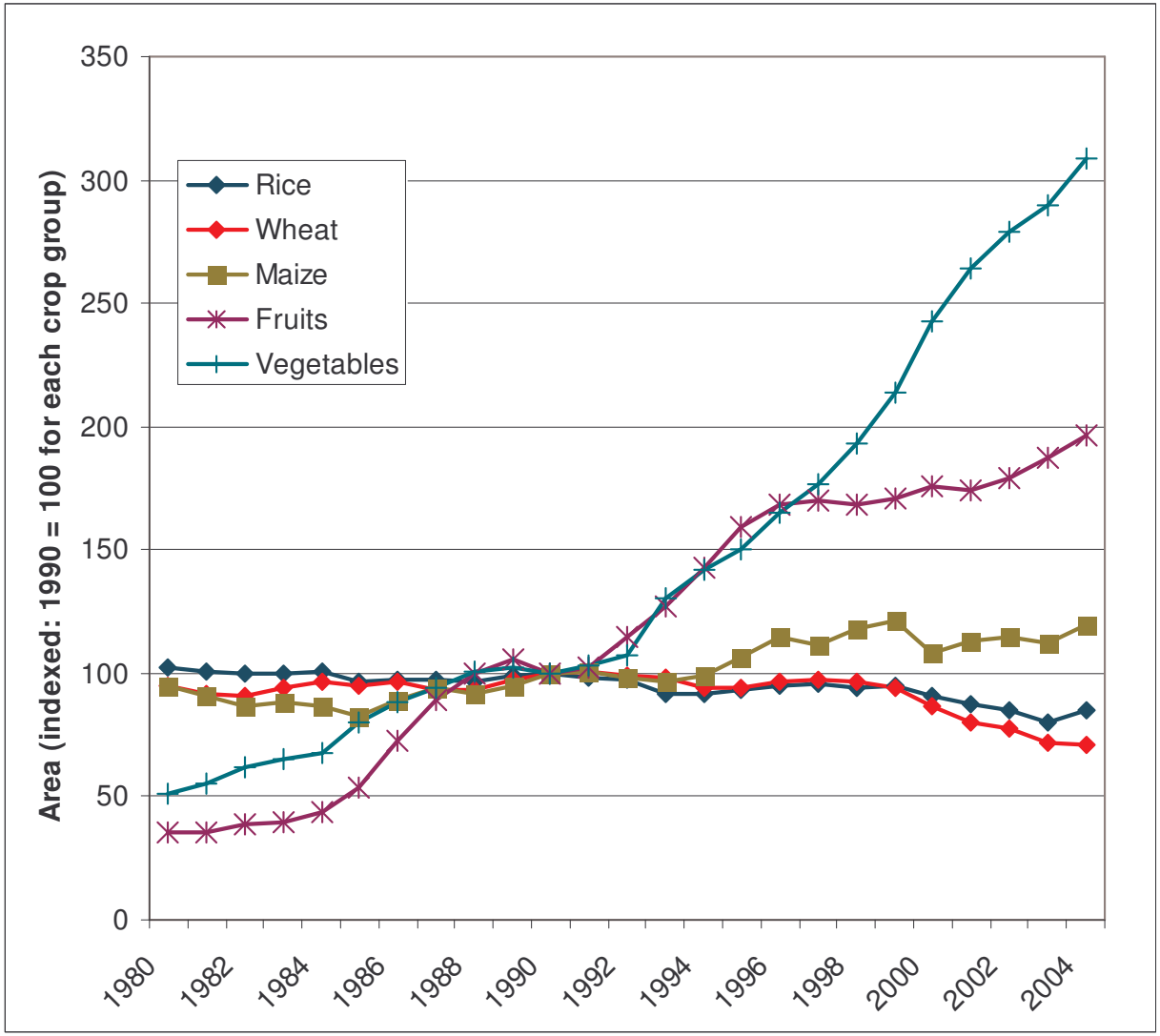
Private groundwater development



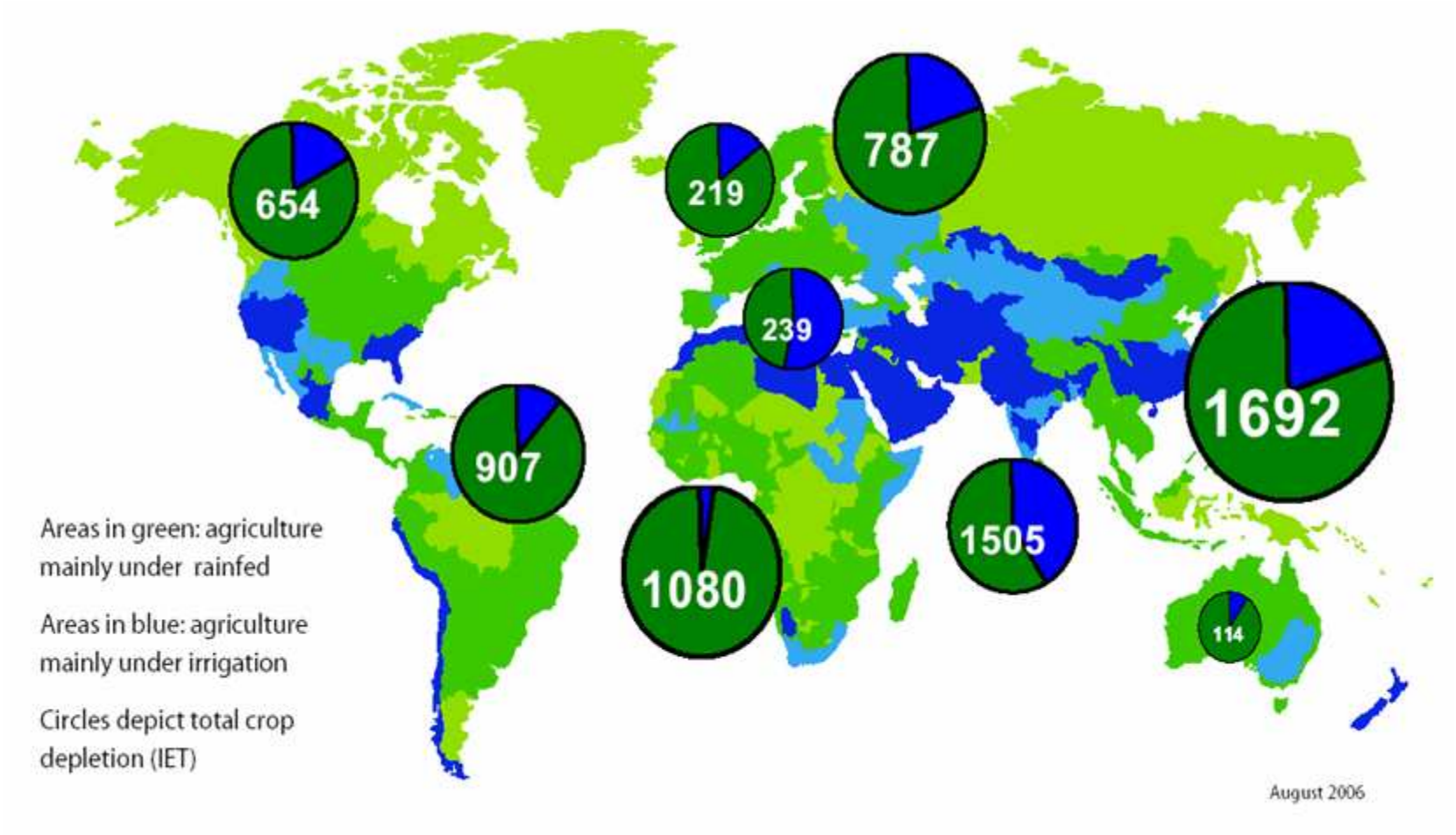
Watertable decline in Luancheng County, 1974-2002

Trends in production- China

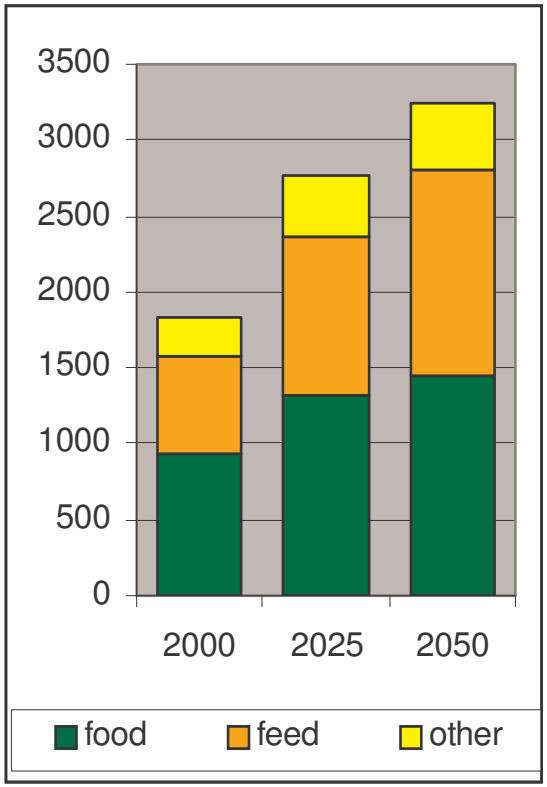
Shifting to Higher Valued Crops



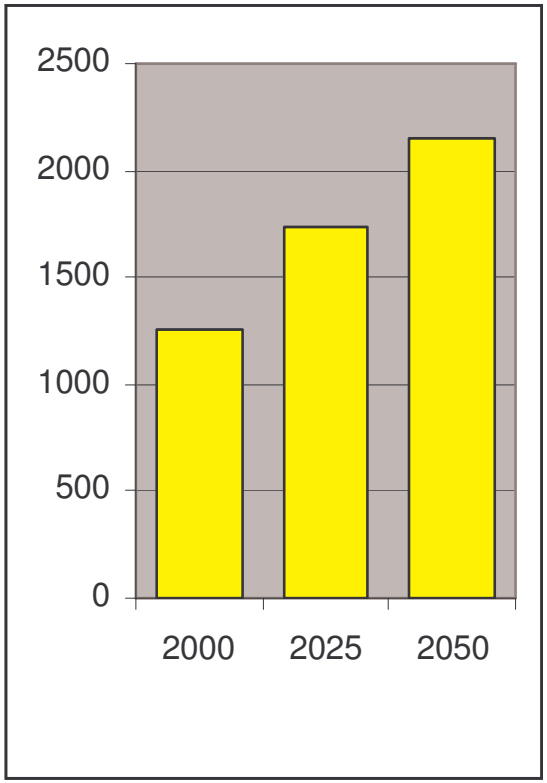
Water depletion for agriculture bcm/yr



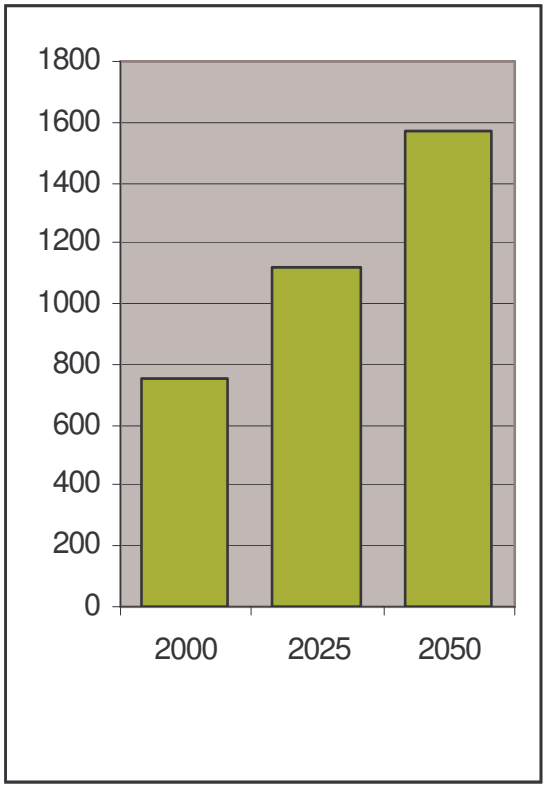
Total food demand nearly doubles by 2050



Grain



Sugarcane



Vegetables

Water (ET) demand also doubles if no increase in water productivity

Optimistic & pessimistic rainfed scenarios