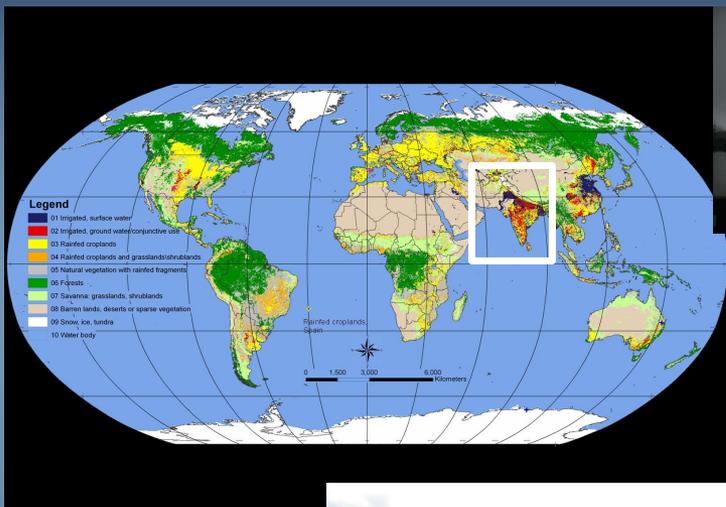
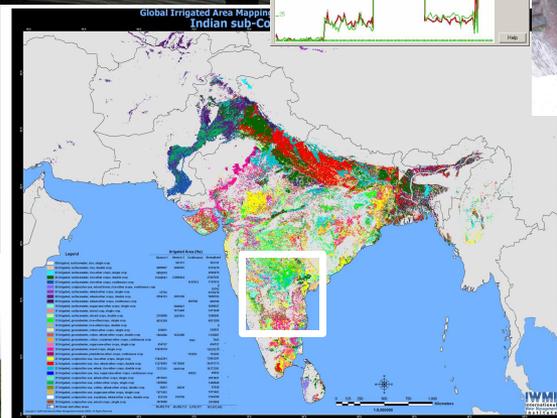
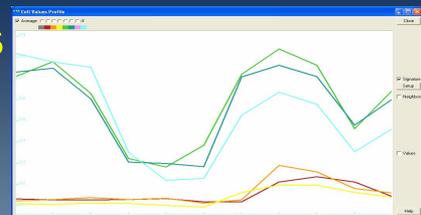


Global Irrigated Area Mapping (GIAM)

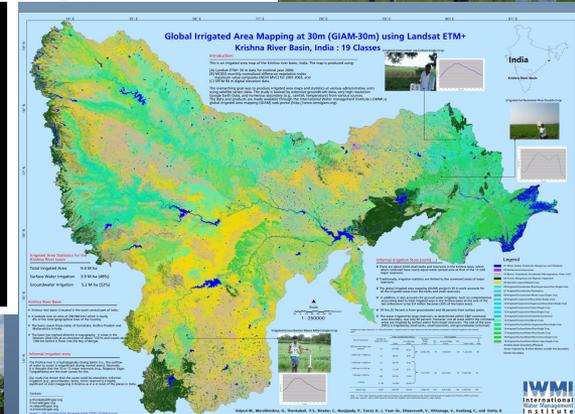
A brief discussion of Advances and Issues



GIAM 10km



GIAM 500m



GIAM 30m



Prasad S. Thenkabail, Chandrashekhar M. Biradar, Praveen Noojipady, Venkateswarlu Dheeravath, Manohar Velpuri, Hugh Turral, Yuanjie Li, and Xueliang Cai

Presented @ the **Second Landsat Science Team Meeting**
Corvallis, OR, USA. June 12-14, 2007

GIAM and GMRCA

Background Scenario

GIAM = Global Irrigated Area Map

GMRCA = Global map of Rainfed Croplands

Global irrigated Area Map (GIAM)

Aggregated 28 class

Satellite Sensor Based Global Irrigated Area Map @ 10km
(GIAM10km - 28 Class) Version 2.0

Legend

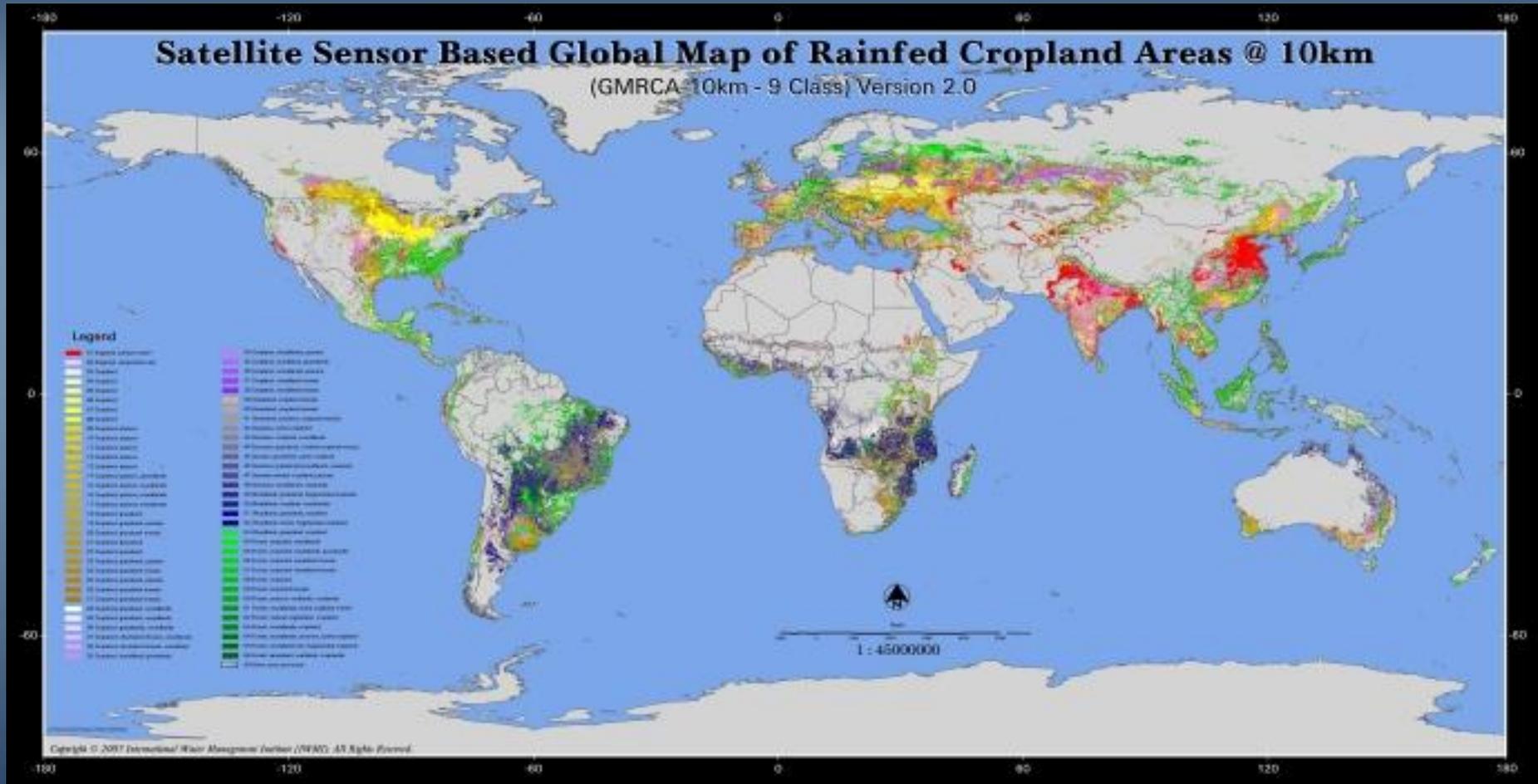
Class Number @ Class Name	Irrigated Area (Ha)	
	Season 1	Season 2
01 Irrigated, surface water, single crop, wheat/corn/cotton	6466129	6466129
02 Irrigated, surface water, single crop, cotton/corn/wheat	9378930	9378930
03 Irrigated, surface water, single crop, mixed crops	6553356	6553356
04 Irrigated, surface water, double crop, rice/wheat/cotton	30762936	48510689
05 Irrigated, surface water, double crop, rice/wheat/cotton/corn	4164165	30333057
06 Irrigated, surface water, double crop, rice/soybean/plantations	26938425	24878762
07 Irrigated, surface water, double crop, sugarcane	1778881	1422213
08 Irrigated, surface water, double crop, mixed crops	22573594	22239001
09 Irrigated, surface water, continuous crop, sugarcane	49302	48352
10 Irrigated, surface water, continuous crop, plantations	5913430	5613430
11 Irrigated, ground water, single crop, rice/sugarcane	6312769	6312769
12 Irrigated, ground water, single crop, corn/soybean	2917041	2917041
13 Irrigated, ground water, single crop, rice and other crops	241994	241994
14 Irrigated, ground water, single crop, mixed crops	4822467	4822467
15 Irrigated, ground water, double crop, rice and other crops	1867442	1807546
16 Irrigated, conjunctive use, single crop, wheat/corn/soybean/rice	14007142	14007142
17 Irrigated, conjunctive use, single crop, wheat/corn/wheat/rice	5052374	5052374
18 Irrigated, conjunctive use, single crop, corn/soybean/other crops	9075419	9075419
19 Irrigated, conjunctive use, single crop, cotton	2287826	2287826
20 Irrigated, conjunctive use, single crop, cotton, wheat, sugarcane	1362811	1362811
21 Irrigated, conjunctive use, single crop, rice/corn	9996422	9996422
22 Irrigated, conjunctive use, double crop, rice/wheat/sugarcane	35740769	51799478
23 Irrigated, conjunctive use, double crop, sugarcane/other crops	720484	510271
24 Irrigated, conjunctive use, double crop, mixed crops	12477289	8710295
25 Irrigated, conjunctive use, continuous crop, rice/wheat	7482588	7482588
26 Irrigated, conjunctive use, continuous crop, rice/wheat/corn	7985182	7985182
27 Irrigated, conjunctive use, continuous crop, sugarcane/other crops	7187415	7187415
28 Irrigated, conjunctive use, continuous crop, mixed crops	12786104	12786104
00 Other area and ocean	262793752	176487941
	41465412	480687106

Note: there is also a 323 disaggregated class map of the World.
See: <http://www.iwmi.org>

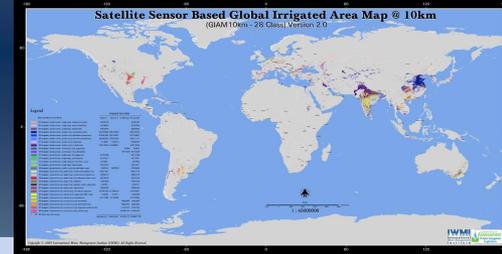
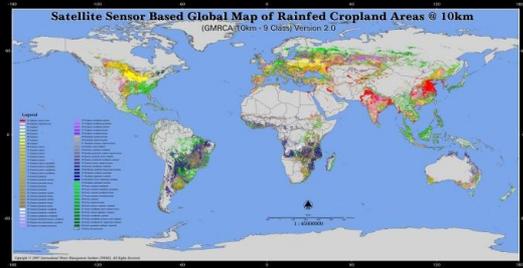


.....we have achieved this.

Global Map of Rainfed Cropland Area (GMRCA) Disaggregated 66 class



.....Recently released.



GIAM and GMRCAs

Blue Water and Green Water

Purely rainfed

Fully irrigated



Field conservation practices

Supplemental Irrigation

Water harvesting

GMRCAs.....to help us understand green water use and food production from green waters....rainfed areas, its extent, variability... contribution to global food security

GIAM.....to help us understand blue water use and food production from blue waters....irrigated areas, its extent, variability... contribution to global food security

Groundwater Irrigation

Surface water Irrigation

Drainage

(Source: CA Synthesis, 2007)

One View of Blue water and Green water Use

But Scenarios Can Change if Areas Change

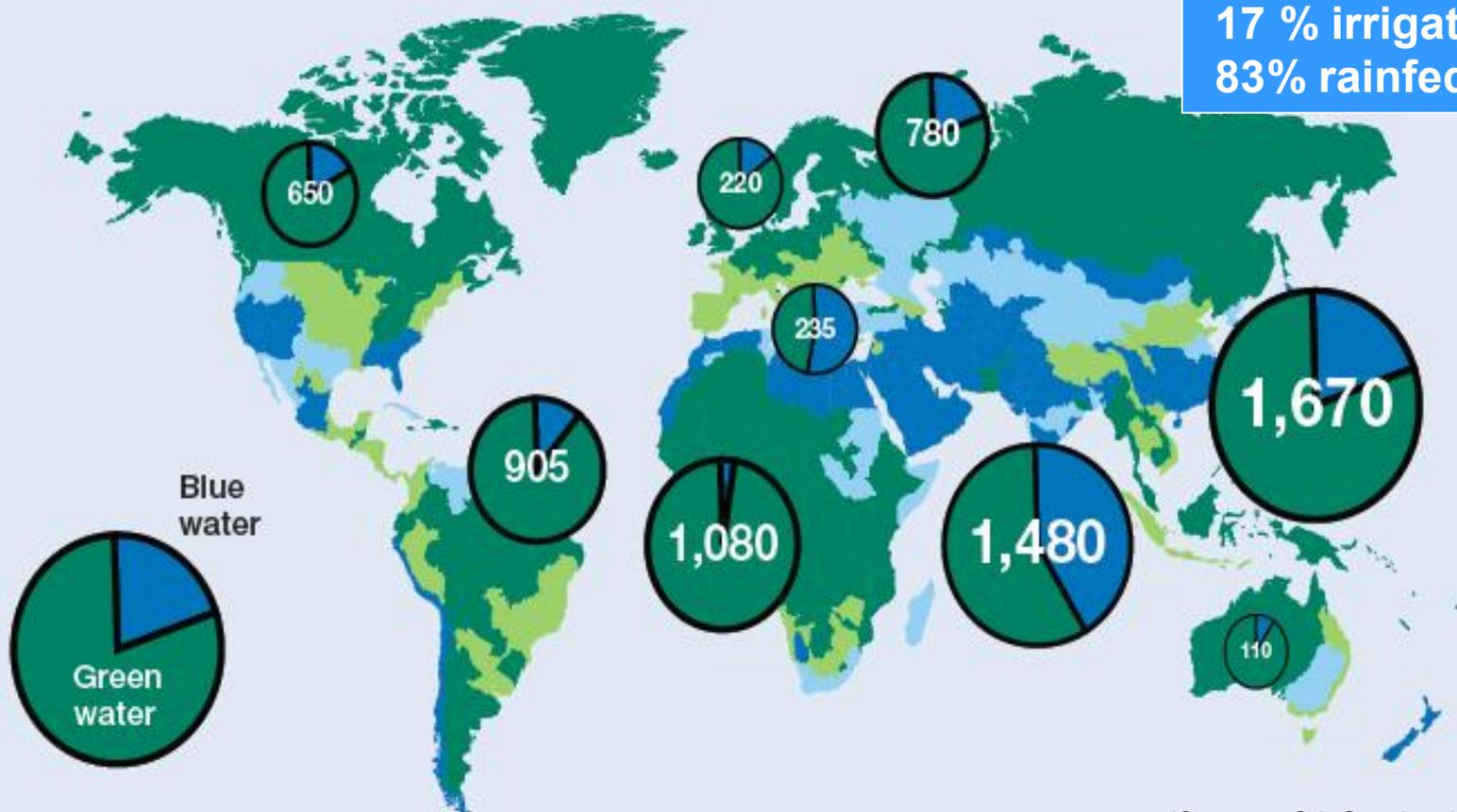
- More than half of production from rainfed areas
- More than 75% of production from rainfed areas

- More than half of production from Irrigated areas
- More than 75% of production from irrigated areas

Note: Blue (water for irrigation) vs. Green (water for rainfed crops)

Global total:
7,130 cubic kilometers

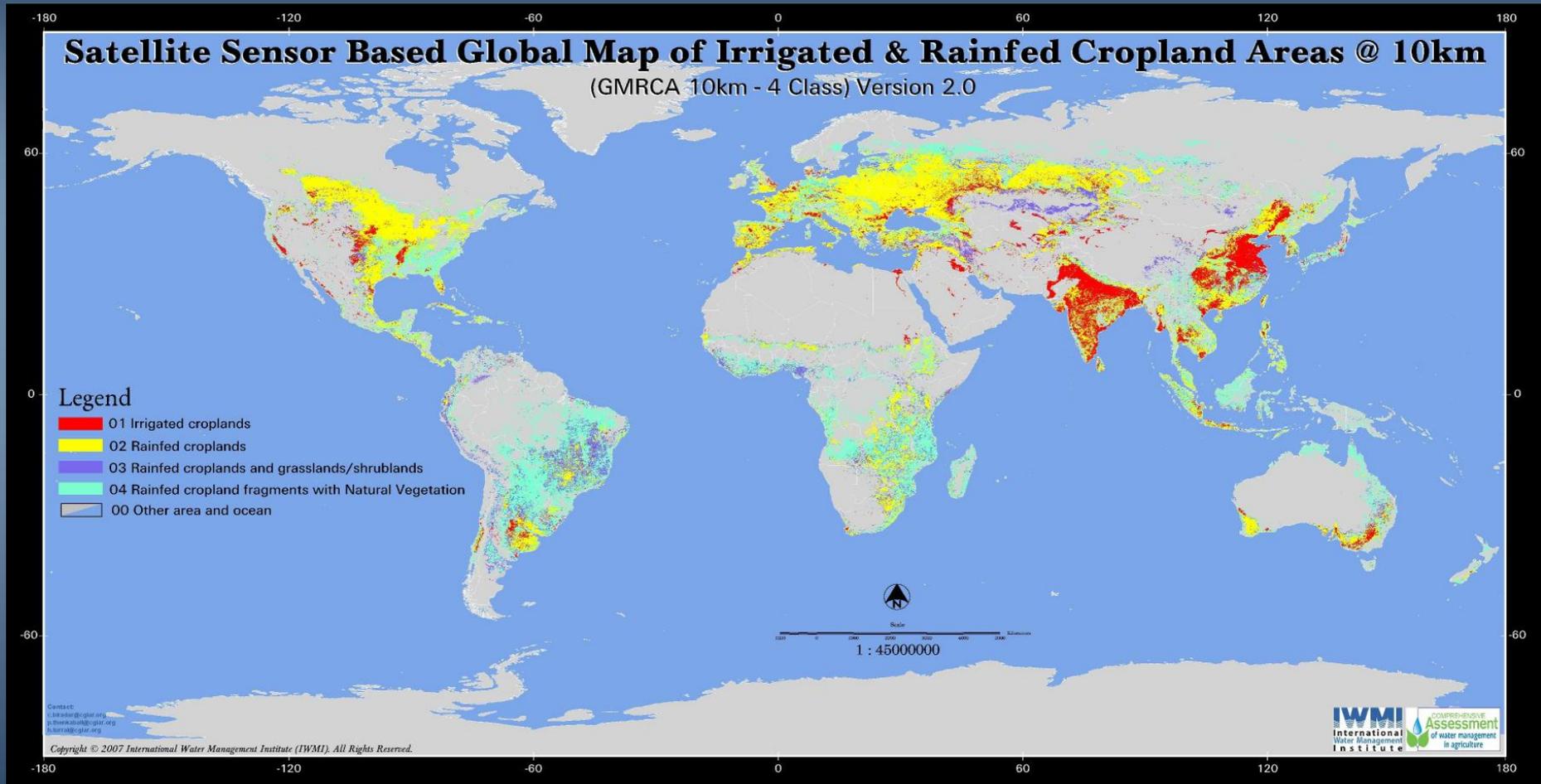
17 % irrigated
83% rainfed



(Source: CA Synthesis, 2007) org

GIAM and GMRCA @ the end of last Millennium

Recent IWMI work



.....irrigated and rainfed areas of the World from remote sensing.

GIAM and GMRCA along with other LULC @ the end of last Millennium: Recent IWMI work

Introduction

This is a composite map of the International Water Management Institute's (IWMI's) global irrigated area map (GIAM), global map of rainfed cropland areas (GMRCA), and other classes. The original GIAM 28-classes are aggregated to surface water (class 1) and ground water (class 2) classes. The original GMRCA 9 classes are aggregated to 2 main classes (class 3 and 4) and a fragmented class that is dominated by natural vegetations (class 5). The classes 6 to 10 are obtained from the global map of land use/land cover areas (GMLULCA).

More details are found at: <http://www.iwmiwiam.org>.

Globally, 61% of all irrigation is from surface water and 39% from ground-water.



Irrigated, Ground water, USA

Legend

- 01 Irrigated, surface water
- 02 Irrigated, ground water/conjunctive use
- 03 Rainfed croplands
- 04 Rainfed croplands and grasslands/shrublands
- 05 Natural vegetation with rainfed fragments
- 06 Forests
- 07 Savanna: grasslands, shrublands
- 08 Barren lands, deserts or sparse vegetation
- 09 Snow, ice, tundra
- 10 Water body

GIAM
Core Team:
Thenkabail, P.S.,
Biradar, C.M.,
Turrall, H., Noolipady, P.,
Li, Y.J., Cai, X.L., Vithanage,
J., Dheeravath, V., Velpuri, M.,
Schull, M., Duza, R., & Krishna, M.G.

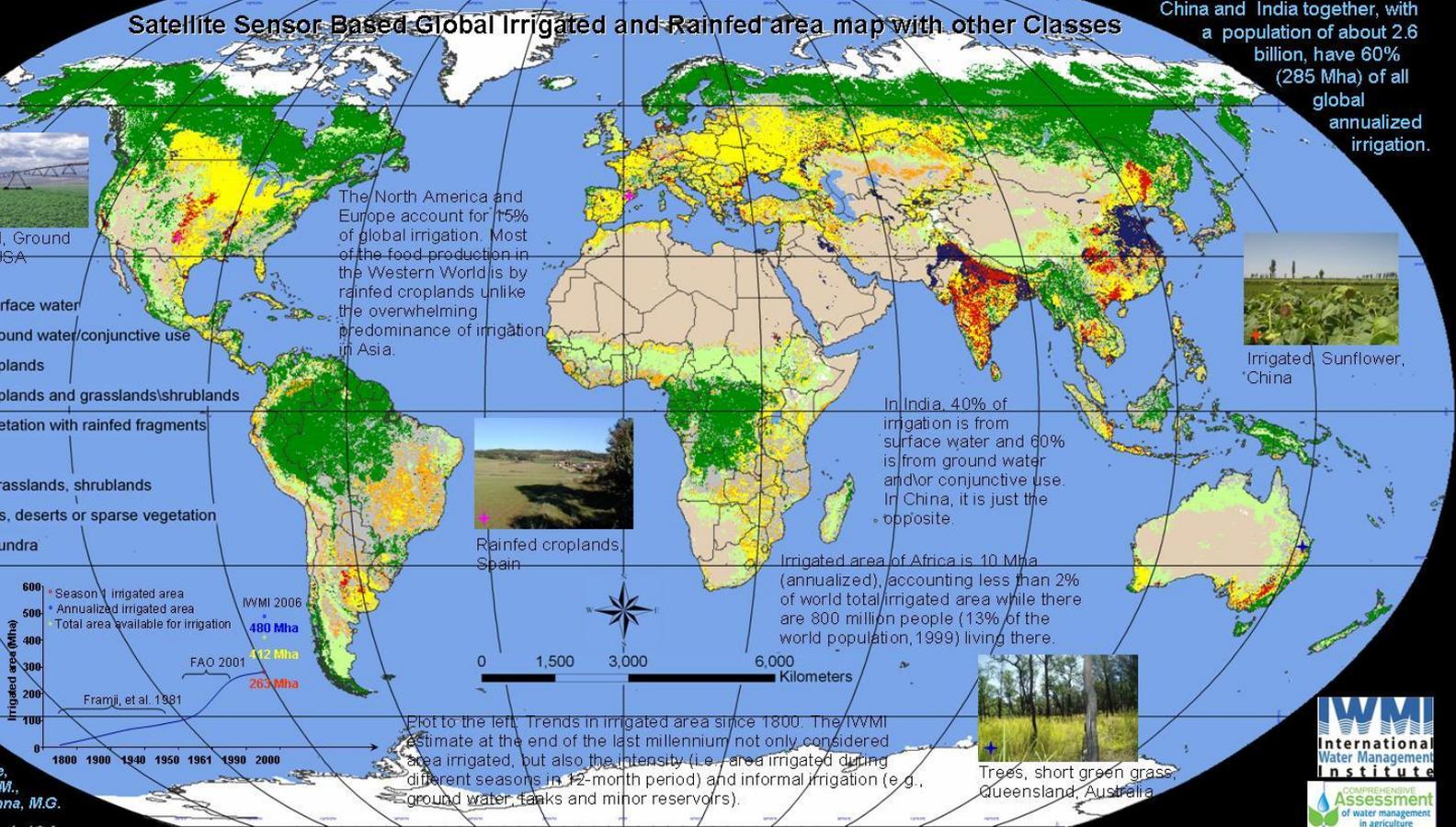
Advanced Datasets @ 1-10 km:

- AVHRR monthly time-series @ 10-km: 1997-1999;
- SPOT monthly time series @ 1-km: 1999;
- Landsat Geocover mosaic one time @ 150-m: nominal 2000;
- DEM of the world from GTOPO30 @ 1-km: mid-1990s;
- Rainfall (monthly) of the world @ 50-km: 1961-2001;
- Temperature (monthly) from AVHRR thermal bands @ 10-km: 1997-1999;
- Forest cover from AVHRR @ 1-km: 1990s; and
- Rainforests from JERS SAR data:1996.

Overarching Goals

1. Produce global irrigated area maps (GIAM) at various resolutions;
2. Produce global map of rainfed cropland areas (GMRCA) at various resolutions;
3. Determine irrigated area and rainfed area statistics and maps for every country in the World;
4. Develop methodologies of mapping irrigated areas using remote sensing;
5. Establish irrigated area mapping and reporting system (IAMRS) for all leading irrigated area Countries in the World; and
6. Propagate irrigated area statistics and maps through a knowledge gateway.

Satellite Sensor Based Global Irrigated and Rainfed area map with other Classes

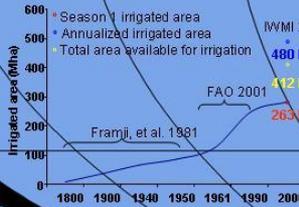


The North America and Europe account for 15% of global irrigation. Most of the food production in the Western World is by rainfed croplands unlike the overwhelming predominance of irrigation in Asia.

China and India together, with a population of about 2.6 billion, have 60% (285 Mha) of all global annualized irrigation.

In India, 40% of irrigation is from surface water and 60% is from ground water and/or conjunctive use. In China, it is just the opposite.

Irrigated area of Africa is 10 Mha (annualized), accounting less than 2% of world total irrigated area while there are 800 million people (13% of the world population, 1999) living there.



Plot to the left: Trends in irrigated area since 1800. The IWMI estimate at the end of the last millennium not only considered area irrigated, but also the intensity (i.e., area irrigated during different seasons in 12-month period) and informal irrigation (e.g., ground water tanks and minor reservoirs).



Trees, short green grass, Queensland, Australia



Assessment of water management in agriculture

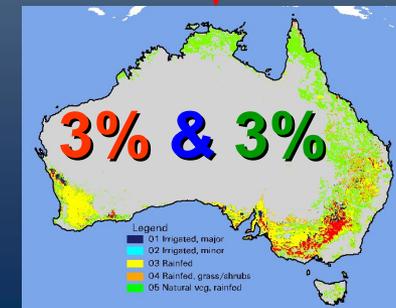
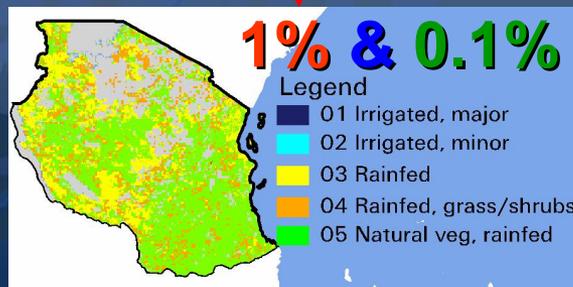
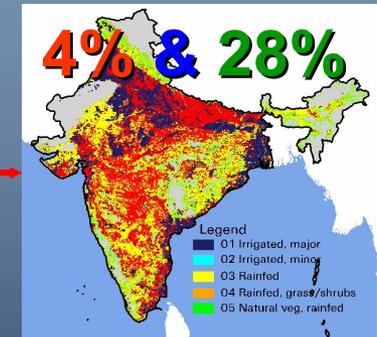
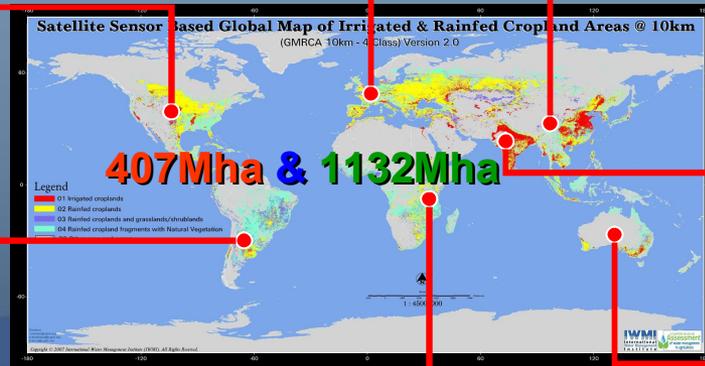
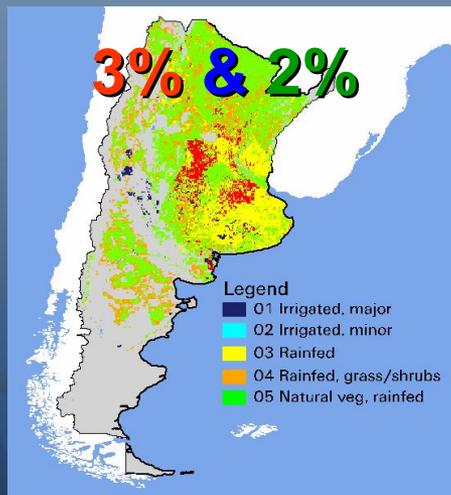
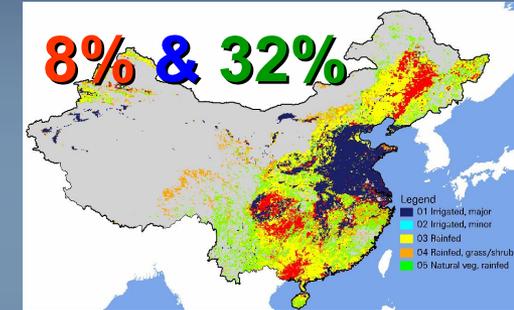
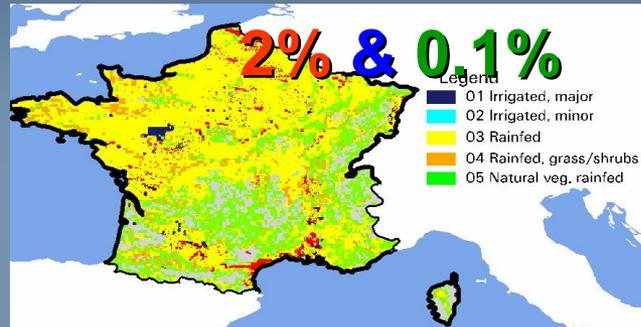
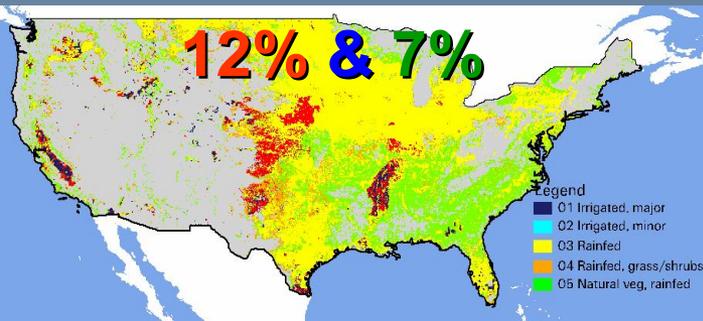
Online access:

- GIAM Web Portal : www.iwmiwiam.org
- GIAM Web Map : giam.iwmi.org/mapper.asp
- GIAM Stats : www.iwmiwiam.org/ists
- GIAM Google Earth : www.iwmiwiam.org/GE

Contact for any queries
p.thenkabail@cgiar.org
c.biradar@cgiar.org
h.turrall@cgiar.org

GIAM and GMRCRA along with other LULC @ the end of last Millennium: Recent IWMI work

Rainfed and Irrigated Areas (% of their, respective, total area)



GIAM and GMRCA @ the end of last Millennium

Traditional View vs. Recent IWMI work

Traditional view (Global estimates):

17% irrigated vs. 83 % rainfed;

Recent IWMI work (Global estimates):

26% irrigated vs. 74 % rainfed.

Sl.#	Continents	Irrigated Area (Million Ha)	Rainfed Area (Million Ha)	Cropland Area (Million Ha)
2	Asia	290.64	327.29	617.93
4	Europe	42.50	227.89	270.39
5	North America	35.43	190.67	226.09
1	Africa	8.69	189.05	197.74
7	South America	17.84	158.44	176.28
3	Australia	11.87	36.76	48.62
6	Oceania	0.13	1.46	1.59
	Total	407.09	1,131.55	1,538.64

Asia's food production comes from both irrigated and rainfed area. However, rest of the world's food production mainly rely on **Rainfed Croplands**



- Main Directory
 - World
 - Continents
 - Nations
 - India Sub National
 - Andaman & Nicobar
 - Andhra Pradesh
 - Adilabad
 - Ananthapur
 - Chittoor
 - Cuddapah
 - East Godavari
 - Guntur
 - Hyderabad
 - Karimnagar
 - Khammam
 - Krishna
 - Kurnool
 - Mahaboobnagar
 - Medak
 - Nalgonda
 - Nellore
 - Nizamabad
 - Prakasham
 - Rangareddy
 - Srikakulam
 - Visakahapatnam
 - Vizianagaram
 - Warangal
 - West Godavari
 - Arunachal Pradesh
 - Assam
 - Bihar

World

Continental

National

State

Districts

Note: When state/district areas are reported by GIMM use the GIMM to km² please note that these are based on Global Irrigated Area Fractions. Further refinement of area is possible with local irrigated area fractions.

LEGEND

Location Map :



GIAM and GMRCA Web Portals

Statistics, Web Maps, in Google Earth, and Data Gateways

1. **GIAM statistics: Irrigated area statistics for 175 Countries**

<http://www.iwmigiam.org/stats>

2. **GIAM Map Server**

<http://giam.iwmi.org/mapper.asp>

3. **GIAM on Google**

<http://www.iwmigiam.org/info/main/index.asp>

4. **GIAM web portal**

<http://www.iwmigiam.org>

Global Map of Irrigated Area (GIAM) - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Address <http://www.iwmigiam.org/info/main/index.asp>

IWMI International Water Management Institute

COMPREHENSIVE ASSESSMENT of water management in agriculture

Satellite Sensor Based Global Irrigated Area Map
At the End of the Last Millennium

Username:
Password:

Forgotten your password?
New user? register here

Home
Read me first
Documentation
Presentation
FAQ
Project Team
Your Comments
Acknowledgements
Contact Us

Director General's Message

- [GIAM Statistics](#)
- [GIAM Web Map](#)
- [GIAM in Google](#)

Global Irrigated Area Map (GIAM)

Satellite Sensor Based Global Irrigated Area Map @ 10km
(GIAM 10km - © Custom, Version 2.0)

This is the version 2.0 release of the International Water Management Institute's (IWMI's) Global Irrigated Area Map (GIAM) and associated products and data.

The GIAM products are produced using time-series data of: (a) AVHRR 10-km monthly from 1987-1999, (b) SPOT 1-km monthly for 1999, (c) GTOPO30 1-km elevation, (d) CRU 50-km grid monthly precipitation from 1961-2000, (e) AVHRR derived 1-km forest cover, and (f) AVHRR 10-km skin temperature. In addition, JERS SAR data was used for the African and South American rainforests.

The front-page provides gateway to 4 product lines. The primary product, and overwhelming emphasis, is on the Global map of irrigated area (GIAM). You can click on appropriate places in this front-page that will lead you to the above product lines.

Areas Computation and their importance
Areas can Change Scenarios Dramatically



Global Croplands for Baseline year 2000 (Irrigated vs. Rainfed Cropland areas)

Global Cropland Area estimates from Literature

Area (Bha)	Year	Source
1.11	2000	Hansen et al., 2000
1.34	1994	Warnanat et al., 1994
1.36	1999	Houghton, 1999
1.39	1999	Loveland et al., 2000
1.40	1991	FAO, 1990,1991
1.47	2002	Strahler,2002
1.48	2001	Klein Goldewijk,2001
1.48	1998	Amtho et al., 1998
1.50	1991	Lal & Pierce, 1991
1.50	2003	WRI,2003
1.51	2000	FAOSTAT,2000
1.54	2001	Tilman et al., 2001
1.60	1998	WBGU,1998
1.79	1998	Ramankutty & Foley, 1998
2.79	2000	WRI,2000
3.62	2000	Wood et al.,2000 and WRI 2000

Evolving Story

**What are the Actual versus Reported
Irrigated Areas of China and India?**

2006

Evolving Story on Irrigated Areas

China and India



GIAM China

10Km vs. National statistics¹

Type	GIAM 10 km (ha)	FAO/UF (GMIAV3.0) (ha)	FAO Aquastat (ha)	National statistics ⁽¹⁾ (ha)
Season1 Irrigated Area	75,880,320	N.A.	N.A.	N.A.
Season2 Irrigated Area	68,233,355	N.A.	N.A.	N.A.
Continuous Irrigated Area	7,688,411	N.A.	N.A.	N.A.
Annualized Irrigated Area	151,802,086	N.A.	N.A.	N.A.
Total Area Available for Irrigation	111,988,772	53,823,000	53,740,000	53,400,000
Total Rainfed Area	91,635,702	N.A.	N.A.	75,805,000
Total Cropland Area	203,624,473	N.A.	N.A.	129,205,000

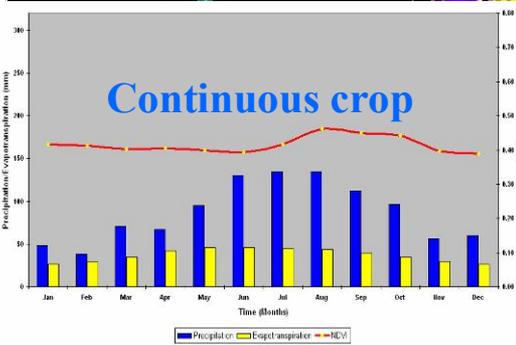
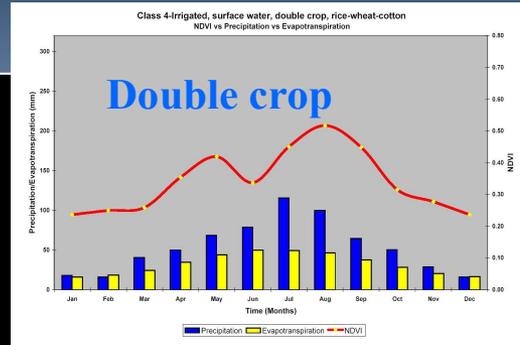
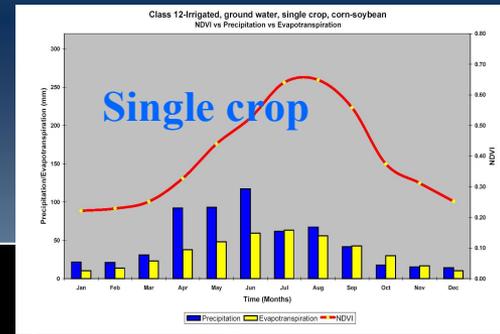
1. Source: CHINA NATURAL RESOURCES DATABASE, CAS

.....what are the causes of differences in areas??

GIAM 10km vs. National Statistics

Evolving Story (when cropping Intensity Considered)

Annualized Irrigated Areas (AIAs) = 152 Mha



01	Irrigated, surface water, single crop, wheat-corn-cotton
02	Irrigated, surface water, single crop, cotton-rice-wheat
03	Irrigated, surface water, single crop, mixed-crops
04	Irrigated, surface water, double crop, rice-wheat-cotton
05	Irrigated, surface water, double crop, rice-wheat-cotton-corn
06	Irrigated, surface water, double crop, rice-wheat-plantations
07	Irrigated, surface water, double crop, sugarcane
08	Irrigated, surface water, double crop, mixed-crops
09	Irrigated, surface water, continuous crop, sugarcane
10	Irrigated, surface water, continuous crop, plantations
11	Irrigated, ground water, single crop, rice-sugarcane
12	Irrigated, ground water, single crop, corn-soybean
13	Irrigated, ground water, single crop, rice and other crops
14	Irrigated, ground water, single crop, mixed-crops
15	Irrigated, ground water, double crop, rice and other crops
16	Irrigated, conjunctive use, single crop, wheat-corn-soybean-rice
17	Irrigated, conjunctive use, single crop, wheat-corn-orchards-rice
18	Irrigated, conjunctive use, single crop, corn-soybeans-othercrops
19	Irrigated, conjunctive use, single crop, pastures
20	Irrigated, conjunctive use, single crop, pasture, wheat, sugarcane
21	Irrigated, conjunctive use, single crop, mixed-crops
22	Irrigated, conjunctive use, double crop, rice-wheat-sugarcane
23	Irrigated, conjunctive use, double crop, sugarcane-other crops
24	Irrigated, conjunctive use, double crop, mixed-crops
25	Irrigated, conjunctive use, continuous crop, rice-wheat
26	Irrigated, conjunctive use, continuous crop, rice-wheat-corn
27	Irrigated, conjunctive use, continuous crop, sugarcane-orchards-rice
28	Irrigated, conjunctive use, continuous crop, mixed-crops

.....equivalent
National
estimates
(CAS,
unpublished)
....is approx.
180 Mha

Area Differences from Different Sources

Causes of Differences

A. National Statistics

- Under reporting in National Stats (for tax purposes);
- Informal irrigation (e.g., ground water, small reservoirs, tanks) is the missing link in National stats;
- Minimum mapping unit in National stats based on Geospatial techniques;

B. GIAM

- Irrigated area fraction (IAF) uncertainties in GIAM;
- Resolution or Scale issues in GIAM;

C. National statistics and GIAM

- Definition issues in National stats and GIAM (e.g., where does supplemental irrigation go?).

Evolving Story

**What are the Actual versus Reported
Irrigated Areas of China and India?**

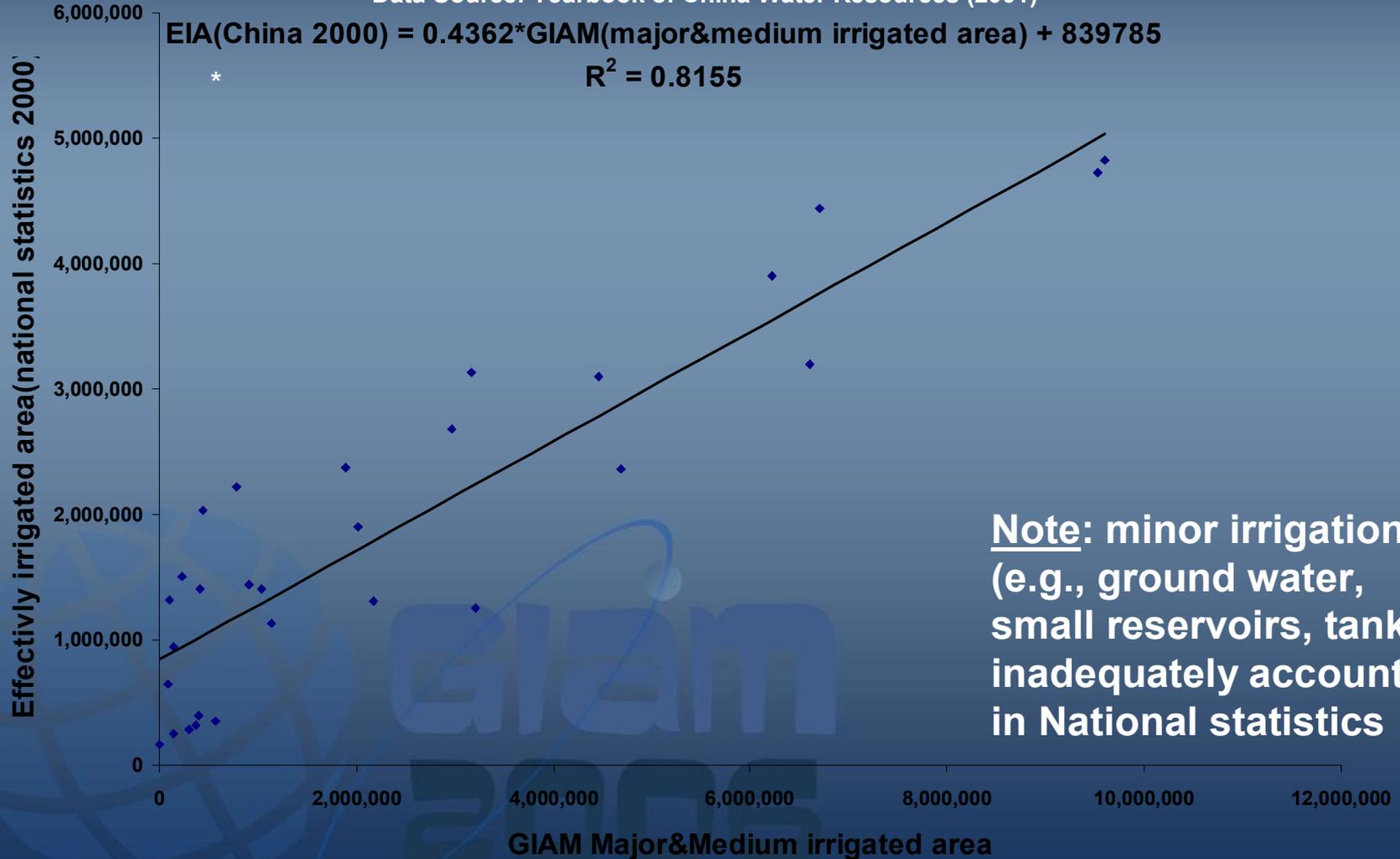
.....national systems typically under report

2006

GIAM China vs. National Statistics

National Statistics accounts mainly Major irrigation

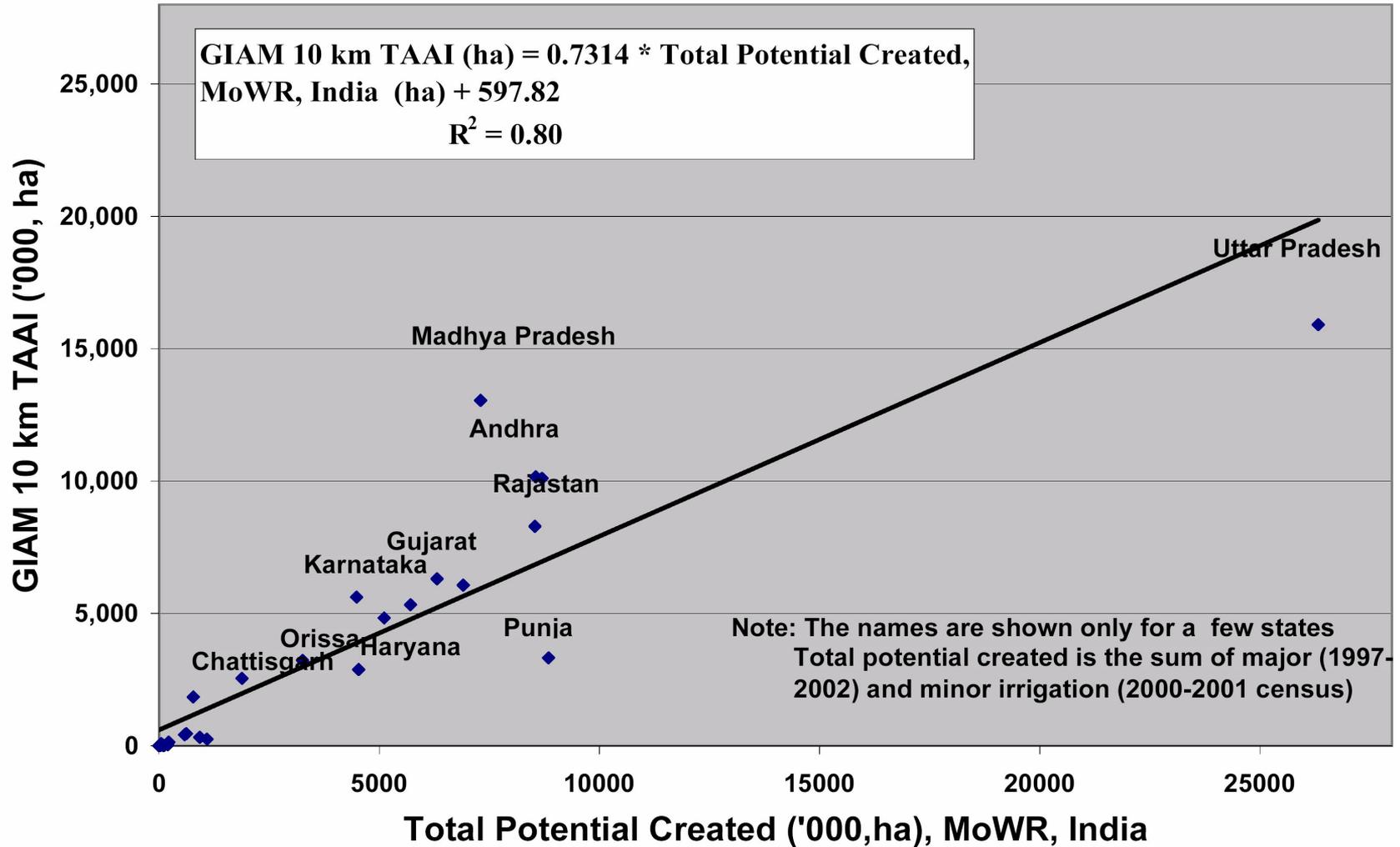
Data Source: Yearbook of China Water Resources (2001)



* Statistical Yearbook of China (1998) [Zhongguo Tongji Nianjian 1998] (Beijing, China Statistical Publishing House).

GIAM India vs. National Statistics

National Statistics includes Major and newly released Minor irrigation Statistics



MoWR = Ministry of Water Resources, India

Irrigated Area Fractions (IAFs)

Full pixel areas (FPAs) versus sub-pixel areas (SPAs)



Area calculations

Definition

Irrigated area is determined by multiplying full pixel area with irrigated area fraction:

$$SPA_n = FPA_n * IAF_n$$

Where n is class number (from 1 to 28)

SPA_n is sub-pixel area of class n

FPA_n is full pixel area of class n

IAF_n is irrigated area fraction of class n calculated through three methods: GEE, HRI and SPDT (see next slide)

IAF by GEE (IAF-GEE)

Illustration for Class # 4 of GIAM28 10km V2.0

Zoom into 10-km window



Point 421

Point 408

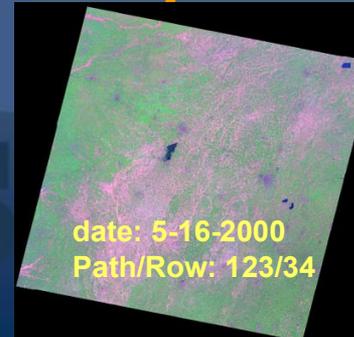
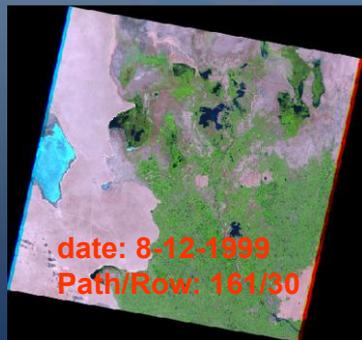
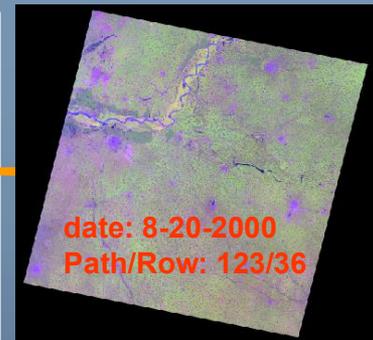
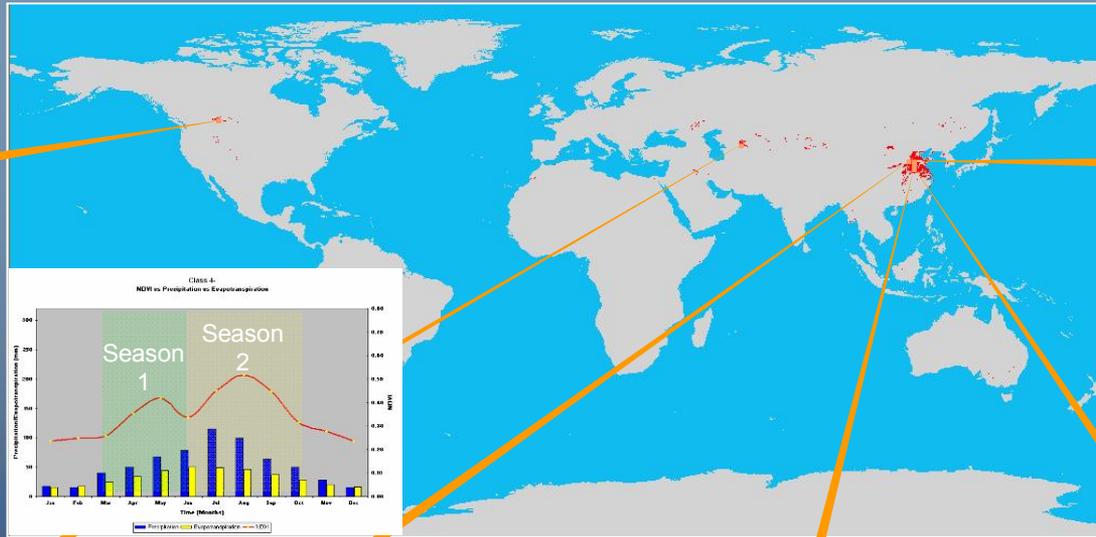
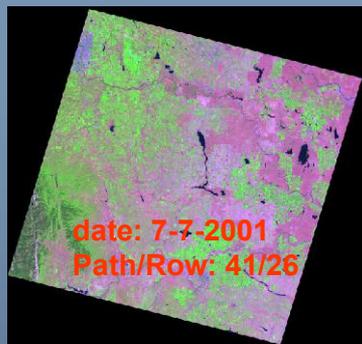
Point 429

Point 428

IAF by HRI (IAF-HRI)

Illustration for Class # 4 of GIAM28 10km V2.0

Six (3 for each season) high resolution images (ETM+/TM) downloaded from GLCF for two cropping seasons of class 4

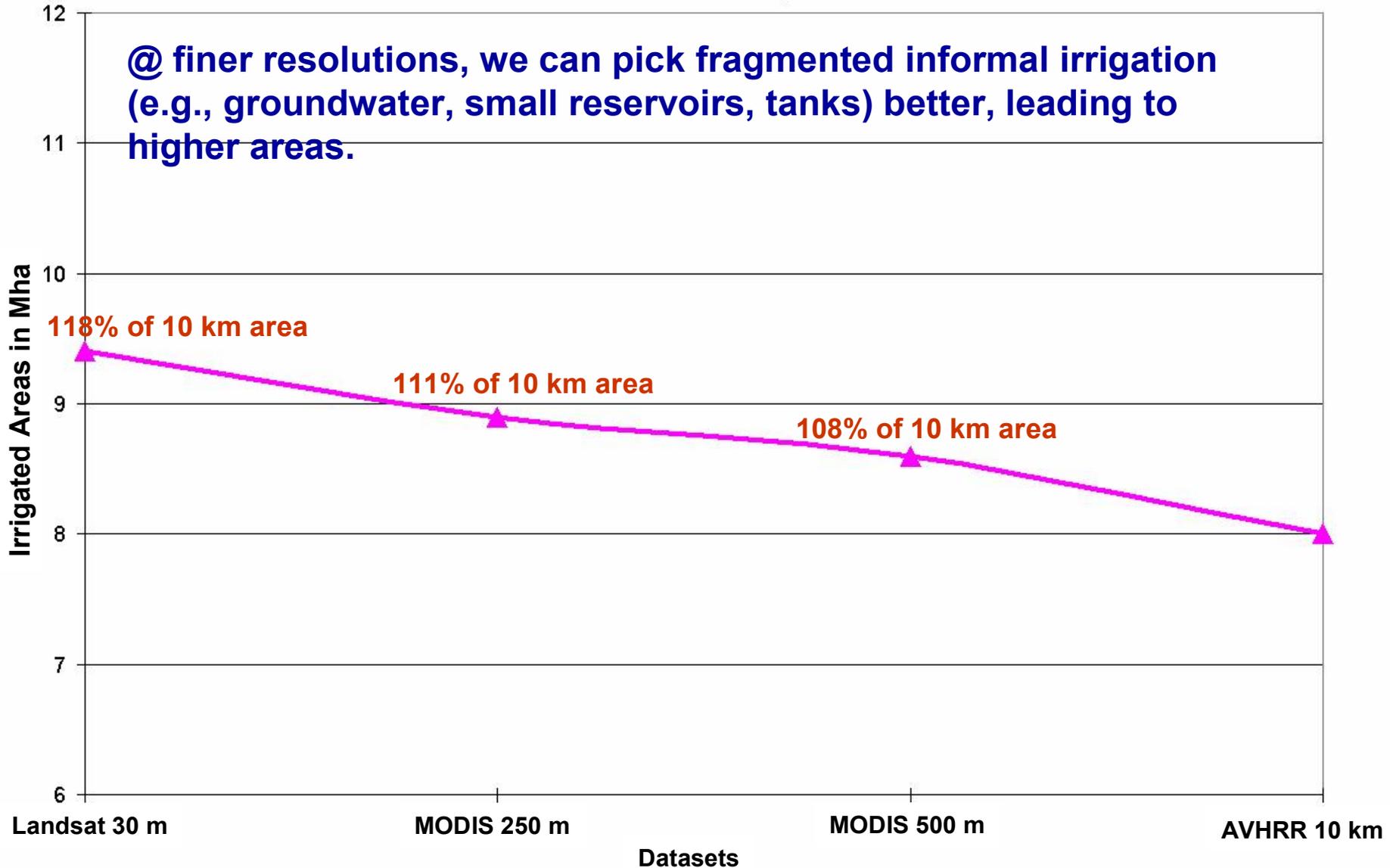


Resolution versus Area

Beginning to Understand Relationships

Resolution Vs. Irrigated Area Relationships

Beginning to understand relationships.....illustrated based on study in 3 river basins (Syr Darya in Central Asia, Ruhuna in Sri Lanka, and Krishna in India)



Informal Irrigation

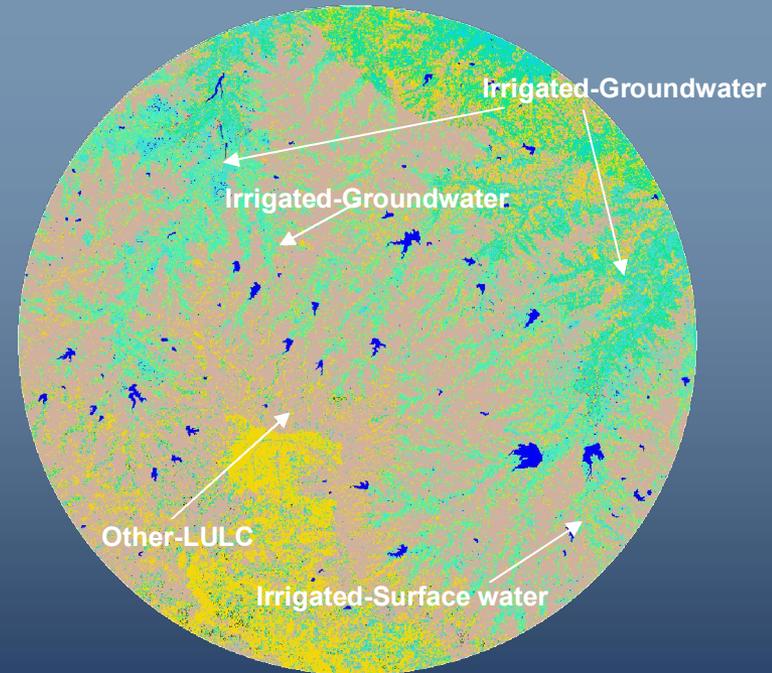
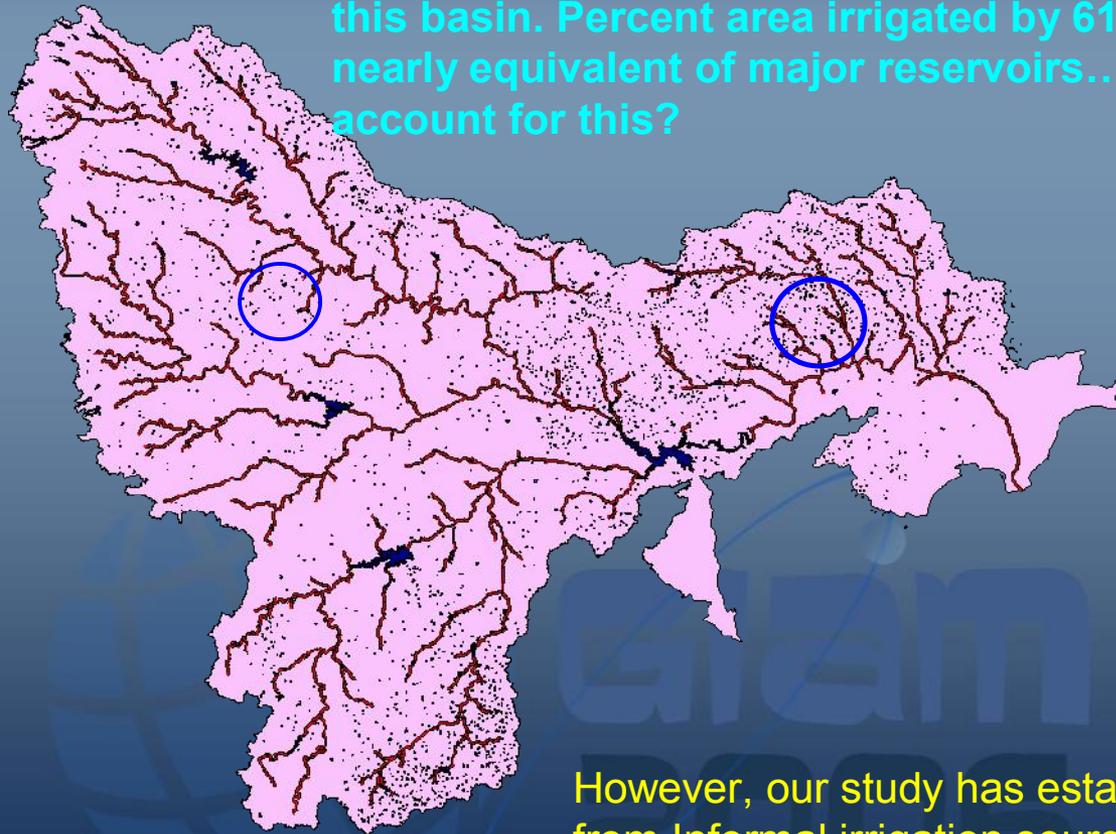
(e.g., groundwater, small reservoirs, tanks)

2006

Informal Irrigation (e.g., groundwater, small reservoirs, tanks) from

Small reservoirs and tanks mapped by Landsat ETM+ 30 m

There are 24 major reservoirs and 6100 minor reservoirs and tanks in this basin. Percent area irrigated by 6100 minor reservoirs and tanks is nearly equivalent of major reservoirs.....but does the statistics account for this?



However, our study has established that the cause could be equally from Informal irrigation sources (e.g., groundwater, tanks, very small reservoirs).

GIAM30m

Data Reduction Strategies

GIAM30m
2006

Data volume of Landsat Tiles

Global Un-Compressed

Total no of tiles needed: **9,770** (Digital number files)

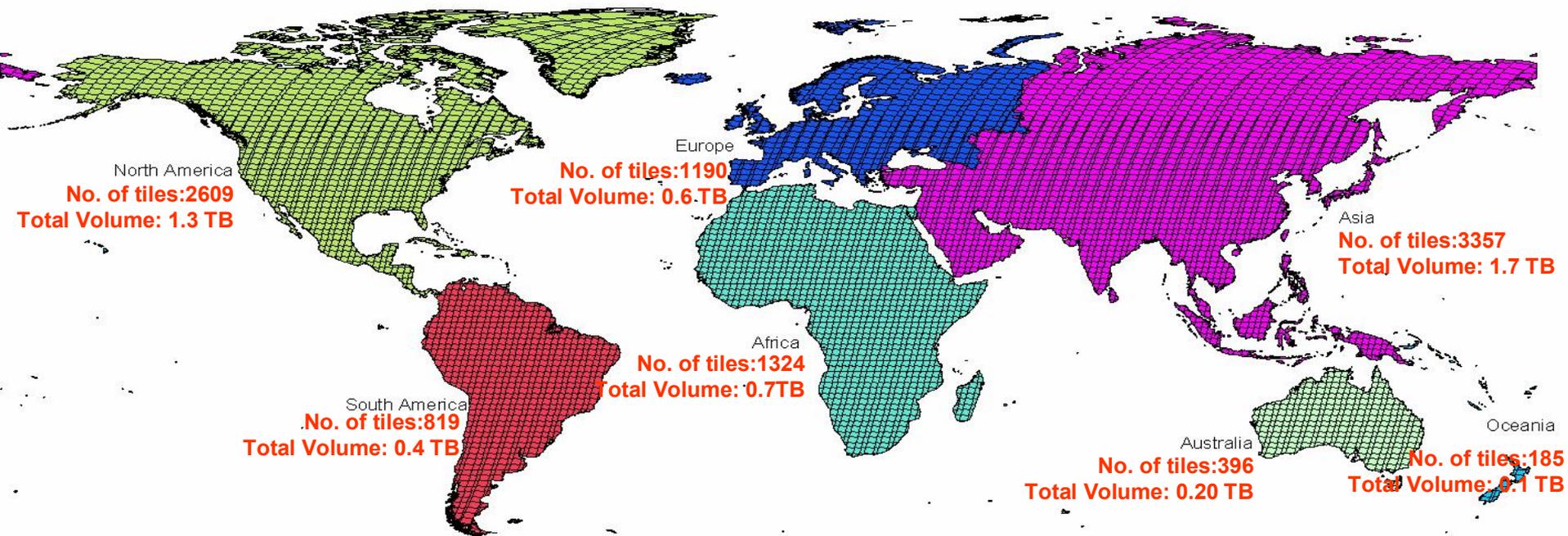
Average size of single tile: **500 Mb** (excluding thermal and panchromatic bands)

Total volume for the Globe*: **~ 4.8 TB** (DN Images)

Total volume for the Globe: **~20.0 TB** (Reflectance Images) #

* For all the landmass, except Antarctica continent

Each reflectance image is 4 times by volume of a DN image



Data volume of Landsat Tiles

Global: Lossless Compressed

Total no of tiles needed: **9,770** (Digital number files)

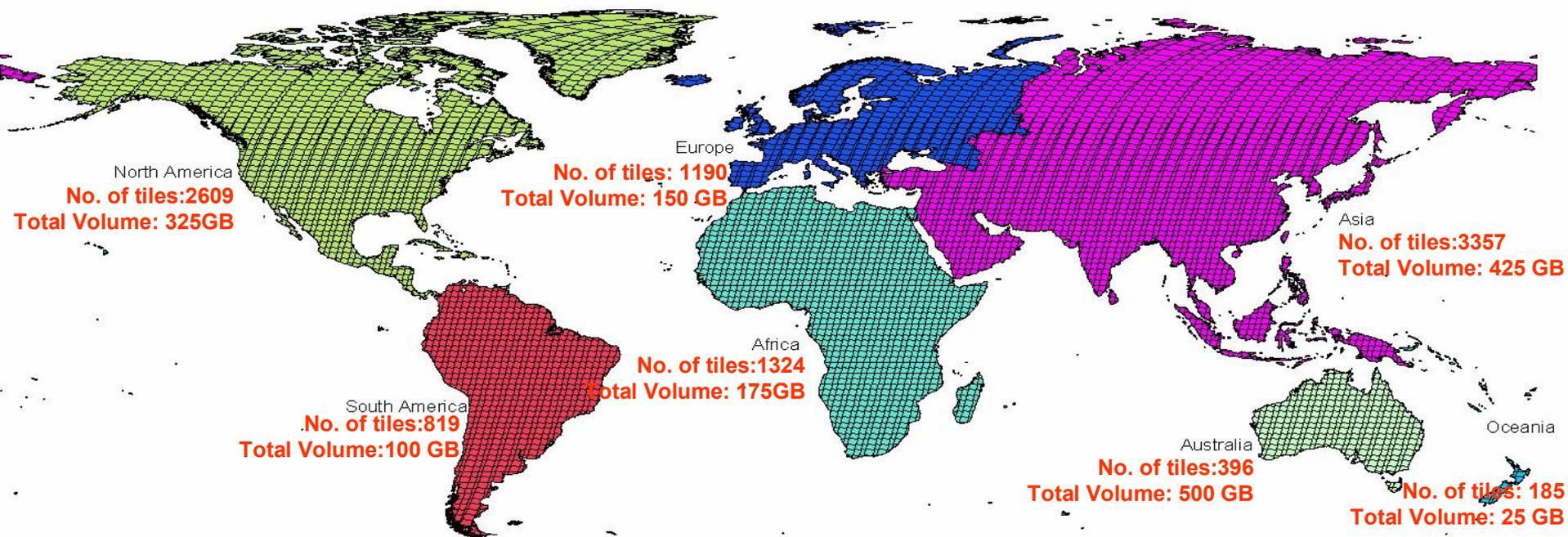
Average size of single tile (compressed): **125 Mb**

Total volume for the Globe*: **~ 1.2 TB** (DN Images)

Total volume for the Globe*: **~ 4.8 TB** (Reflectance Images) #

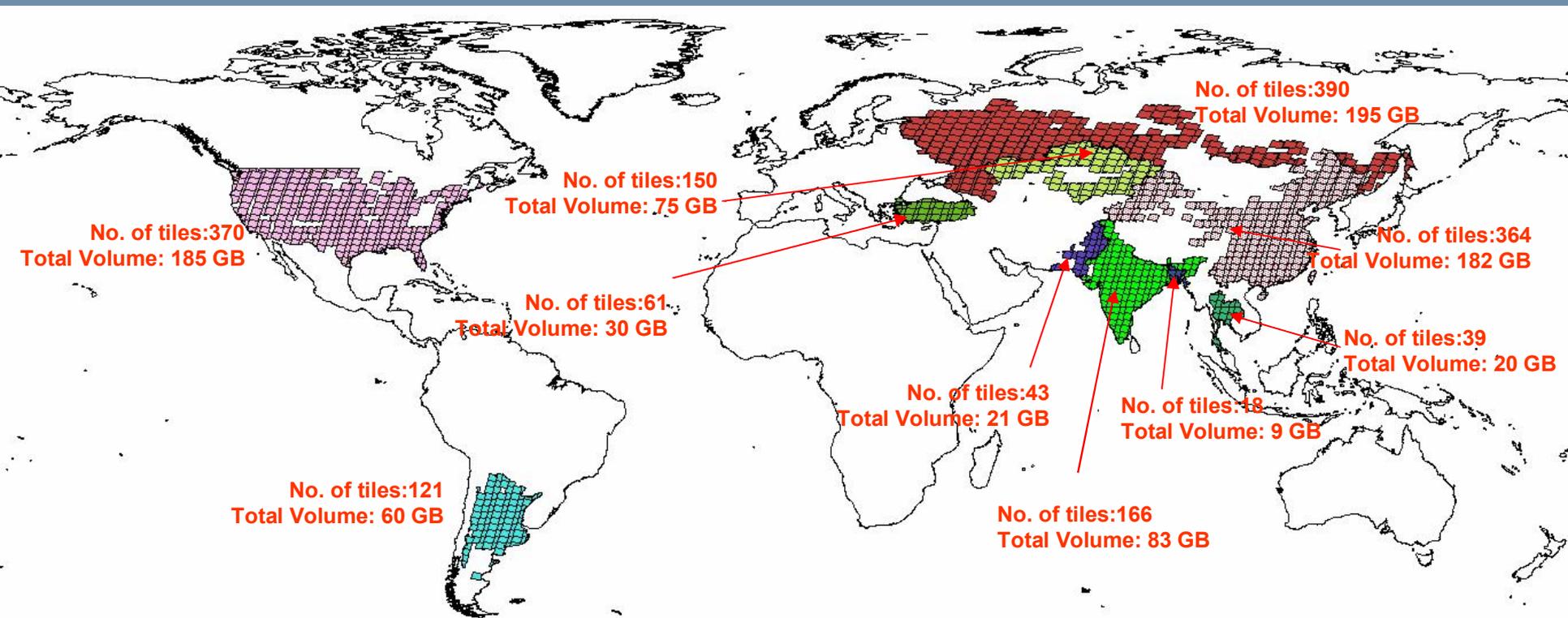
* For all the landmass, except Antarctica continent

Each reflectance image is 4 times by volume of a DN image



Data volume of Landsat Tiles (Compressed)

Limiting Data over Irrigated Areas Mapped by GIAM10km: Top ten Country example



.....total of about 0.9 TB for top 10 countries.....if all irrigated areas of the world are included, and not limited to top 10 countries, then the volume goes up to 1.2 TB

* Covers nearly 80% of the global Irrigated areas

Data volume of Landsat Tiles

Data Reduction Techniques Techniques (Global)

1. JPEG 2000 lossless compression of all 7-bands

- Reduces reflectance data volume by about 75 % (from 20 TB to 4.8 TB for the World);

2. Vegetation indices as opposed to all 7-bands: selecting 3 best indices that explains about 90 % of all variability

- Reduces data volume by a further 56 % (from 4.8 TB to about 2.1 TB).

3. Limiting 30m images to irrigated areas mapped by GIAM10km

- Reduces data volume by further 75 % (from 4.8 TB to about 1.2 TB). [Roughly, 0.9 TB for 10 leading irrigated area countries which combines has 80% global irrigation].

4. Principal Component Analysis (PCA)

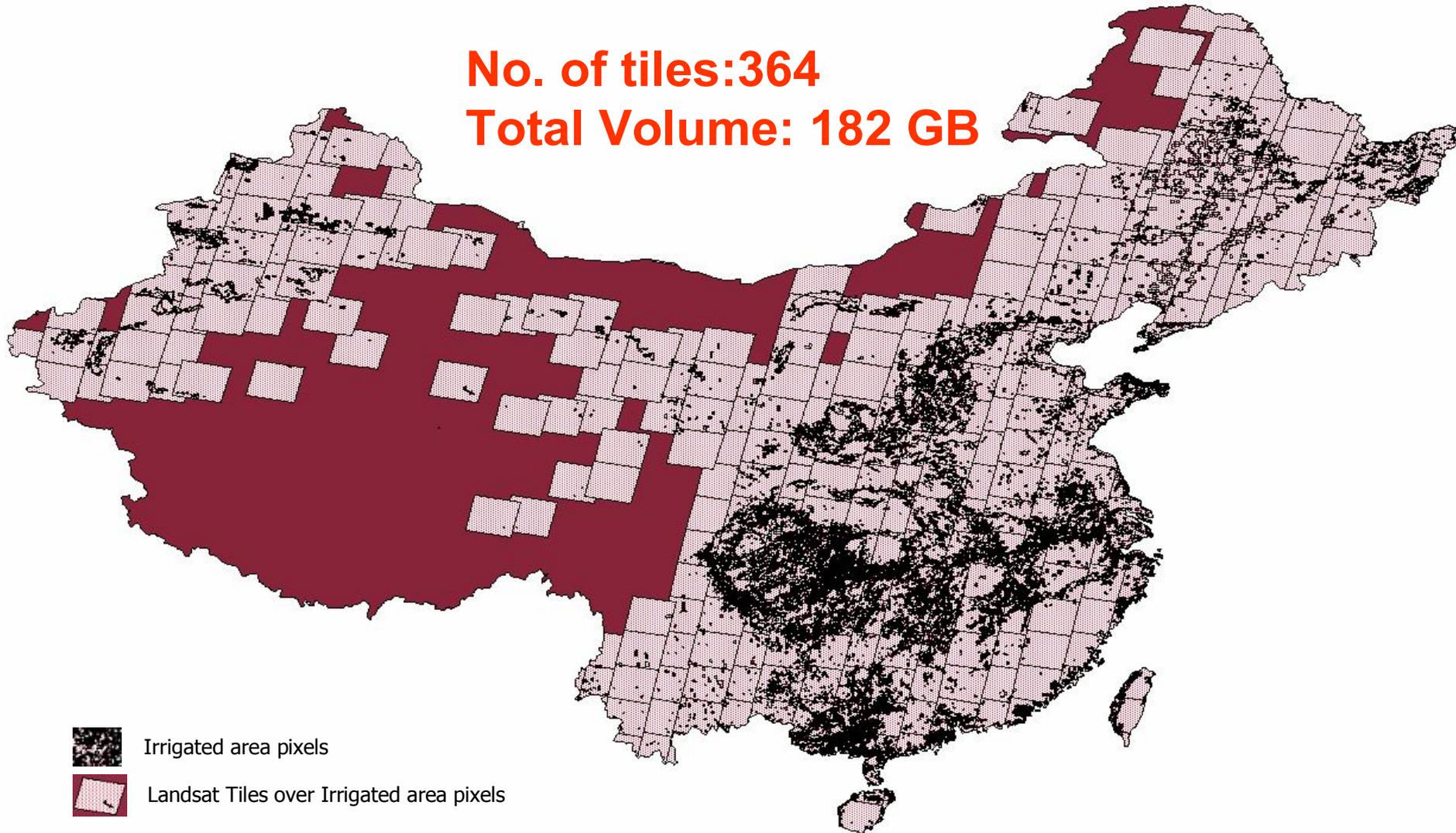
- First 2 to 3 PCA's reduce volume like in point 2. But, not necessarily the best approach since data in each PCA has some component of multiple wavebands. This will cause difficulties in physical explanation of data variability

.....possible to reduce data volume to just 5 to 10 percent of the original 20 TB volume for the World.

Data volume of Landsat Tiles (Compressed)

Limiting Data over Irrigated Areas mapped in GIAM 10km: China example

No. of tiles: 364
Total Volume: 182 GB



Global Trends in

Irrigation, Rainfed Croplands, Food Production,
Population Growth, and Water Use

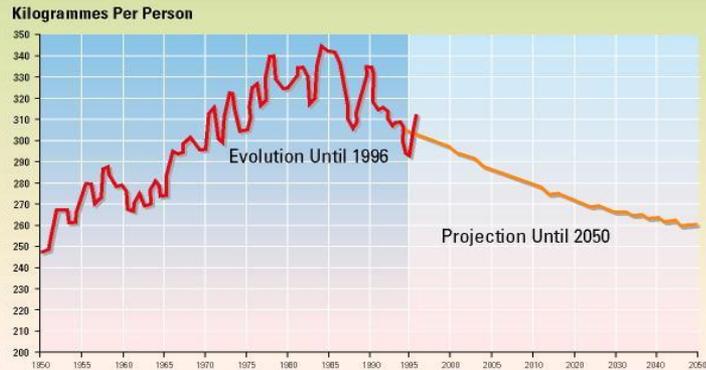
WORLD
2006

Global Trends in Irrigated and Rainfed Croplands

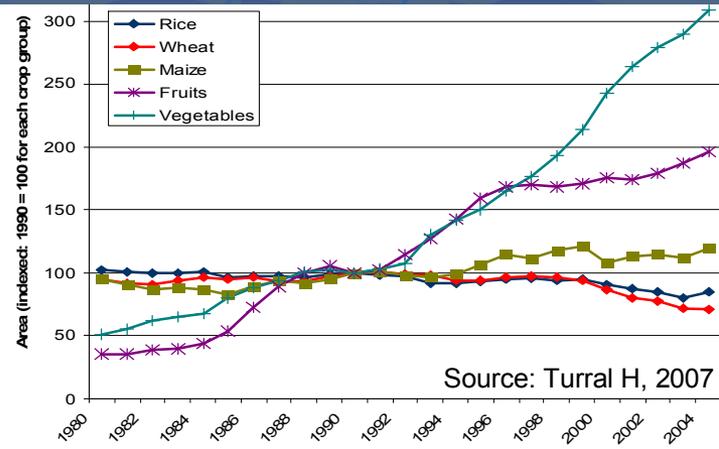
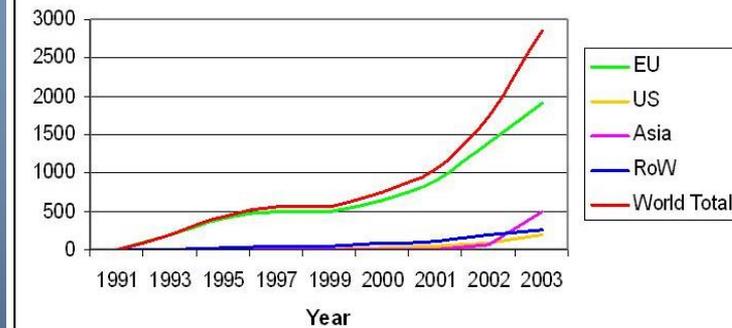
Issues Affection Global Water use, Food production, and possible virtual water trade

- A. Areas under grains are decreasing;
- B. Diversification of irrigated croplands (e.g., fruits and vegetables);
- C. Befouls putting stress on global food production and water consumption; and
- D. there is more irrigation than we think, and less pure rainfed than we think.....overall croplands have stabilized;

World Grain Production



World Biodiesel Production '000t



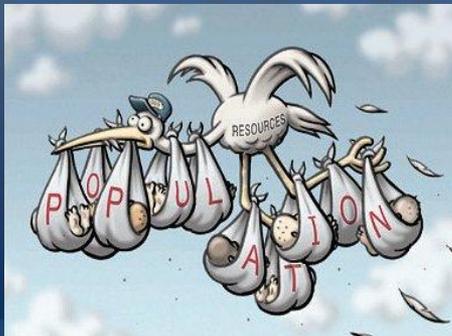
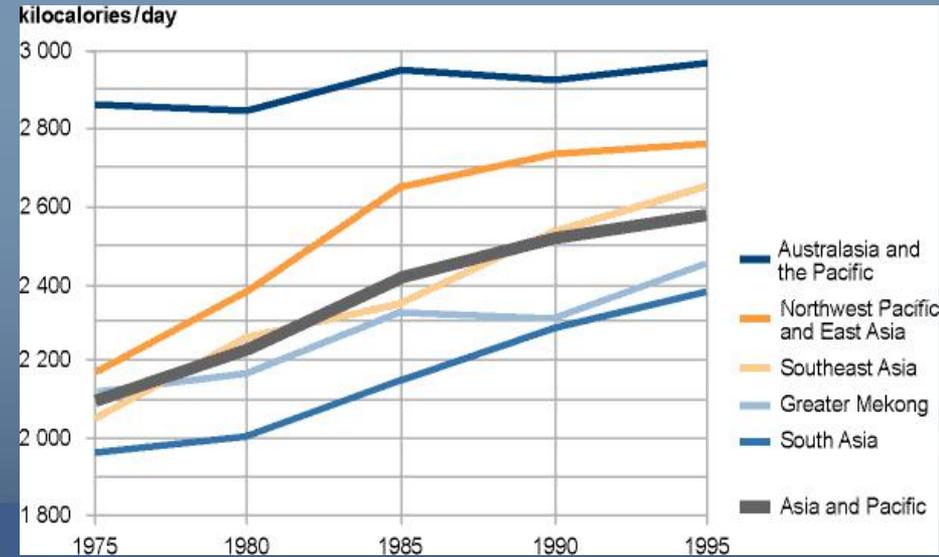
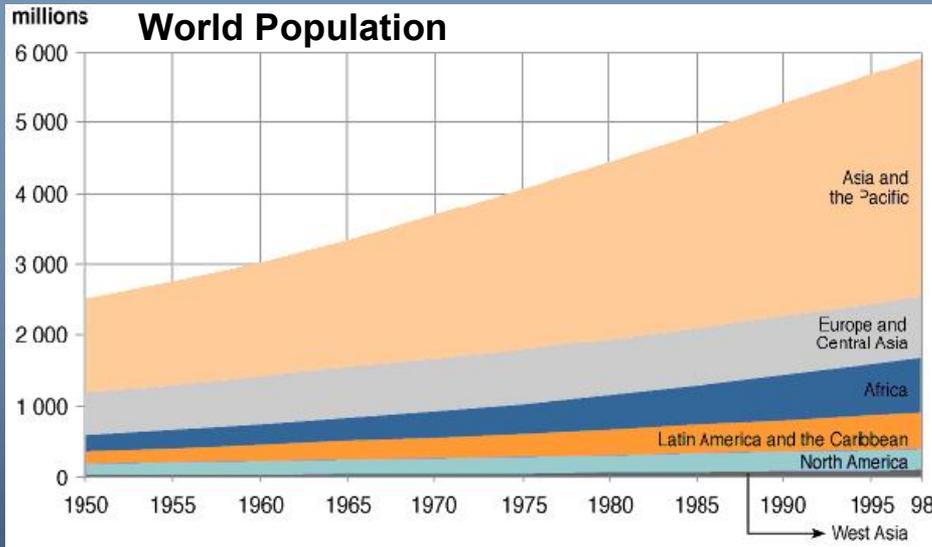
- Trends in crop production:**
- Shifting to high valued / cash crops
 - Fruits and vegetables
 - Bio-fuels crops?

Global Trends in Irrigated and Rainfed Croplands

Issues Affecting Global Water use, Food production, and possible virtual water trade

A. More consumption (and wastage) than we think?;

B. more production than we think? (otherwise how do we feed the 100 million + population added every year?).



where we Go from here?
Opportunity-success-challenge-vision

WORLD
2006

Where We Go from Here?

with GIAM @ Finer Resolution as Focus: Challenge and Vision

1. Refine and perfect GIAM 10 km;
2. GIAM 500m and GIAM 30m: Map and generate statistics for GIAM 500m and 30m leading to sub-national statistics;
3. Harmonize and synthesize: GIAM with National statistics;
4. Define: irrigated areas in widely understood terms;
5. Irrigated area mapping and reporting system: an online irrigated area mapping and reporting system for the Countries (e.g., IAMRS China).

GIAM
2006