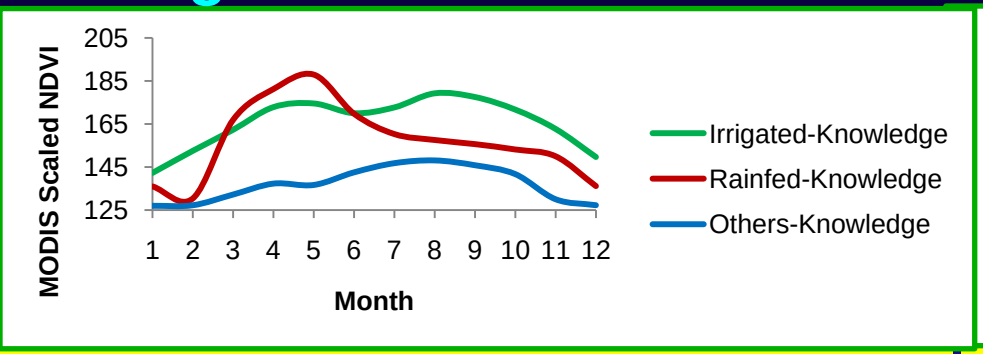
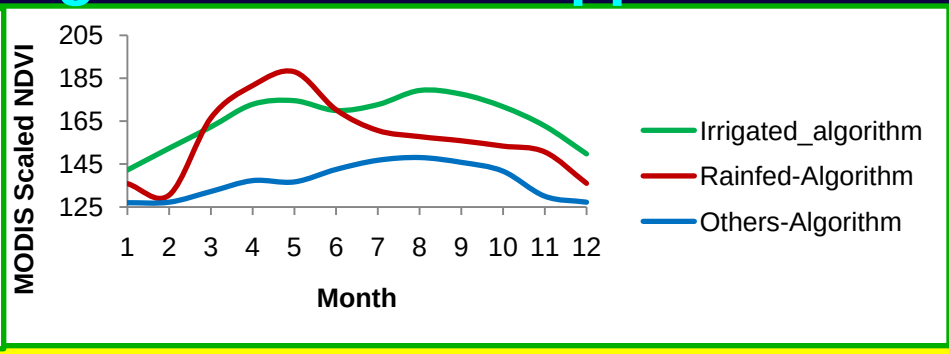
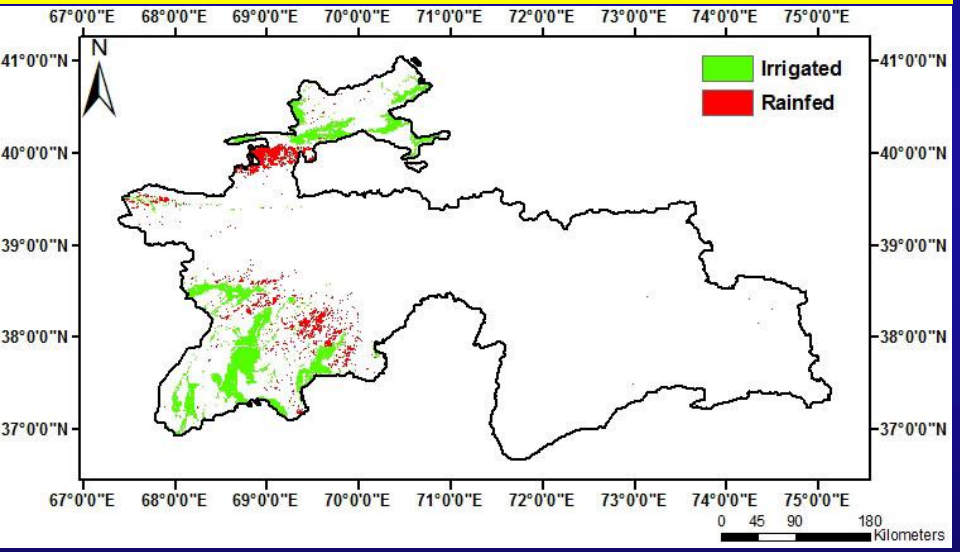
# A Knowledge-based Automated Cropland Mapping Algorithm using Advanced Remote Sensing Methods and Approaches

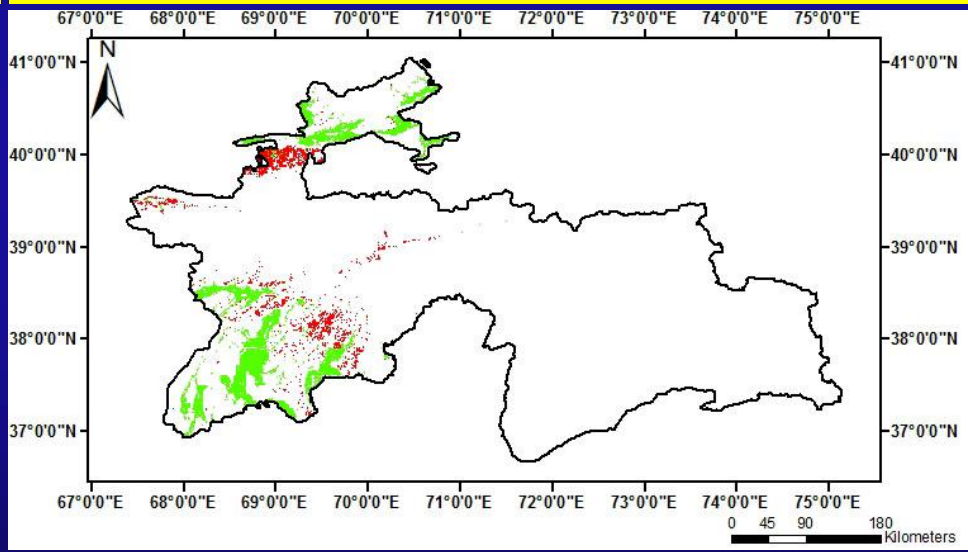



## Knowledge Based Cropland Layer




## Algorithm Derived Cropland Layer





**Prasad S. Thenkabail[1] and Zhouting Wu[2]**

1, 3, 4 = U.S. Geological Survey (USGS), USA; 2 = Northern Arizona University (NAU), USA



Landsat Science Meeting. March 1-3, 2011, held at Phoenix, AZ, USA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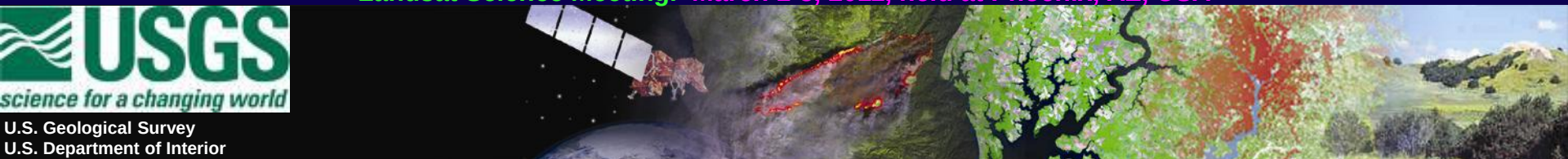


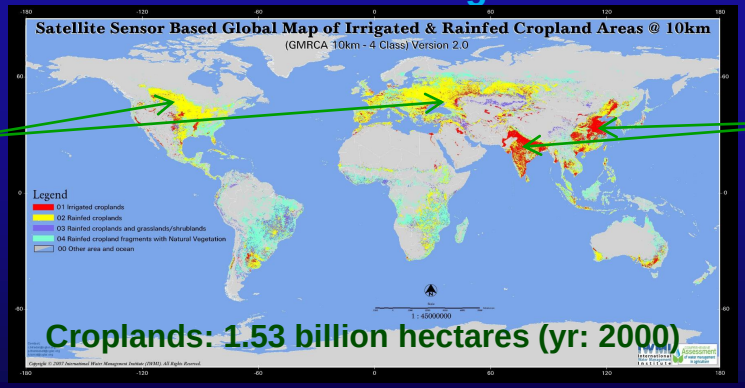

# Importance, Need, and Scope

# A Knowledge-based Automated Cropland Mapping Algorithm

## Importance, Need, and Scope for an Automated Cropland Algorithm

1. **Croplands:**
   - **A.** Rapid and repeatable (e.g., year after year, season after season) mapping of croplands requires an automated algorithm;
     Accuracy of the algorithm will depend on an accurate knowledge layer of croplands;
   - **B.** Currently absence of such accurate algorithms make cropland mapping tedious and\or inaccurate;
   - **C.** Need for advance methods (e.g., automated algorithms), and approaches (e.g., multiple remote sensing data fusion) is critical;
   - **D.** Accurate cropland mapping using advanced remote sensing enables: (a) frequent (e.g., yearly, seasonal) update of agricultural statistics, (b) spatial view of croplands distribution and their changes over space and time;
2. **Water use by croplands:**
   Helps us determine blue water use and green water use accurately;
3. **Food security:**
   If we can achieve 1 and 2 we can make significant contribution towards a food secure world

Green water use: water used by rainfed cropland areas coming from rainfed croplands and soil moisture stored in unsaturated zone




Blue water use: water used by irrigated areas coming from reservoirs, lakes, rivers, deep aquifer water, and even direct rainfall over irrigated areas

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# Uncertainties in Existing Cropland Data

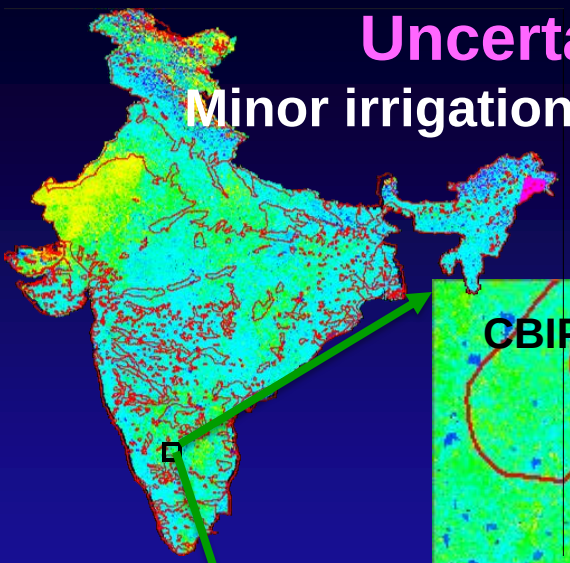
## Causes of Uncertainties

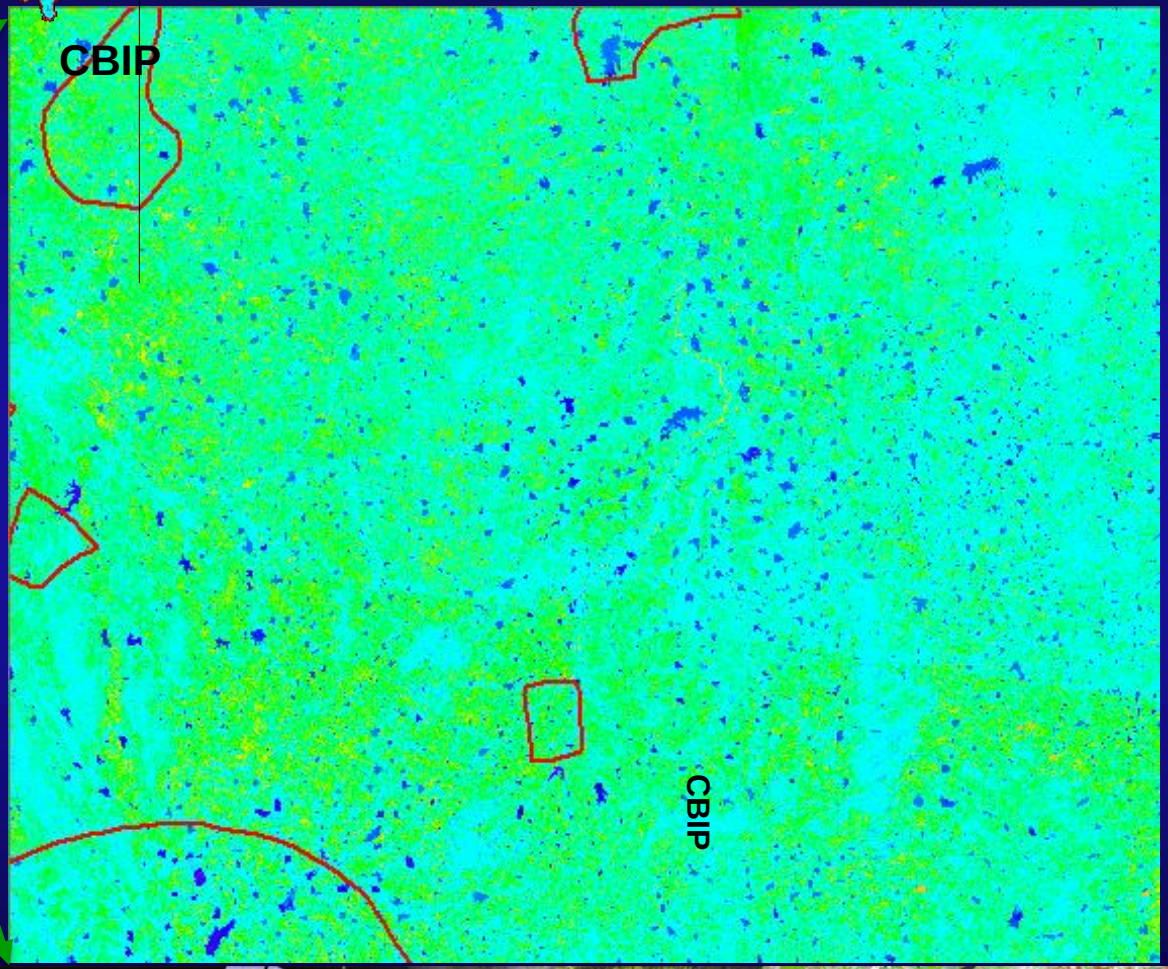
1. Resolution or Scale: Resolution too coarse;
2. Area fractions: uncertainties in determining fractional areas;
3. Definition issues (e.g., does supplemental irrigation fall into irrigated areas?);
4. Type of data used (e.g., traditional vs. remote sensing);
5. Methodologies: complexity or simplicity of methods;
6. Data sharing issues: reluctance to share data due to vested interests;
7. Inadequate accounting of minor irrigation (e.g., ground water, small reservoirs, tanks);



# Uncertainties in Existing Cropland Data

## Minor irrigation not properly Accounted in Coarse Resolution



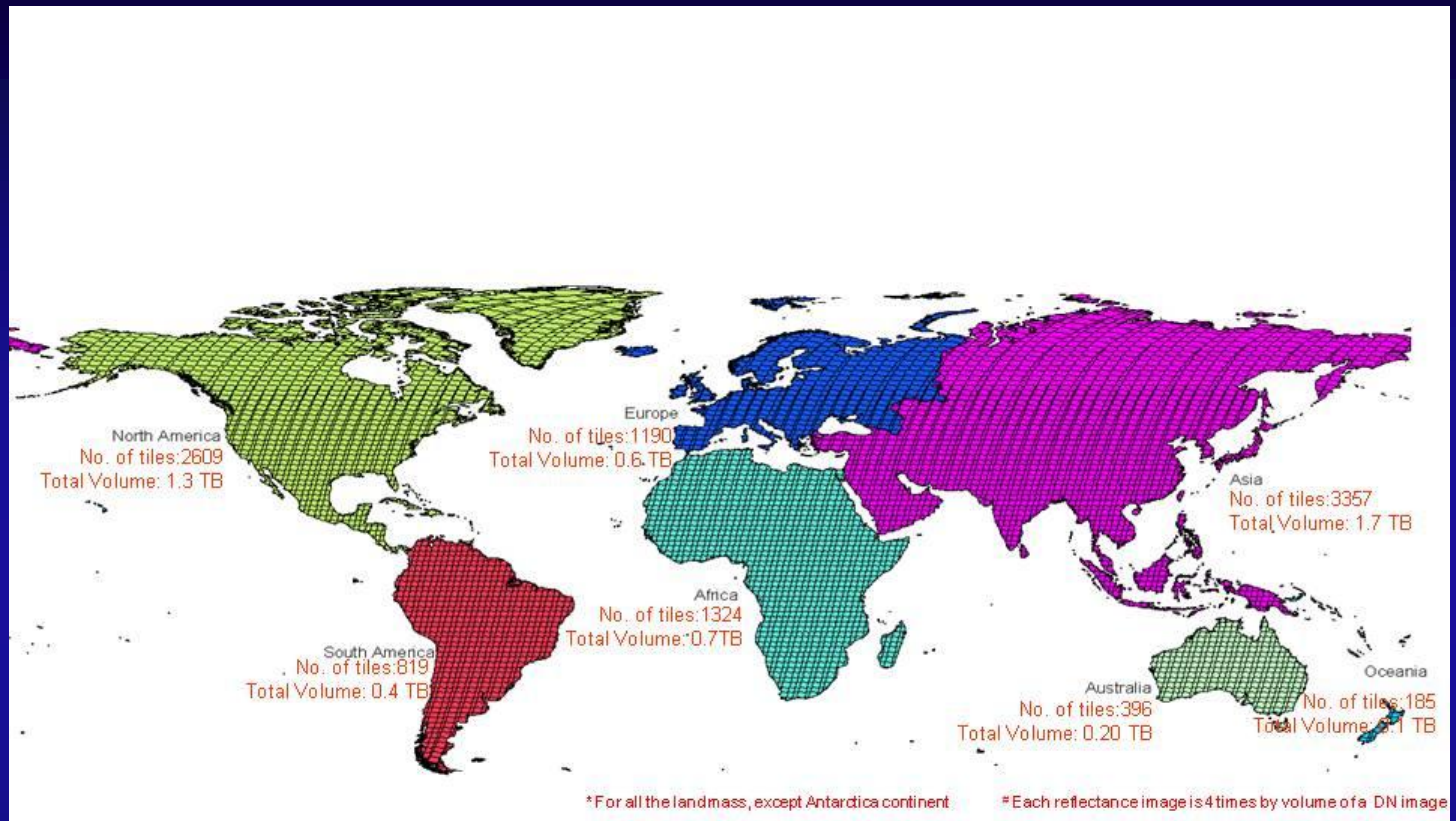



**30m Landsat Data highlights small water bodies such as tanks and small reservoirs**



# Overcoming Uncertainties in Existing Cropland Data

## Is Landsat Data Panacea?




**Finer resolution (e.g., Landsat) in combination with temporal resolution (e.g., MODIS), secondary data, and in-situ data will bring: (a) crop type\dominance; (b) precise location of crops, (c) watering methods (e.g., rainfed, irrigated), (d) cropping intensity……..leading to an advanced agricultural monitoring system…..that allows precise water use assessments.**


# Overarching Goal

# A Knowledge-based Automated Cropland Mapping Algorithm

## Overarching Goal

**The Overarching Goal**
**of this study is to develop**
**an Automated Algorithm, that is Knowledge-Based,**
**to Map Irrigated and Rainfed Cropland Areas**
**of a Country, Continent, and The World**
**using Advanced Remote Sensing Methods and Approaches**

**This Presentation will Focus on a Country and Demonstrate the Working of such an Algorithm**

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# A New Strategy for Mapping Croplands Accurately and Rapidly

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# A Knowledge-based Automated Cropland Mapping Algorithm

## Strategy in Developing the Algorithm

1. **Establish crop calendars:** Divide the world into distinct zones cropping calendars. Develop algorithm for each zone separately;
2. **Multi-data Fusion:** Develop mega-file data cube that makes use of multiple sources of remotely sensed data and numerous other data such as (a) Landsat 30m, (b) MODIS NDVI MVC monthly composites, (c) Suite of Secondary data (e.g., elevation, slope, temperature, rainfall), (d) higher resolution imagery as ground-truth, and (e) in-situ data;
3. **Knowledge Layer of Croplands:** Obtain and\or generate an accurate knowledge layer of irrigated croplands, rainfed croplands, and other LCLU classes;
4. Develop automated algorithm for a country and\or a region;
5. Develop automated cropland algorithm for the entire world by integrating suite of cropland algorithm of different countries and\or regions;
6. Test the algorithm on independent datasets; and
7. Establish accuracies and errors.

……today, we will illustrate the development, working, and testing of this cropland algorithm for one Central Asian Country.

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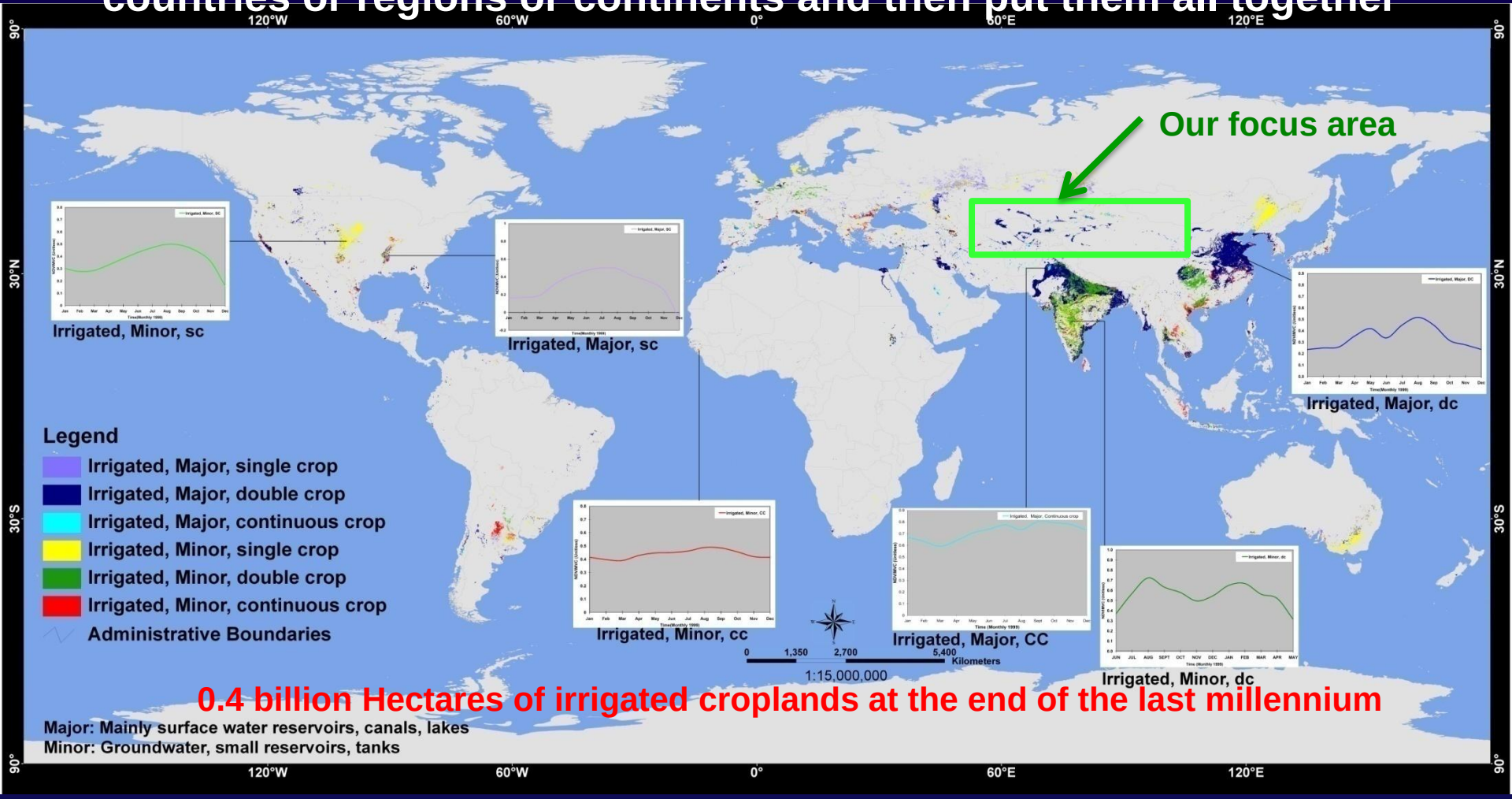
# Global Irrigated Areas: Spatial Distribution

## Develop Algorithm for Automated Cropland Mapping based on countries or regions or continents and then put them all together




**0.4 billion Hectares of irrigated croplands at the end of the last millennium**

Major: Mainly surface water reservoirs, canals, lakes
Minor: Groundwater, small reservoirs, tanks

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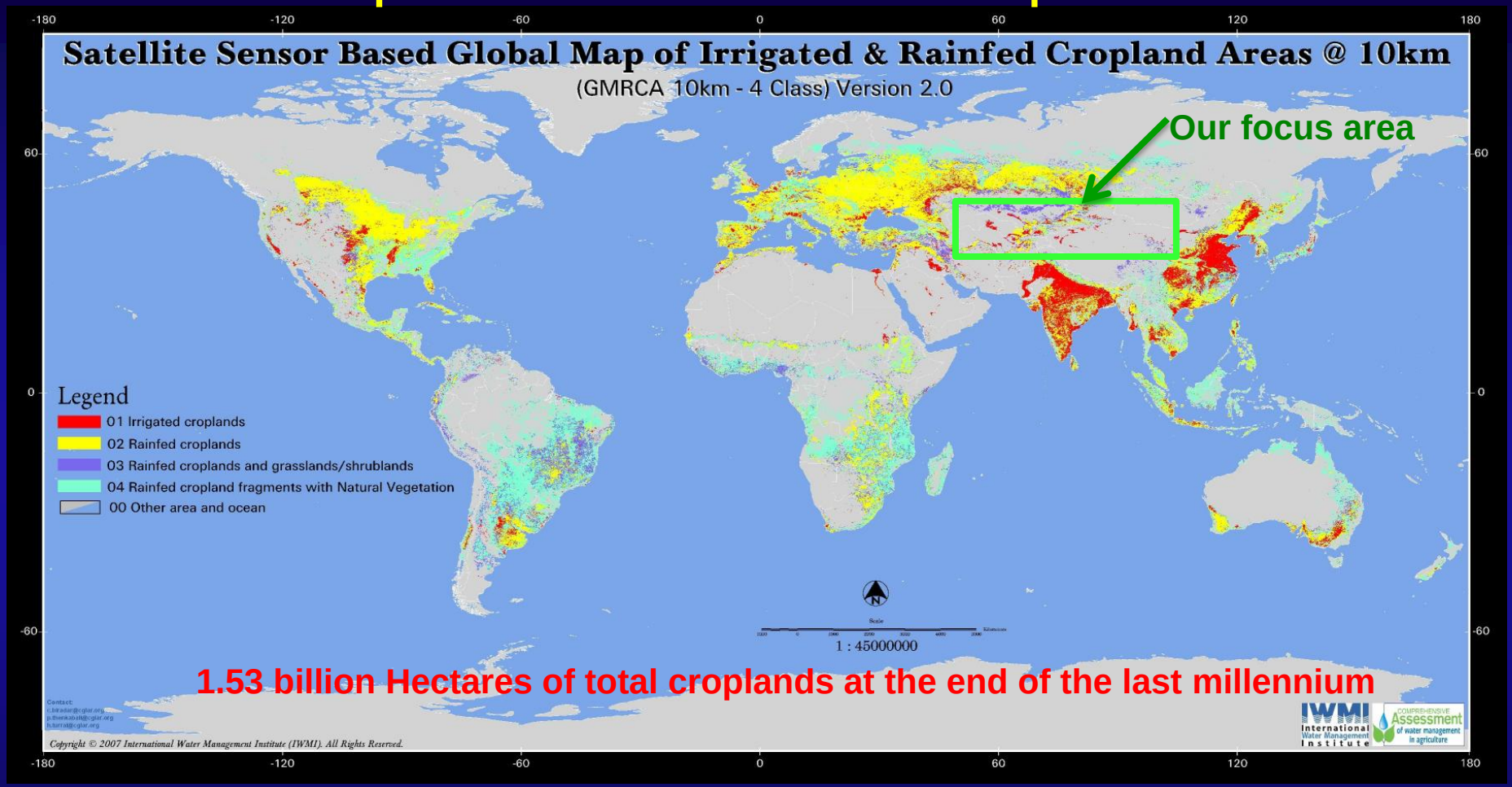
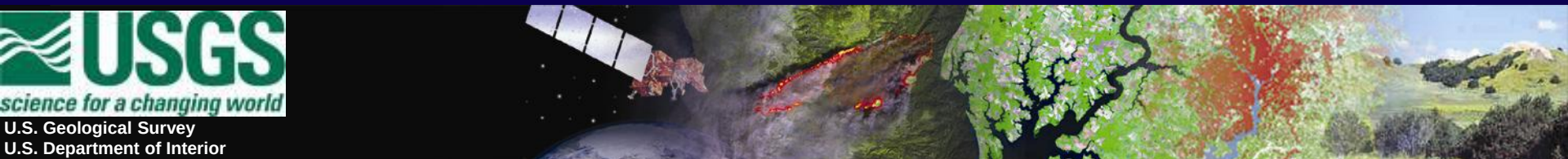
# Global Irrigated Areas + Rainfed Areas

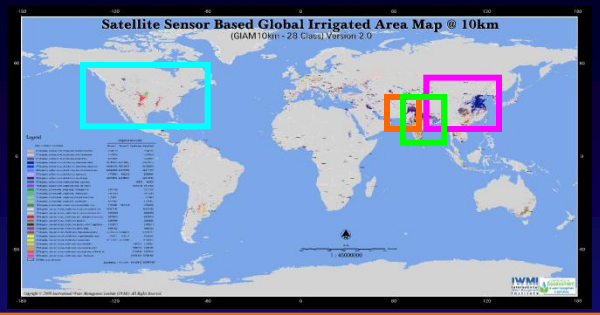
## Spatial Distribution of Global Croplands



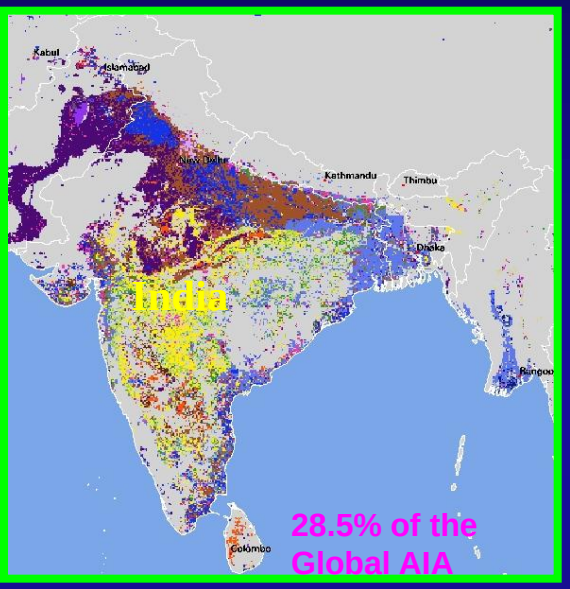
# Irrigated Areas

## Dominant Countries

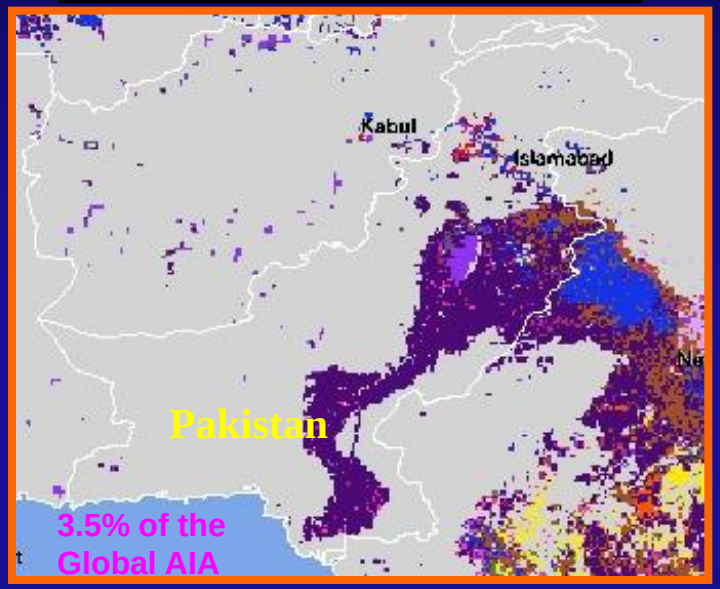



Note: AIA = annualized irrigated areas.

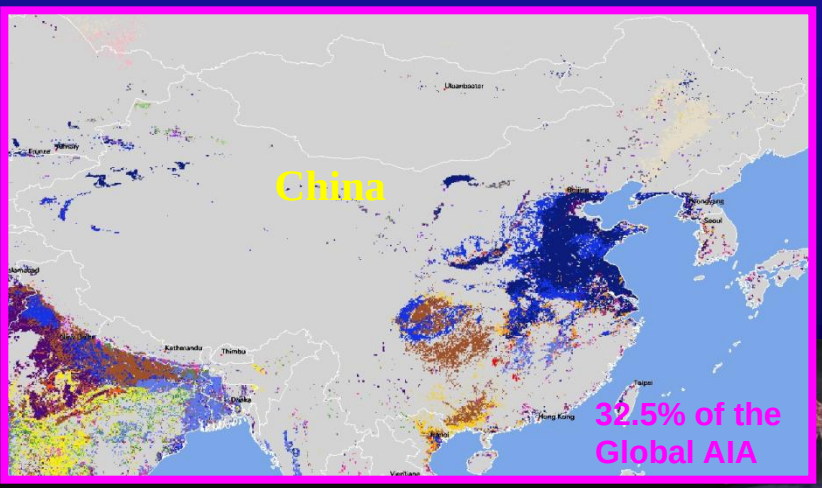
01 Irrigated, surface water, single crop, wheat-corn-cotton
02 Irrigated, surface water, single crop, cotton-rice-wheat
03 Irrigated, surface water, single crop, mixed-crops
04 Irrigated, surface water, double crop, rice-wheat-cotton
05 Irrigated, surface water, double crop, rice-wheat-cotton-corn
06 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-other crops
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-sugacane
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



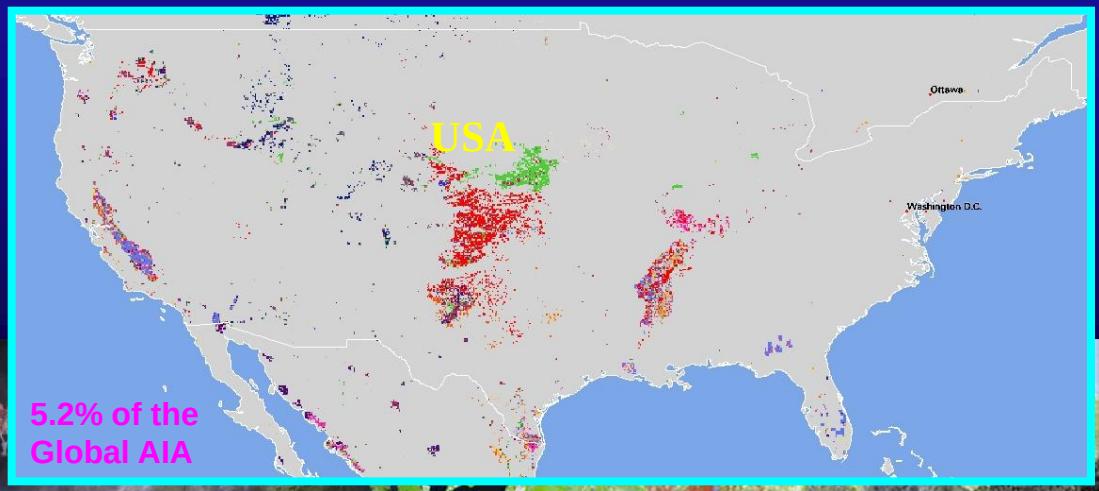

28.5% of the Global AIA




3.5% of the Global AIA



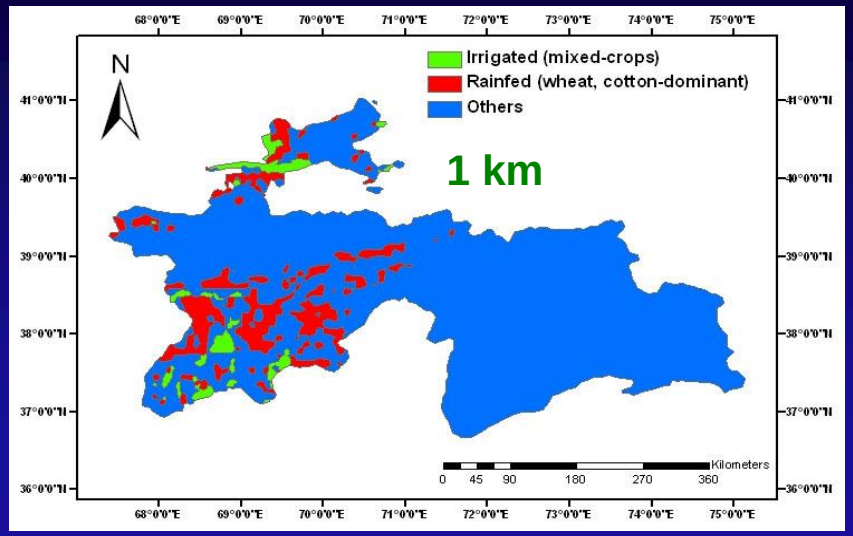

32.5% of the Global AIA

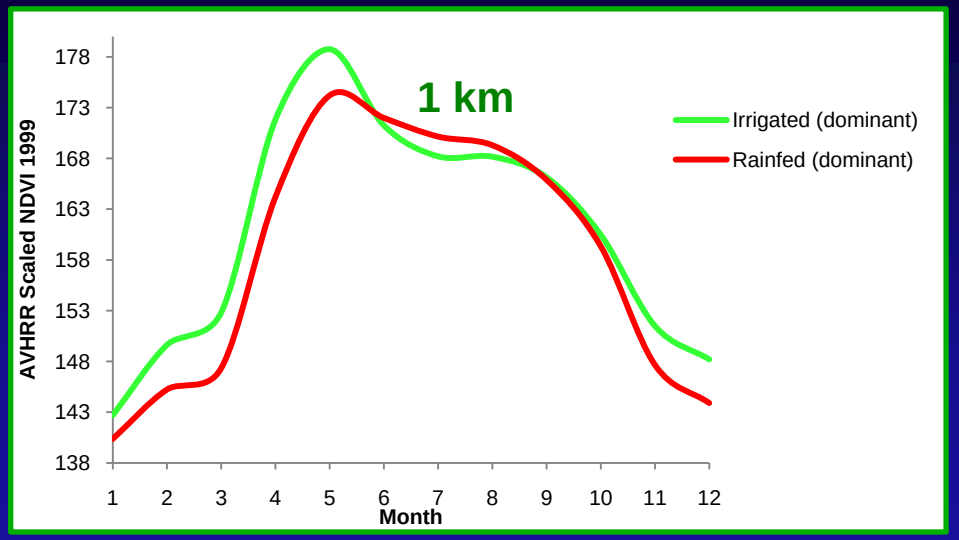


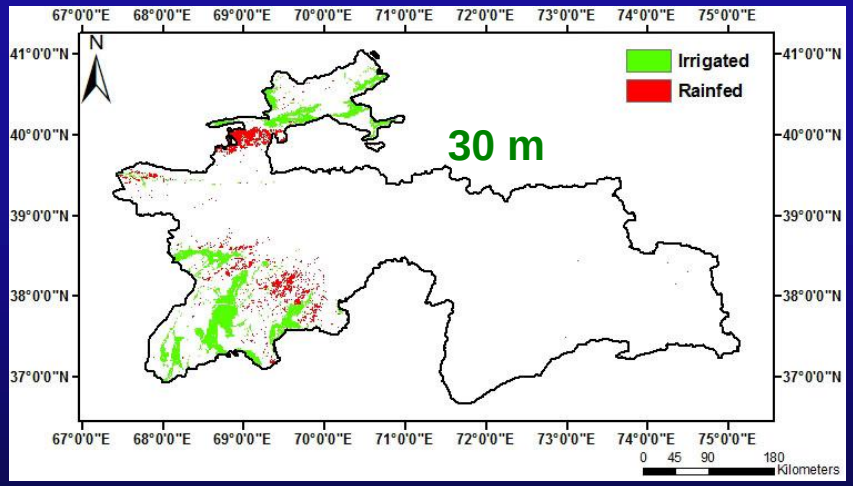

5.2% of the Global AIA

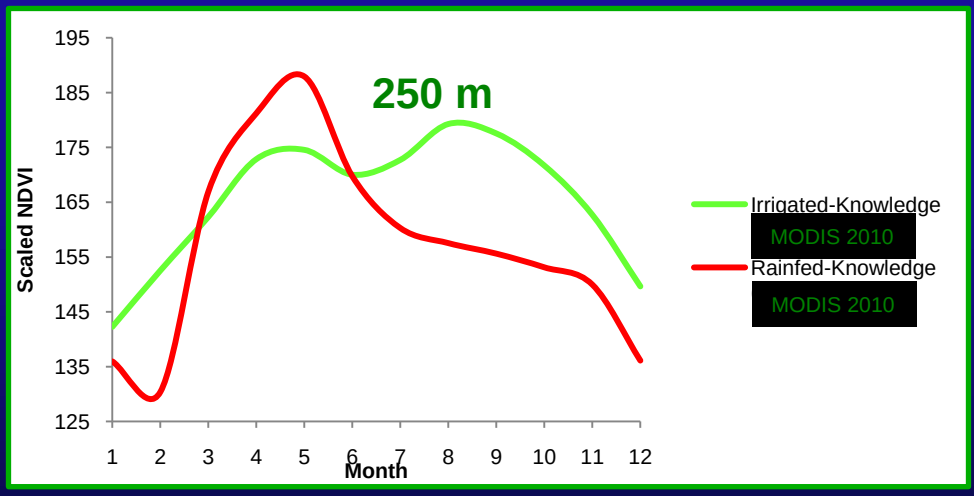
# A Knowledge-based Automated Cropland Mapping Algorithm

## Coarse vs. Fused Multi-Resolution

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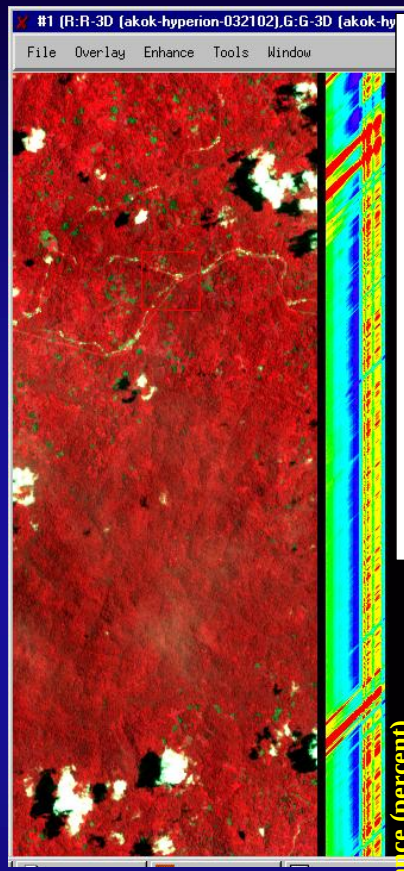
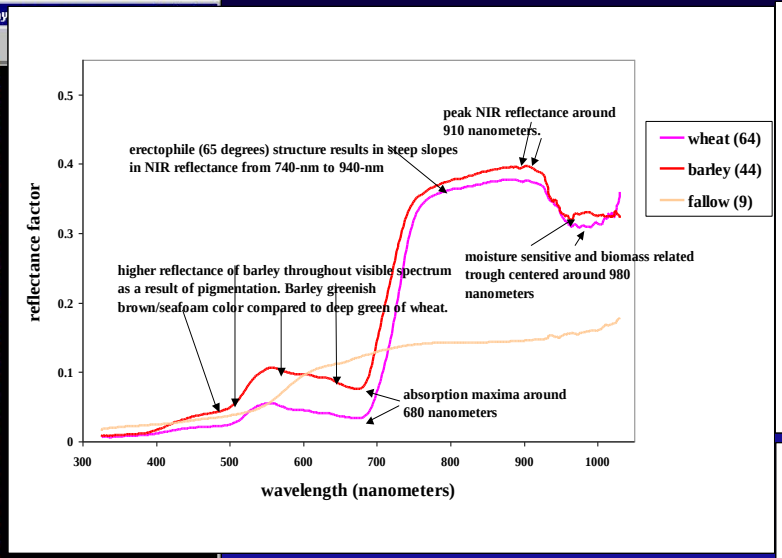
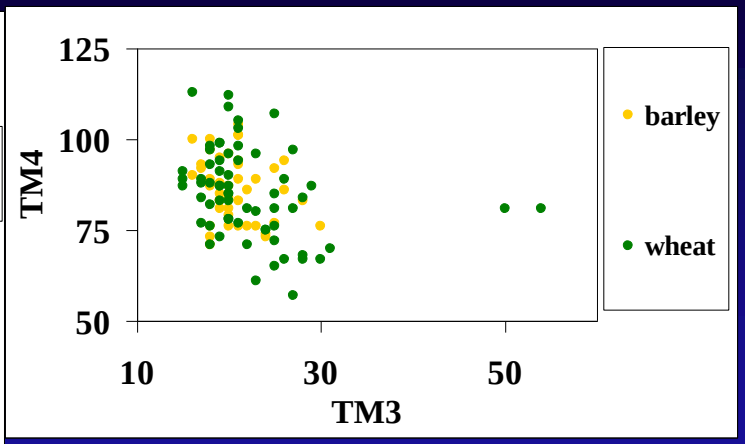
# A Knowledge-based Automated Cropland Mapping Algorithm

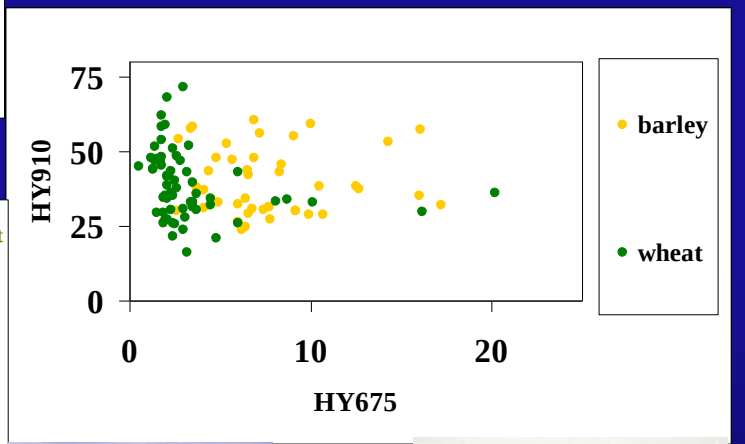
## Landsat compared to hyperspectral Narrow-bands in Discriminating Wheat vs. Barley

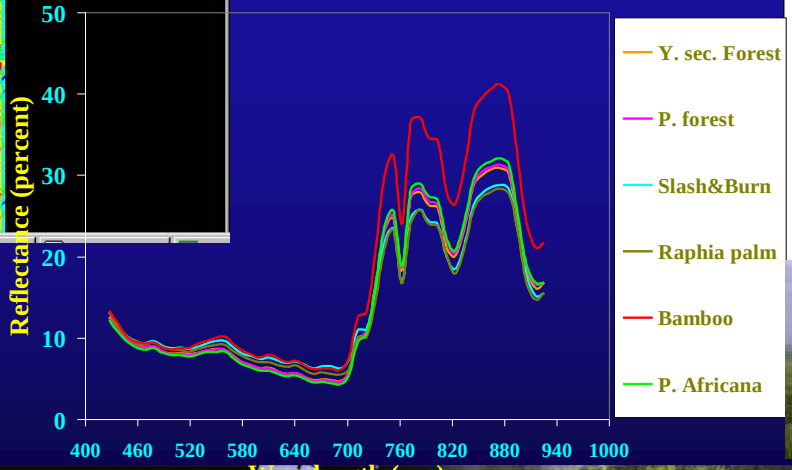



Hyperion Data Cube

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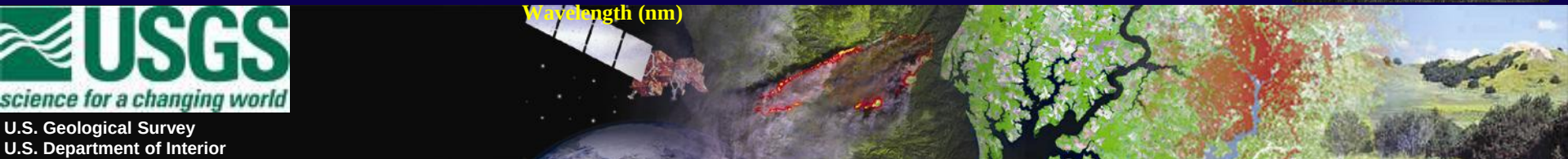
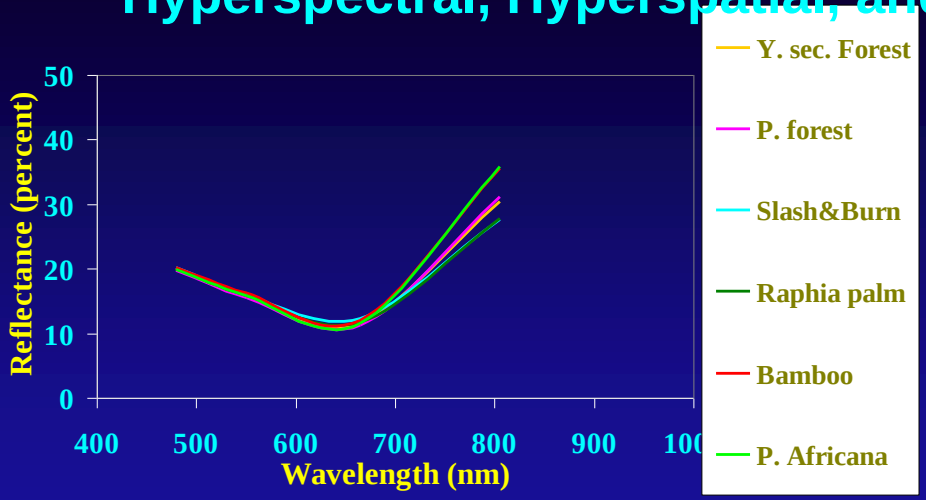
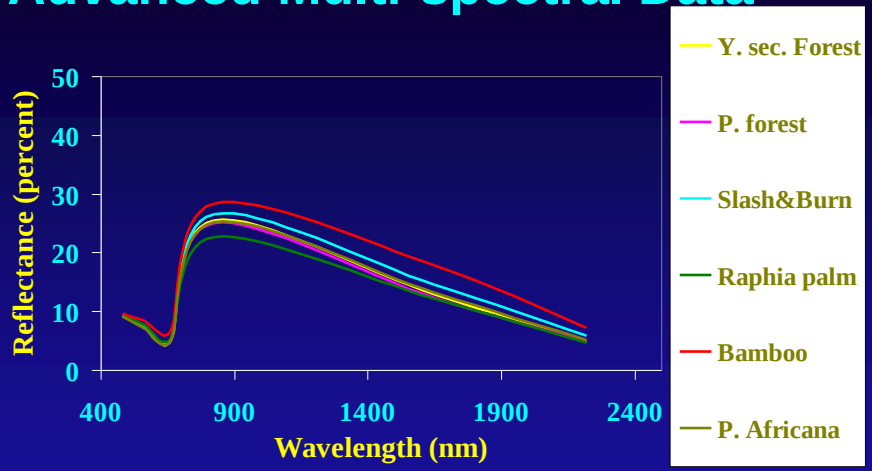


# Comparison of Hyperspectral Data with Data from Other Advanced Sensors

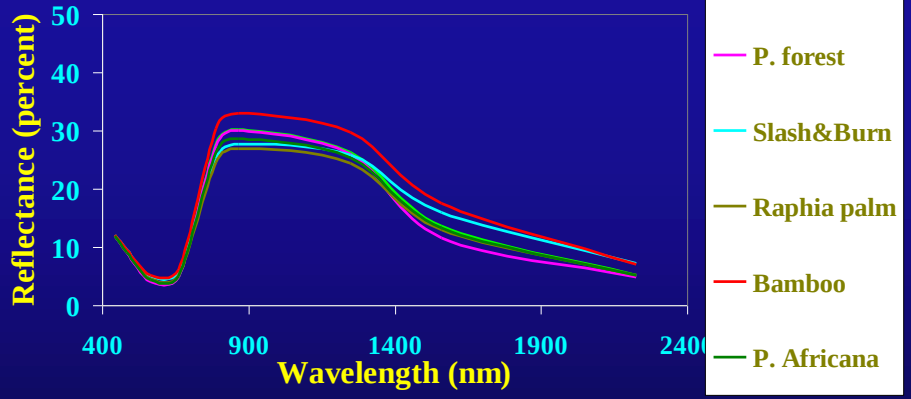
## Hyperspectral, Hyperspatial, and Advanced Multi-spectral Data



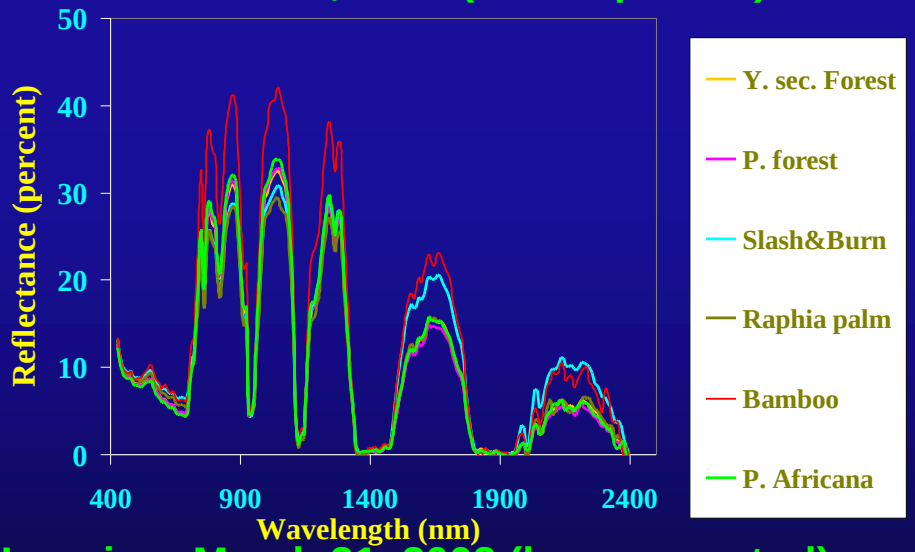

IKONOS: Feb. 5, 2002 (hyper-spatial)



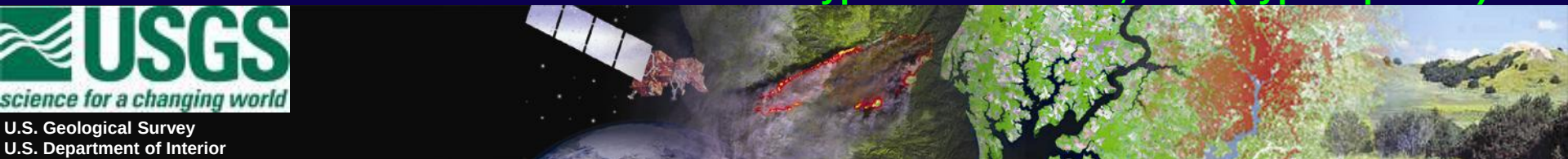

ETM+: March 18, 2001 (multi-spectral)




ALI: Feb. 5, 2002 (multi-spectral)




Hyperion: March 21, 2002 (hyper-spectral)

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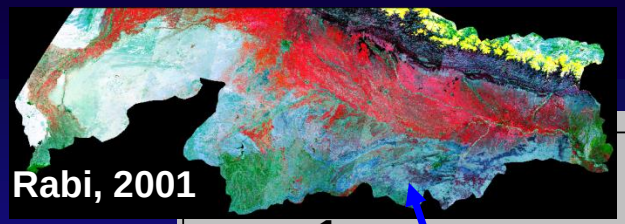
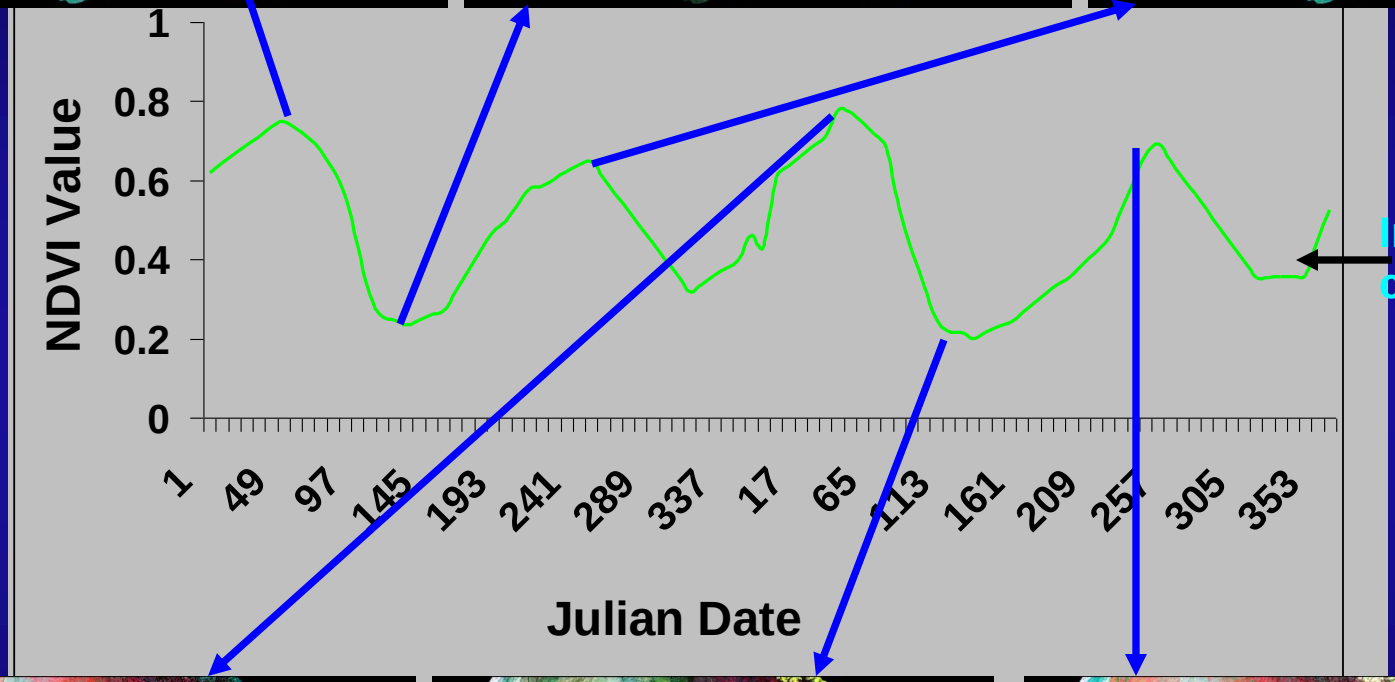
# Need for Temporal Data in Cropland Mapping

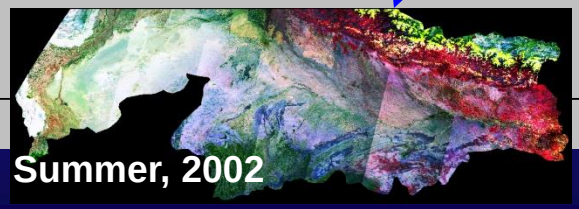
## MODIS Time-Series for Ganges River basin











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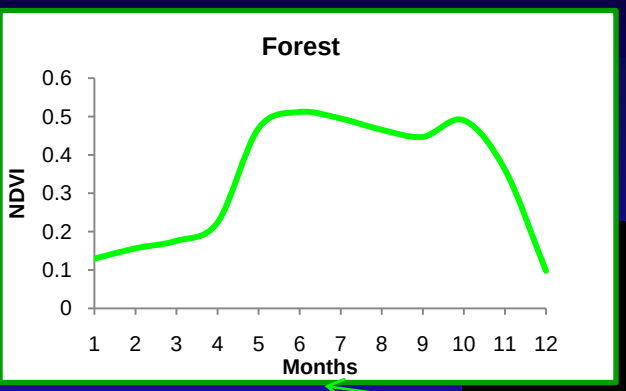
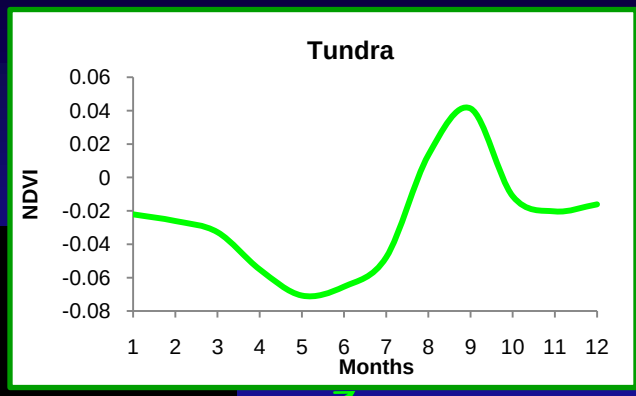
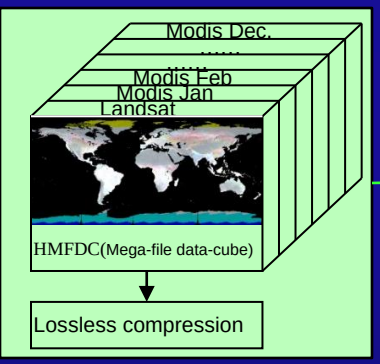
# A Knowledge-based Automated Cropland Mapping Algorithm

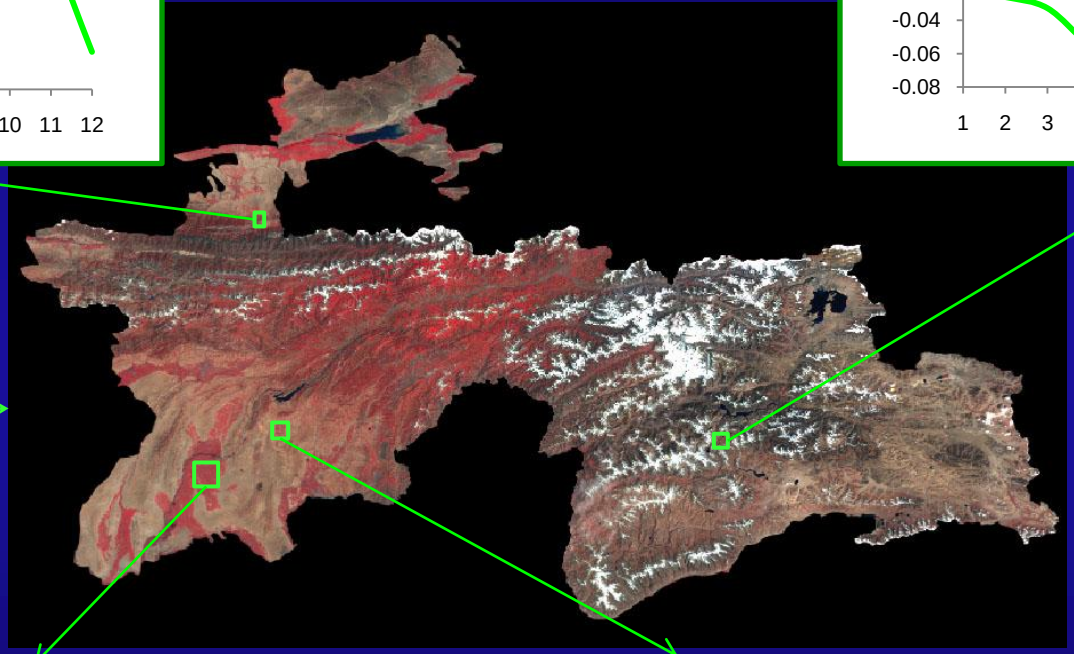
## Mega-file Data Cube (MFDC) showing Fusion of Landsat and MODIS Datasets

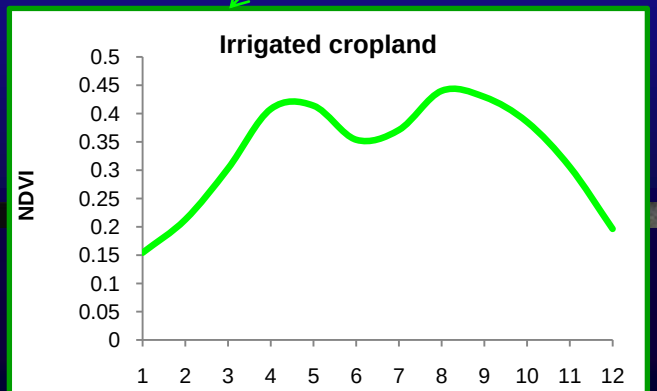
**Typical spectral profile illustrations of different land cover classes derived from MODIS 250m NDVI time-series**

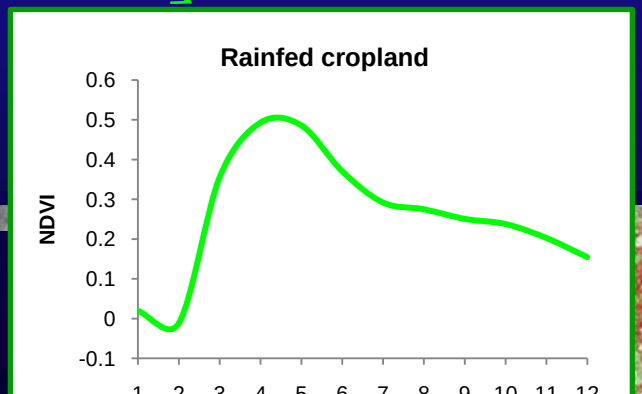






# Datasets used to Generate Knowledge Layer (year 2005)

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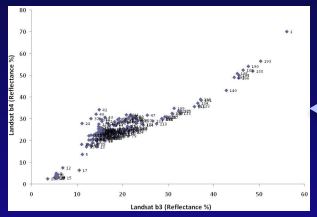
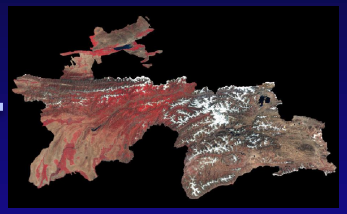
# A Knowledge-based Automated Cropland Mapping Algorithm

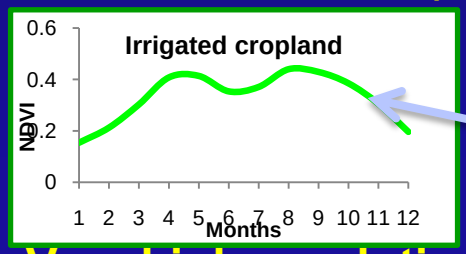
## Datasets used to produce Knowledge Layer on Croplands for Tajikistan

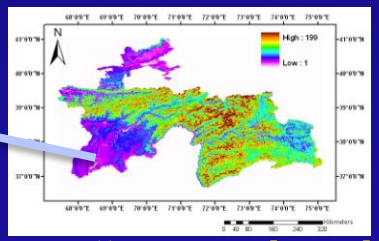
1. **Landsat 30 m Data:** Landsat GLS2005 (nominal 2005) dataset;



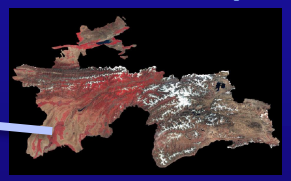



2. **MODIS NDVI MVC, monthly:** MODIS NDVI MVC monthly data for 2005;

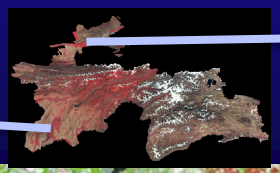



3. **Very high resolution data as "groundtruth":** sub-meter to 4 meter (very high resolution data) for nominal 2005 as "groundtruth";



4. **In-Situ data as "groundtruth":** in-situ data gathered from various sources as "groundtruth".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# A Knowledge-based Data Layer Derived by Classifying the MFDC

## Identifying and Labeling the 199 Information Classes: Bispectral Plots

Very high resolution imagery: sub-meter to 6m (e.g., quickbird, IKONOS, Geoeye, Rapideye)

**Croplands versus non-cropland identification based on Tassel cap bi-spectral plots and Very High Resolution Imagery**

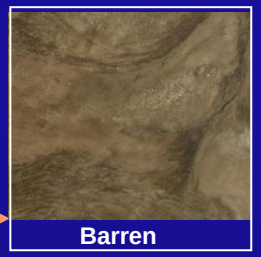
Very high resolution imagery: sub-meter to 6m (e.g., quickbird, IKONOS, Geoeye, Rapideye)

Cropland

Forest

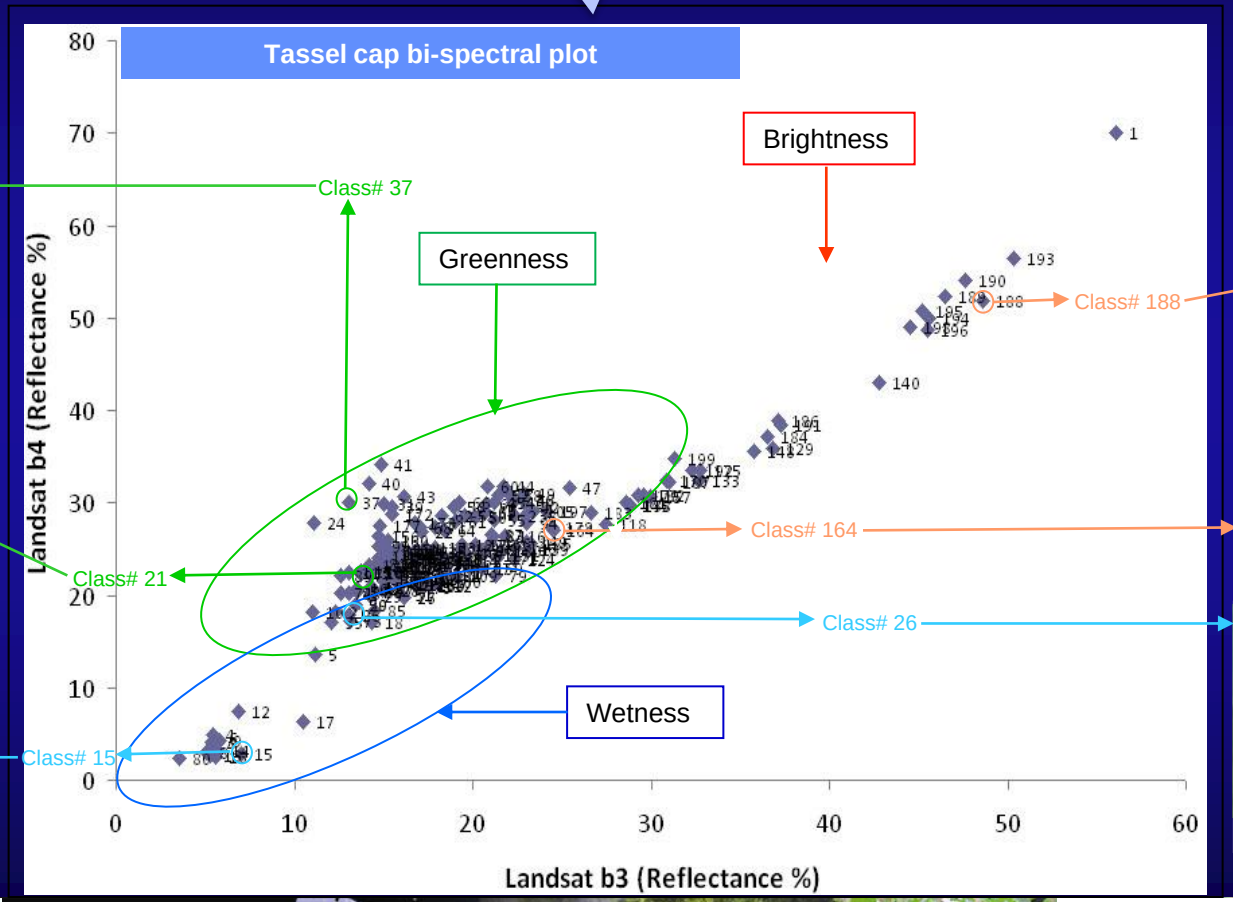
Water

Snow



Barren

Wetland





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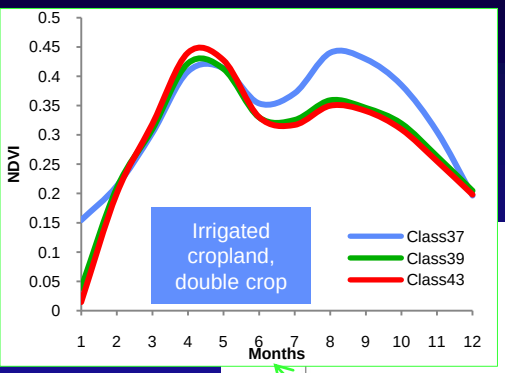
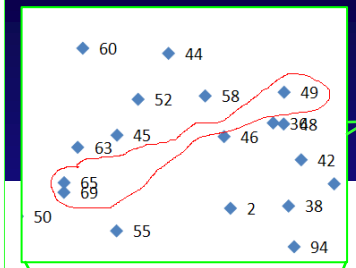
# A Knowledge-based Data Layer Derived by Classifying the MFDC

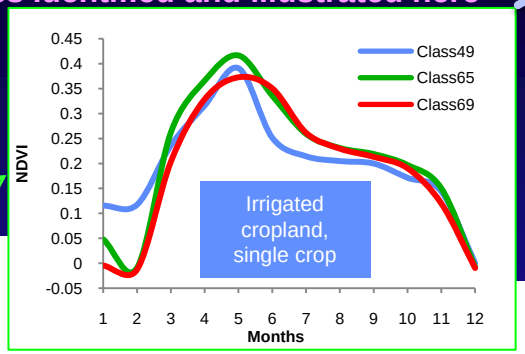
## Identifying and Labeling the 199 Information Classes: MODIS Temporal NDVI Plots for Certain Classes

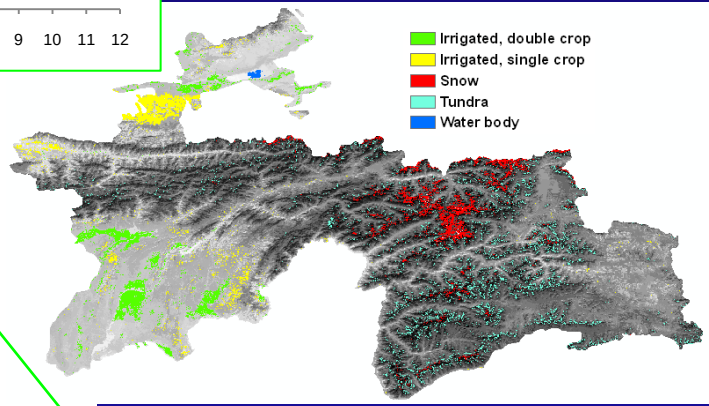
23 out of 199 classes identified and illustrated here

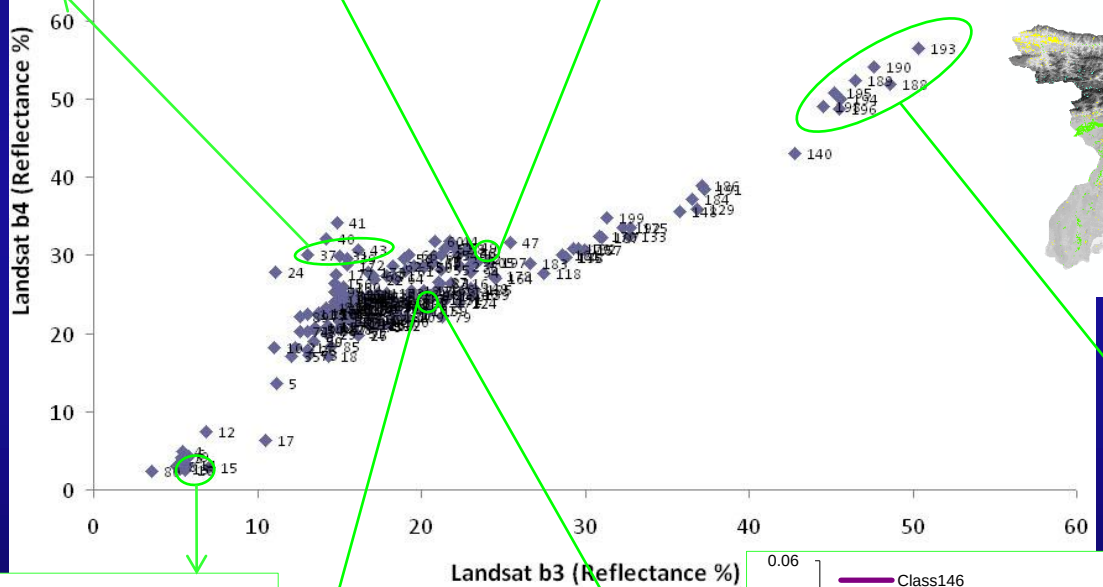
**Multiple measures used in algorithms to identify and label agricultural cropland classes**

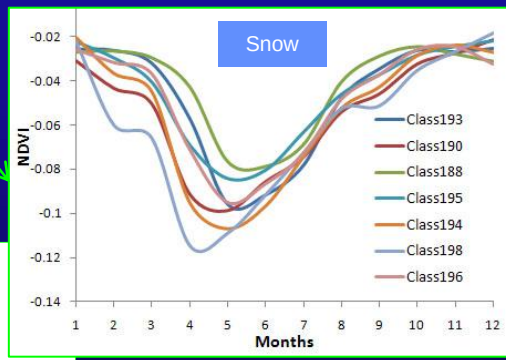


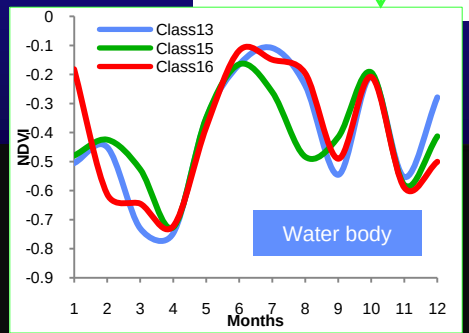



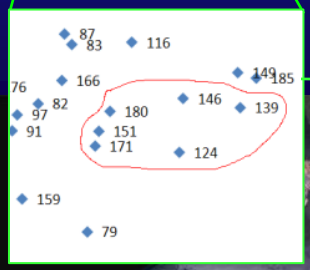



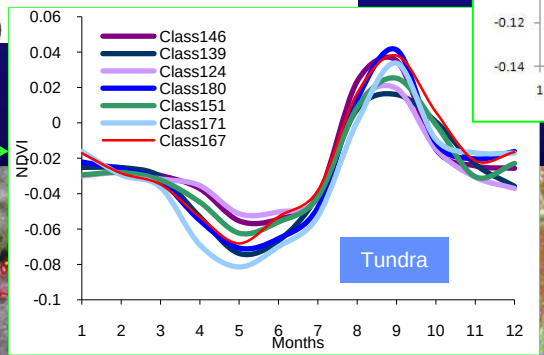



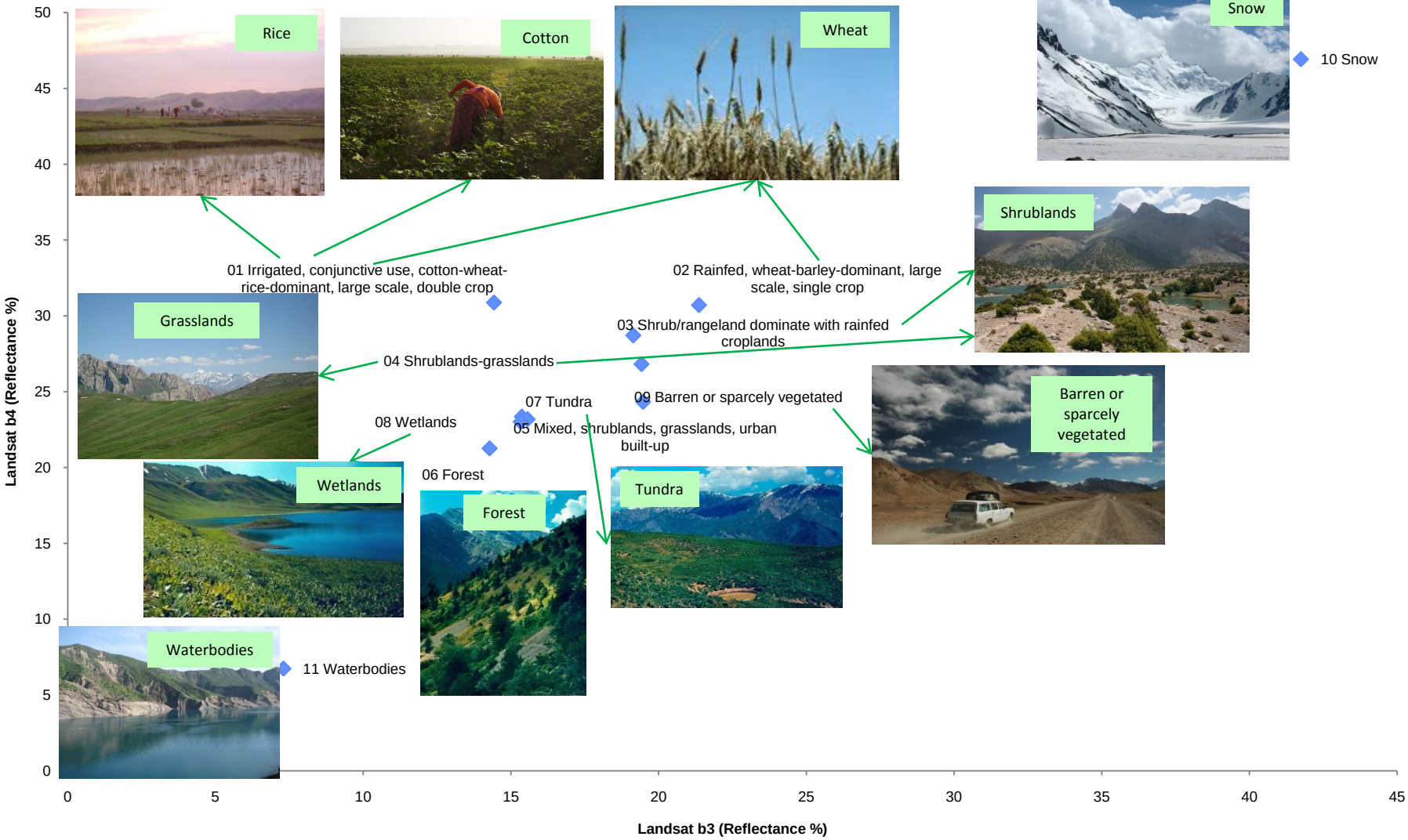




# A Knowledge-based Data Layer Derived by Classifying the MFDC

## Identifying and Labeling the 199 Information Classes: Final 11 Classes with typical "groundtruth" view





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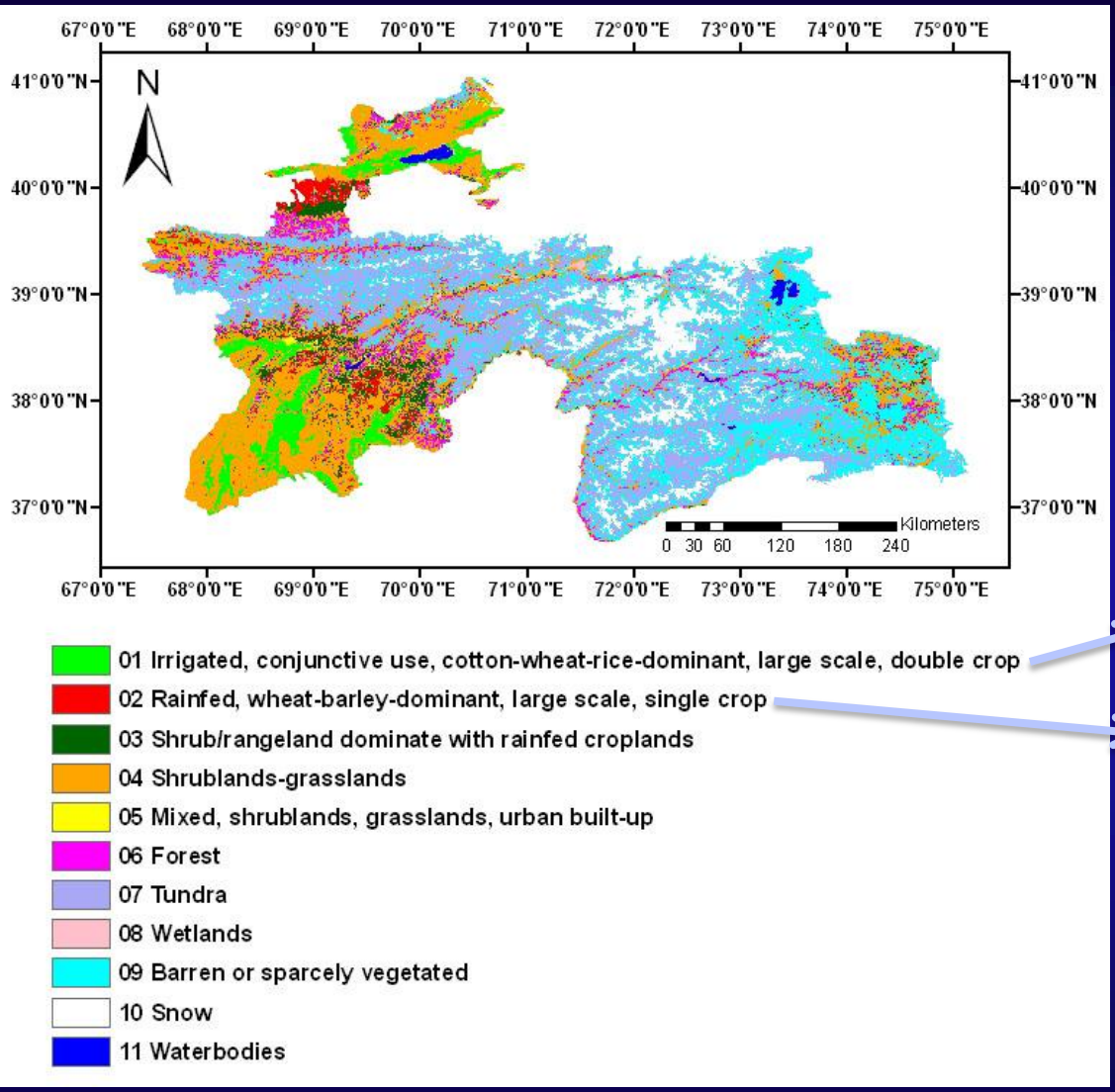
# A Knowledge-based Data Layer Derived by Classifying the MFDC
## Final 11 unique knowledge-based classes of Tajikistan




**1 irrigated class**

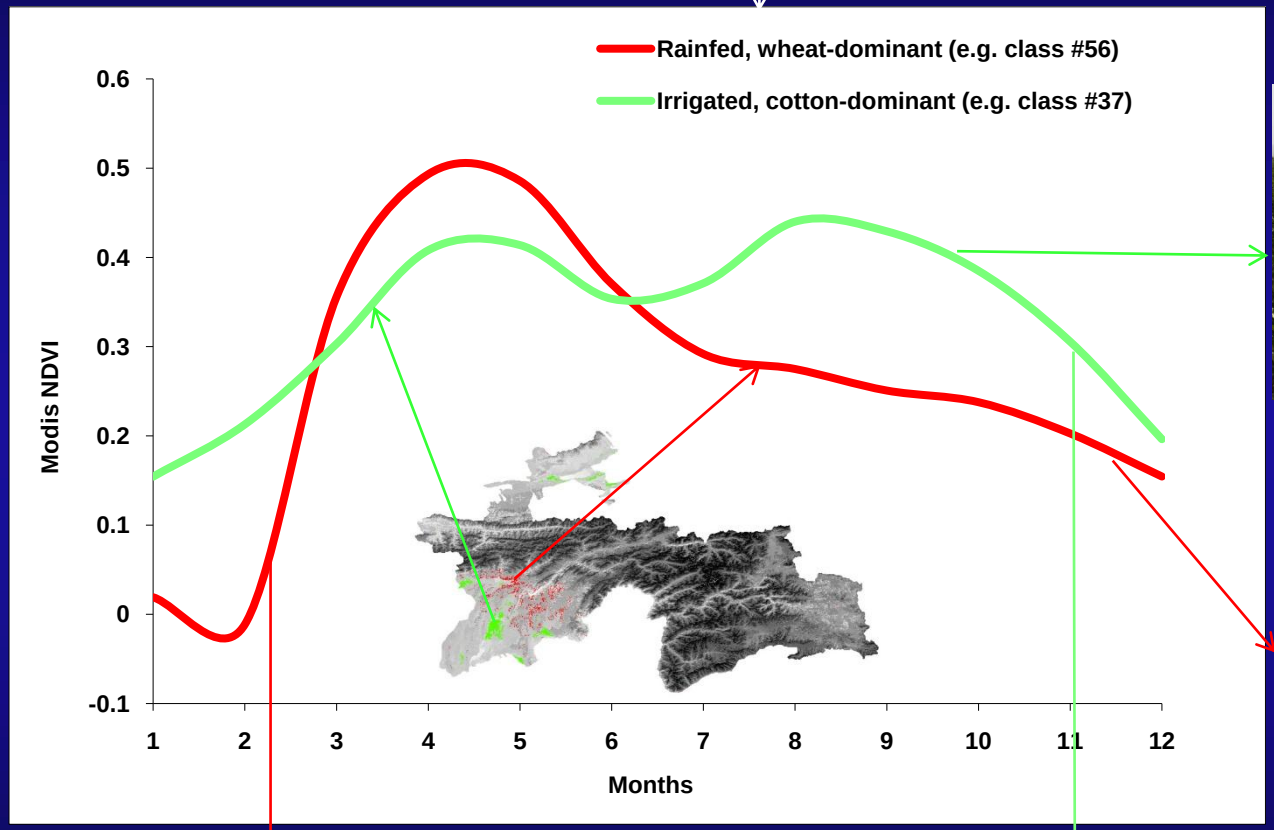
**1 rainfed class.**

**Note: there is also highly fragmented rainfed class mixed with other LCLUC.**

# A Knowledge-based Data Layer Derived by Classifying the MFDC

## Identifying and Labeling 199 Information Classes: "Groundtruth" Data used in Conjunction with MODIS NDVI Time-series

**Cropping intensities**

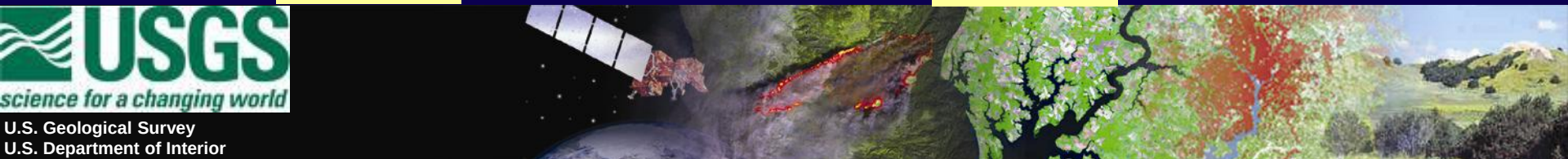



Irrigated, double crop, cotton

Rainfed, single crop, wheat dominant

**Single crop**

**Double crop**



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# Generating
# Algorithm Derived Cropland Layer
## using same (2005) Landsat and MODIS Datasets
## as Knowledge Layer

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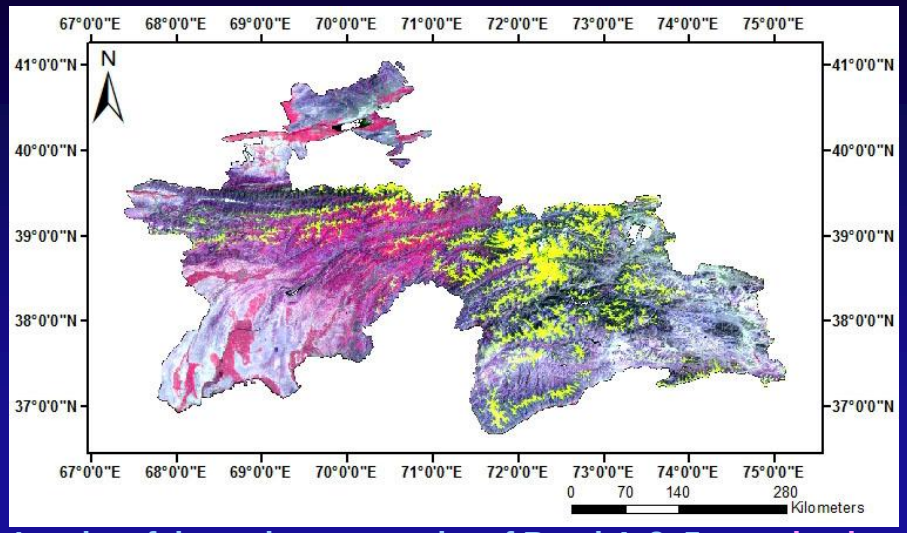
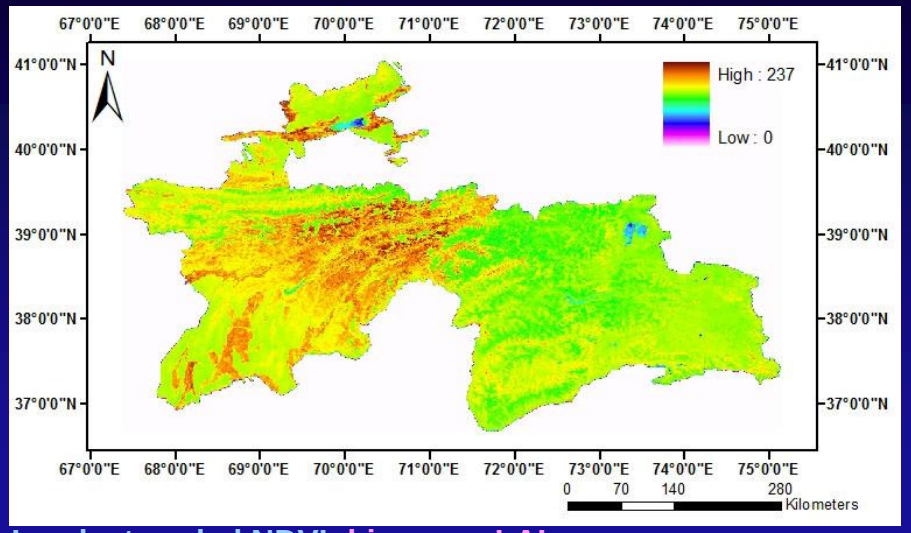
U.S. Geological Survey

**An Automated Cropland Mapping Algorithm** Applied to Same Dataset used to Derive Knowledge Layer

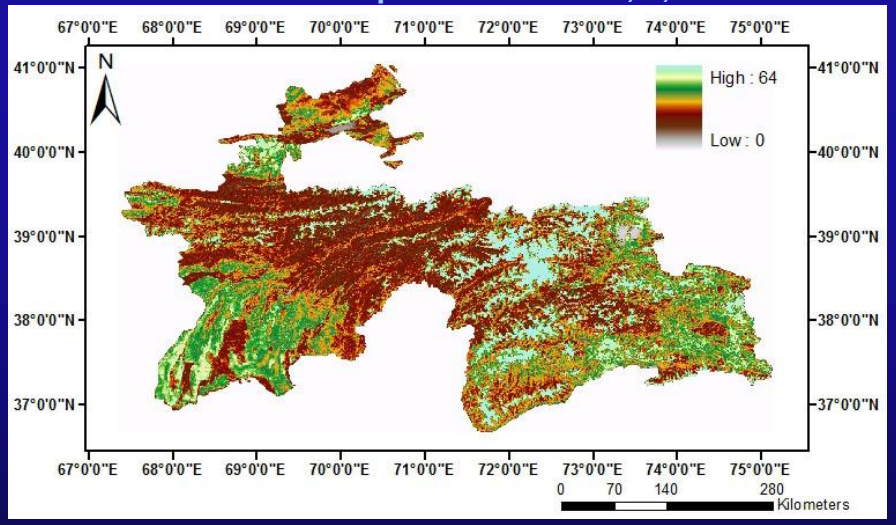
# Datasets used: Landsat 2005



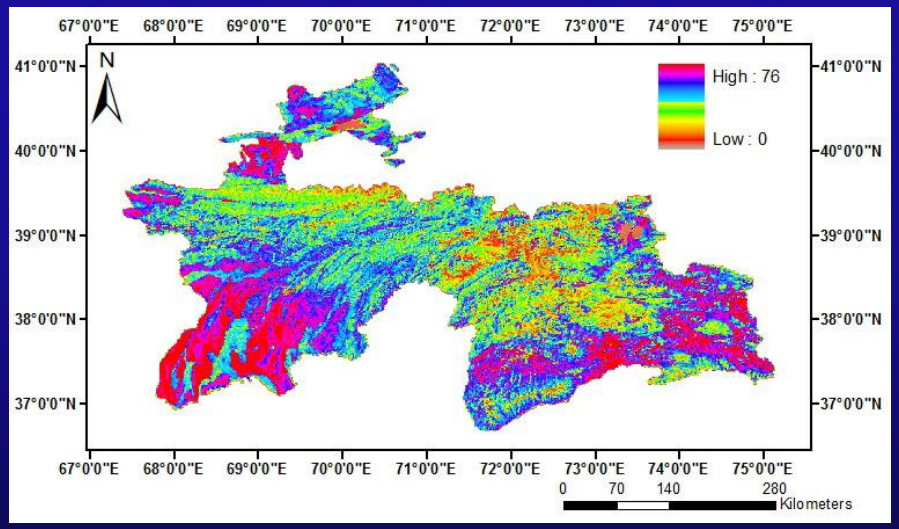

Landsat false color composite of Band 4, 3, 5: terrain view




Landsat scaled NDVI: biomass, LAI




Landsat band 3 reflectance (%): chlorophyll absorption




Landsat band 5 reflectance (%): moisture sensitivity

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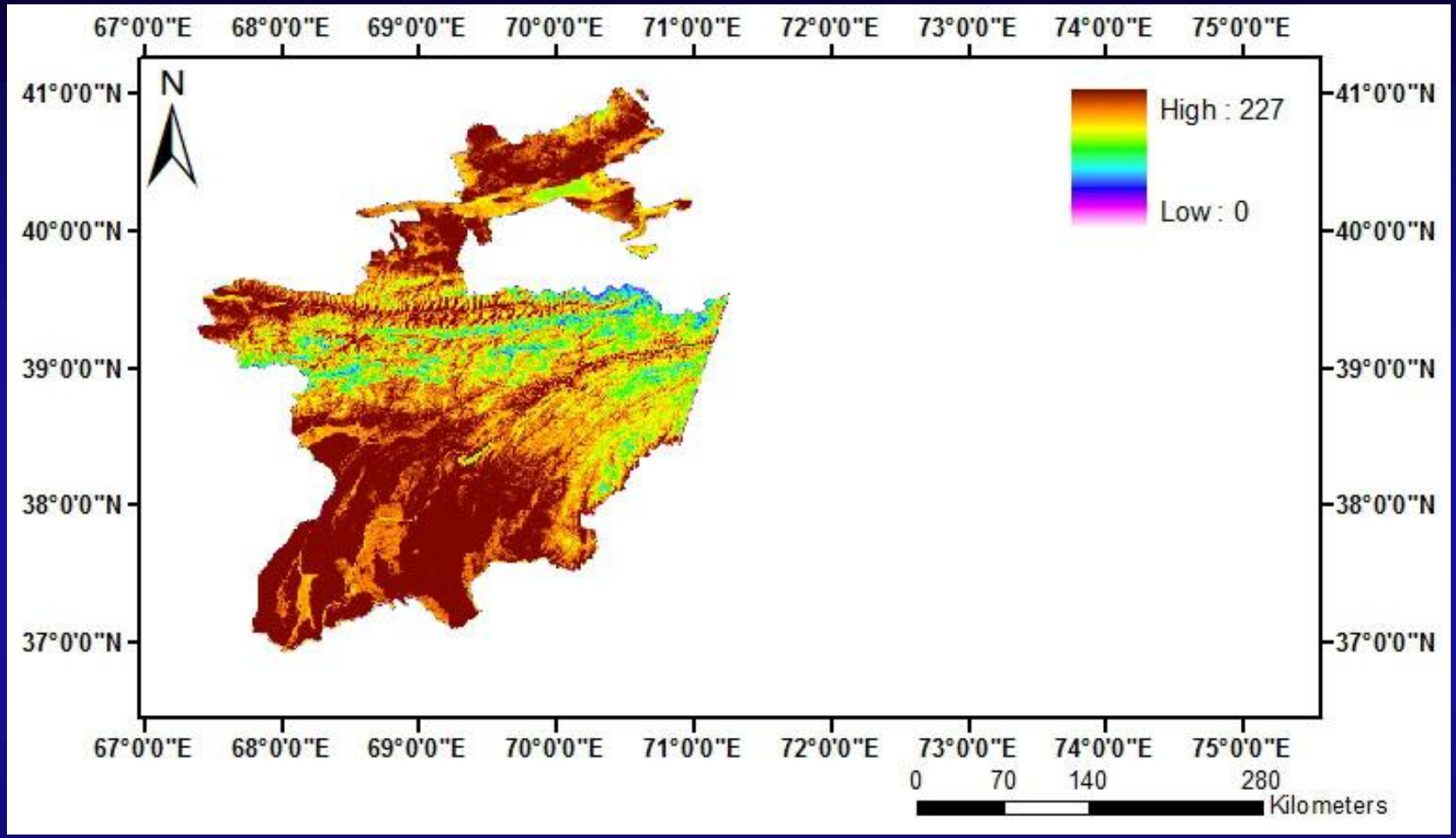
# Datasets used: Landsat Thermal Data

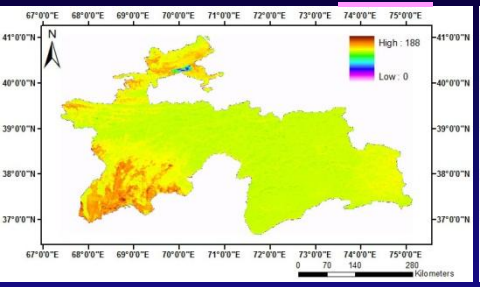



Landsat thermal emissivity

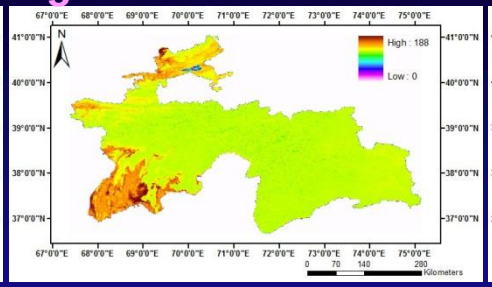
# An Automated Cropland Mapping Algorithm Applied to Same Dataset used to Derive Knowledge Layer

## Datasets used: MODIS NDVI monthly MVC.

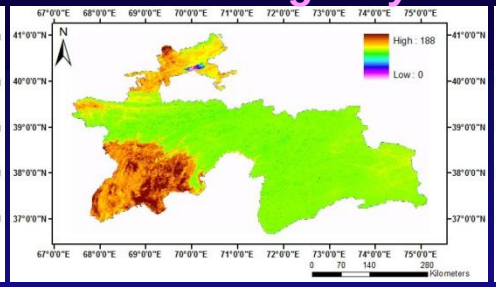
### Note: irrigated areas most discernable during July-November



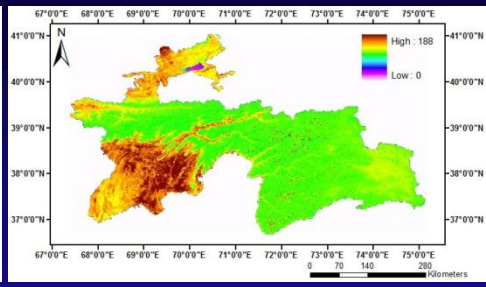

Jan



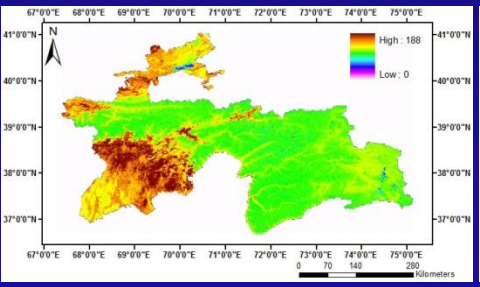

Feb



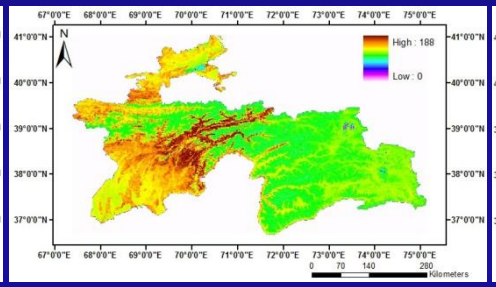

Mar



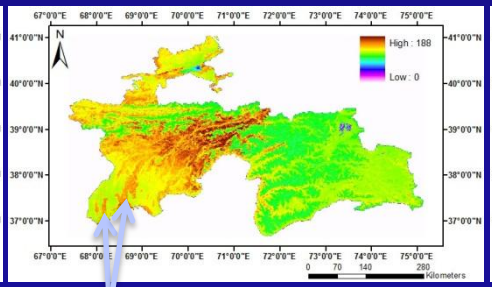

Apr




May

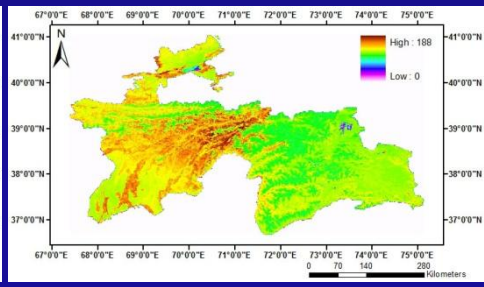



Jun

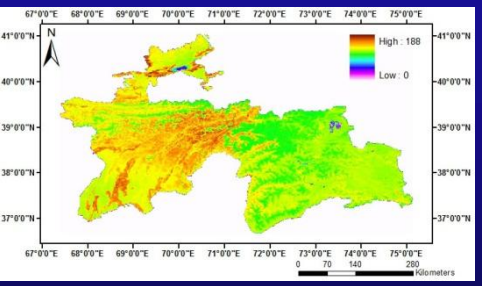



Irrigated areas begin to be distinct

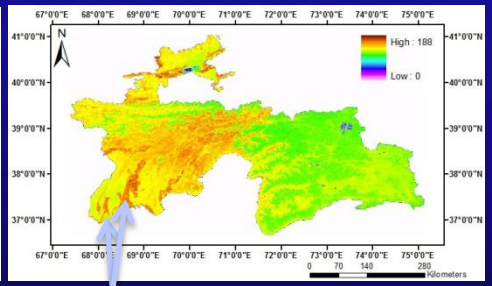
Jul




Aug

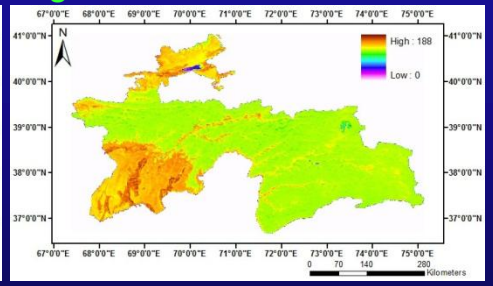



Sep

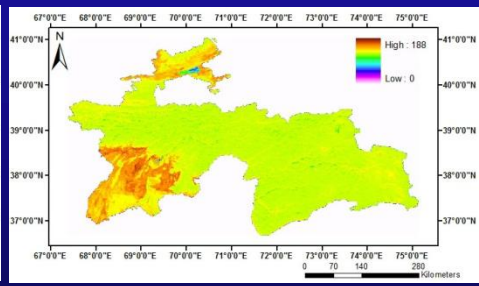



Irrigated areas become very distinct

Oct




Nov




Dec

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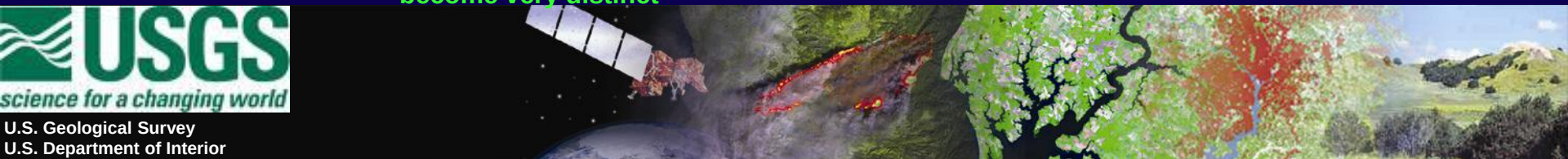
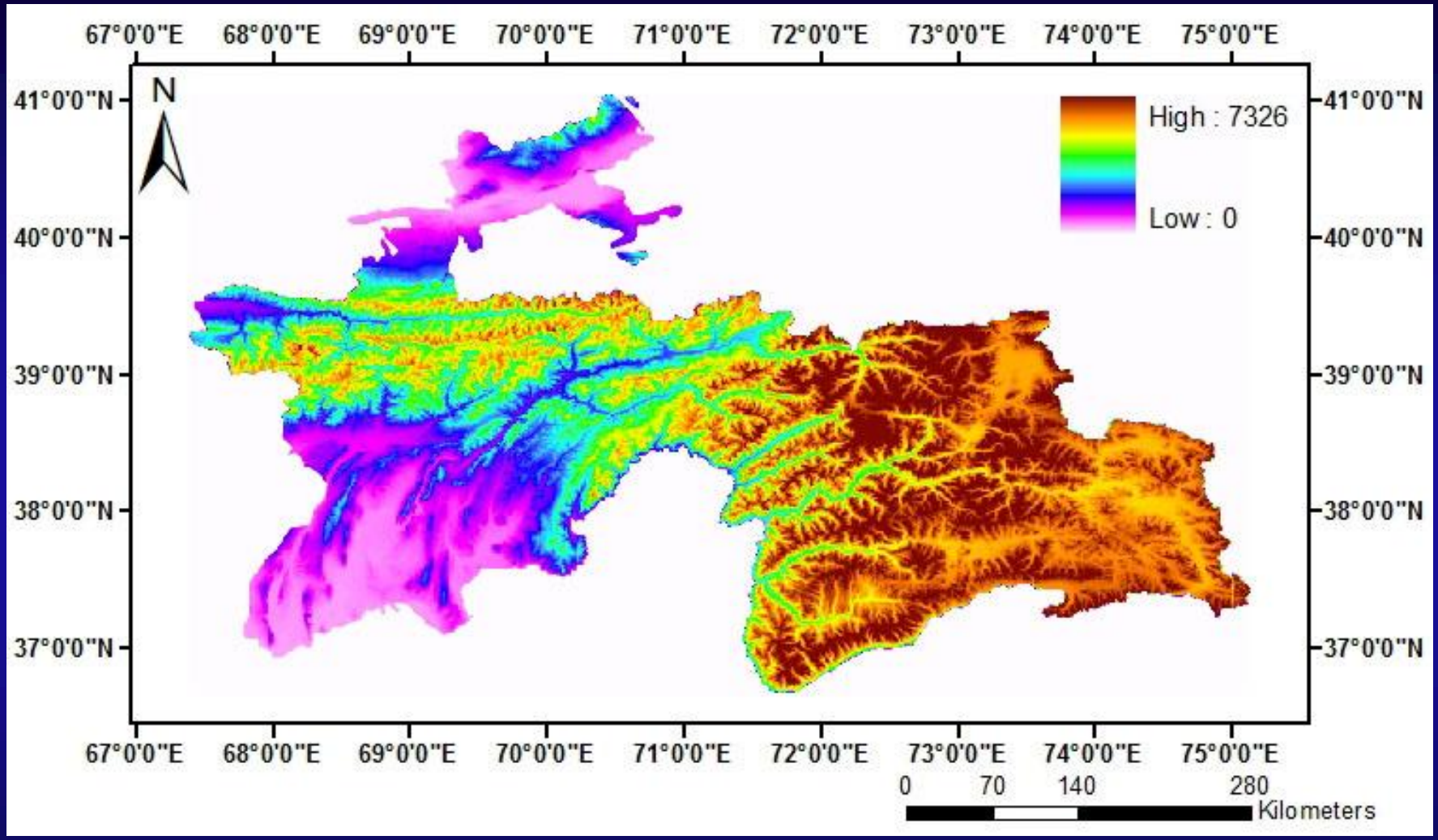


An Automated Cropland Mapping Algorithm Applied to Same Dataset used to Derive Knowledge Layer

# Datasets used: SRTM 90 m Elevation




Note: most irrigated areas in elevation < 550 m

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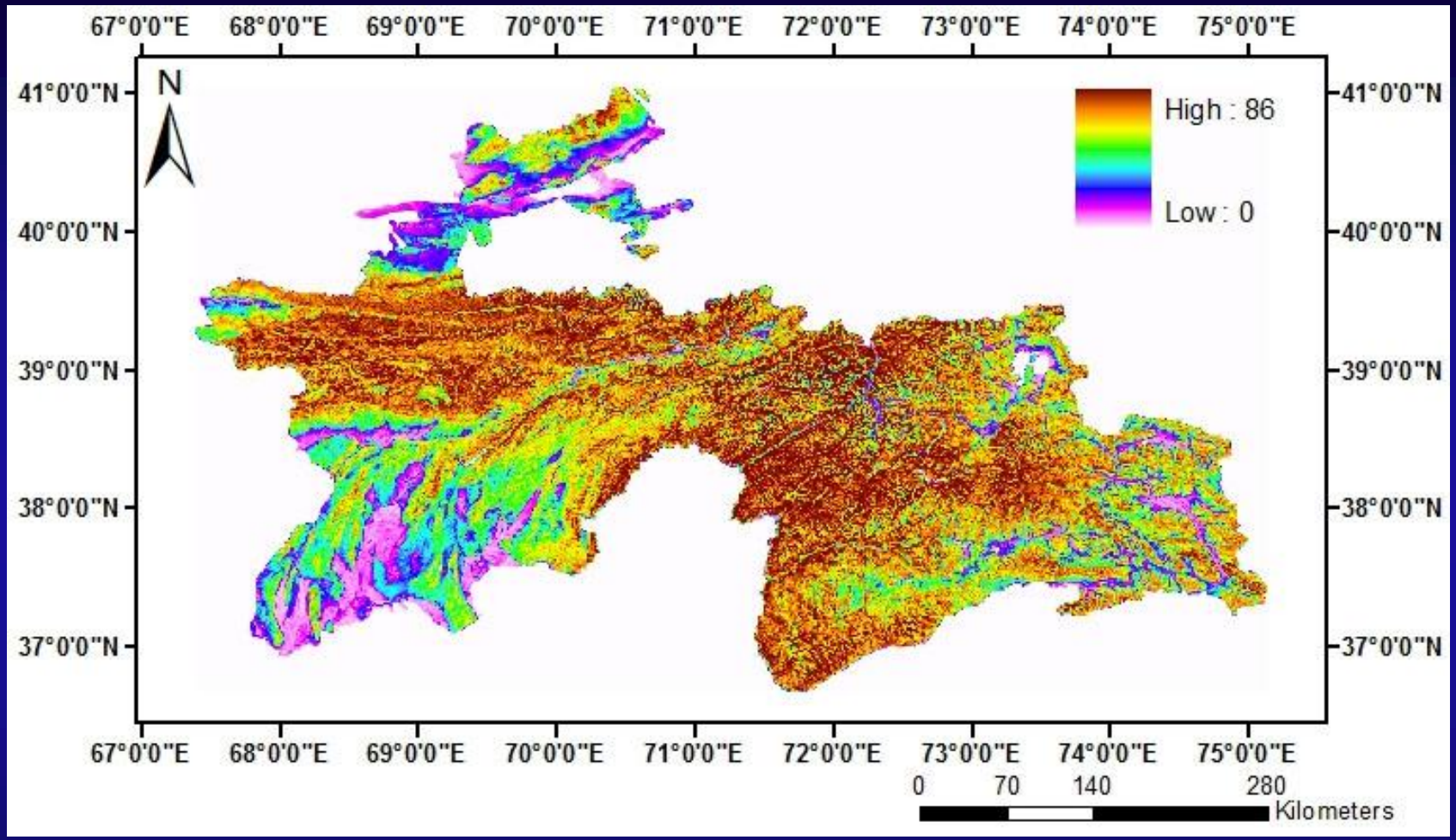
An Automated Cropland Mapping Algorithm Applied to Same Dataset used to Derive Knowledge Layer

# Datasets used: SRTM derived Slopes




**Note: most irrigated areas in slopes < 3%**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# Algorithm for Irrigated Areas using Data for the Years Same (2005)as Knowledge Layer

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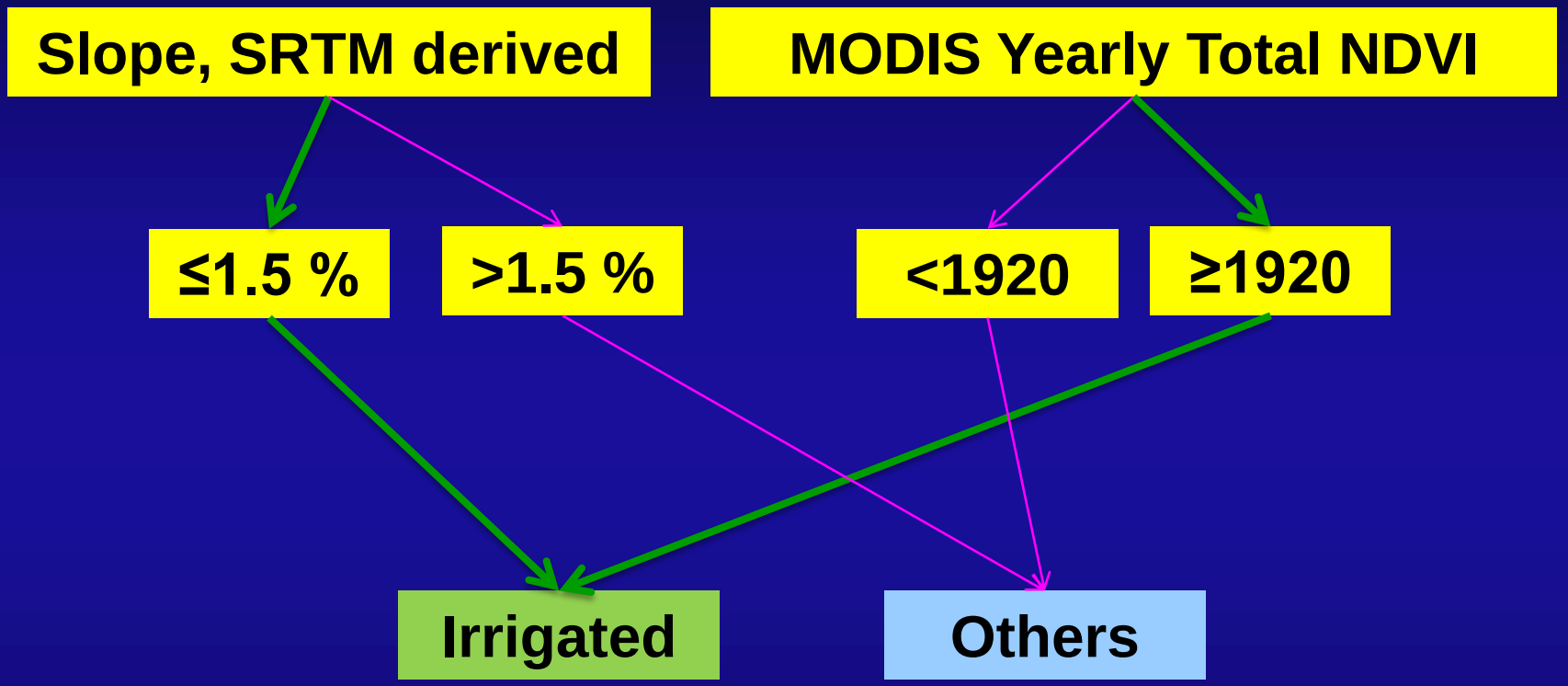
U.S. Geological Survey

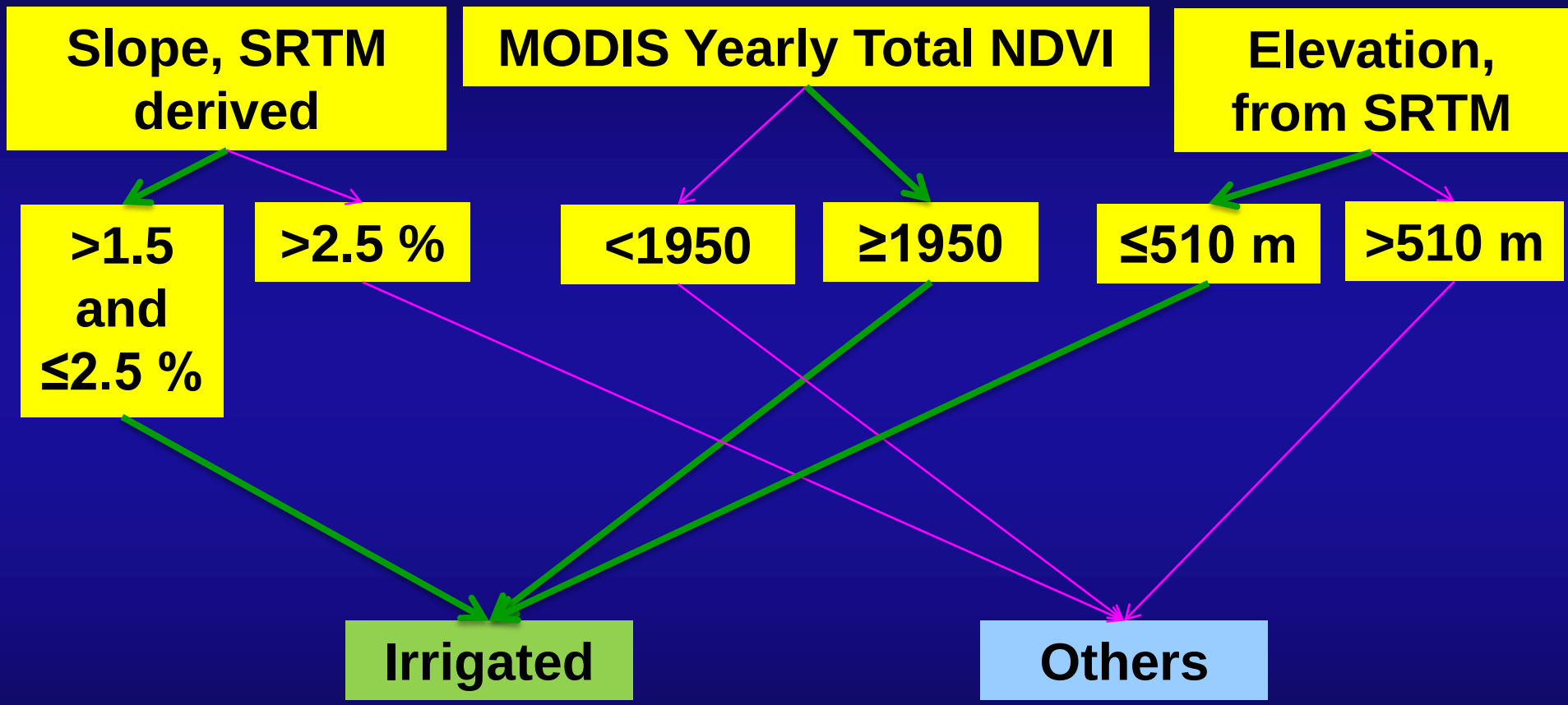
# Automated Mapping of Irrigated Areas of Tajikistan

## Algorithm 1a



# Automated Mapping of Irrigated Areas of Tajikistan

## Algorithm 1b

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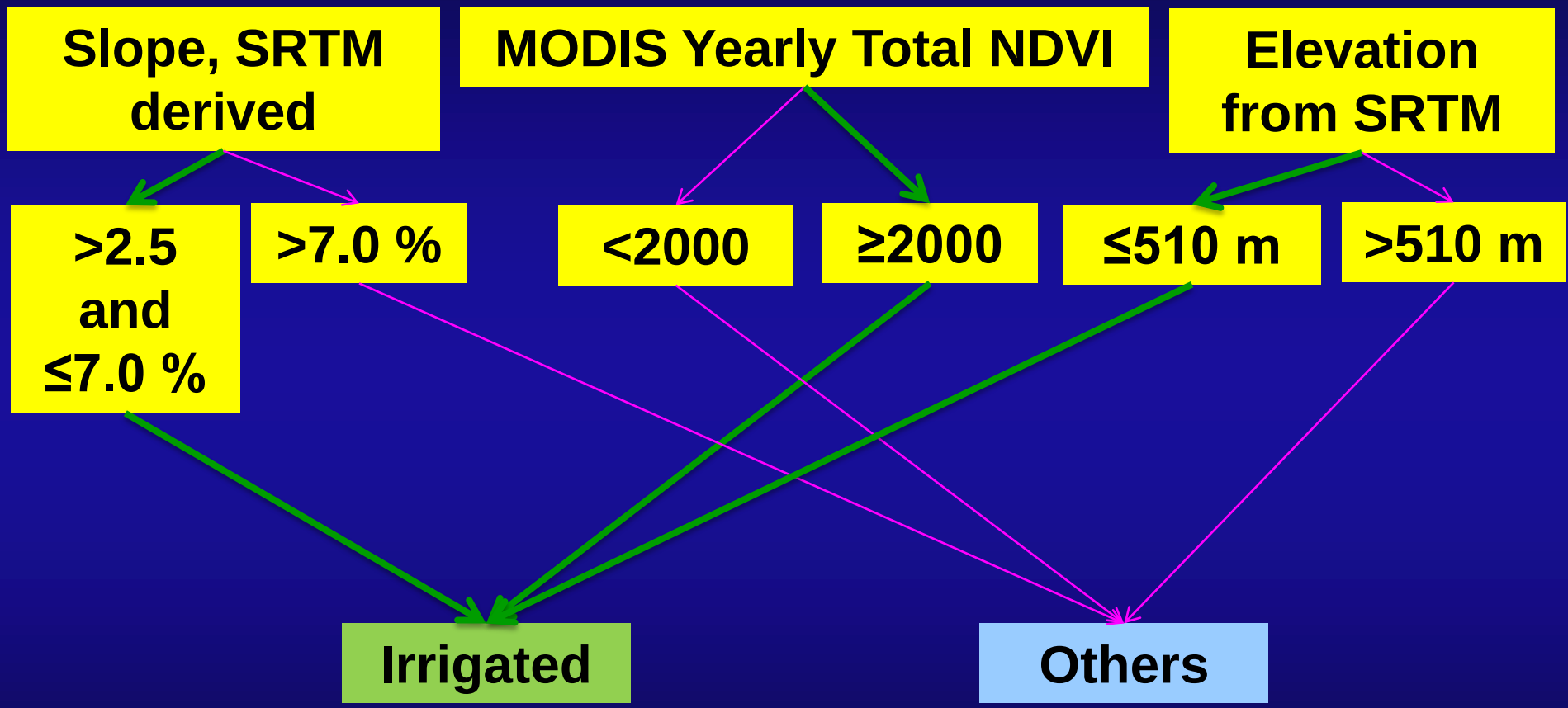
# Automated Mapping of Irrigated Areas of Tajikistan

## Algorithm 1c

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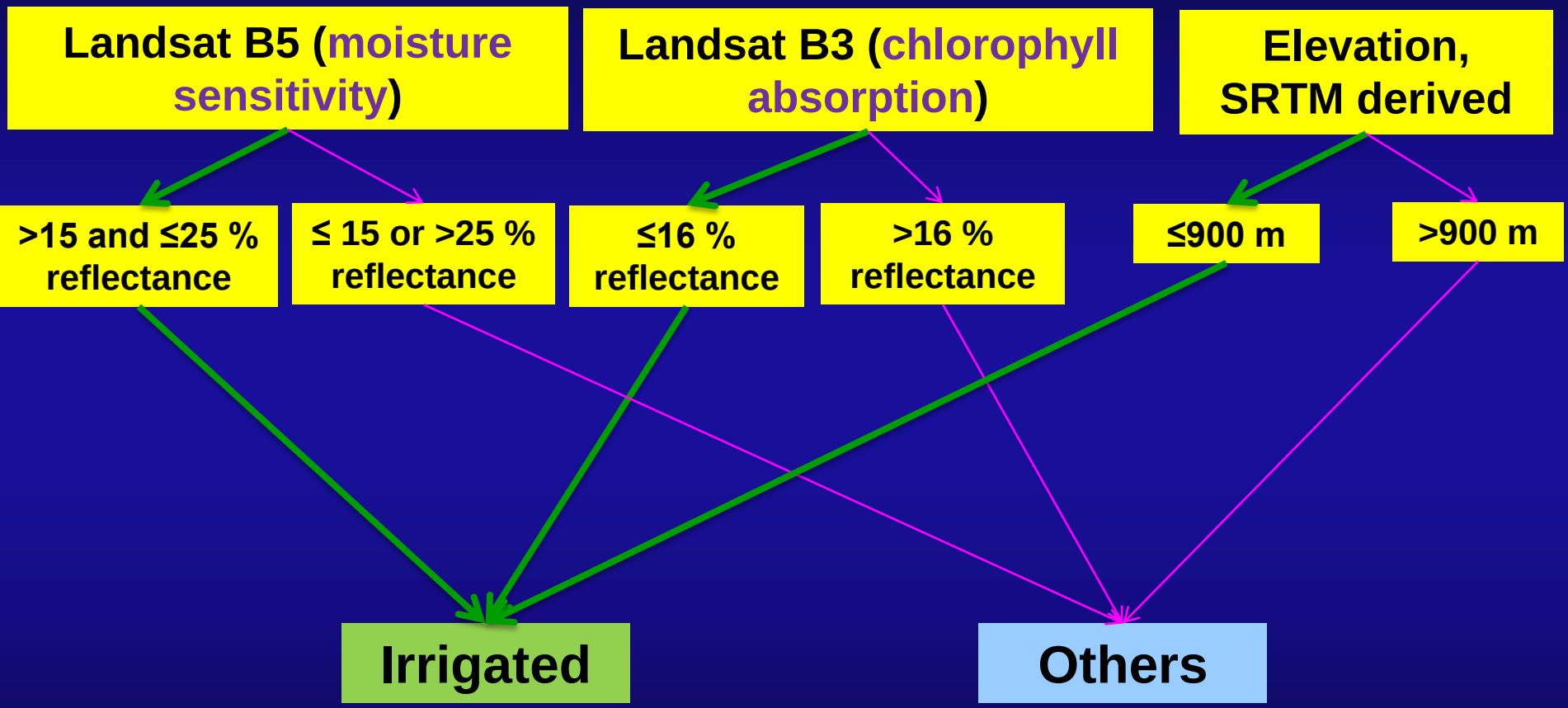
# Automated Mapping of Irrigated Areas of Tajikistan

## Algorithm 2a





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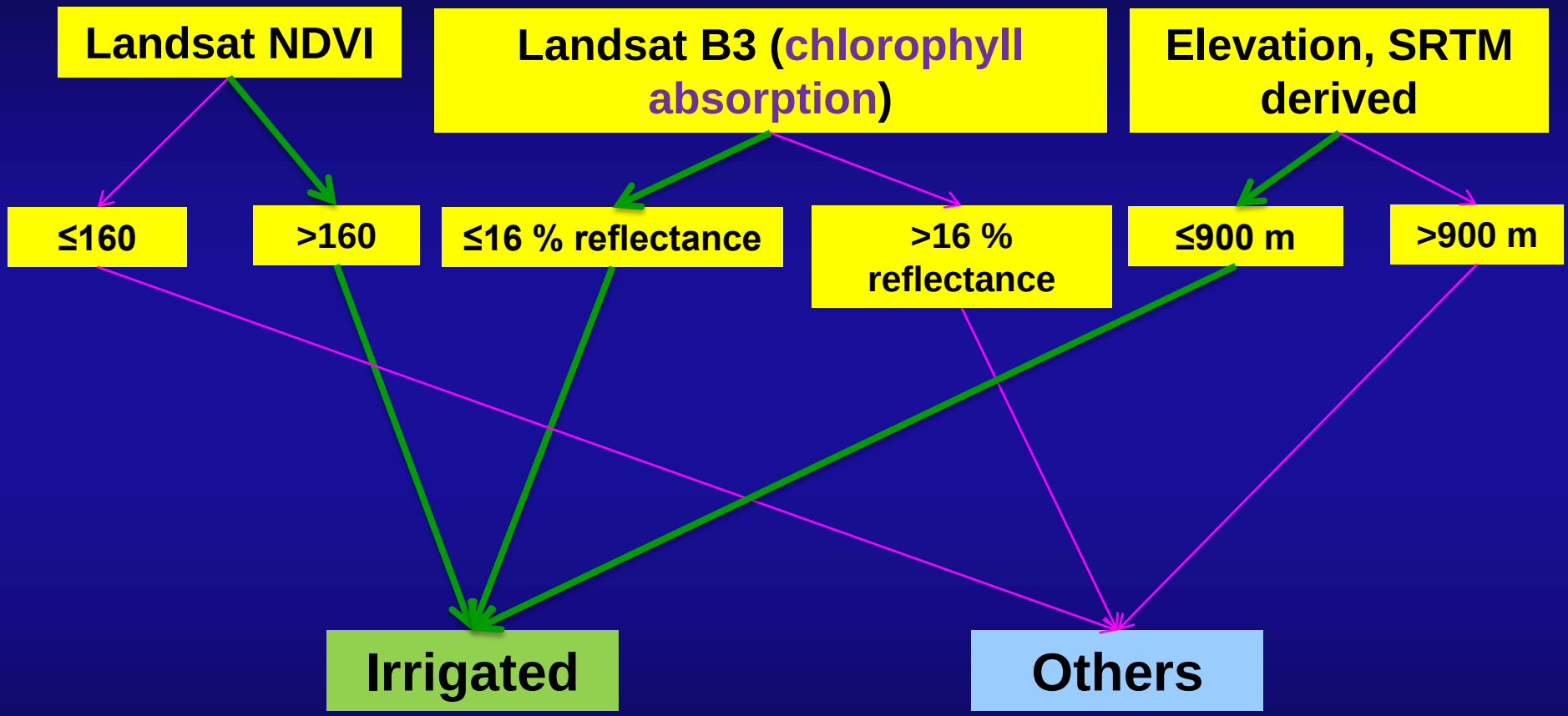
# Automated Mapping of Irrigated Areas of Tajikistan

## Algorithm 2b

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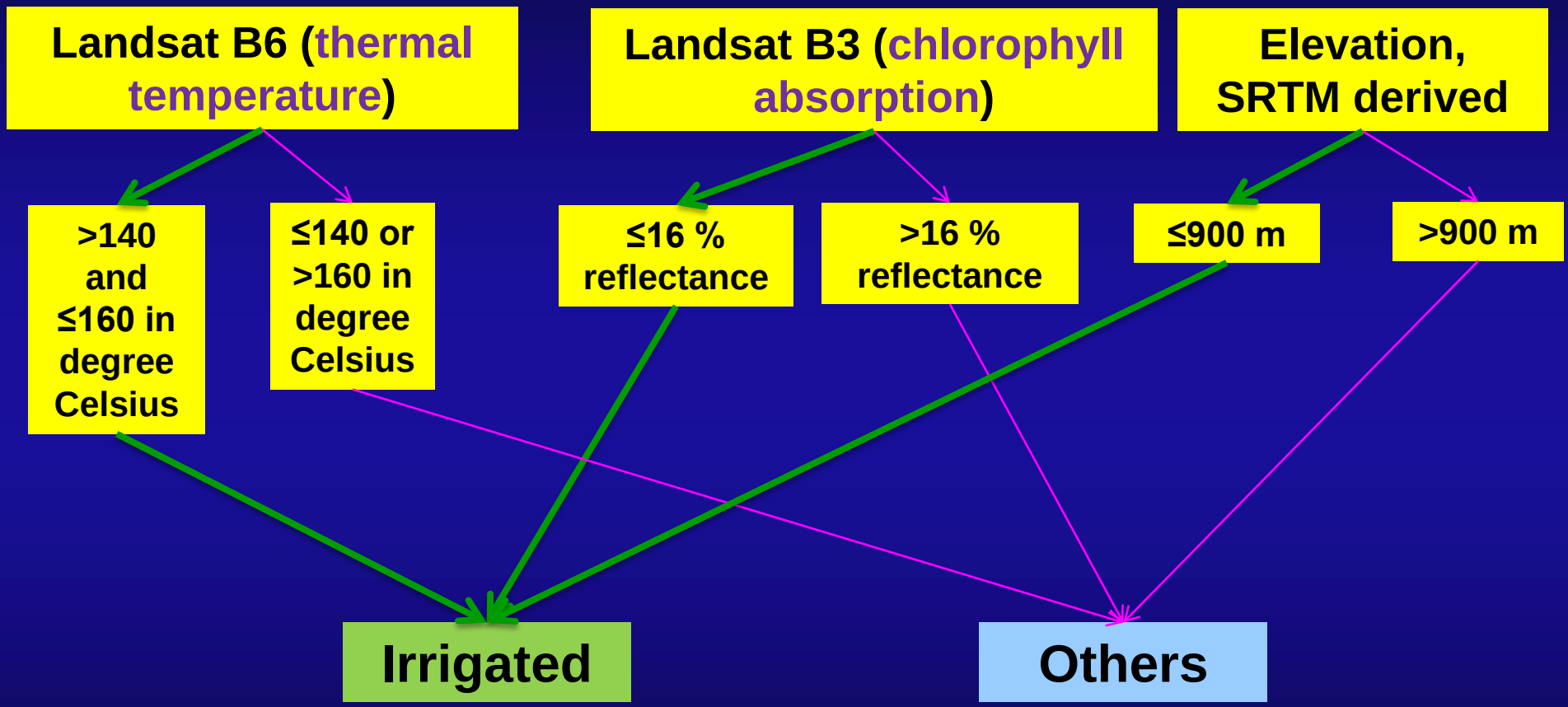
# Automated Mapping of Irrigated Areas of Tajikistan

## Algorithm 2c





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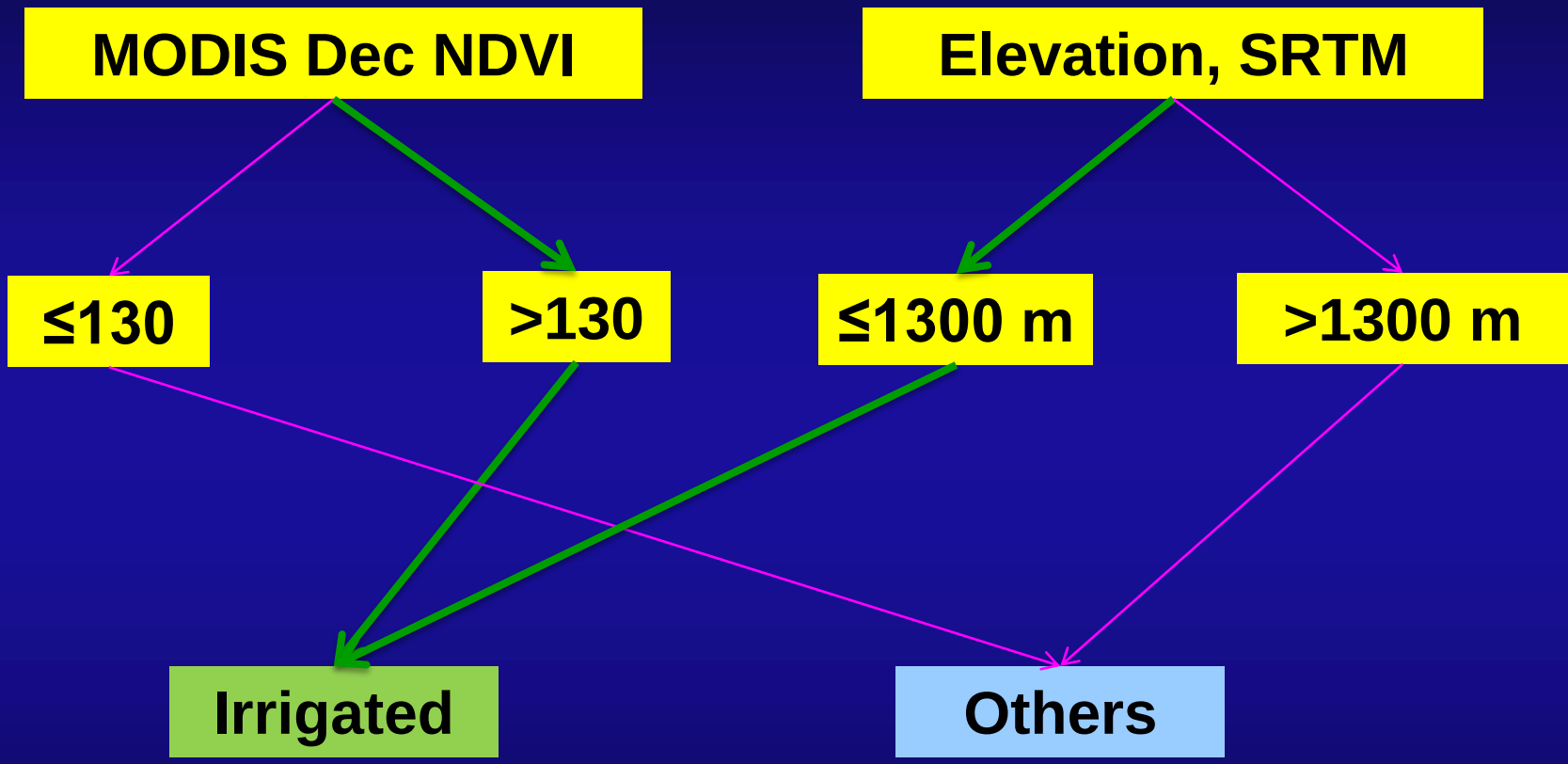
# Automated Mapping of Irrigated Areas of Tajikistan

## Algorithm 3

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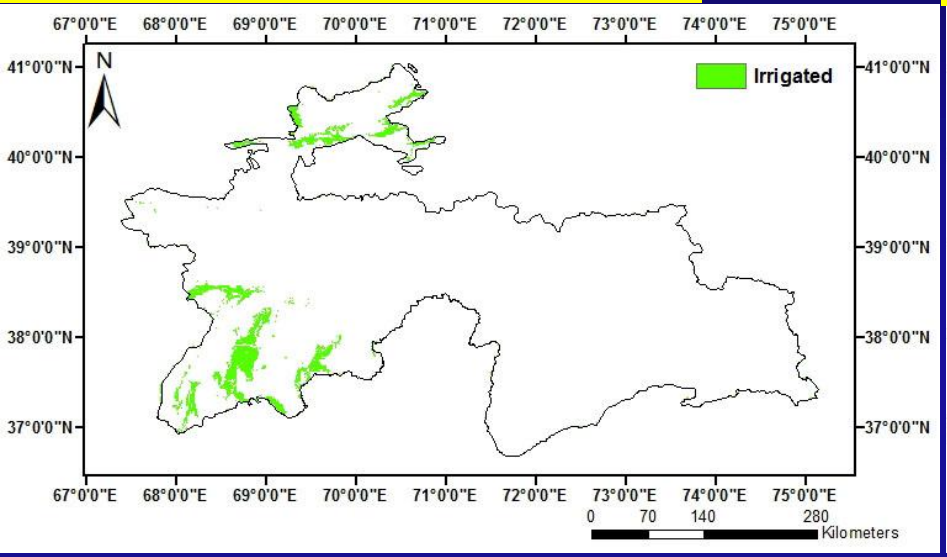
# Irrigated Areas of Tajikistan for year 2005: Whole Country View

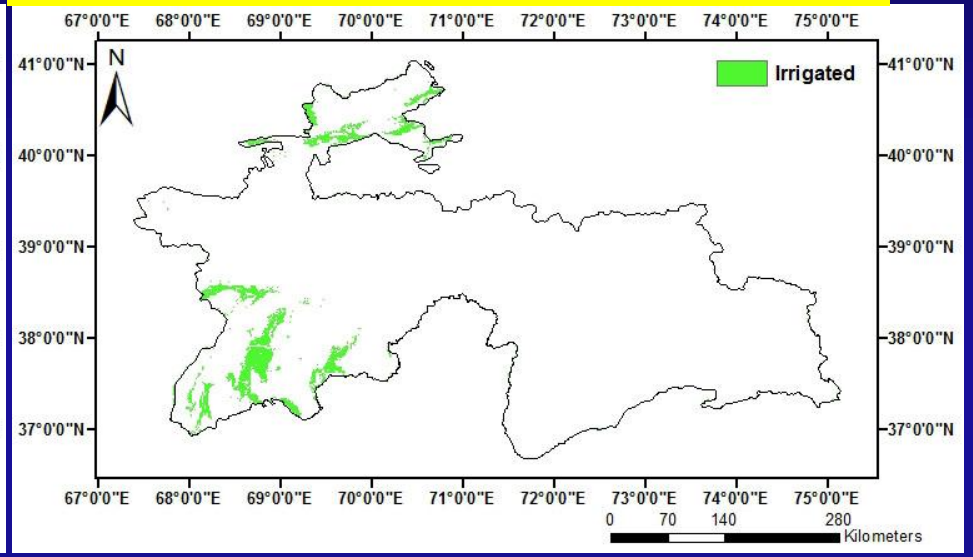
## Comparison: Knowledge Layer vs. Algorithm Derived Layer

**Knowledge Layer (truth) for year 2005**



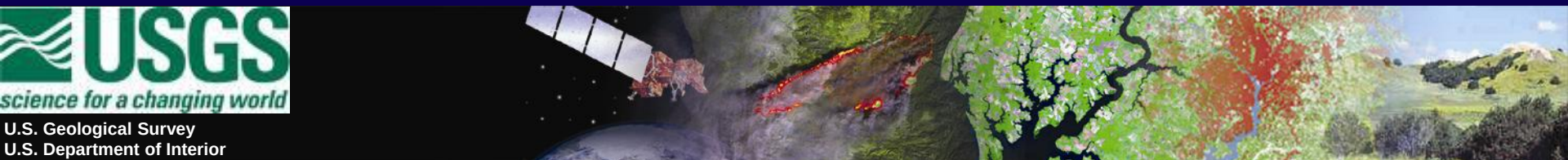

30 m spatial resolution

**Algorithm derived layer also for year 2005**

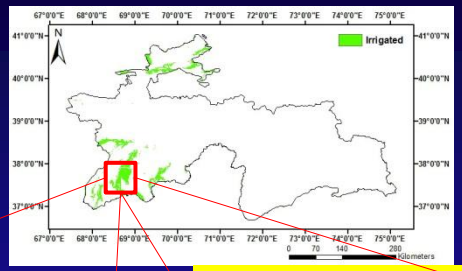



30 m spatial resolution

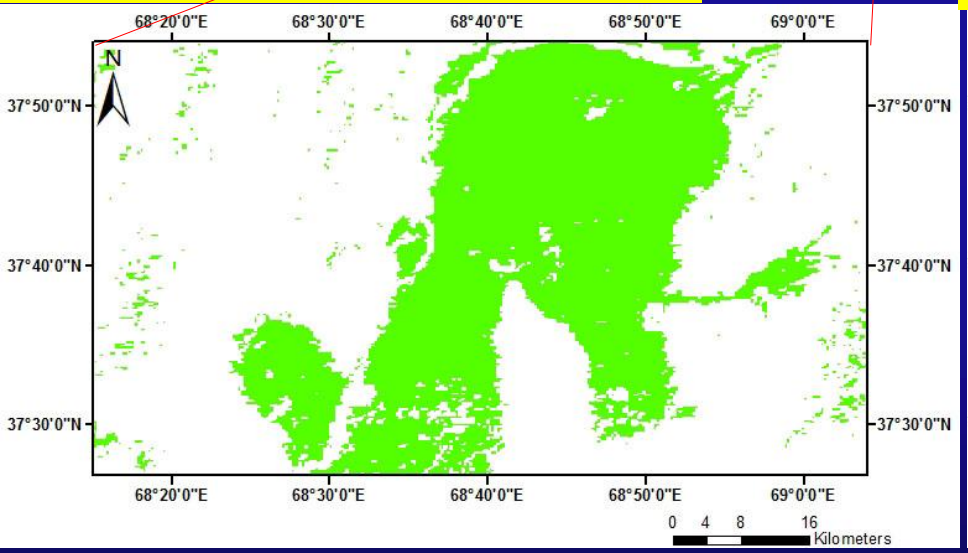
**Note: Once you have the algorithm, it takes only a few minutes to derive irrigated areas.**



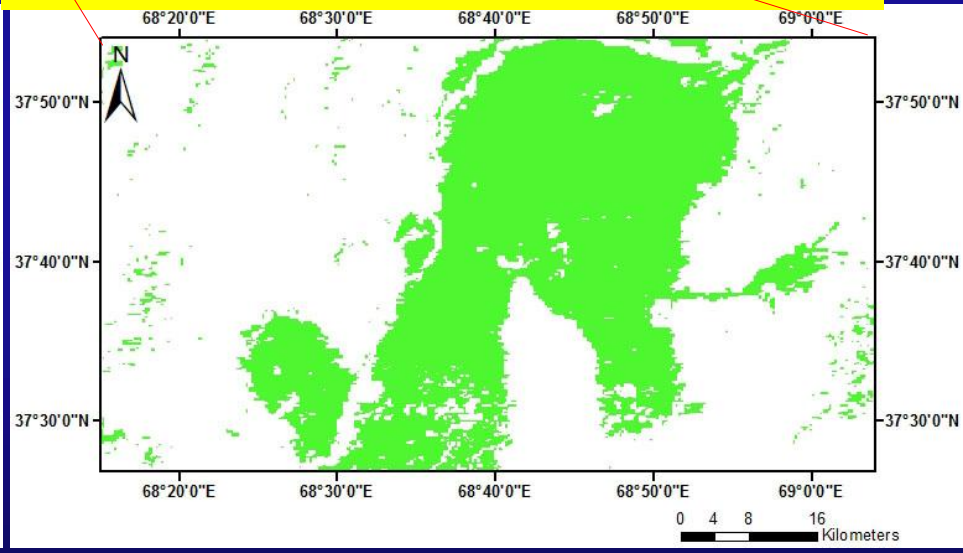
# Irrigated Areas of Tajikistan for year 2005: Zoom in View
## Comparison: Knowledge Layer vs. Algorithm Derived Layer




**Knowledge Layer (truth) for year 2005**




**Algorithm derived layer also for year 2005**




**Note: Once you have the algorithm, it takes only a few minutes to derive irrigated areas.**

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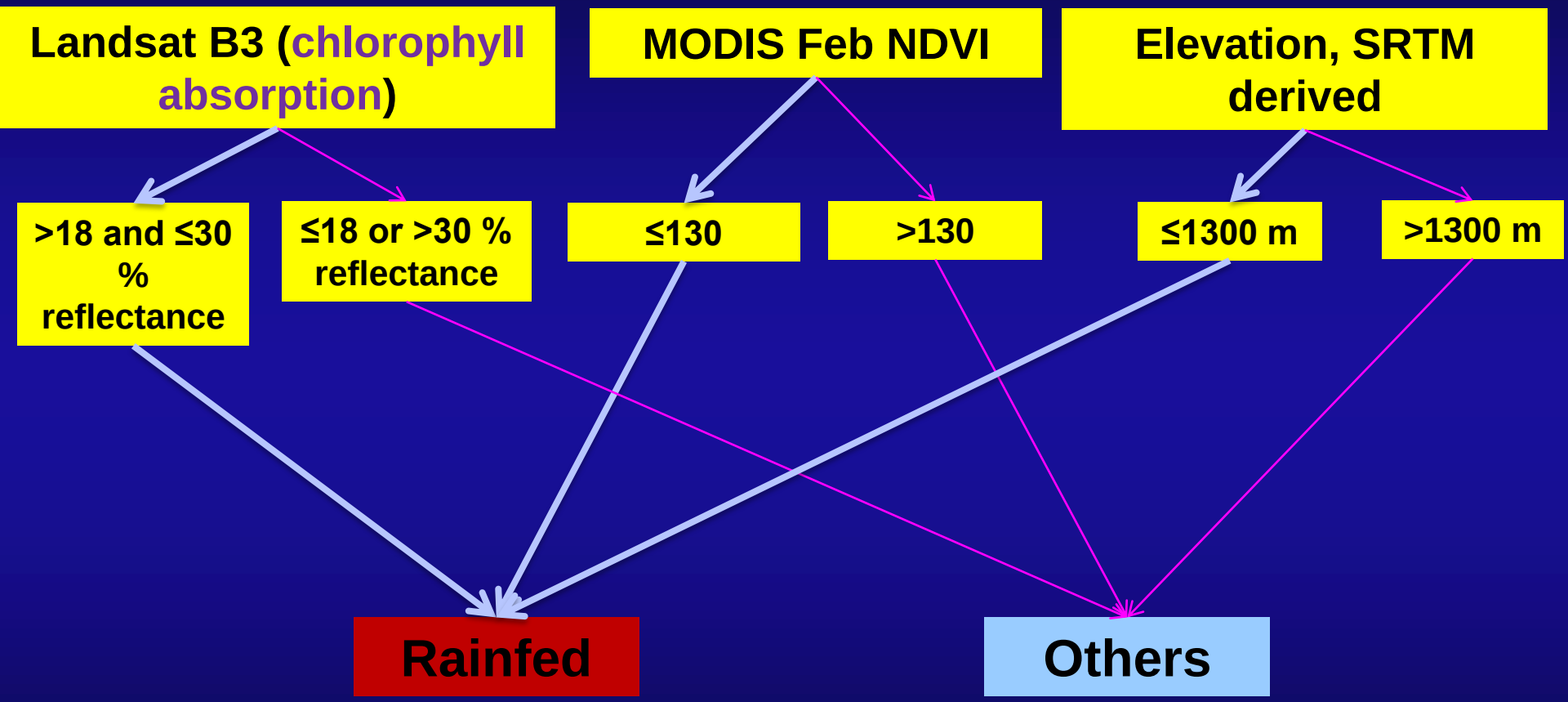
# Algorithm for rainfed Areas using Data for the Years Same (2005)as Knowledge Layer

U.S. Department of the Interior
U.S. Geological Survey

# Automated Mapping of Rainfed Areas of Tajikistan

## Algorithm 4a





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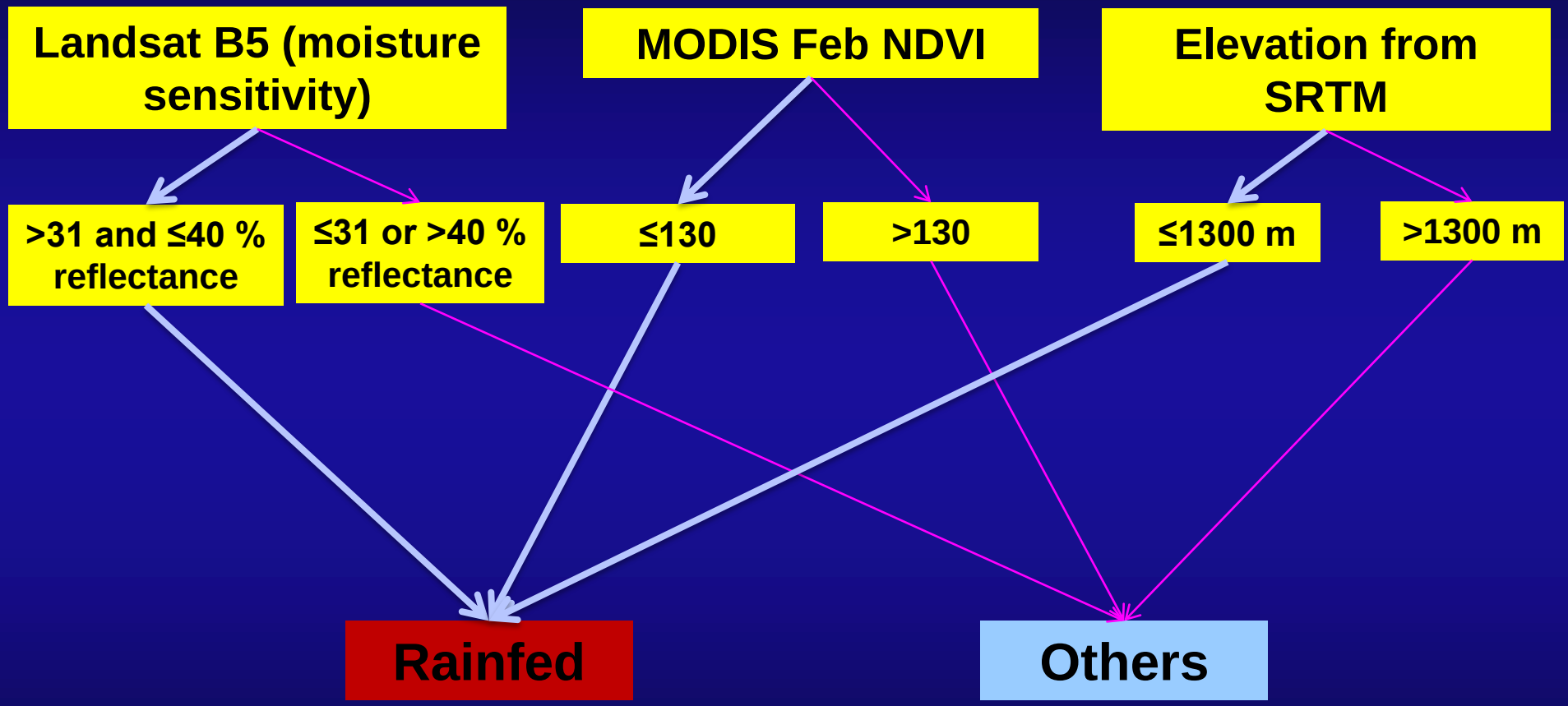
# Automated Mapping of Rainfed Areas of Tajikistan

## Algorithm 4b





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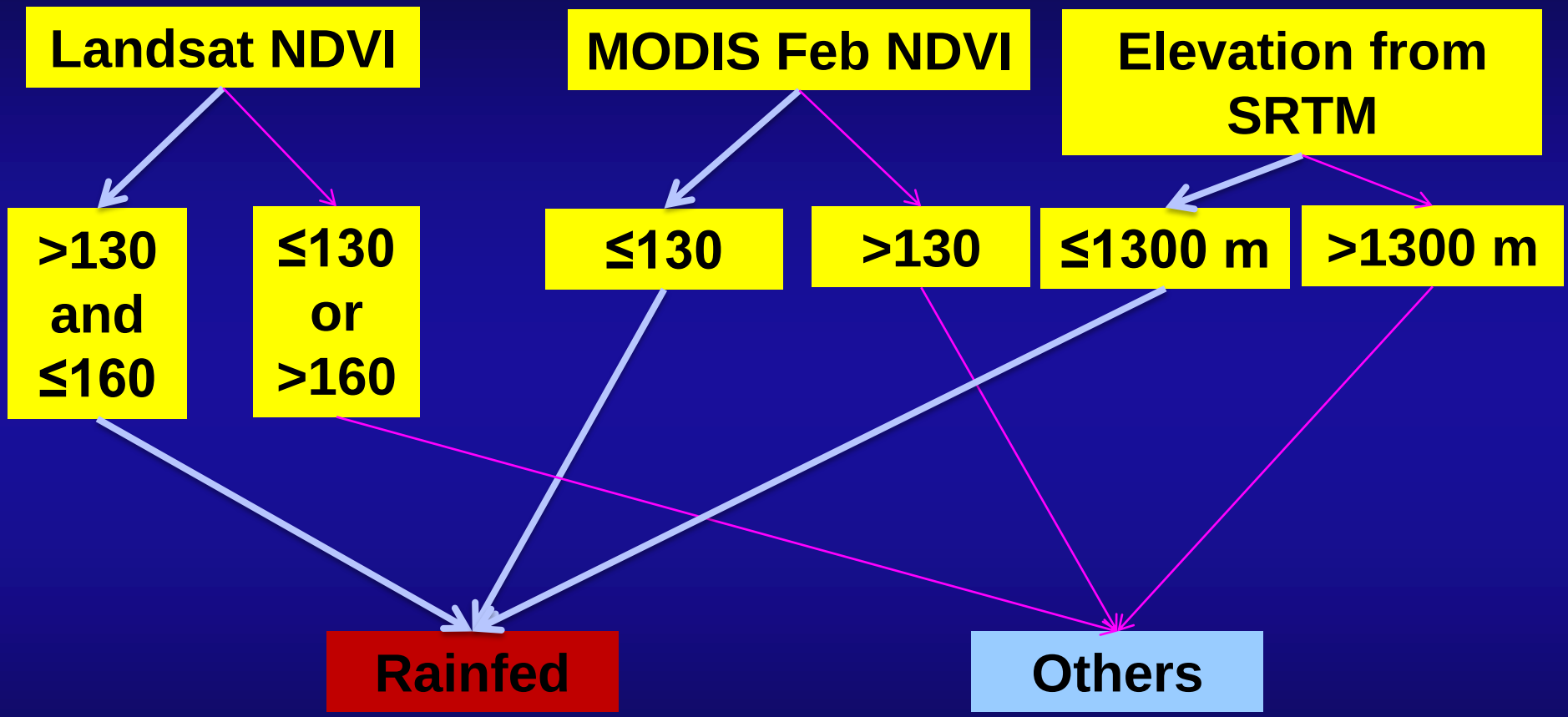
# Automated Mapping of Rainfed Areas of Tajikistan

## Algorithm 4c

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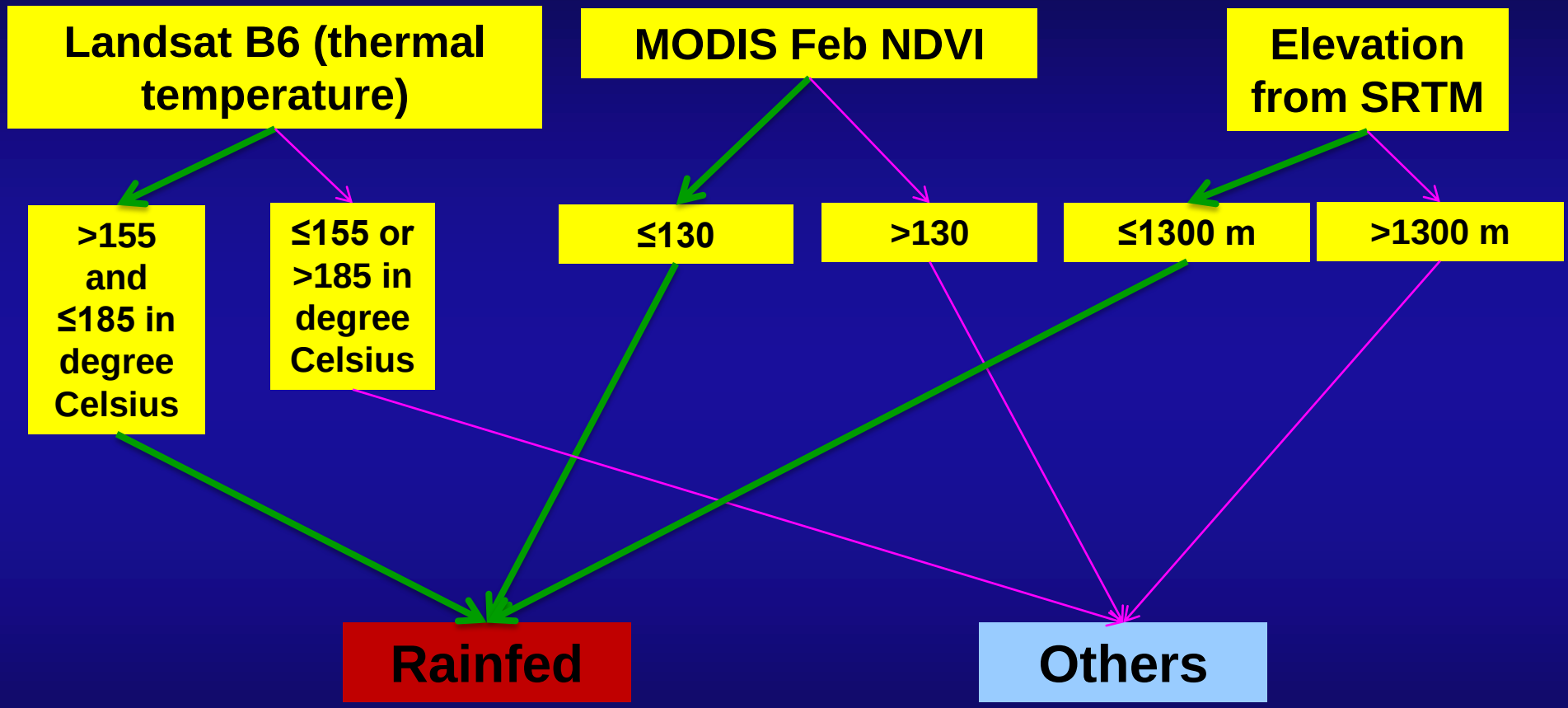
# Automated Mapping of Rainfed Areas of Tajikistan

## Algorithm 4d

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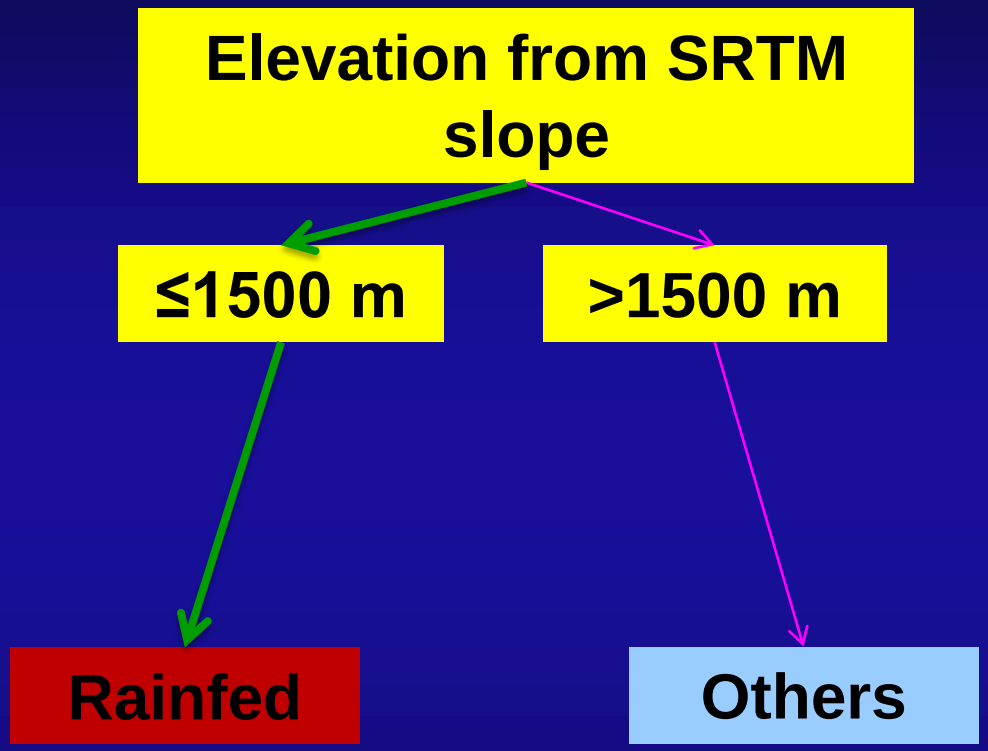
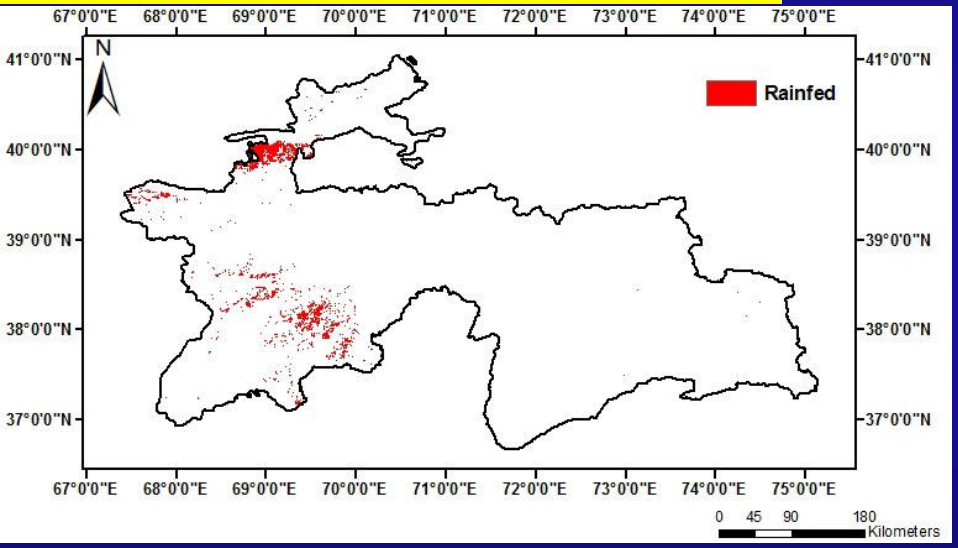
# Automated Mapping of Rainfed Areas of Tajikistan

## Algorithm 4e



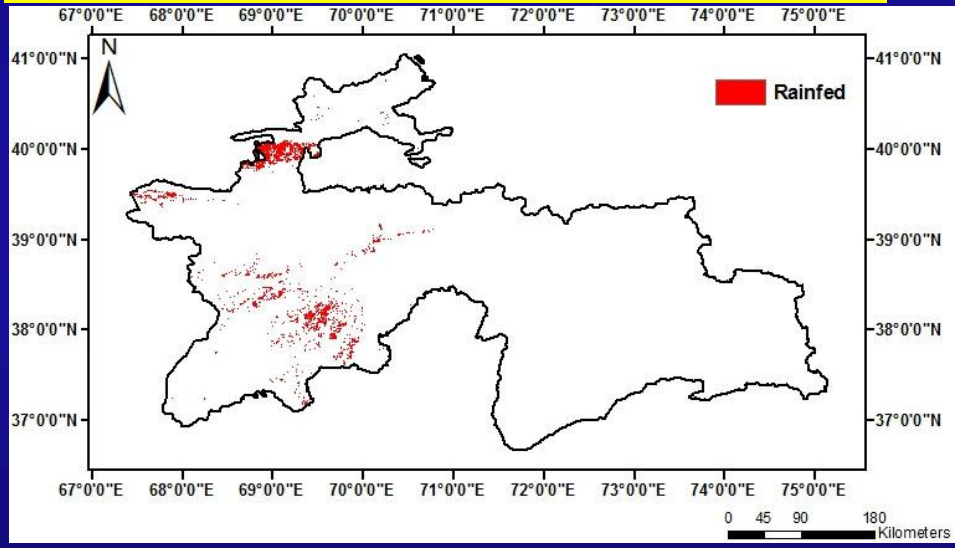
# Rainfed Areas of Tajikistan for year 2005: Full Country View
# Comparison: Knowledge Layer vs. Algorithm Derived Layer

**Knowledge Layer (truth) for year 2005**




**30 m spatial resolution**

**Algorithm derived layer also for year 2005**




**30 m spatial resolution**

**Note: Once you have the algorithm, it takes only a few minutes to derive rainfed areas.**

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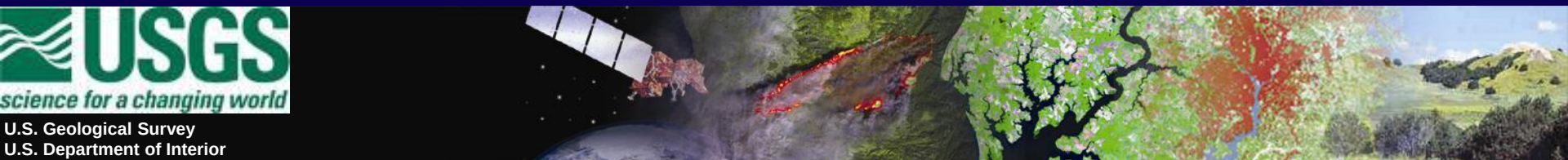
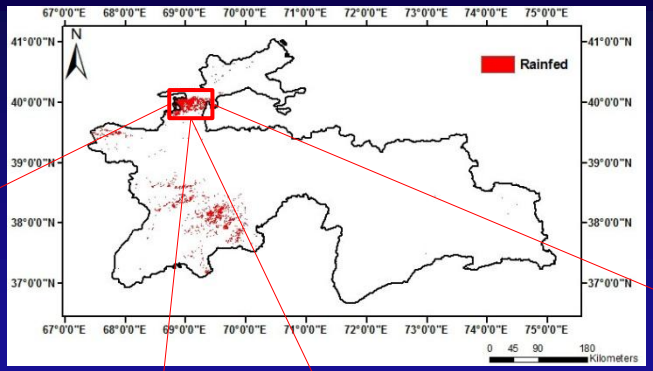
U.S. Department of Interior

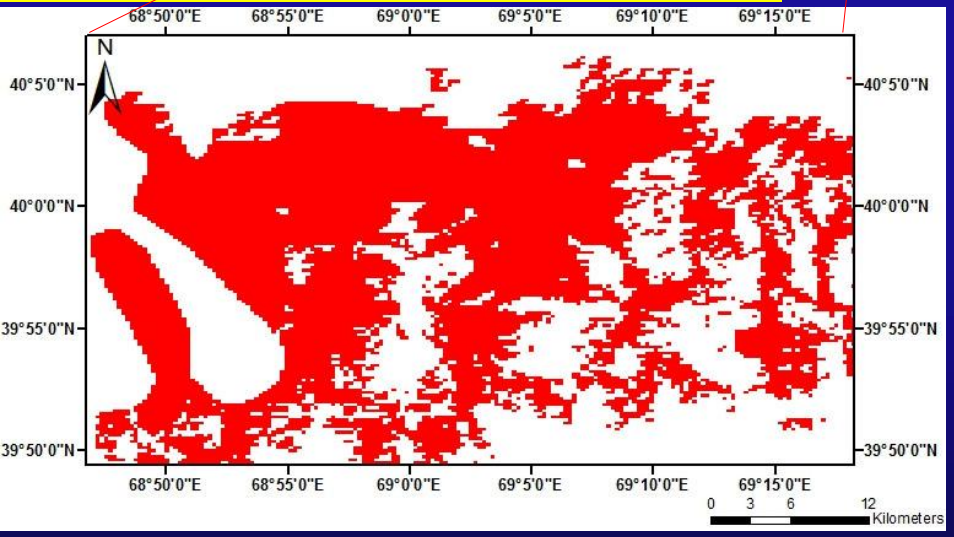


# Rainfed Areas of Tajikistan: Zoom in view

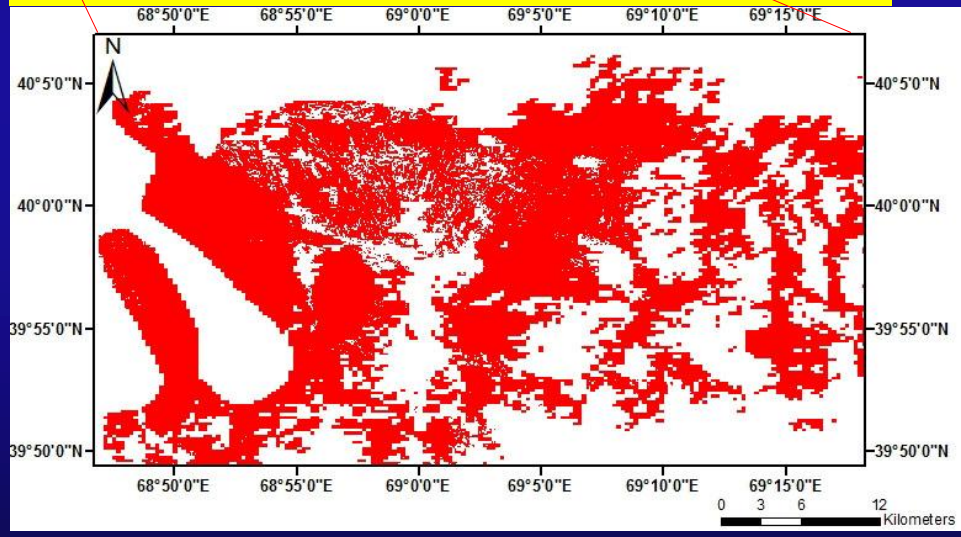
## Comparison: Knowledge Layer vs. Algorithm Derived Layer




**Knowledge Layer (truth) for year 2005**




**Algorithm derived layer also for year 2005**




**Note: Once you have the algorithm, it takes only a few minutes to derive rainfed areas.**

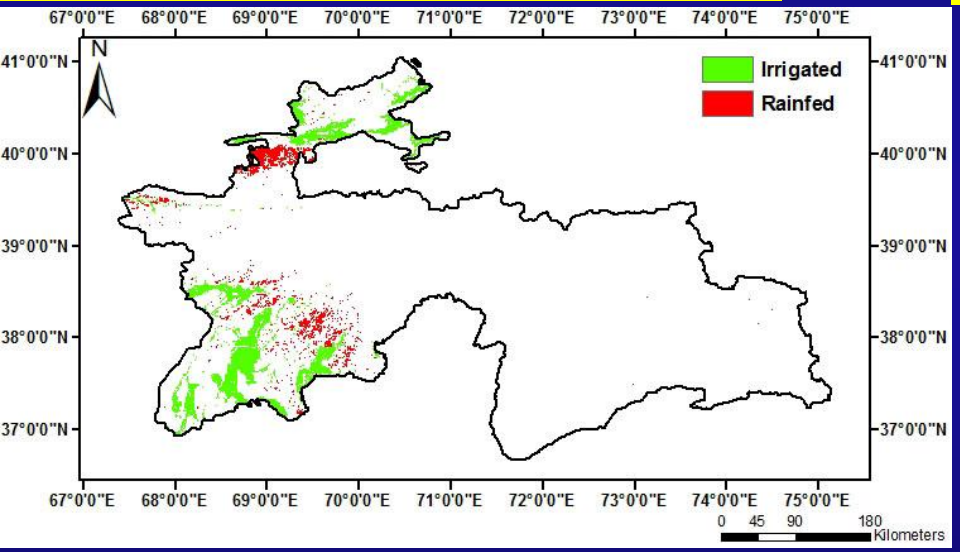

# Algorithm for irrigated +rainfed Areas using Data for the Years Same (2005)as Knowledge Layer

U.S. Department of the Interior
U.S. Geological Survey

# Irrigated + Rainfed Areas of Tajikistan: Full Country View

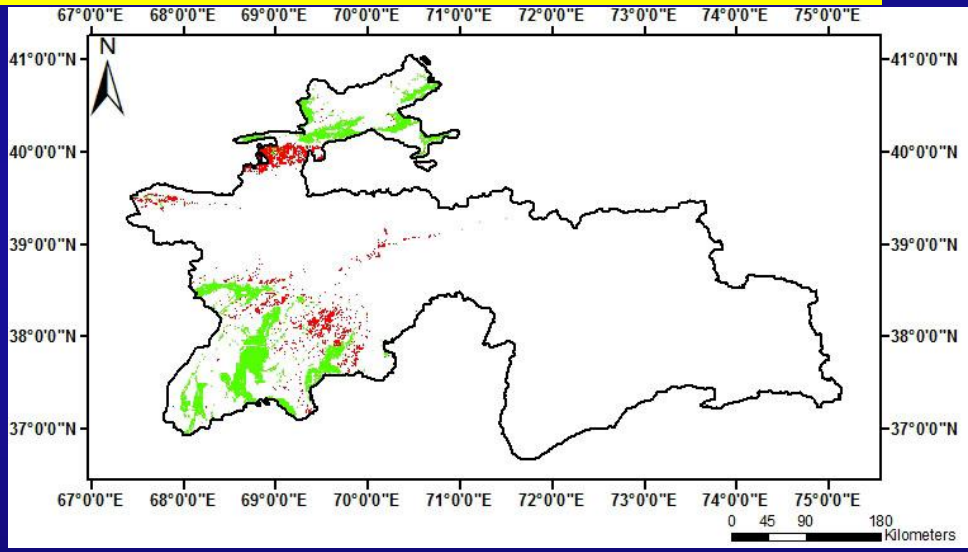
## Comparison: Knowledge Layer vs. Algorithm Derived Layer

**Knowledge Layer (truth) for year 2005**




**30 m spatial resolution**

**Algorithm derived layer also for year 2005**




**30 m spatial resolution**

**Note: Once you have the algorithm, it takes only a few minutes to derive irrigated and rainfed areas.**

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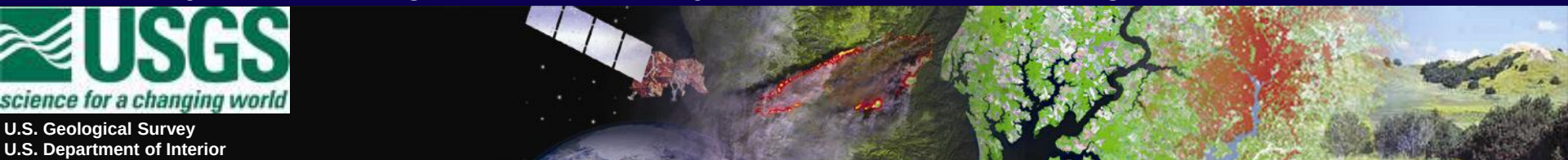
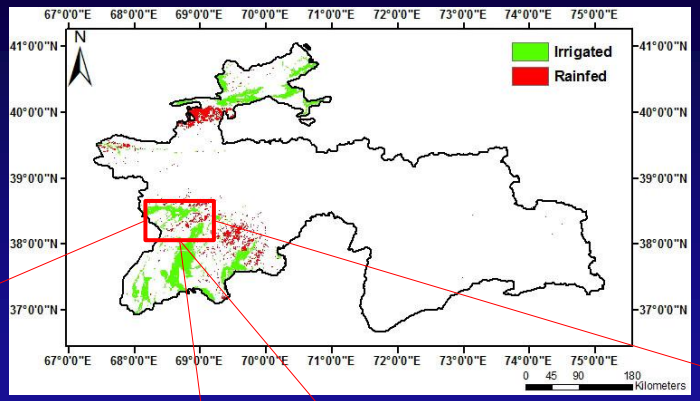
U.S. Department of Interior

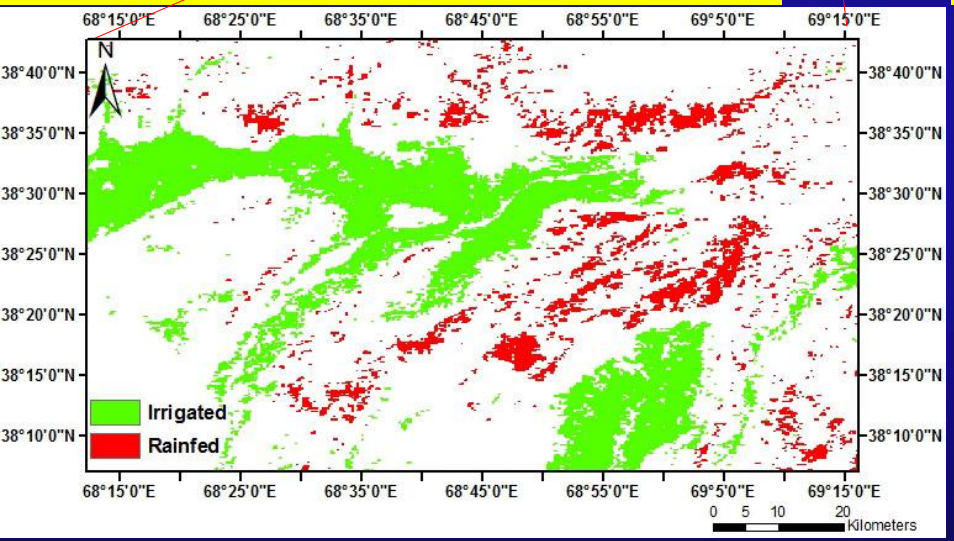


# Irrigated + Rainfed Areas of Tajikistan: Zoom in View

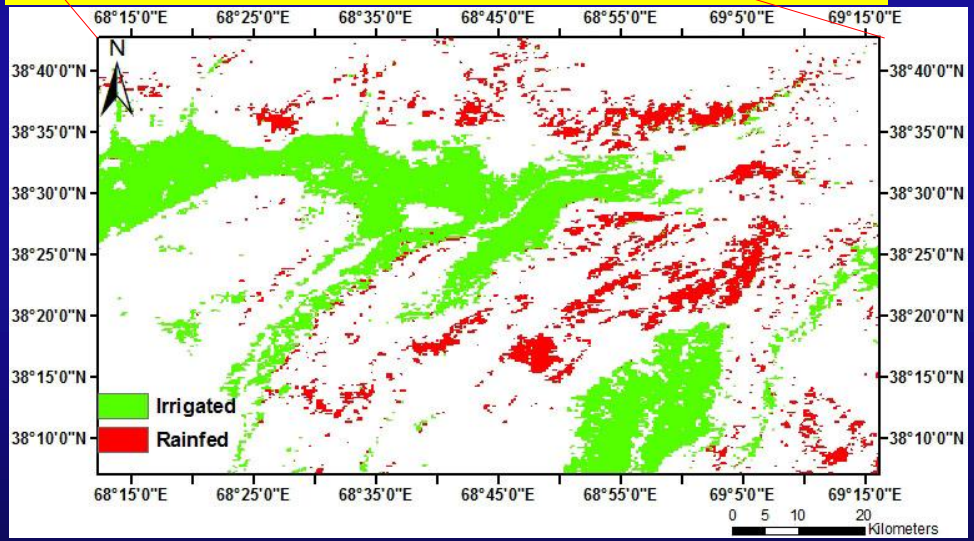
## Comparison: Knowledge Layer vs. Algorithm Derived Layer




**Knowledge Layer (truth) for year 2005**




**Algorithm derived layer also for year 2005**




**Note: Once you have the algorithm, it takes only a few minutes to derive irrigated and rainfed areas.**

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# Accuracy Assessment

## Error matrix

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U.S. Geological Survey

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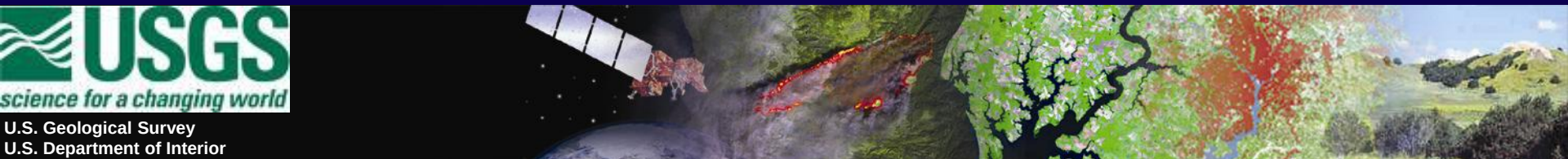
# Irrigated, Rainfed, and Other Areas of Tajikistan

## Error Matrix: Knowledge Layer vs. Algorithm Derived

| | | Algorithm Derived Data | | | | | |
|---|---|---|---|---|---|---|---|
| | | Irrigated Areas | Rainfed areas | All other LCLU classes | Row total | Producer's accuracy | Errors of Omissions |
| Reference Data | Irrigated Areas | 7398009 | 152145 | 30263 | 7580417 | 97.6 | 2.4 |
| | Rainfed areas | 143604 | 2520206 | 252235 | 2916045 | 86.4 | 13.6 |
| | All other LCLU classes | 33029 | 129403 | 142088064 | 142250496 | 99.9 | 0.1 |
| | Column total | 7574642 | 2801754 | 142370562 | 152006279 | | |
| | User's accuracy | 97.7 | 90.0 | 99.8 | 152746958 | | |
| | Errors of Commission | 2.3 | 10.0 | 0.2 | | | |
| | | | | Overall accuracy | 99.5 | | |
| | | | | $K_{hat}$ | 0.96 | | |

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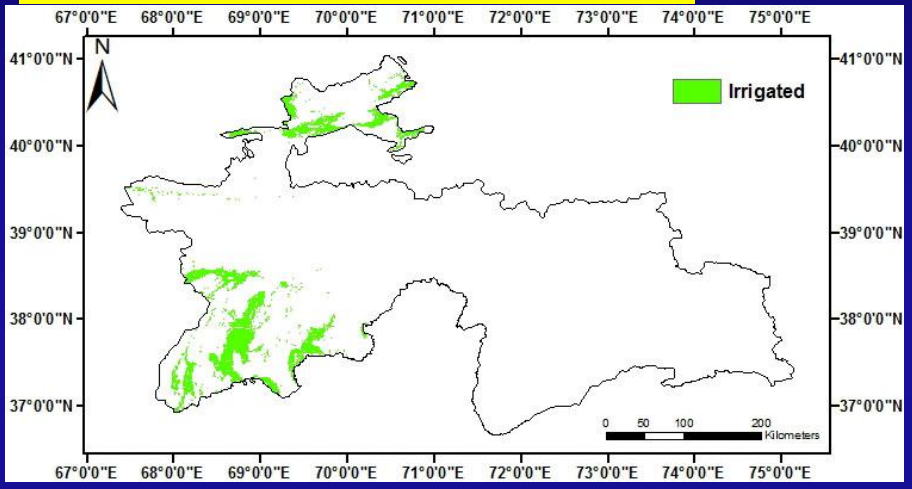
U.S. Department of Interior


# Algorithm Applied for Independent Data Layer (year 2010) Showing Irrigated Areas

U.S. Department of the Interior
U.S. Geological Survey

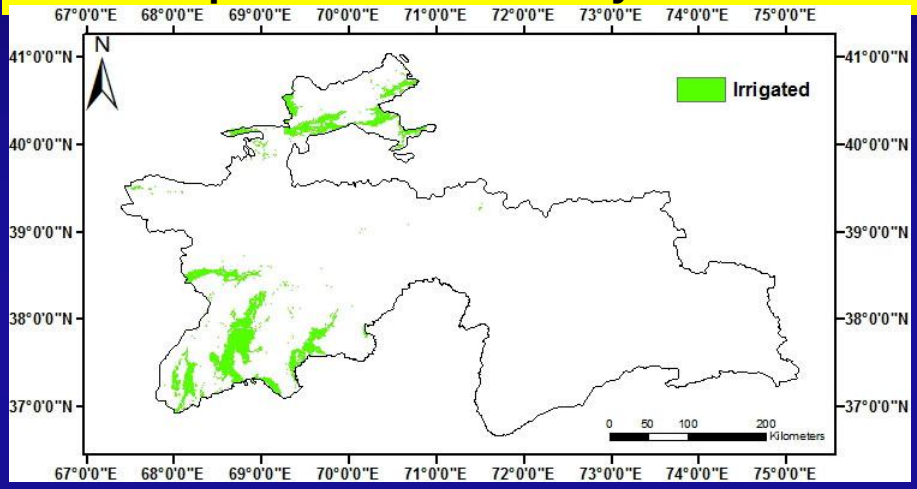
# Irrigated Areas of Tajikistan 2010: Whole Country View
## Comparison: Knowledge Layer vs. Algorithm Derived Layer

**Knowledge Layer (truth) of irrigated areas**




30 m spatial resolution

**Algorithm derived irrigated areas for independent data set of year 2010**




30 m spatial resolution

**Note: Once you have the algorithm, it takes only a few minutes to derive irrigated areas.**

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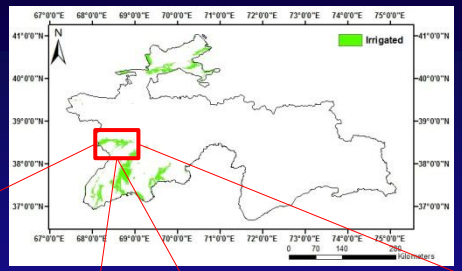
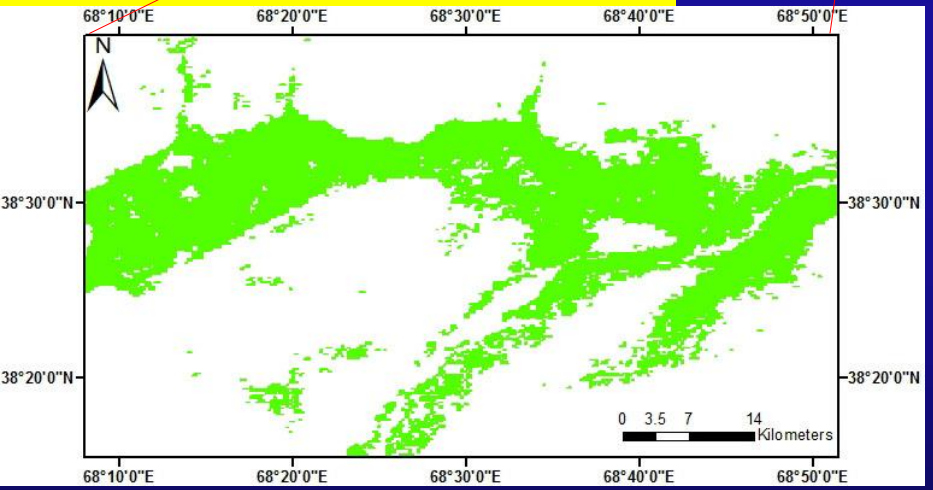
U.S. Department of Interior

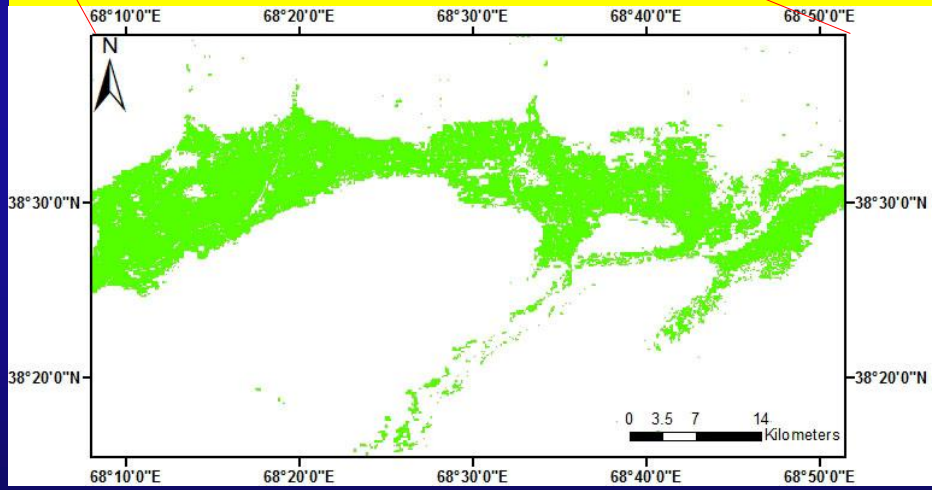
# Irrigated Areas of Tajikistan 2010: Zoom in View
# Comparison: Knowledge Layer vs. Algorithm Derived Layer




**Knowledge Layer (truth) of irrigated areas**




**Algorithm derived irrigated areas for independent data set of year 2010**




**Note: Once you have the algorithm, it takes only a few minutes to derive irrigated areas.**

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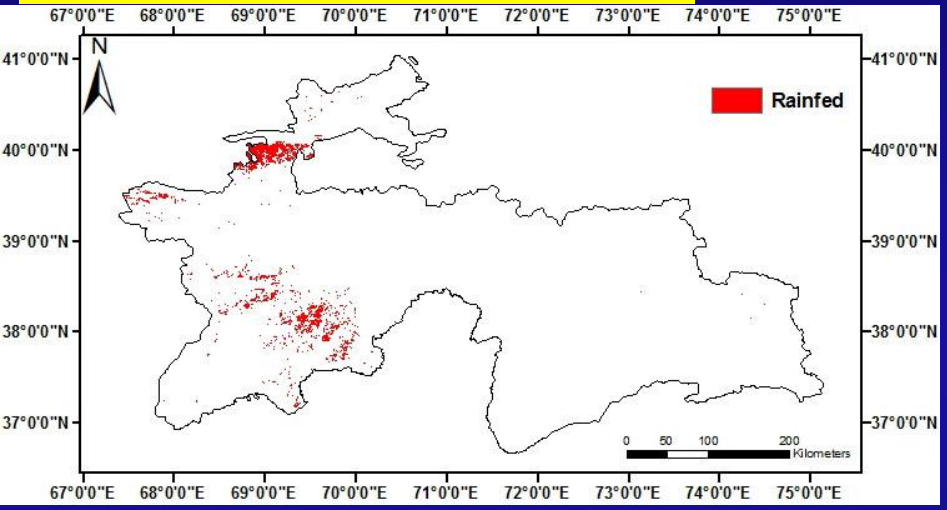
U.S. Department of Interior


# Algorithm Applied for Independent Data Layer (year 2010) Showing Rainfed Areas

U.S. Department of the Interior
U.S. Geological Survey

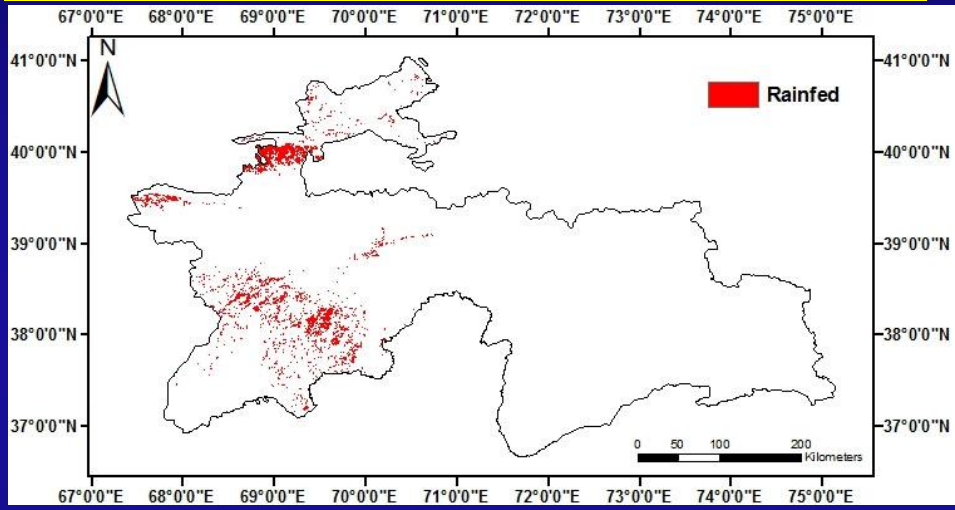
# Rainfed Areas of Tajikistan 2010: Full Country View
## Comparison: Knowledge Layer vs. Algorithm Derived Layer

**Knowledge Layer (truth) of rainfed areas**




30 m spatial resolution

**Algorithm derived rainfed areas of independent data set of year 2010**




30 m spatial resolution

**Note: Once you have the algorithm, it takes only a few minutes to derive rainfed areas.**

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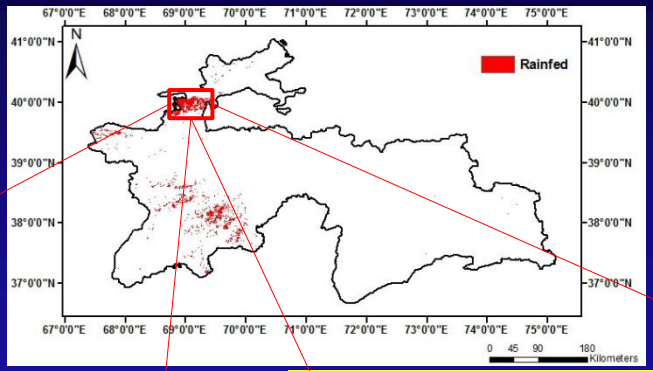
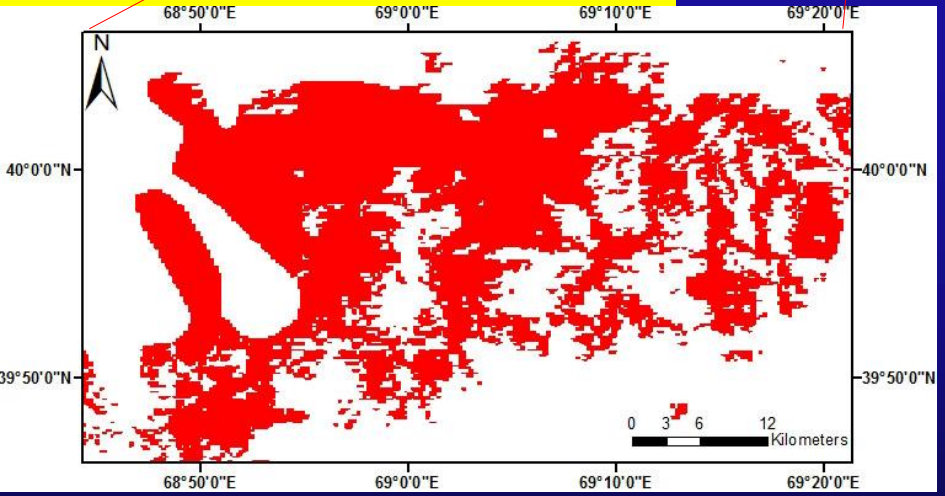
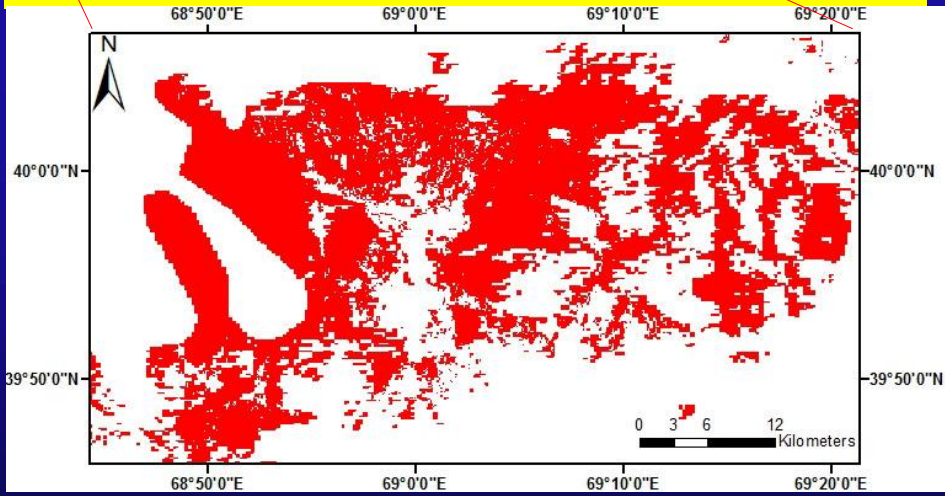
# Rainfed Areas of Tajikistan 2010: Zoom in view
## Comparison: Knowledge Layer vs. Algorithm Derived Layer




**Knowledge Layer (truth) of rainfed areas**




**Algorithm derived rainfed areas of independent data set of year 2010**




**Note: Once you have the algorithm, it takes only a few minutes to derive rainfed areas.**

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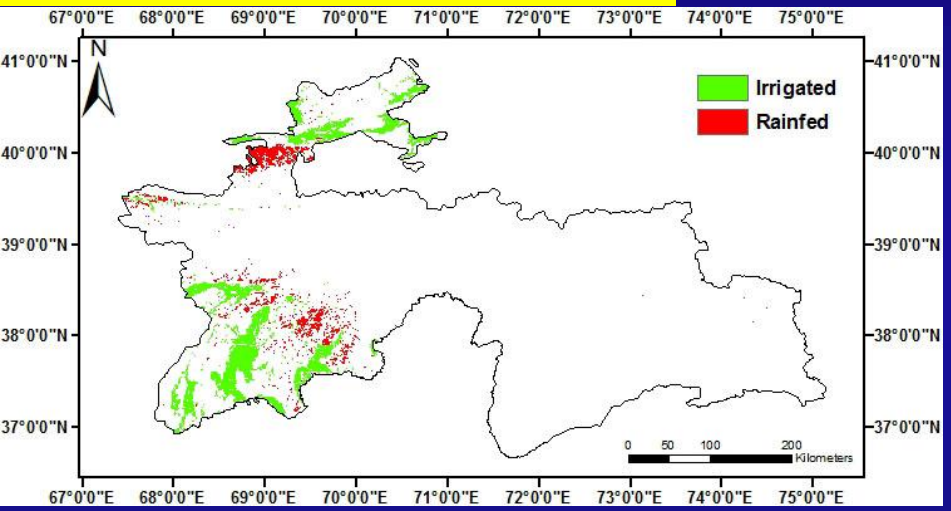
# Algorithm Applied for Independent Data Layer (year 2010) Showing Rainfed Areas

U.S. Department of the Interior
U.S. Geological Survey

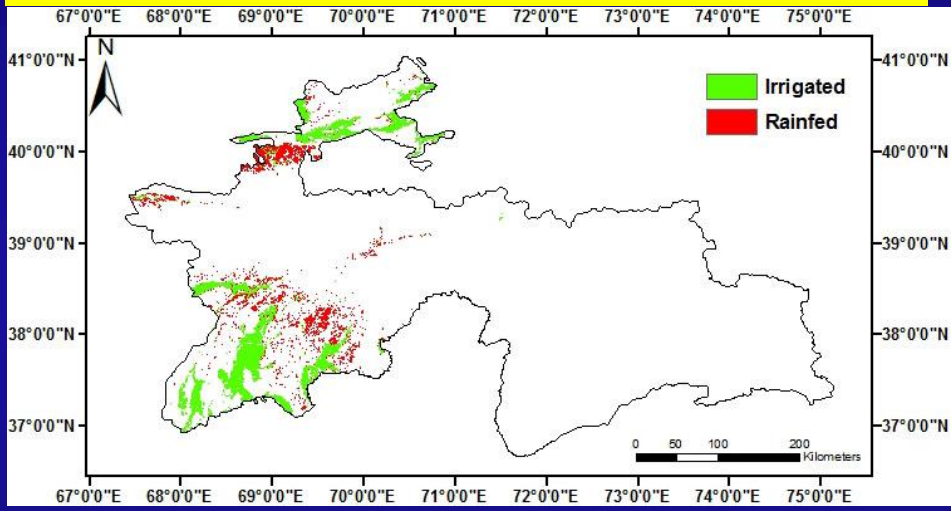
# Irrigated + Rainfed Areas of Tajikistan 2010: Full Country View
## Comparison: Knowledge Layer vs. Algorithm Derived Layer

**Knowledge Layer (truth) of irrigated + rainfed areas**




30 m spatial resolution

**Algorithm derived irrigated + rainfed areas of independent data set of year 2010**




30 m spatial resolution

**Note: Once you have the algorithm, it takes only a few minutes to derive irrigated and rainfed areas.**

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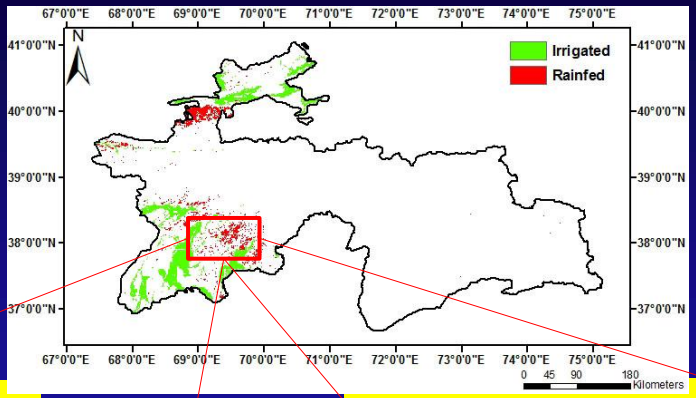
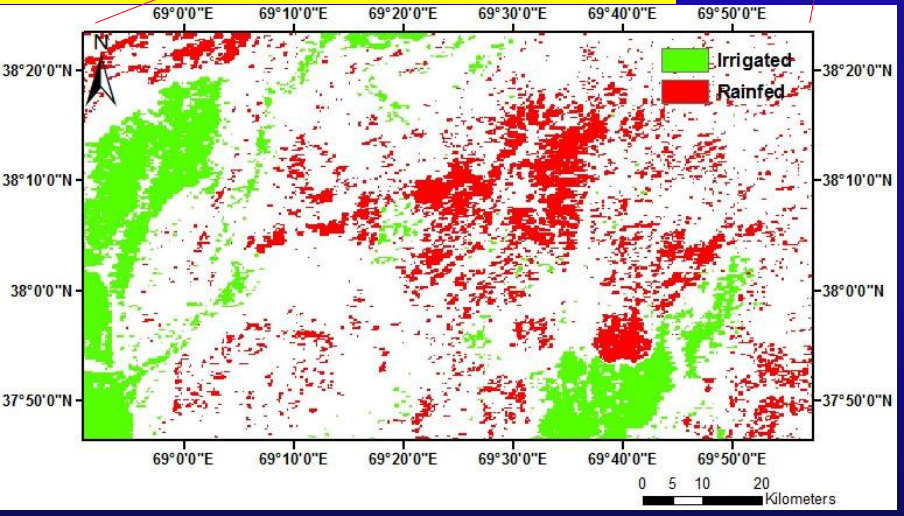
# Irrigated + Rainfed Areas of Tajikistan 2010: Zoom in View

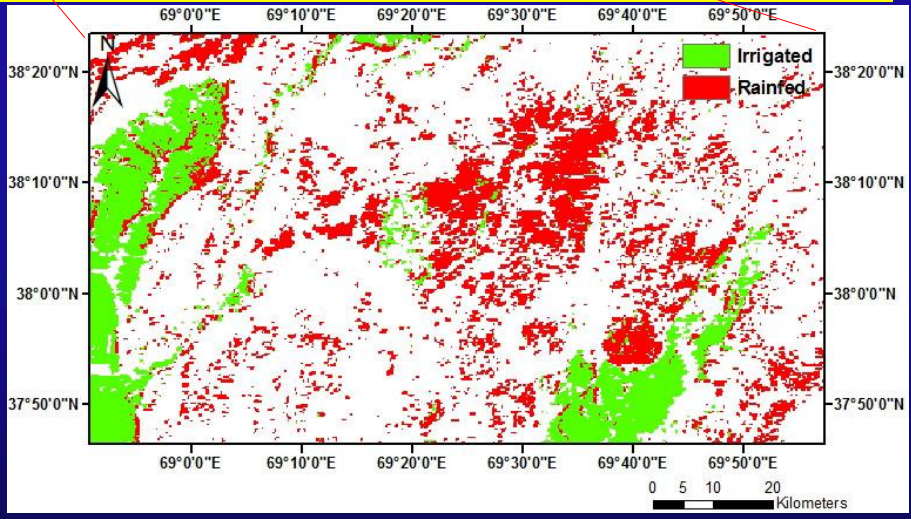
## Comparison: Knowledge Layer vs. Algorithm Derived Layer




**Knowledge Layer (truth) of irrigated + rainfed areas**




**Algorithm derived irrigated + rainfed areas of independent data set of year 2010**




**Note: Once you have the algorithm, it takes only a few minutes to derive irrigated and rainfed areas.**

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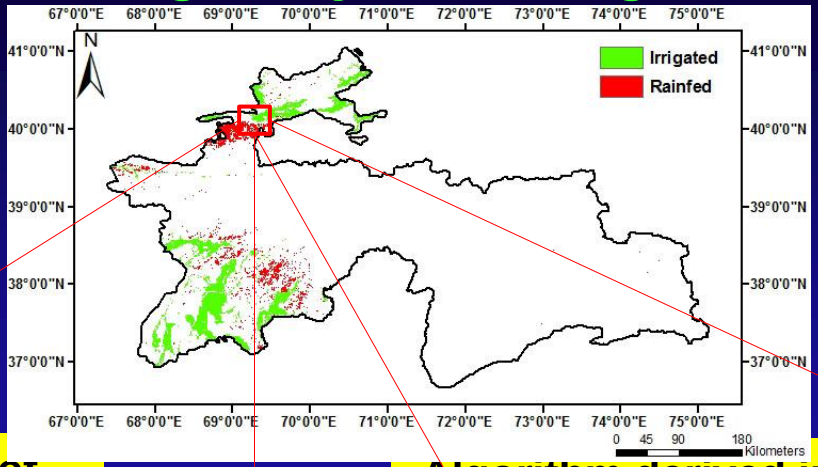
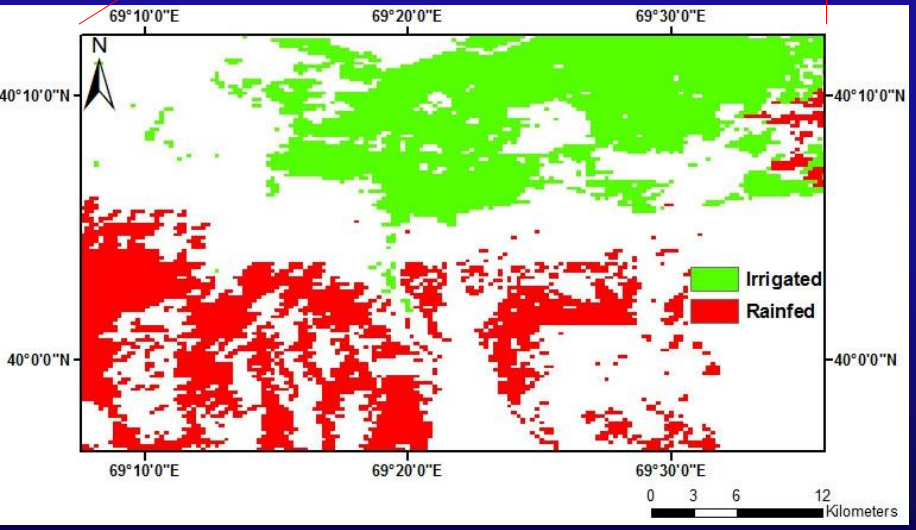
# Irrigated + Rainfed Areas of Tajikistan 2010: Zoom in View

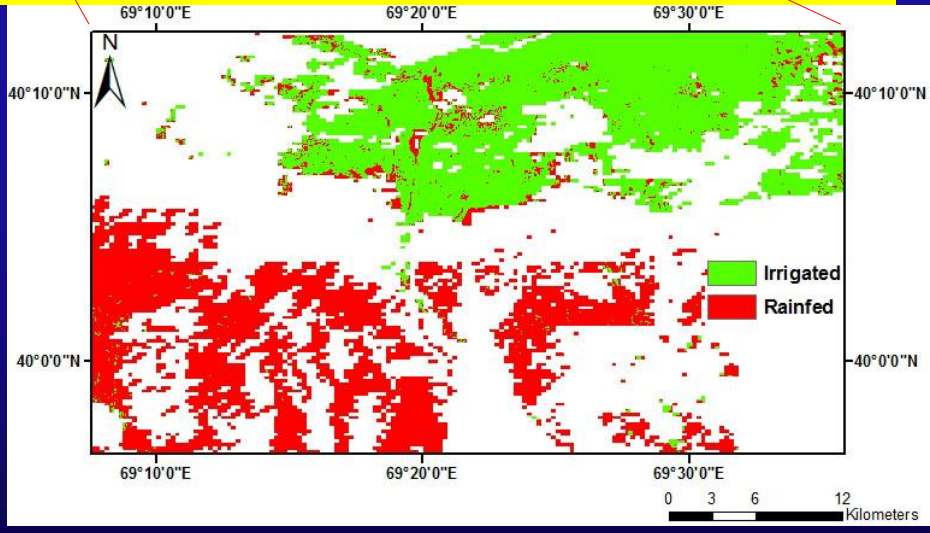
## Comparison: Knowledge Layer vs. Algorithm Derived Layer




**Knowledge Layer (truth) of irrigated + rainfed areas**




**Algorithm derived irrigated + rainfed areas of independent data set of year 2010**

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U.S. Department of Interior


# Accuracy Assessment

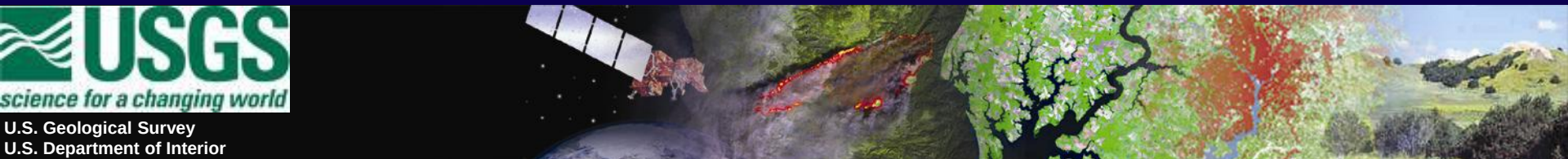
## Error matrix

U.S. Department of the Interior
U.S. Geological Survey

# Irrigated, Rainfed, and Other Areas of Tajikistan

# Error Matrix: Knowledge Layer vs. Algorithm Derived (2010)

| | | Algorithm Derived Data | | | | | |
|---|---|---|---|---|---|---|---|
| | | Irrigated Areas | Rainfed areas | All other LCLU classes | Row total | Producer's accuracy | Errors of Omissions |
| Reference Data | Irrigated Areas | 6514801 | 1035399 | 30217 | 7580417 | 85.9 | 14.1 |
| | Rainfed areas | 206960 | 2456860 | 252225 | 2916045 | 84.3 | 15.7 |
| | All other LCLU classes | 40163 | 127180 | 142083136 | 142250479 | 99.9 | 0.1 |
| | Column total | 6761924 | 3619439 | 142365578 | 151054797 | | |
| | User's accuracy | 96.3 | 67.9 | 99.8 | 152746941 | | |
| | Errors of Commission | 3.7 | 12.1 | 0.2 | | | |
| | | | | Overall accuracy | 98.9 | | |
| | | | | $K_{hat}$ | 0.91 | | |

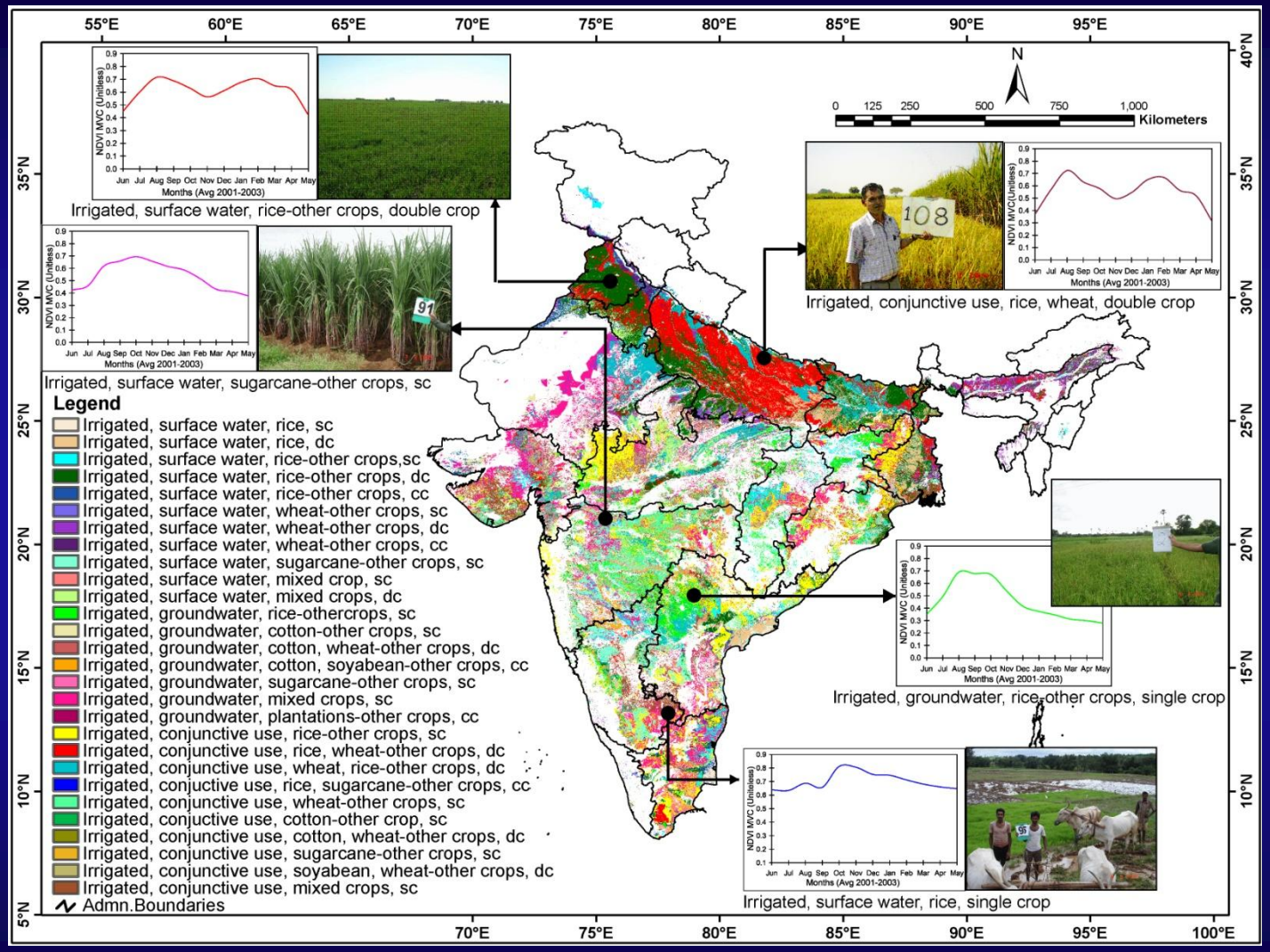



U.S. Geological Survey
U.S. Department of Interior


# Way Forward

# Irrigated and Rainfed Areas of India

## MODIS 500 m time-series data




**Uncertainties still exist since Landsat was not used in this study**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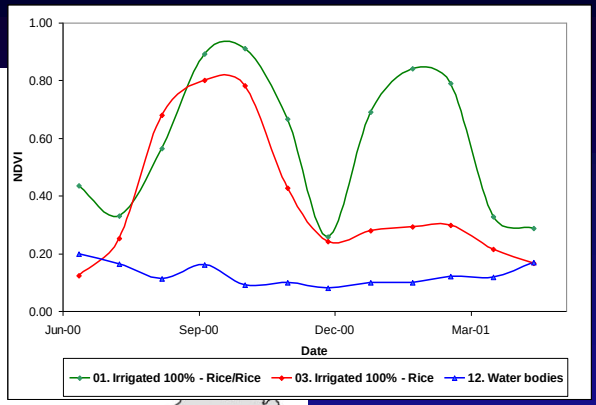
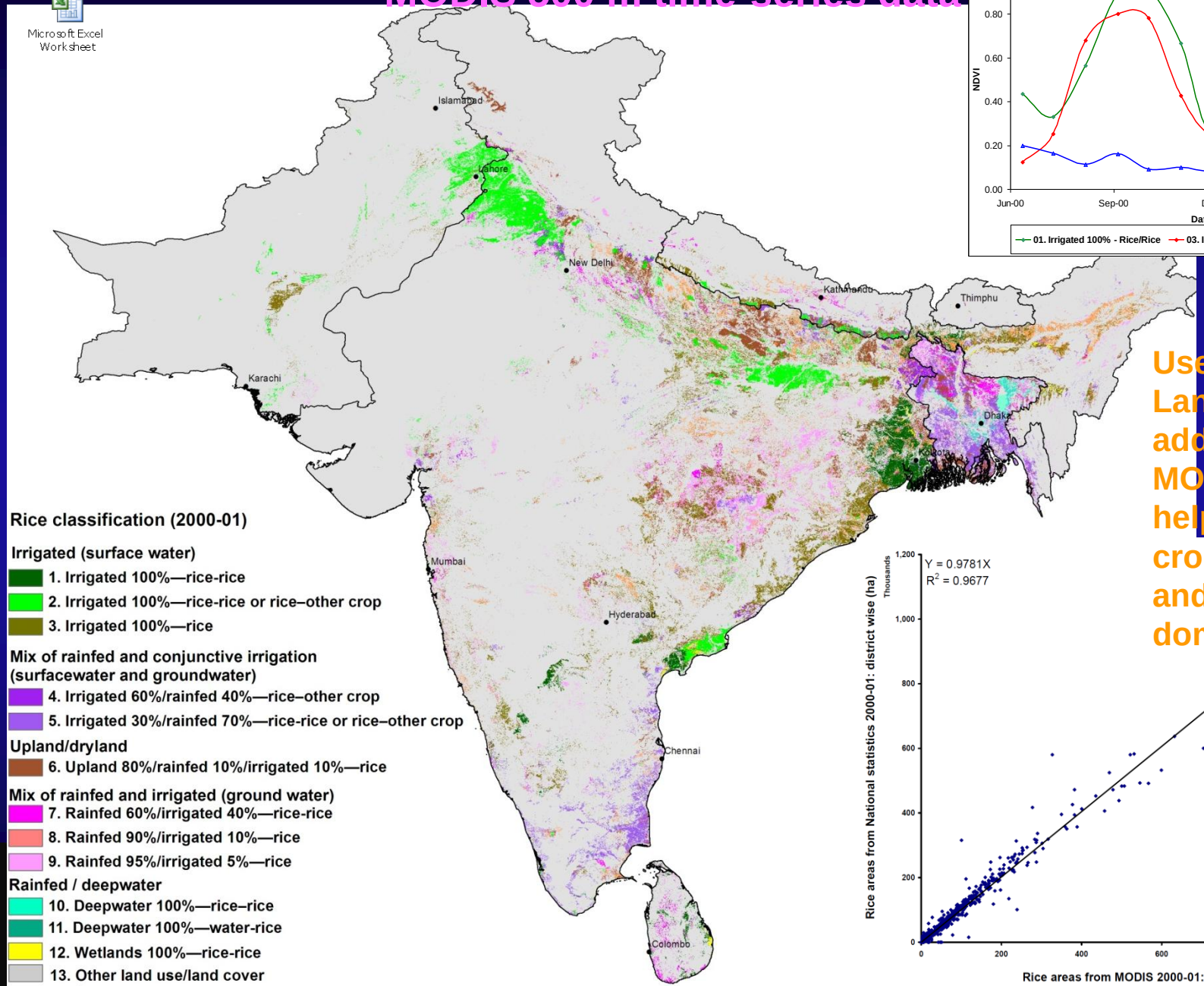
# Irrigated Rice Areas of South Asia

## MODIS 500 m time-series data

Microsoft Excel Worksheet




**Rice classification (2000-01)**

**Irrigated (surface water)**
- 1. Irrigated 100%—rice-rice
- 2. Irrigated 100%—rice-rice or rice–other crop
- 3. Irrigated 100%—rice

**Mix of rainfed and conjunctive irrigation (surfacewater and groundwater)**
- 4. Irrigated 60%/rainfed 40%—rice–other crop
- 5. Irrigated 30%/rainfed 70%—rice-rice or rice–other crop

**Upland/dryland**
- 6. Upland 80%/rainfed 10%/irrigated 10%—rice

**Mix of rainfed and irrigated (ground water)**
- 7. Rainfed 60%/irrigated 40%—rice-rice
- 8. Rainfed 90%/irrigated 10%—rice
- 9. Rainfed 95%/irrigated 5%—rice

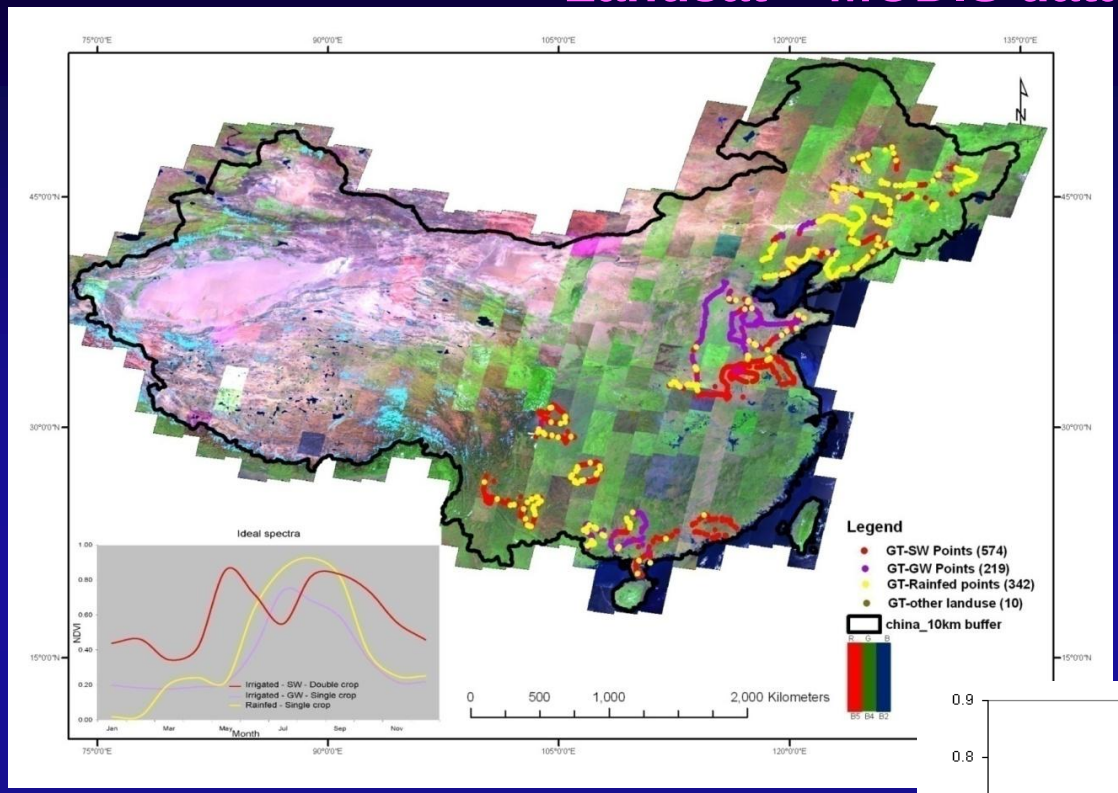
**Rainfed / deepwater**
- 10. Deepwater 100%—rice–rice
- 11. Deepwater 100%—water-rice
- 12. Wetlands 100%—rice-rice
- 13. Other land use/land cover



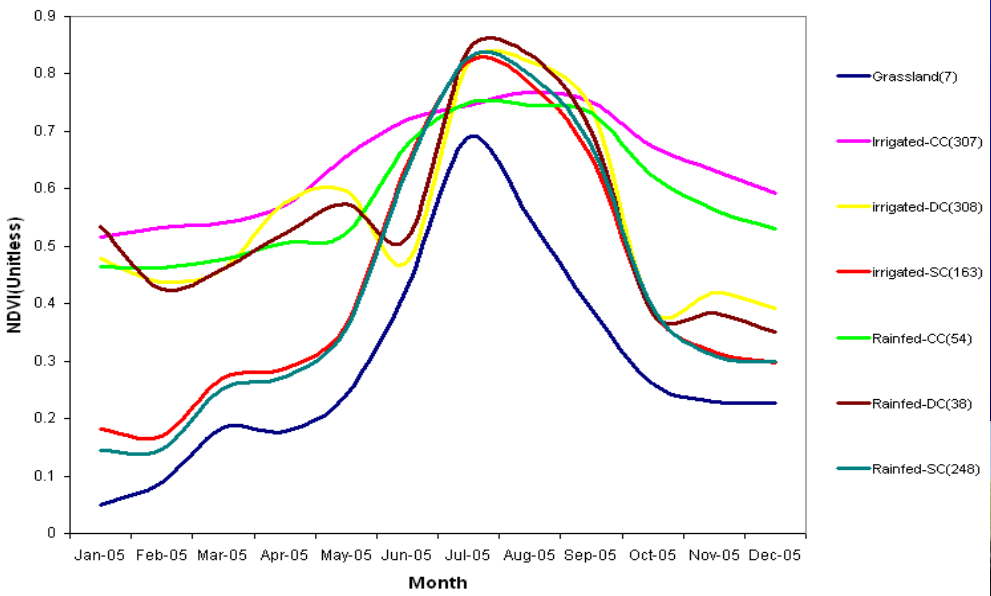

**Use of Landsat, in addition to MODIS, will help establish crop type and\or dominance**

# Irrigated and Rainfed Areas of China

## Landsat + MODIS data Fusion




**Large sample of field plot data for entire China from precise locations in addition to Landsat and MODIS data**

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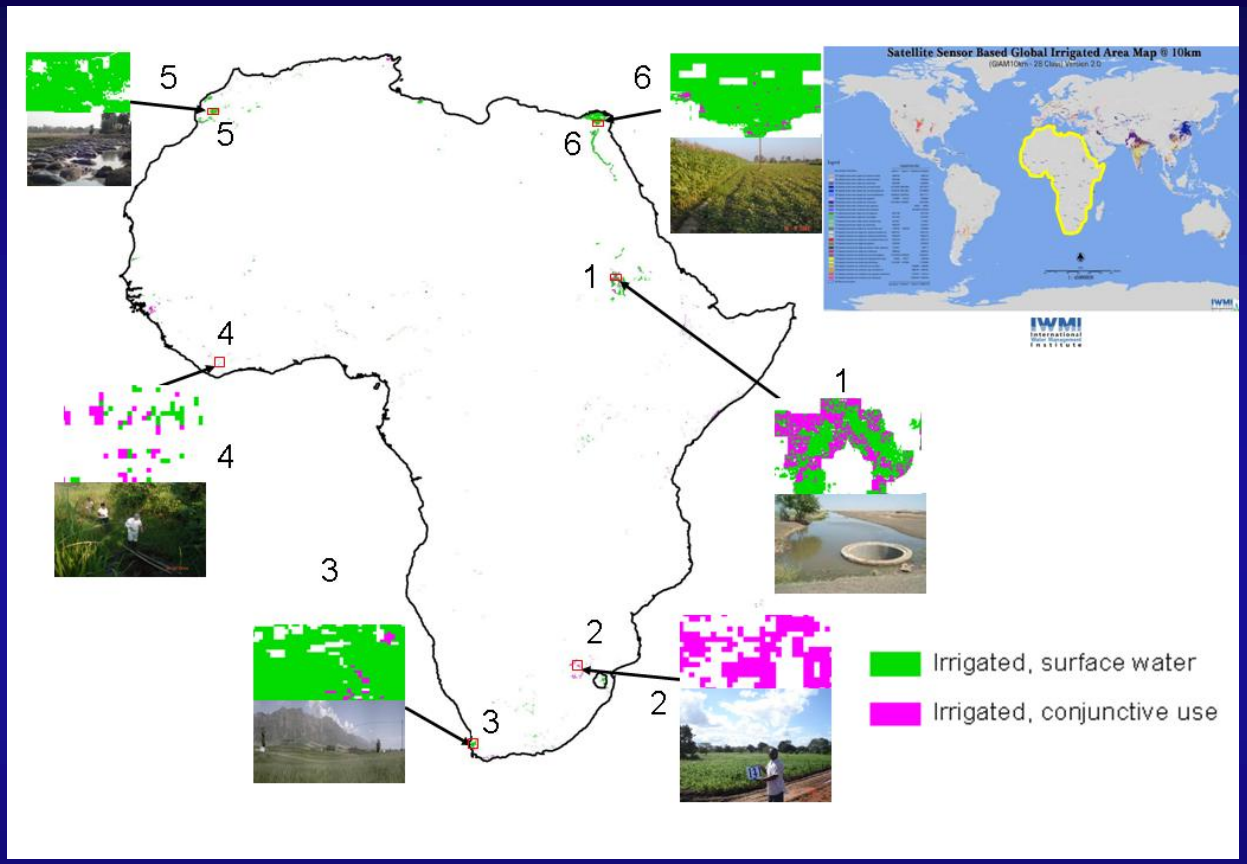
# Irrigated Areas of Africa

## Based on Multi-resolution Data




**Fragmented irrigated cropland areas of Africa certainly needs fine spatial resolution……probably even IKONOS\Quickbird\Rapideye etc.**

**Irrigated cropland areas of Africa. The global annualized irrigated area (AIA) in the African continent is only about 2% compared to 14% of the global population. There is a real opportunity to expand irrigated areas in Africa to facilitate green and blue revolutions.**

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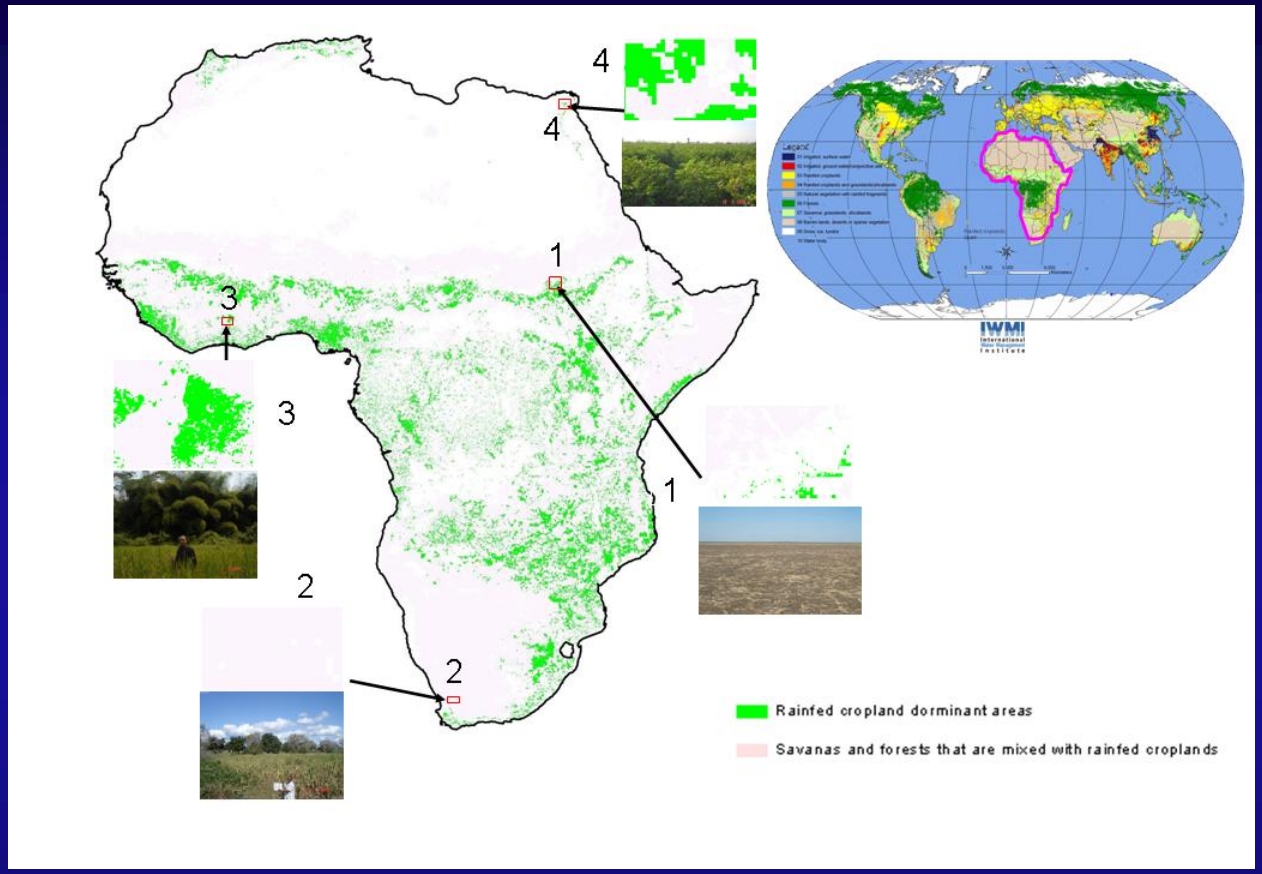
# Rainfed Areas of Africa

## Based on Multi-resolution Data




**Fragmented irrigated cropland areas of Africa certainly needs fine spatial resolution……probably even IKONOS\Quickbird\Rapideye etc.**

**Distribution of rain-fed croplands in the African continent. The total global rain-fed cropland area (Global: 1.13 Bha) in Africa is 17% and its productivity can be improved through irrigation and better land management practices to help move towards a green revolution.**

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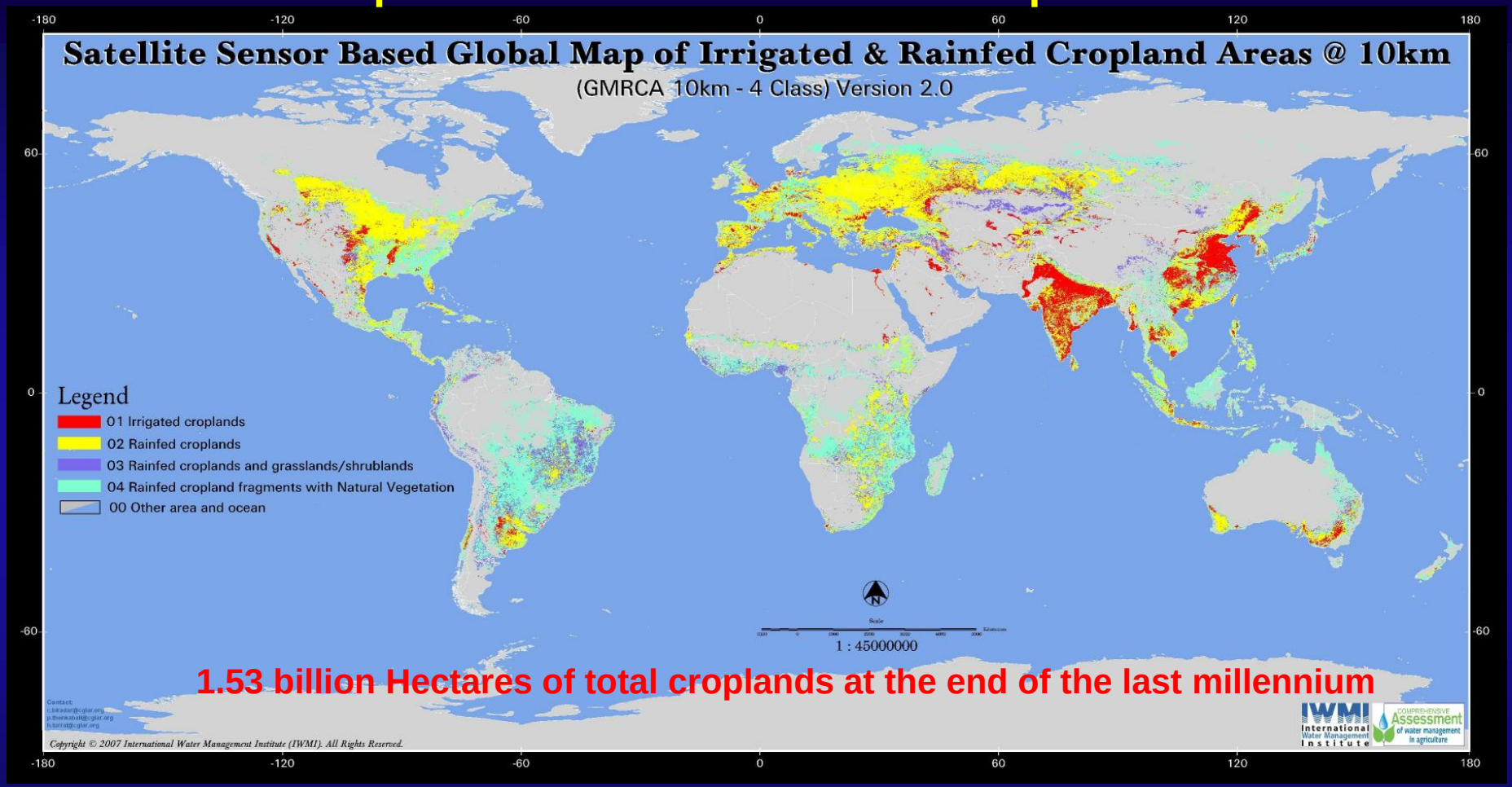
# Global Irrigated Areas + Rainfed Areas

## Spatial Distribution of Global Croplands




**Combine algorithms to derive global croplands**

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# PE&RS Special Issue on

## Remote Sensing of Global Croplands and Their Water Use: Call for Papers

*Photogrammetric Engineering & Remote Sensing (PE&RS)*

**August 2012 Special Issue Call for Papers**

**"Remote Sensing of Global Croplands and their Water Use for Food Security in the Twenty-First Century"**

The precise estimation of the extent and locations of global croplands is imperative for ensuring sustainable water and food security to the people of the world. Coarse resolution global cropland mapping has become feasible by integrating agricultural statistics and census data from national systems, and spatial mapping technologies involving geographic information systems (GIS). While useful, the coarse resolution cropland maps have many limitations that include: (a) absence of precise spatial location of the cropland areas; (b) uncertainties in differentiating irrigated areas from rainfed areas; and (c) absence of crop types and cropping intensities. The greatest difficulty and differences in global cropland estimates is in differentiating between rainfed croplands versus irrigated croplands. This is a crucial difference because water use assessments depend heavily on whether an area is irrigated or rainfed. Global croplands are also water guzzlers, consuming between 60-90% of all human water use. About 80% of all blue water use (i.e., water from lakes, rivers, reservoirs, and deep aquifer ground water) by humans goes for irrigated agriculture and about 70% of all green water use (i.e., water in unsaturated zone of soil moisture coming from direct rains) by humans goes for rainfed agriculture.

Advanced remote sensing data available from multiple satellite systems (e.g., Landsat, MODIS, Rapideye, Resourcesat, CEBERS, SPOT, AWiFS) along with secondary data and recent advances in data access, quality, processing, and delivery have provided real opportunity to reduce uncertainty and increase accuracies in mapping and modeling croplands and their water use at local, regional, and global levels. Specific recent remote sensing advances enabling global cropland mapping and generation of their statistics include factors such as: (a) free access to well calibrated and guaranteed data such as Landsat and frequent temporal coverage of MODIS; (b) free access to high quality secondary data such as long-term precipitation, evapotranspiration, surface temperature, soils, and ASTER global digital elevation model (GDEM); and (c) advances in computer technology and data processing (e.g., NASA NEX super-computing capacity to process and mosaic entire Global collection of Landsat data within a week, ability to visualize the entire global data on the fly "hyperwall").

**The goal of this special issue is to seek papers** providing cutting-edge research on remote sensing of global croplands and their water use. We solicit papers that: (A) espouse advance methods and algorithms for cropland mapping at local, regional, and global levels using remote sensing data from advanced multispectral, hyperspectral, and hyperspatial sensors and\or fusion of them, (B) model water use assessments using thermal and\or optical sensors along with surface energy balance approaches, and (C) develop spatial models for food security analysis based on remote sensing derived cropland maps and water use assessments. The papers of specific interest will be those that: (1) develop methods and techniques for consistent and unbiased estimates of agricultural croplands over space and time; (2) account for watering source (e.g., irrigated, rainfed, other LULC) of croplands, (3) elaborate on cropping intensity over a year; (4) define the actual area and spatial distribution of croplands in the world; (5) determine change in croplands extent or intensity (e.g., expansion of croplands into natural vegetation, reduction due to urbanization and bio-fuels, change in intensity of cropping); and (6) assess accuracies, errors, and uncertainties.

All submissions will be peer-reviewed in line with *PE&RS* policy. Because of page limits, not all submissions recommended for acceptance by the review panel may be included in the special issue. Under this circumstance, the guest editors will select the most relevant papers for inclusion in the special issue. Authors must prepare manuscripts according to the *PE&RS* Instructions to Authors, published in each issue of *PE&RS* and also available on the ASPRS web site at http://www.asprs.org/society/committees/jpc/jpc_instr.html.

**IMPORTANT DATES**

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| Manuscripts due: | October 1, 2011 |
| Decision to Authors: | January 1, 2012 |
| Final papers due: | February 1, 2012 |
| Publication: | August 1, 2012 |

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