2013年秋季地球系统科学前沿系列讲座之七

全球地表覆盖制图与应用
Global Land Cover Mapping and Applications

俞 乐

清华大学地球系统科学研究中心

leyu@tsinghua.edu.cn

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Outlines

- Introductions
- History of global land cover mapping
- Progress in land cover mapping
- An example: 30 meter global land cover mapping
- Applications

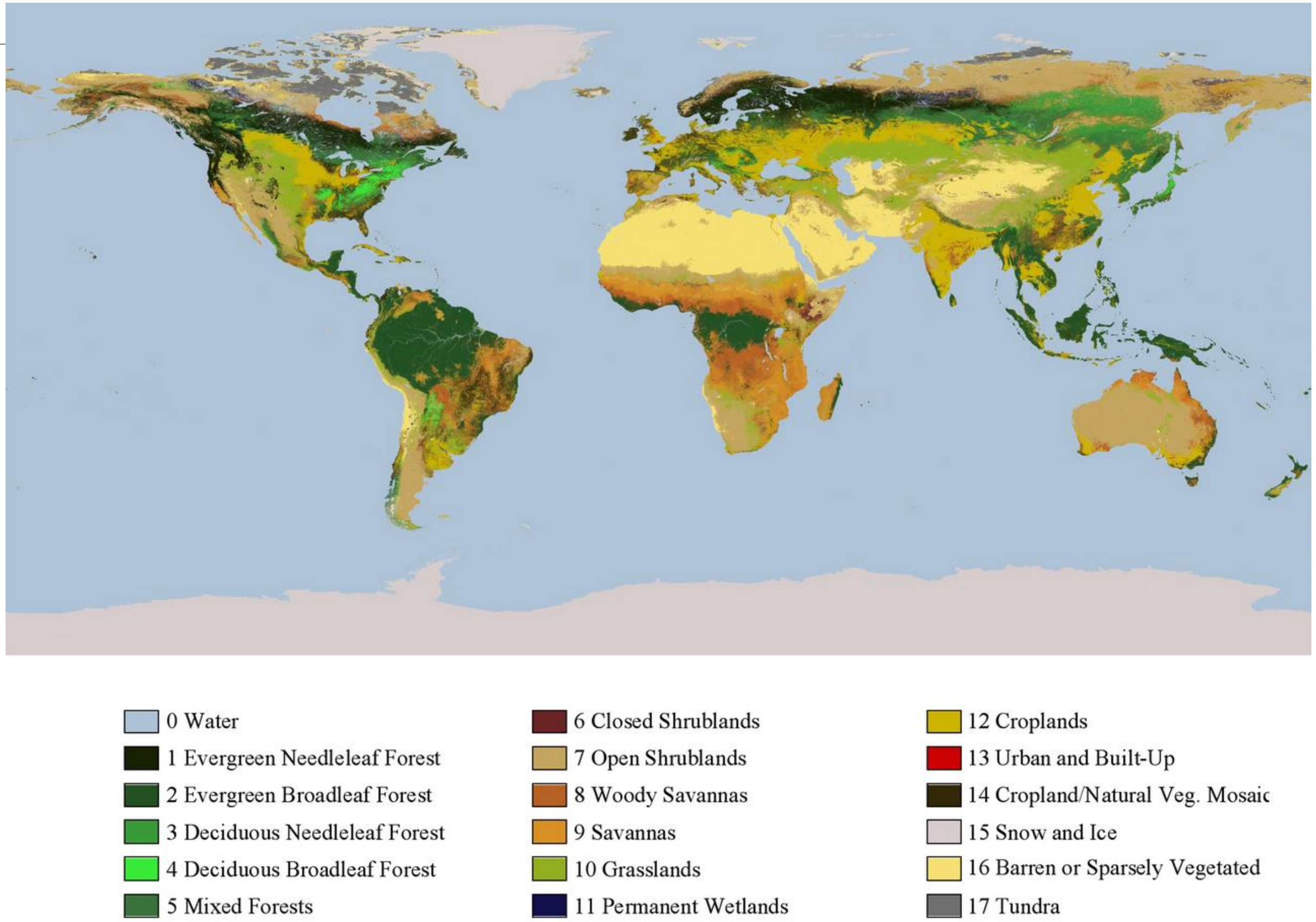
Background

Land cover is the physical material at the surface of the earth, e.g. vegetation, water, bare soil or other.

Why mapping land cover: Identifying, delineating and mapping land cover is important for ***monitoring studies***, ***resource management***, and ***planning activities***.

Land cover vs. land use

Land use is the human activities on the land, which are directly related to the land.



Remote sensing land cover mapping

- Major components:
  - (1) Remote sensing dataset
  - (2) Classification system (legend)
  - (3) Sample
  - (4) Algorithm
  - (5) Validation
  - And others.

History (1980s)

Trace back to early 1980s, three global land cover maps (i.e. Matthews, 1983; Olson et al., 1985; Wilson & Henderson-Sellers, 1985) aiming for climate modelling and carbon assessment were compiled in digital form drawing upon variety of ground based sources at one degree or sub-degree spatial resolution.

Although those compilation maps benefit from regional experts' knowledge (might describes proper land cover characteristic at regional scale), globally speaking, because these maps were compiled from various sources produced at different times and employing different definitions of cover type, they are should not be used to estimate the total area occupied by major cover types (Townshend et al. 1991), and low map similarity (only 26%, DeFries & Townshend, 1993) due to differences in sources, methods and classification systems (DeFries & Townshend, 1994, Loveland et al., 2000).

History (1990s)

Since the advent of satellite remote sensing, land cover mapping has been one of the most widely studied applications (Kiefer et al., 1975; Tucker et al., 1985; Running, 2008).

Global land cover maps were then possible to be made in a new fashion using identical source at same time with same classification system. The large body of land cover maps of different places, regions, countries, and continents were dispersed throughout various published literatures since the first land observation satellite – Landsat-1 released.

To improve the reliability of geographically-referenced data sets of global land cover, many remotely sensed imagery based global land cover mapping were started in 1990s for applications such as climate modelling, i.e. UMD-1 degree product (DeFries & Townshend, 1994), UMD-8km product (DeFries et al., 1998), BU MODIS LC V003 (Strahler et al., 1999).

History (2000s)

In 2000s, six types of global land cover maps derived from remotely sensed data are freely available at 1km and sub-km scale, i.e.

- IGBP DISCover (Loveland et al., 2000)
- UMD 1km product (Hansen et al., 2000)
- BU MODIS LC (Friedl et al., 2002, 2010)
- GLC2000 (Bartholome & Belward, 2005)
- GlobCover (Arino et al., 2008; Bontemps et al., 2010)
- GLCNMO (Tateishi et al., 2011)

Satellite-Sensor	Spatial Resolution	Spectral Resolution
NOAA-AVHRR	1km	5
SPOT-Vegetation	1km	4
Terra/Aqua-MODIS	250m/500m/1km	36
Envisat-MERIS	300m	15
Landsat-TM/ETM+	30m/60m	7

The accuracy ranges from 60% to 80%, which is lower than 1990s' products (ranges between 76% - 86%).

Progress in land cover mapping

Over a period of 4 decades since the launch of the first land observation satellite (Landsat) in 1972, nearly 3 million scenes of images have acquired by the end of 2011, and the world has been covered by Landsat images for several hundreds of times.

Remote sensing based land cover mapping activities has accumulated a wide range of knowledge in peer-reviewed literatures.

Using a spatialized literature database.

Method

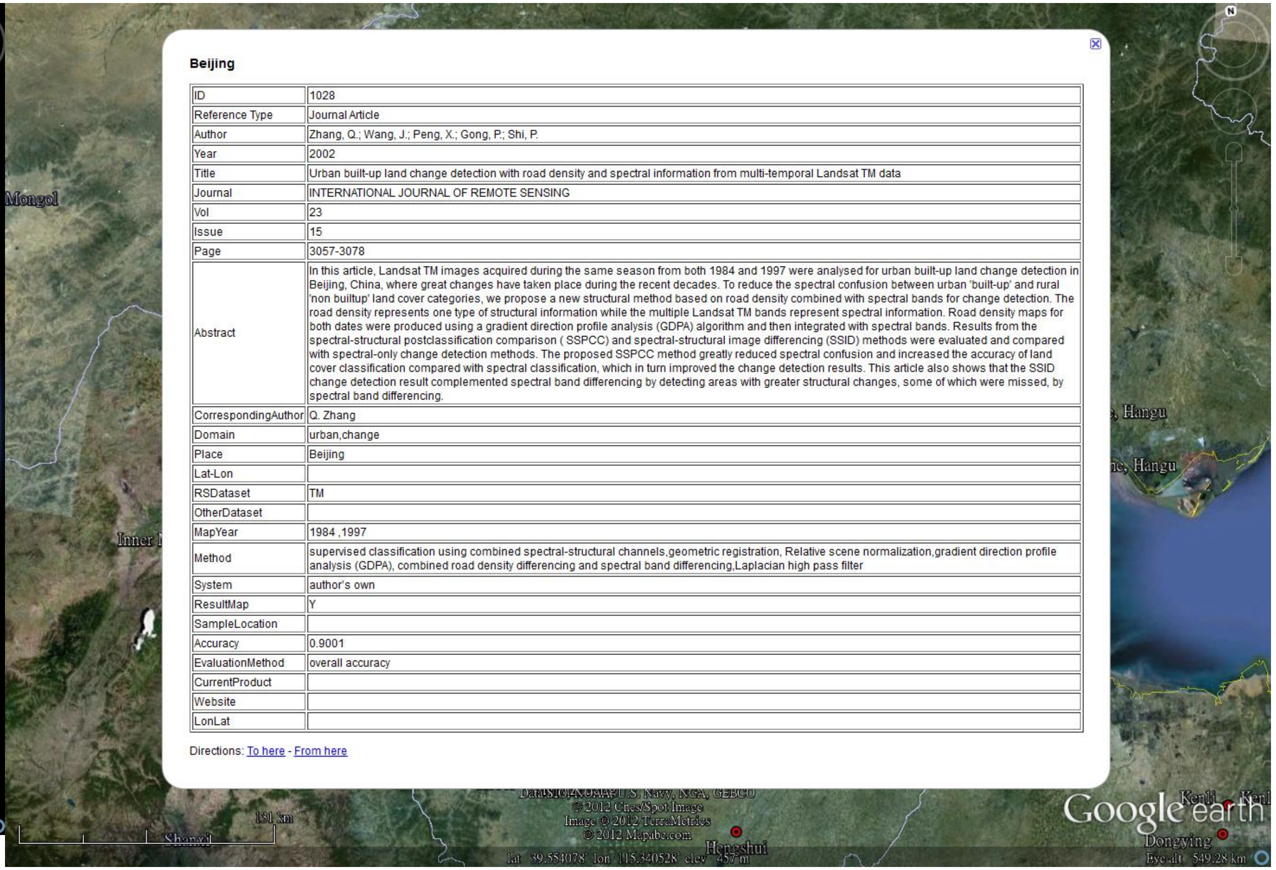
ISI Web of Knowledge (http://apps.isiknowledge.com/).

Query: "*Topic=("land cover" and "mapping") OR Topic=("land cover" and "classification") OR Topic=("remote sensing" and "classification") Timespan=All Years. Databases=SCI-EXPANDED, SSCI.*"

The following information (if exists) was extracted from each paper:

- (1) research domain; (2) place name; (3) latitude/longitude; (4) boundary of study area; (5) remote sensing data; (6) other dataset; (7) years of datasets for mapping; (8) classification algorithm; (9) classification system; (10) resultant map; (11) sample locations; (12) classification accuracy; (13) how the accuracy is evaluated; (14) existing global land-cover product was evaluated; (15) websites.

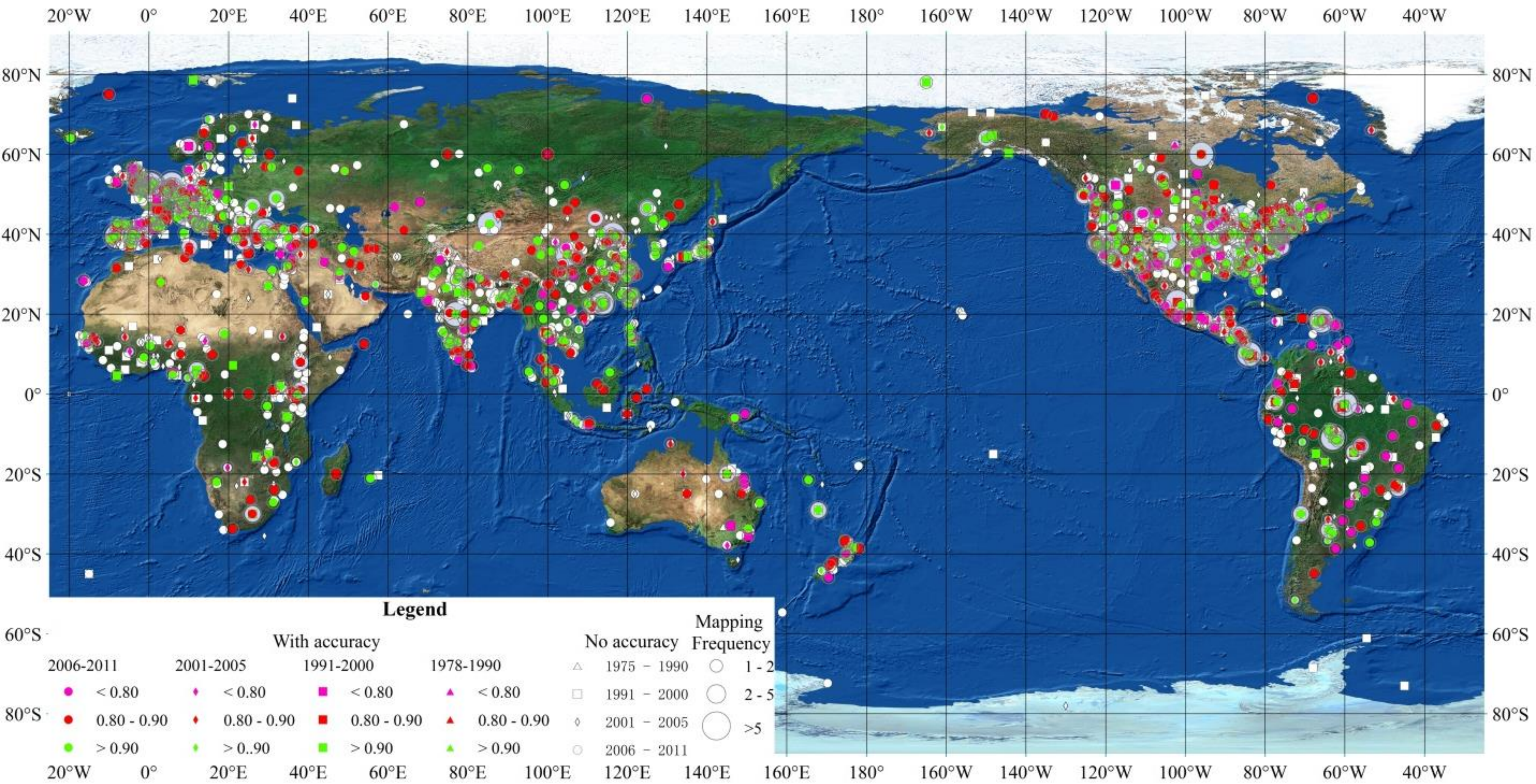
Spatialized literature database


Beijing

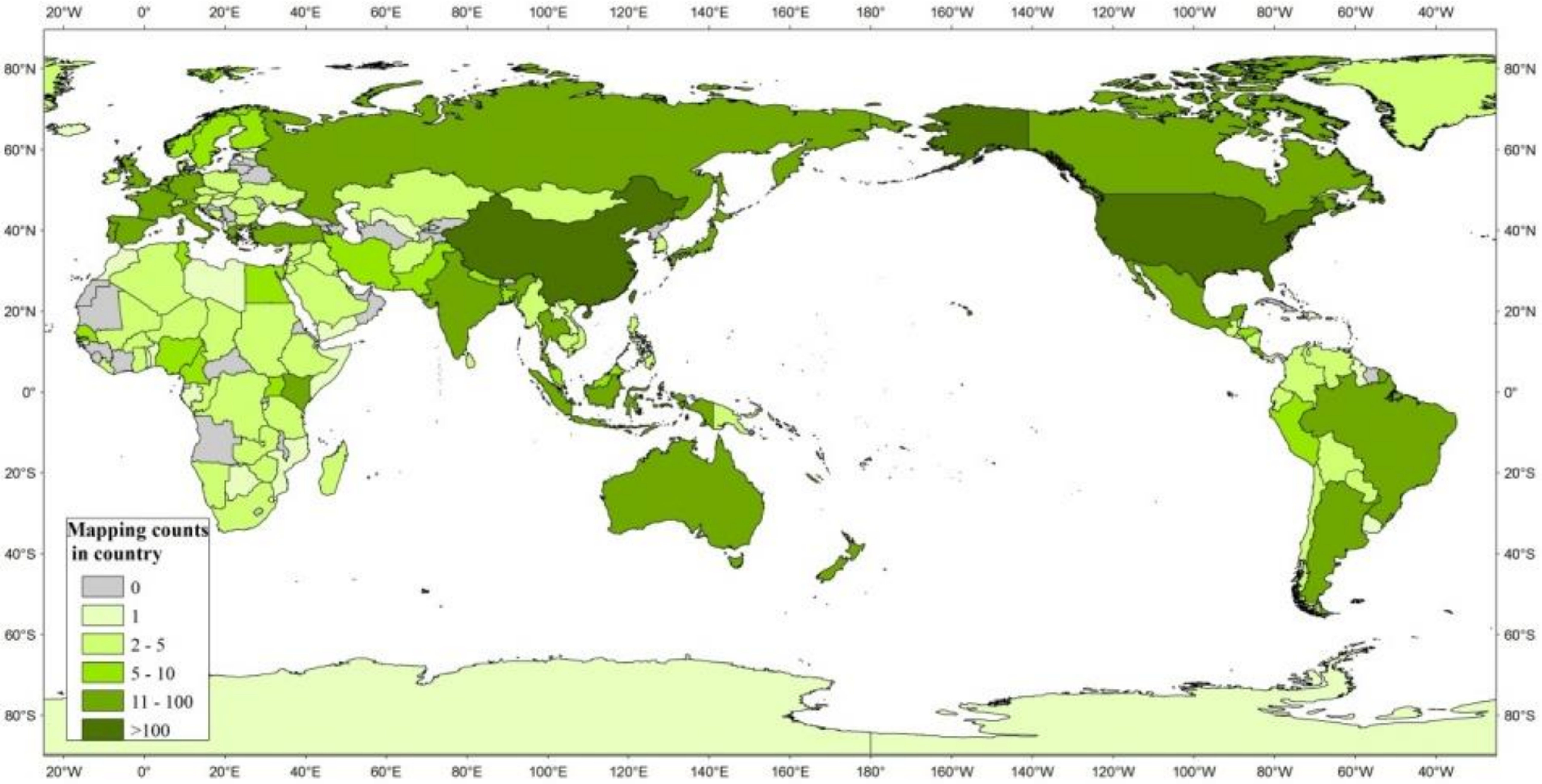
ID	1028
Reference Type	Journal Article
Author	Zhang, Q.; Wang, J.; Peng, X.; Gong, P.; Shi, P.
Year	2002
Title	Urban built-up land change detection with road density and spectral information from multi-temporal Landsat TM data
Journal	INTERNATIONAL JOURNAL OF REMOTE SENSING
Vol	23
Issue	15
Page	3057-3078
Abstract	In this article, Landsat TM images acquired during the same season from both 1984 and 1997 were analysed for urban built-up land change detection in Beijing, China, where great changes have taken place during the recent decades. To reduce the spectral confusion between urban 'built-up' and rural 'non builtup' land cover categories, we propose a new structural method based on road density combined with spectral bands for change detection. The road density represents one type of structural information while the multiple Landsat TM bands represent spectral information. Road density maps for both dates were produced using a gradient direction profile analysis (GDPA) algorithm and then integrated with spectral bands. Results from the spectral-structural postclassification comparison (SSPCC) and spectral-structural image differencing (SSID) methods were evaluated and compared with spectral-only change detection methods. The proposed SSPCC method greatly reduced spectral confusion and increased the accuracy of land cover classification compared with spectral classification, which in turn improved the change detection results. This article also shows that the SSID change detection result complemented spectral band differencing by detecting areas with greater structural changes, some of which were missed, by spectral band differencing.
CorrespondingAuthor	Q. Zhang
Domain	urban,change
Place	Beijing
Lat-Lon	
RSDataset	TM
OtherDataset	
MapYear	1984 ,1997
Method	supervised classification using combined spectral-structural channels,geometric registration, Relative scene normalization,gradient direction profile analysis (GDPA), combined road density differencing and spectral band differencing,Laplacian high pass filter
System	author's own
ResultMap	Y
SampleLocation	
Accuracy	0.9001
EvaluationMethod	overall accuracy
CurrentProduct	
Website	
LonLat	

Directions: To here - From here

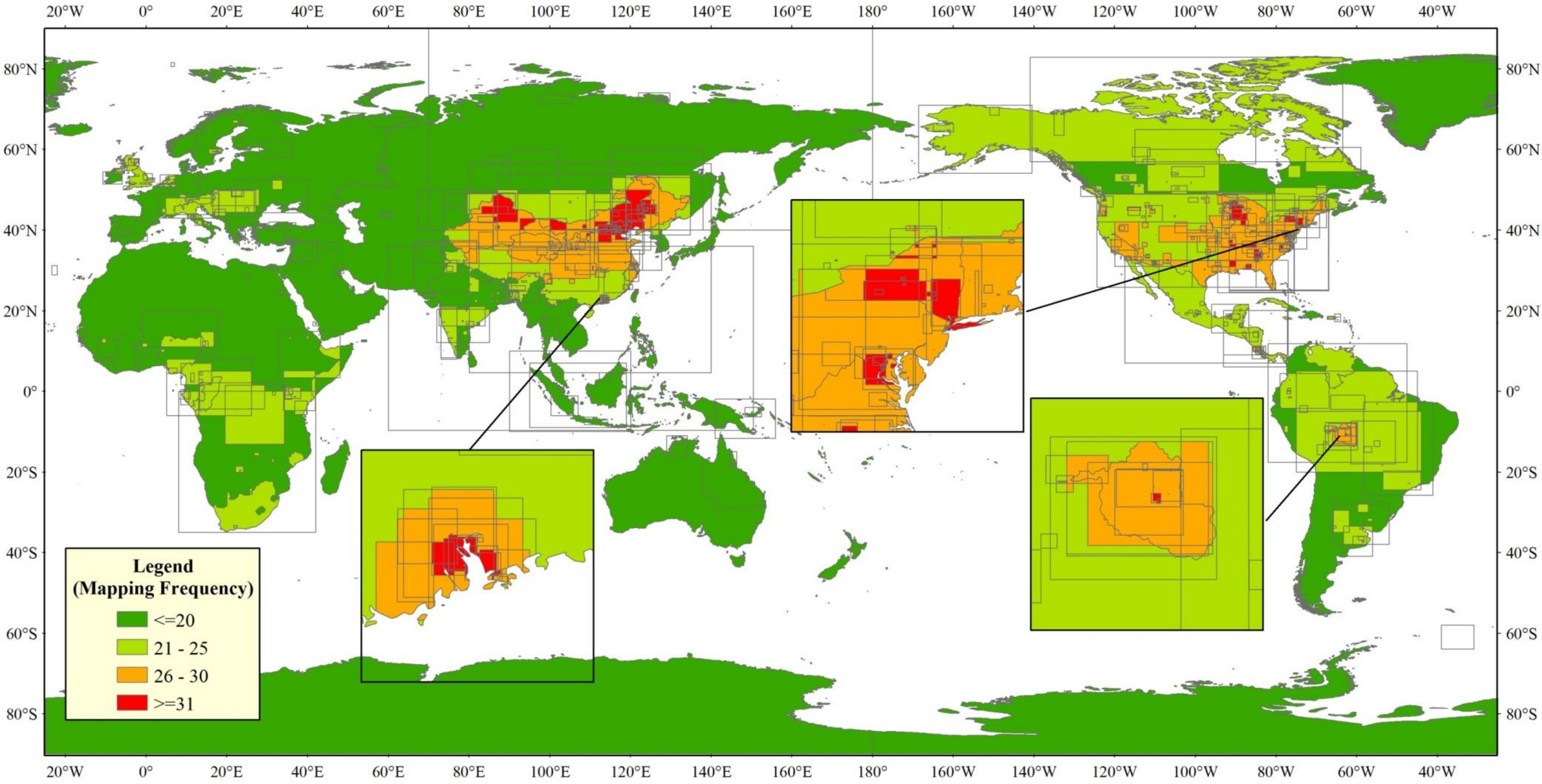
Yu et al. in preparation



Yu et al. in preparation



Yu et al. in preparation



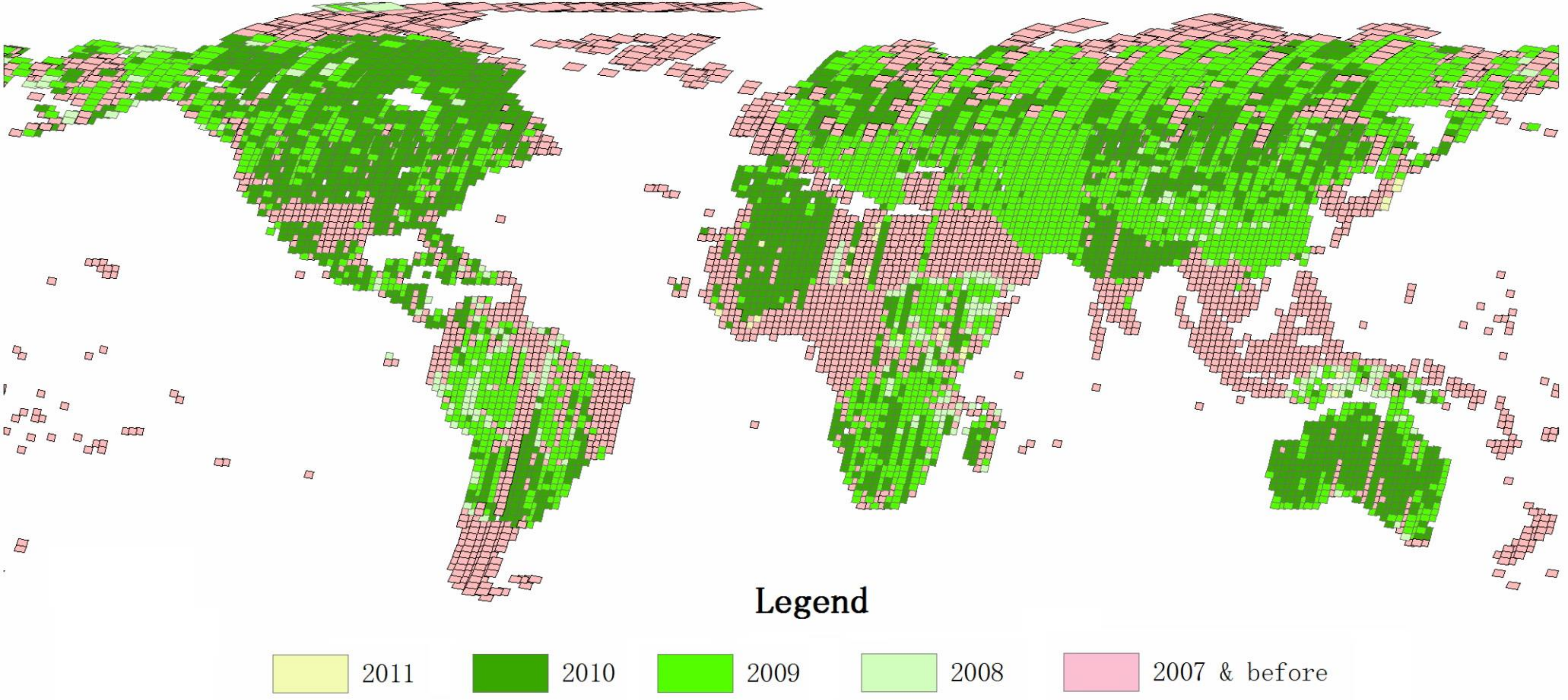
Legend
(Mapping Frequency)
<=20
21 - 25
26 - 30
>=31
20°W
0°
20°E
40°E
60°E
80°E
100°E
120°E
140°E
160°E
180°
160°W
140°W
120°W
100°W
80°W
60°W
40°W
80°N
60°N
40°N
20°N
0°
20°S
40°S
60°S
80°S

The first 30m global land cover map

5 components:

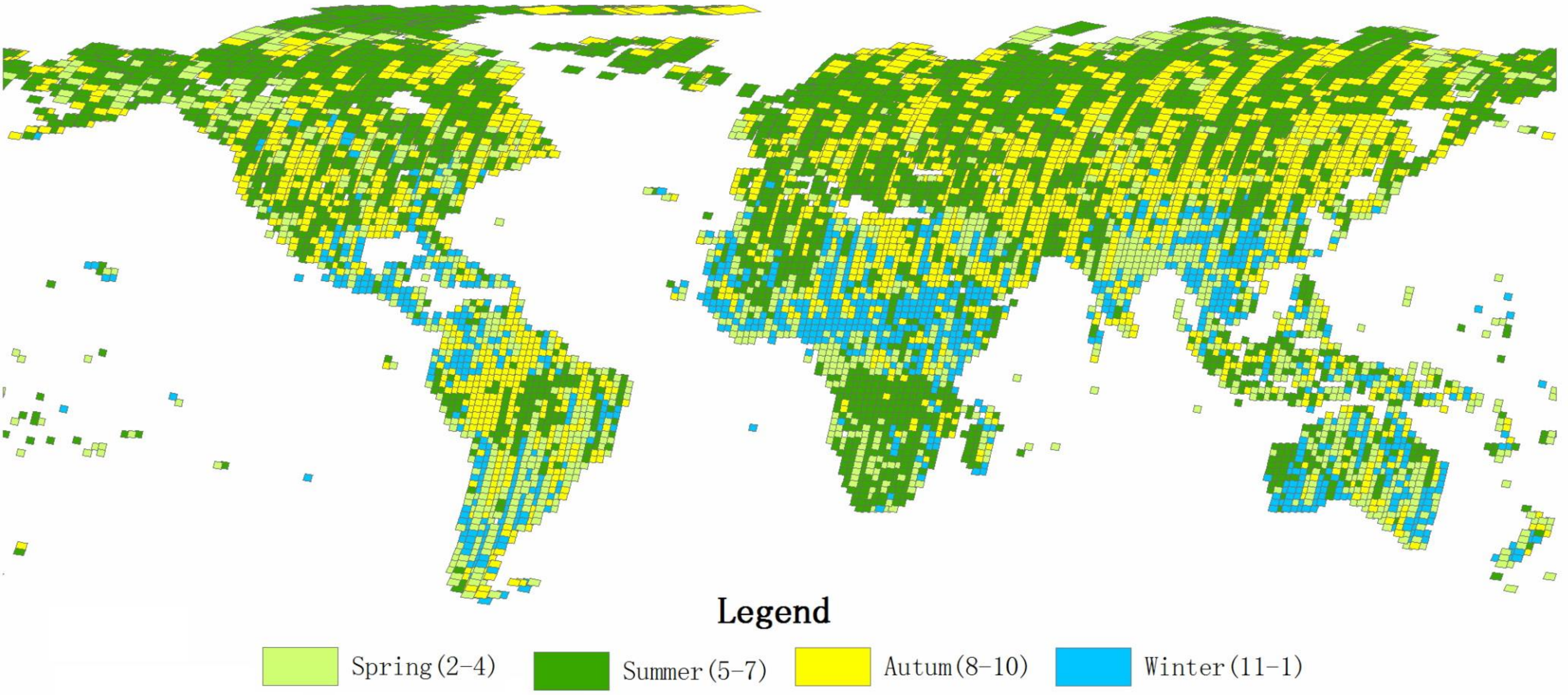
(1) Remote sensing dataset
(2) Classification system (legend)
(3) Sample
(4) Algorithm
(5) Validation

RS data collection



Gong et al., 2013

Spatial-temporal data distribution



Gong et al., 2013

Classification scheme developing

Physical, natural features – land cover

Support use of multi-source data

Web-based information and literature as much as possible

A balanced use of machine and human interpretation

Compatible with existing classification schemes

Minimum mapping unit determined based on work volume and data characteristics

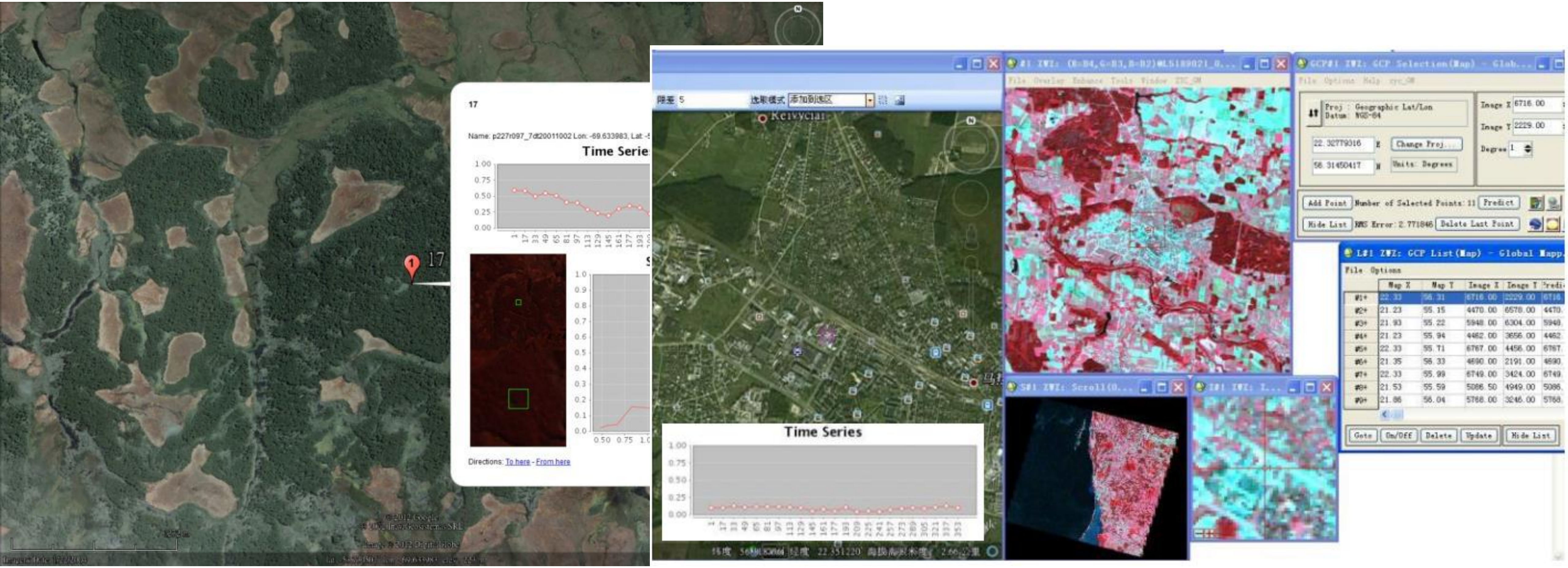
Gong et al., 2013

UN LCCS	Definition	Land cover type 10 classes	Form	PFT	Closure	Hgt	Remark
11	Post flooding or irrigated cr	Cropland (1)		C3/C4			Corn/Wheat
14	Rainfed croplands	Cropland		C3/C4			Corn/Wheat
20	Mosaic cropland/vege	Crop/Vege		C3/C4	50-70%		
30	Mosaic vege/cropland	Crop/Vege		C3/C4	50-70%		
40	>15%-BL-EG/Semi D Fo>5m	Forest (2)	BL EG/Dec (1)		>15%	>5m	
50	>40% BL D Fo>5m	Forest	BL D (2)		>40%	>5m	
60	15—40% BL D Fo>5m	Forest	BL D		15-40%	>5m	
70	>40% NL EG Fo>5m	Forest	NL EG (3)		>40%	>5m	
90	15-40% NL D EG Fo>5m	Forest	BL D/EG		15-40%	>5m	
100	>15% ML Fo > 5m	Forest	BL/NL		>15%	>5m	
110	MoFo/Sh (50-70%)/G(20-50)	Fo/Shrub/Gras		C3/C4	50-70%		
120	MoG(50-70)/F/Sh(20-50)	Fo/Shr/Grass		C3/C4	50-70%		
130	>15% Sh(<5m)	Shr (3)		C3/C4	>15%	<5m	
140	>15% G	Grassland (4)		C3/C4	>15%		Tall/S/Tundra
150	<15% Vege	Vege		C3/C4	<15%		
160	>40% BL Fo Reg Fl Fresh	Inland fo wetl	BL		>40%		
170	>40% Semi BL EG reg Fl Sal	Coastal fo wetl	BL Semi D/EG		>40%		
180	>15% vege on reg Fl or w log	Marshland (5)	Watered veg (4)	C3/C4	>15%		Inund/Floa
190	Artificial (urban > 50%)	Urban (6)			>50%		Imp/Perv/Roof/
200	Bare	Bare (7)	Wd/Wt form				R/G/Sd/St
210	Water	Water (8)					L/Rv/Riv
220	Permanent Snow/Ice	Snow/Ice (9)					

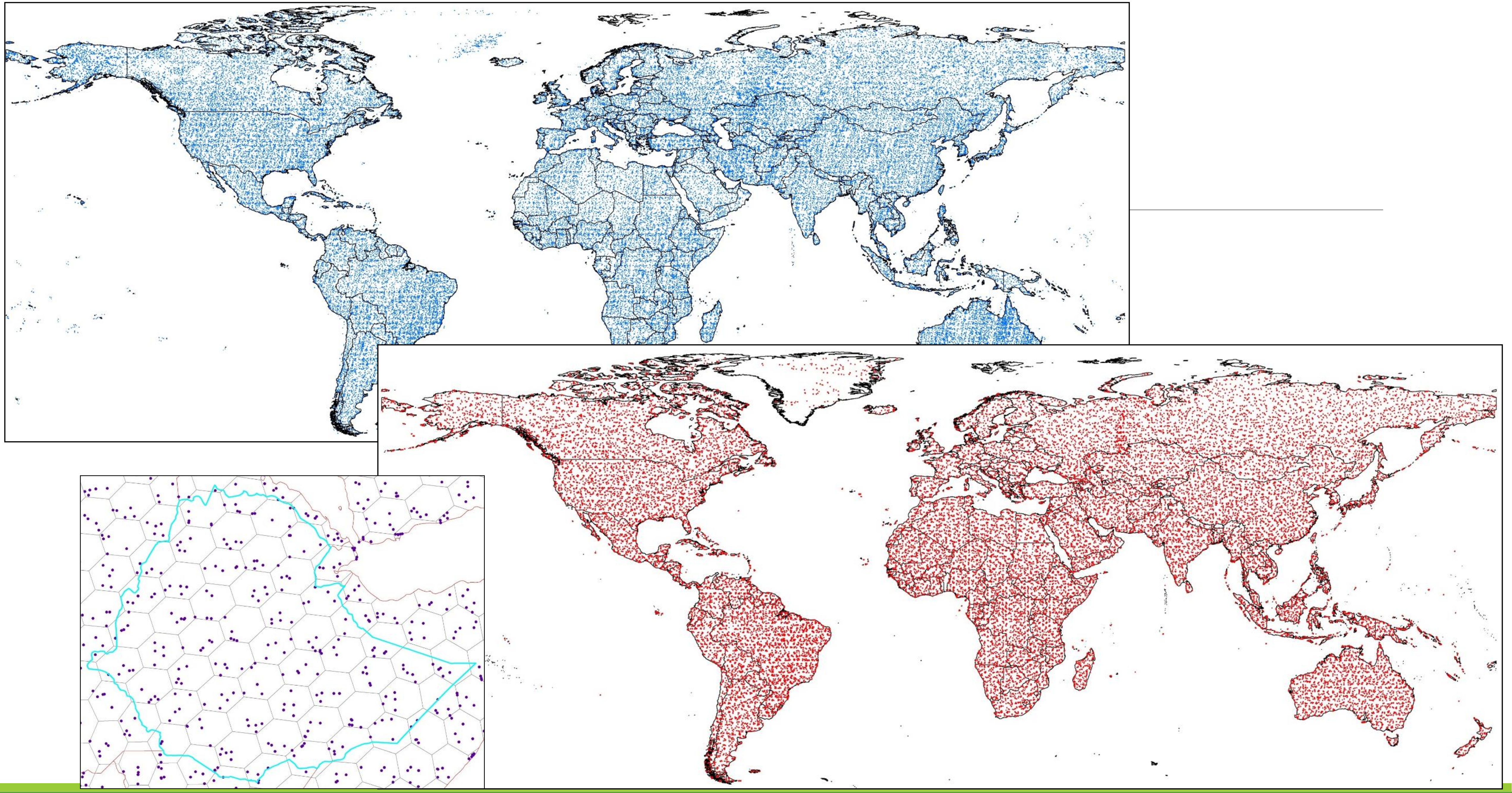
Classification System

Gong et al., 2013

Sample collection

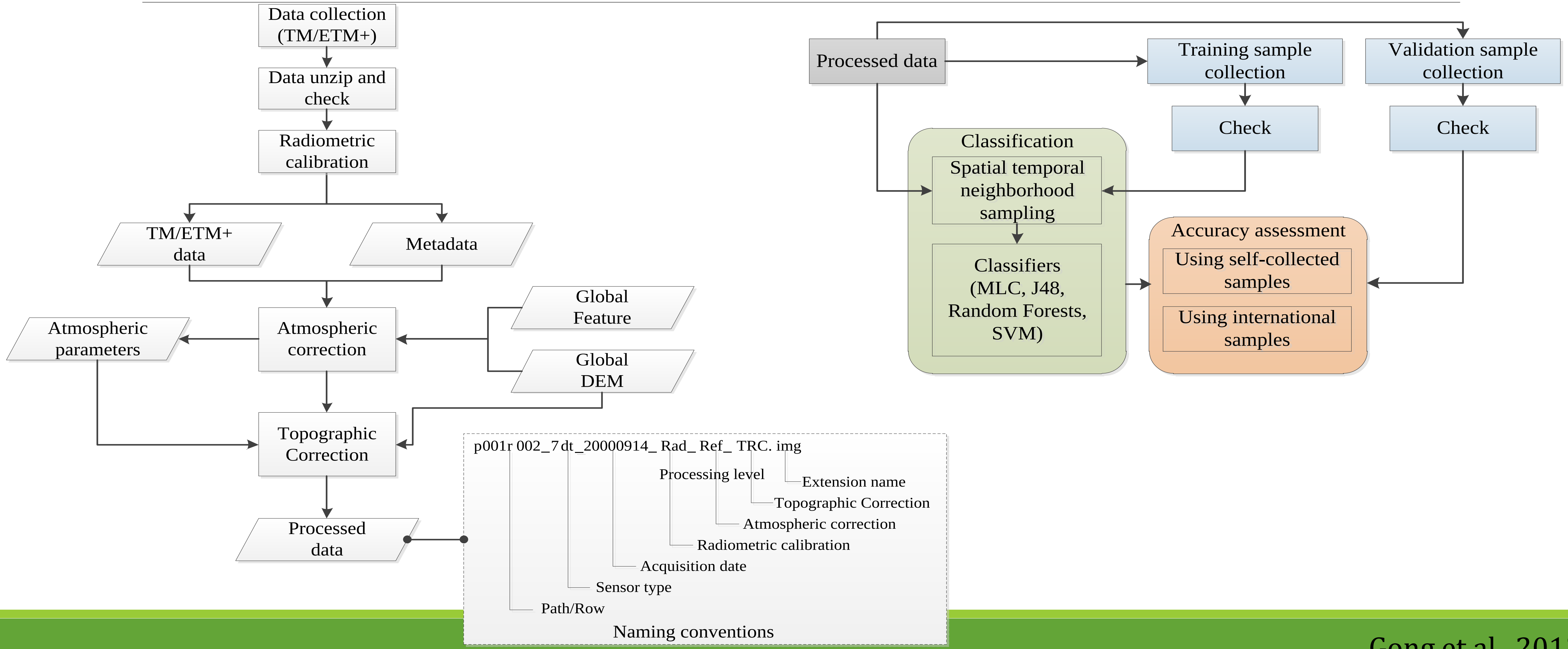


Gong et al., 2013

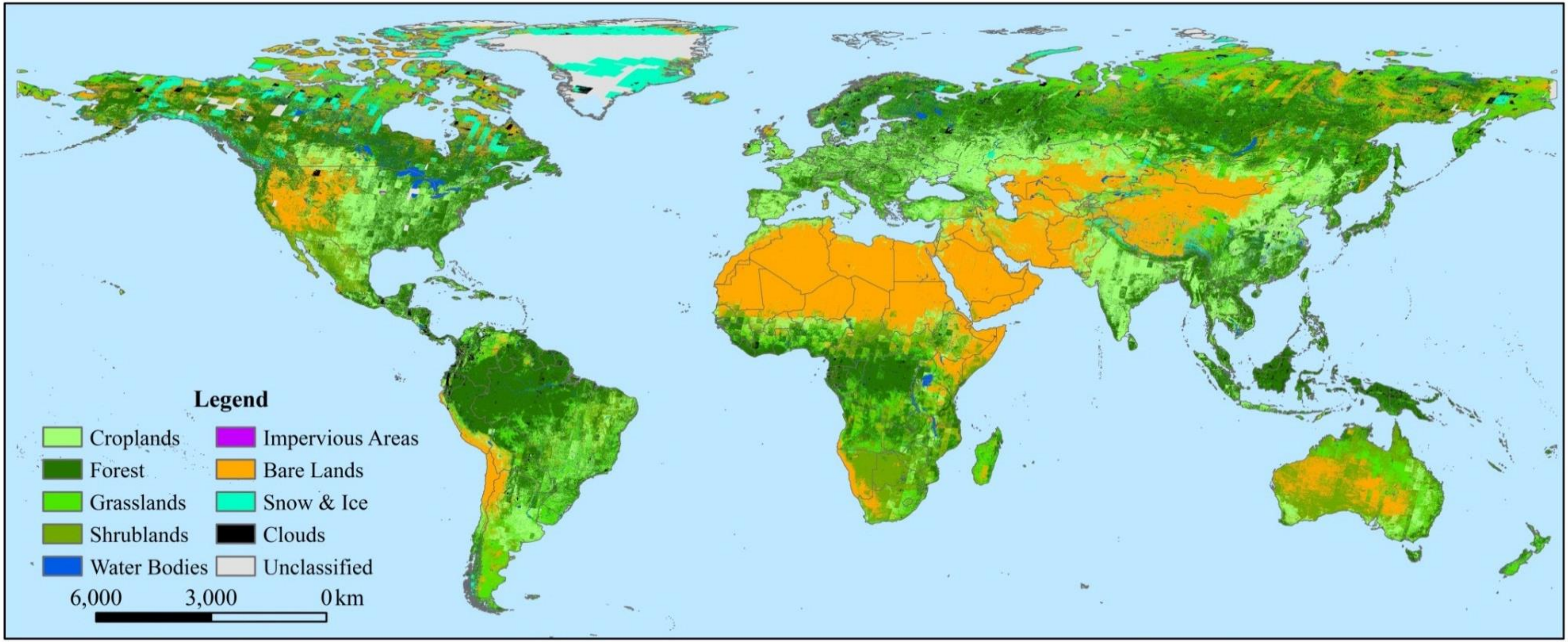


Gong et al., 2013

Workflow

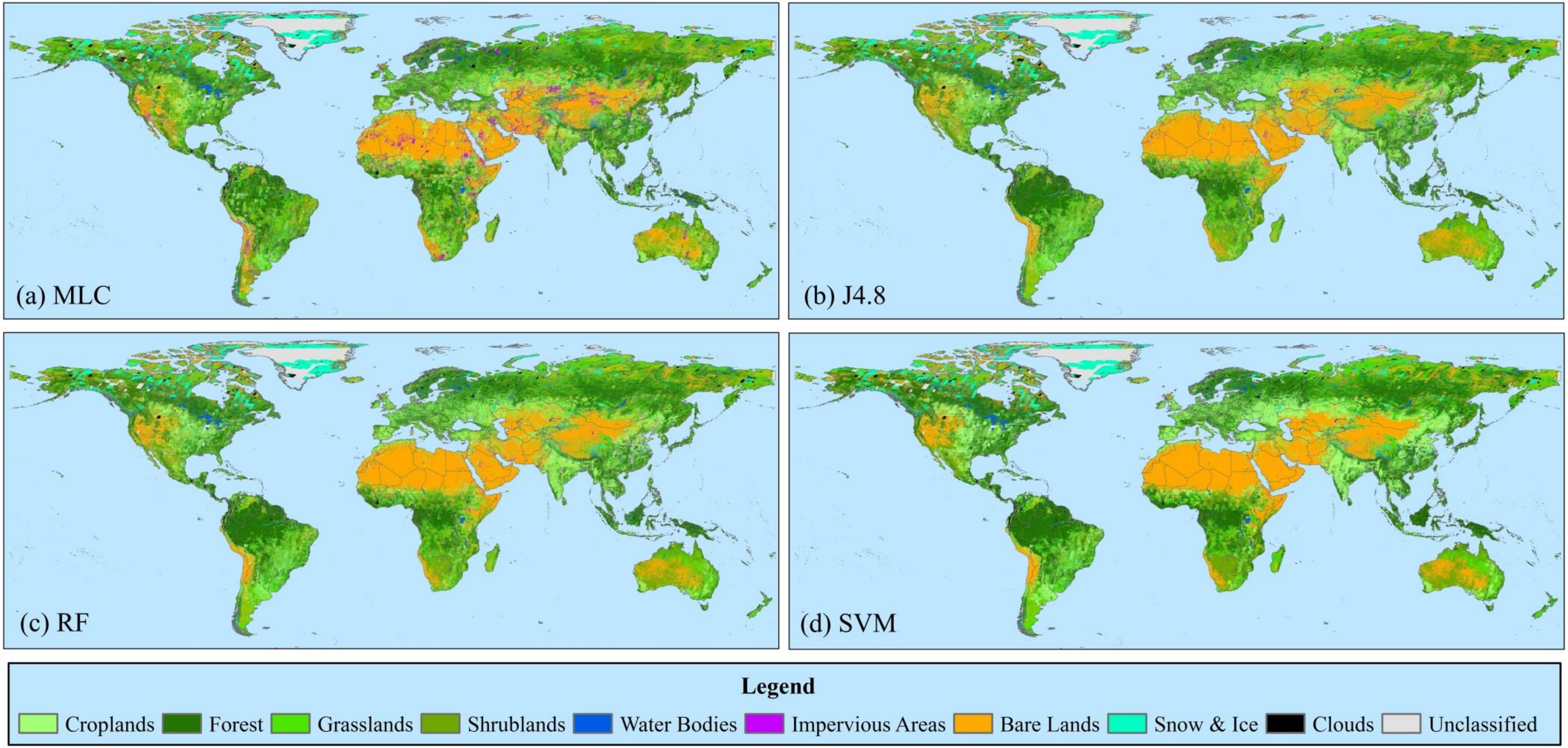


Gong et al., 2013



Gong et al., 2013

Global land cover products



Gong et al., 2013

Continent-wide classification accuracies

All samples, N=36630

	SVM	RF	MLC	J48
Africa	69.54%	64.32%	57.28%	62.28%
Asia	67.49%	62.21%	55.73%	59.89%
Europe	62.03%	56.40%	49.84%	53.37%
North America	57.90%	54.74%	50.63%	53.52%
Oceania	58.87%	52.92%	51.78%	50.88%
South America	66.65%	60.22%	52.32%	58.95%
Global	64.89%	59.83%	53.88%	57.88%

Good quality samples, N=8629

	SVM	RF	MLC	J48
Africa	69.75%	64.34%	57.57%	62.81%
Asia	77.65%	72.42%	65.60%	69.04%
Europe	64.41%	57.63%	53.51%	55.21%
North America	65.44%	61.78%	56.44%	61.33%
Oceania	68.55%	60.48%	61.29%	58.06%
South America	69.27%	63.00%	57.73%	60.45%
Global	**71.54%**	**66.08%**	**60.09%**	**63.84%**

Gong et al., 2013

Classification accuracy for the top 20 countries

Country	Area Rank	J48	MLC	RF	SVM	Ave
Russia	1	54.76%	52.78%	57.78%	**62.93%**	57.06%
Canada	2	58.90%	54.71%	60.69%	**63.52%**	59.46%
United States of America	3	49.15%	48.12%	50.26%	**52.33%**	49.96%
China	4	56.95%	55.94%	60.61%	**66.23%**	59.93%
Brazil	5	58.57%	49.94%	59.45%	**65.48%**	58.36%
Australia	6	47.61%	49.45%	49.88%	**55.90%**	50.71%
India	7	49.49%	44.95%	52.40%	**56.06%**	50.73%
Argentina	8	46.50%	46.78%	47.48%	**55.60%**	49.09%
Kazakhstan	9	**41.91%**	39.88%	40.32%	38.87%	40.25%
Democratic Republic of the Congo	10	62.35%	47.21%	63.55%	**69.12%**	60.56%
Algeria	11	93.02%	86.82%	94.57%	**96.90%**	92.83%
Mexico	12	41.37%	36.92%	40.51%	**50.26%**	42.27%
Saudi Arabia	13	91.65%	88.52%	93.74%	**97.08%**	92.75%
Indonesia	14	65.48%	52.51%	68.41%	**78.24%**	66.16%
Sudan	15	76.80%	71.73%	77.87%	**80.80%**	76.80%
Libya	16	90.63%	93.23%	93.75%	**97.66%**	93.82%
Iran	17	75.58%	67.53%	76.88%	**83.38%**	75.84%
Mongolia	18	**57.19%**	50.34%	55.48%	53.08%	54.02%
Peru	19	75.78%	58.20%	75.39%	**78.13%**	71.88%
Chad	20	71.48%	66.55%	73.24%	**78.87%**	72.54%

Gong et al., 2013

Further improvements

Improving vegetation types

- Integrate time series MODIS and auxiliary datasets using a segmentation based approach
- Time series analysis of global land cover and plant trait
- Object-based global land cover mapping

Improving non-vegetation types

- Map aggregation

Improving vegetation accuracy

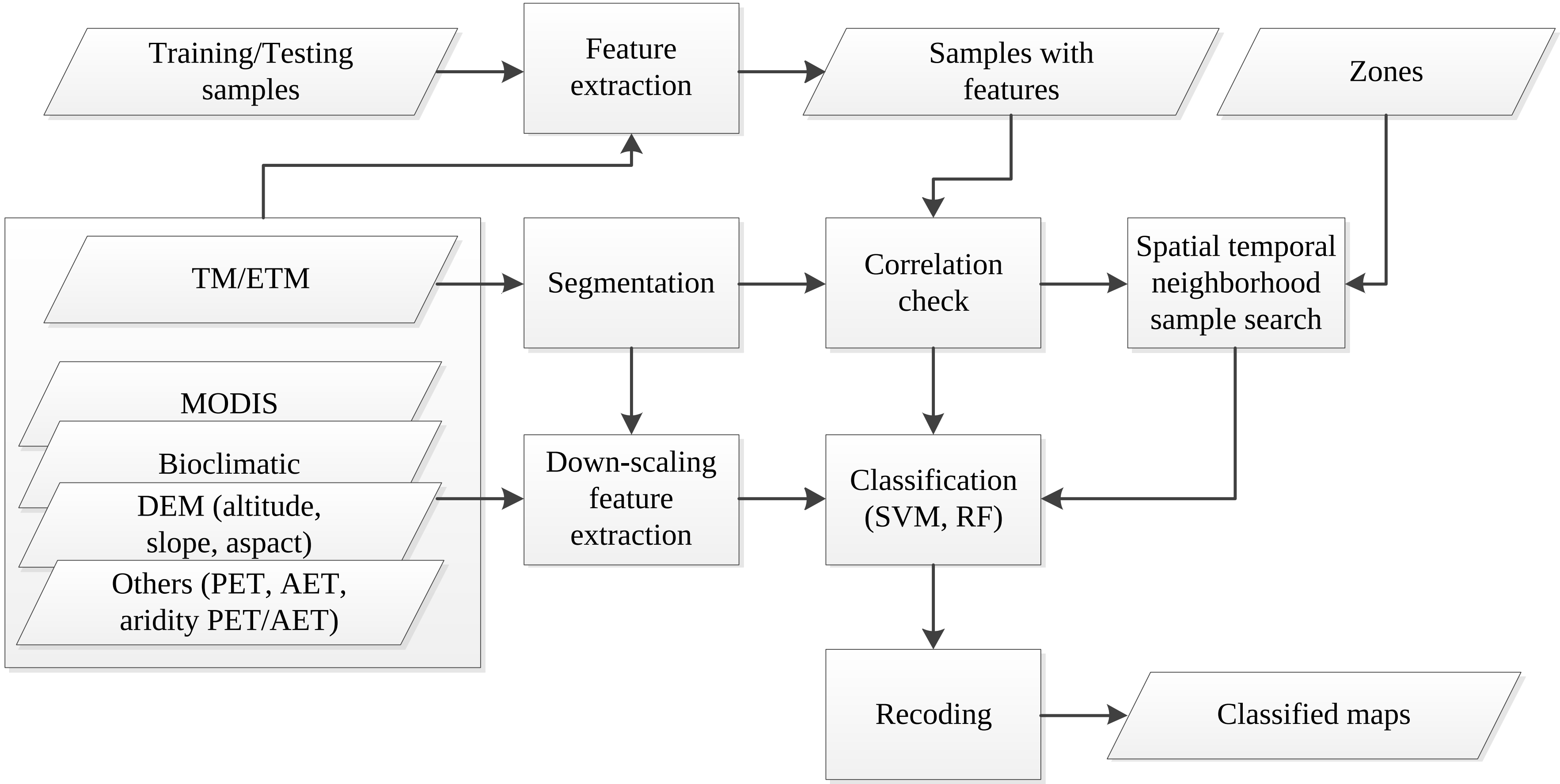
Seasonal variation in the “greenness” of vegetation described by temporal dynamics of vegetation indices is important for mapping of vegetation covered surfaces.

All existing 1km and sub-km global land cover products utilized time series NDVI/EVI data

- AVHRR NDVI (DeFries & Townshend, 1994; DeFries et al., 1998; Loveland et al., 2000; Hansen et al., 2000)
- MODIS EVI (Friedl et al., 2002, 2010; Tateishi et al., 2011)
- SPOT-VEGETATION NDVI (Bartholeme & Belward, 2005)
- MERIS-FR NDVI (Bicheron et al., 2008; Arino et al., 2010)

FROM-GLC-seg Workflow

- Multi-source
- Multi-resolution
- Down-scaling
- Segmentation
- STS (spatial temporal search)
- SVM
- RF



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MODIS vegetation index

MODerate-resolution **I**maging **S**pectroradiometer (**MODIS**) is a payload scientific instrument capturing data in 36 spectral bands ranging in wavelength from 0.4 µm to 14.4 µm and at varying spatial resolutions (250 m, 500 m, 1 km).

Vegetation index – a indicator of plant health, productivity, and density, e.g. NDVI, EVI

VI time series - a temporal curve that summarizes the various stages that green vegetation undergoes during a complete growing season.

MODIS vegetation index product – MOD13Q1

- EVI
- 250m
- 16Day

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Bioclimatic variables

Bioclimatic variables (Hijmans et al., 2005)

- Generated through interpolation of average monthly climate data from weather stations on a 30 arc-seconds resolution grid.
  - BIO1 = Annual Mean Temperature; BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp))
  - BIO3 = Isothermality (BIO2/BIO7) (* 100) ; BIO4 = Temperature Seasonality (standard deviation *100)
  - BIO5 = Max Temperature of Warmest Month ; BIO6 = Min Temperature of Coldest Month
  - BIO7 = Temperature Annual Range (BIO5-BIO6); BIO8 = Mean Temperature of Wettest Quarter
  - BIO9 = Mean Temperature of Driest Quarter; BIO10 = Mean Temperature of Warmest Quarter
  - BIO11 = Mean Temperature of Coldest Quarter; BIO12 = Annual Precipitation
  - BIO13 = Precipitation of Wettest Month; BIO14 = Precipitation of Driest Month
  - BIO15 = Precipitation Seasonality (Coefficient of Variation); BIO16 = Precipitation of Wettest Quarter
  - BIO17 = Precipitation of Driest Quarter; BIO18 = Precipitation of Warmest Quarter
  - BIO19 = Precipitation of Coldest Quarter

Yu et al., 2013

DEM and soil-water condition maps

DEM (Digital Elevation Model)

- 3 arcs spatial resolution 'hole-filled' SRTM data set was aggregated to 30 arcs using the median value. GTOPO30 database for the areas used where there no SRTM data was available, i.e. north of 60° N (Hijmans et al., 2005)
- Slope calculated
- Aspect calculated

Global aridity and PET (Potential EvapoTranspiration) database (Zomer et al., 2007; Zomer et al., 2008)

- 30 arc seconds
- PET ($PET=0.0023*RA*(Tmean+17.8)*TD^{0.5}$)
- Aridity index (AI=Mean annual precipitation/Mean Annual PET)

Global high-resolution soil-water balance database (Trabucco & Zomer, 2010)

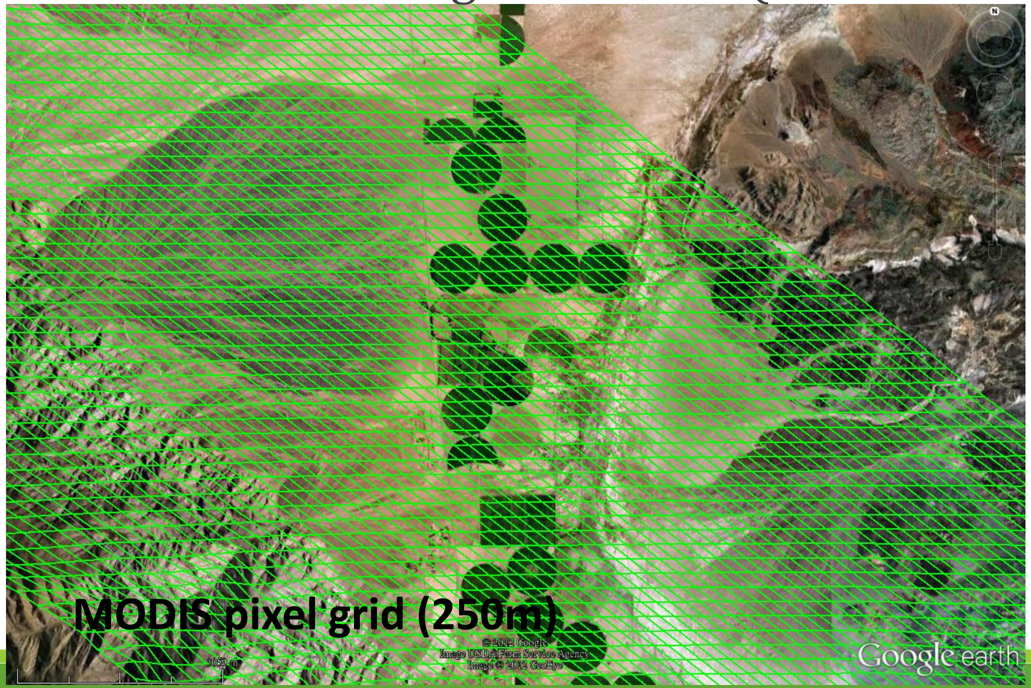
- AET (Actural EvapoTranspiration) (AET=PET*Kveg*Ksoil)
- Priestley-Taylor Alpha (annual AET/PET)

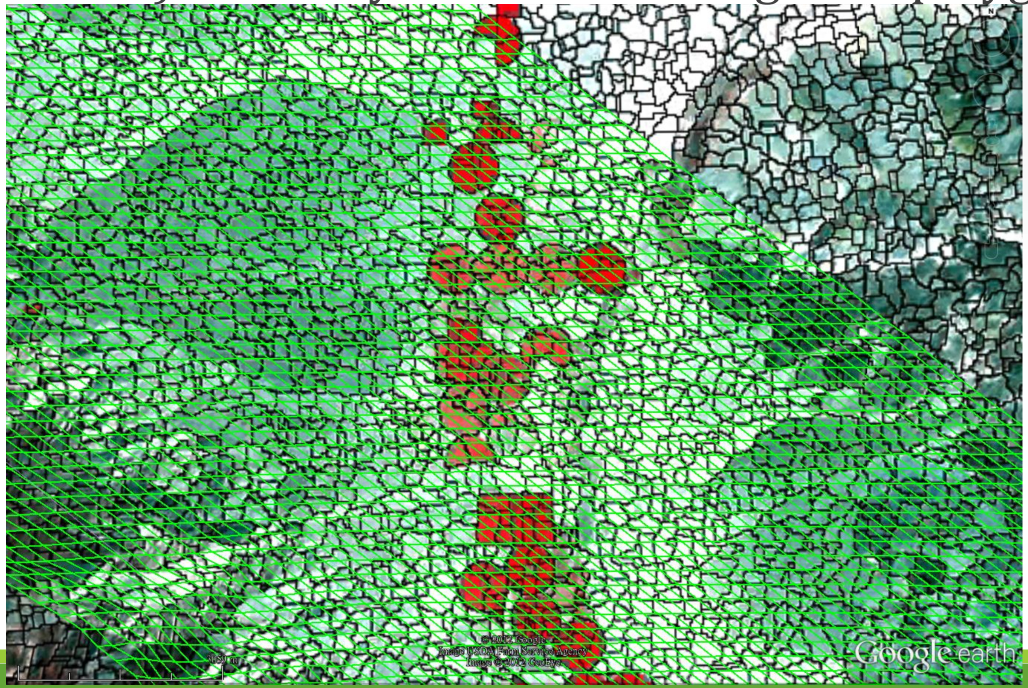
Multi-resolution integration

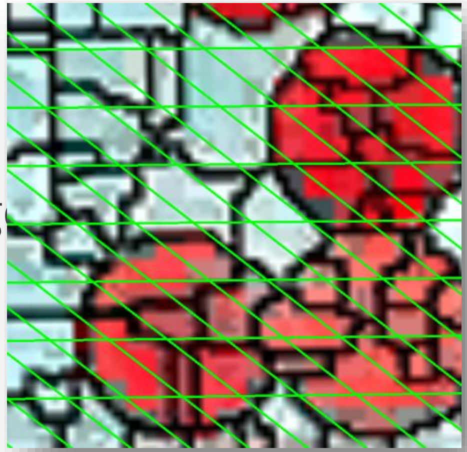
Spatial down-scaling

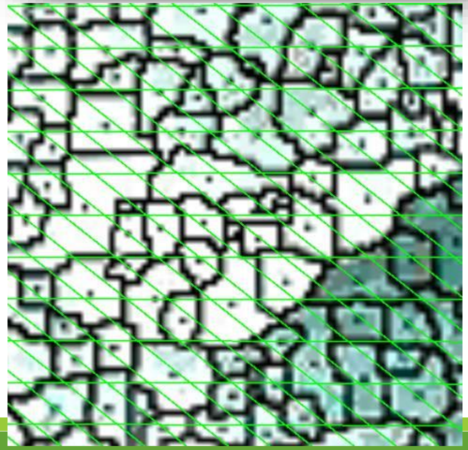
- TM/ETM 30m -> MODIS EVI 250m, Bio/DEM/Soil-Water1km
- Homogeneous polygon (watershed segmentation)

Extracting MODIS EVI (and other features) values by the center of segment polyg









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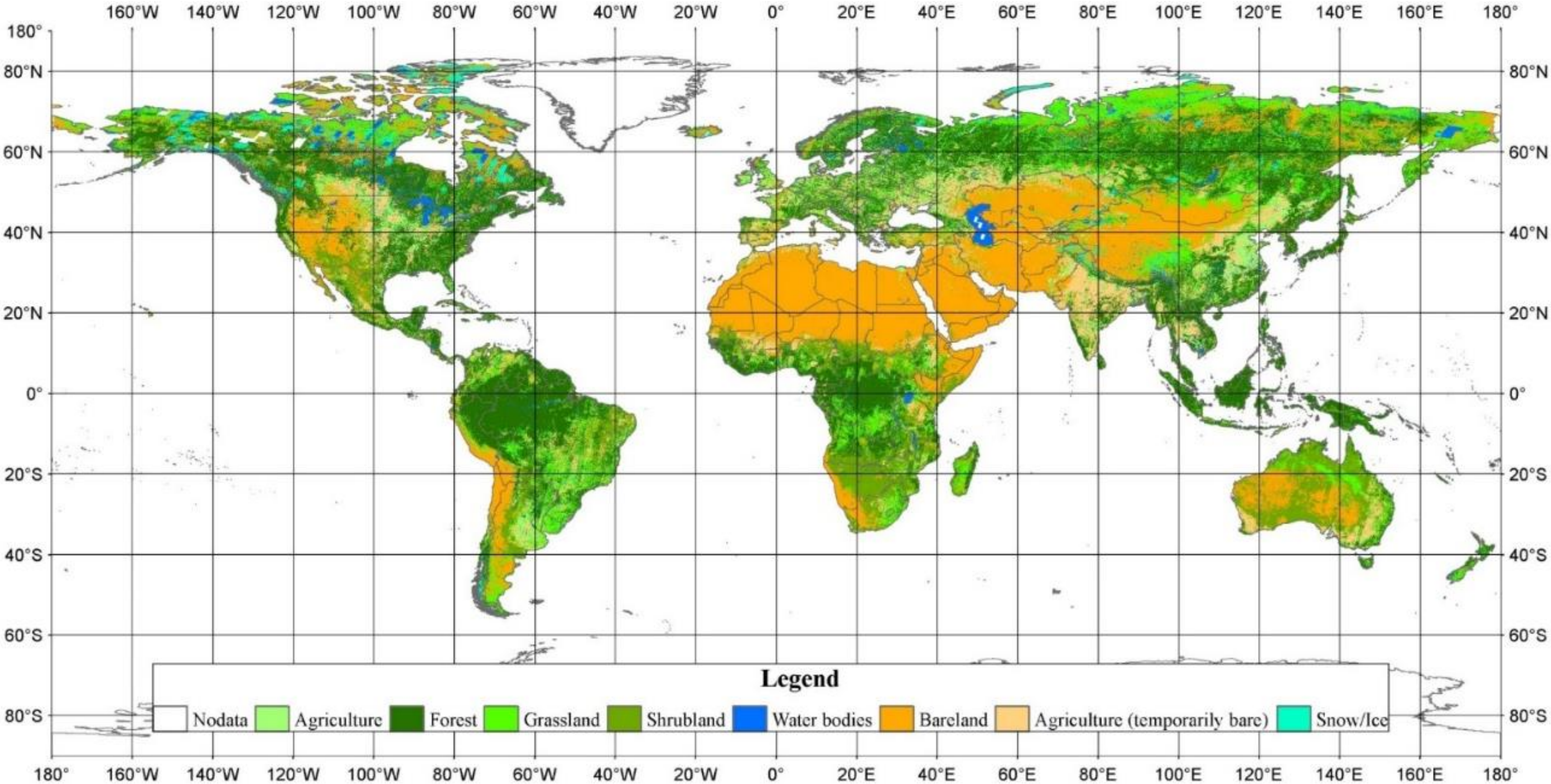
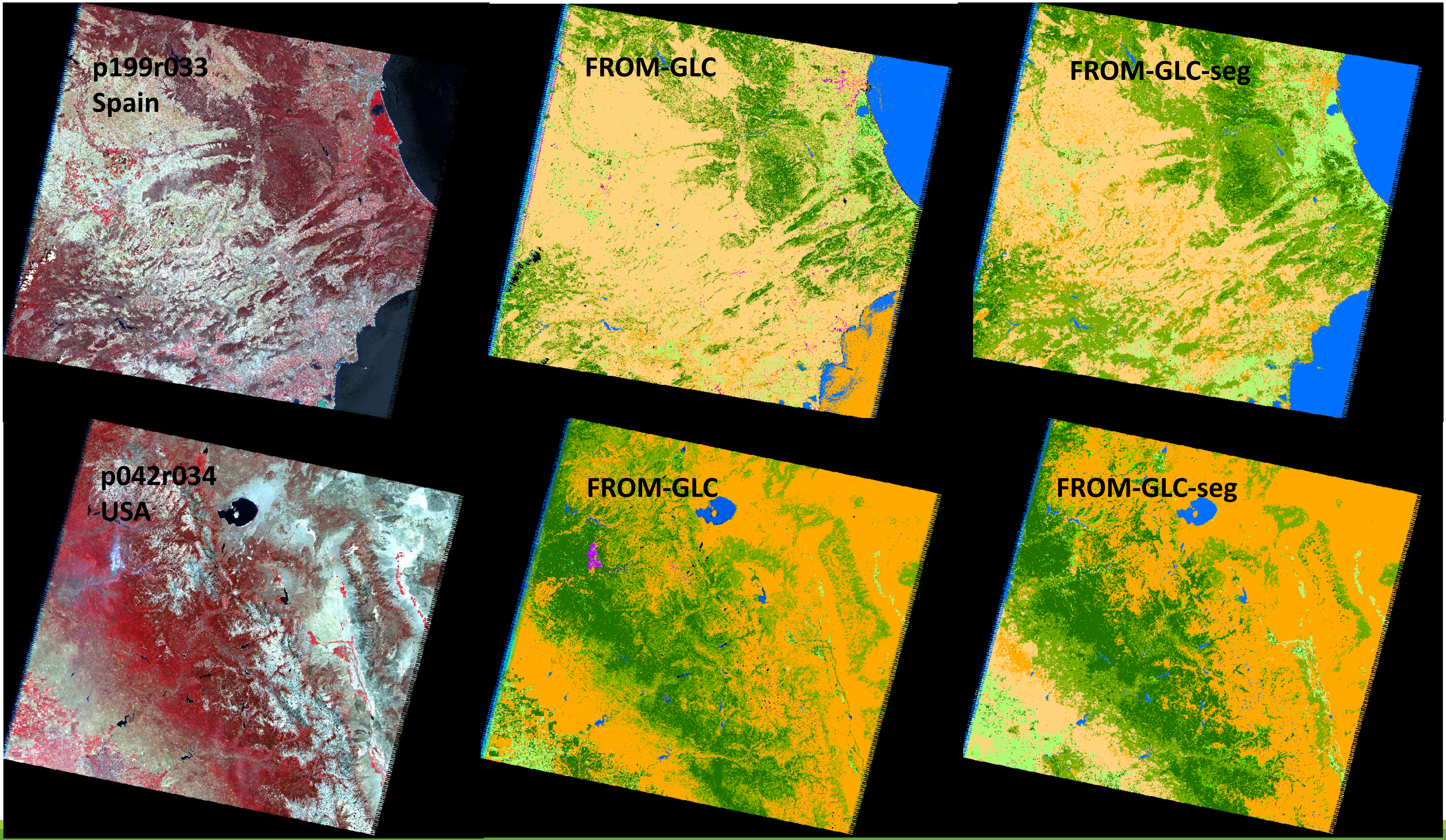
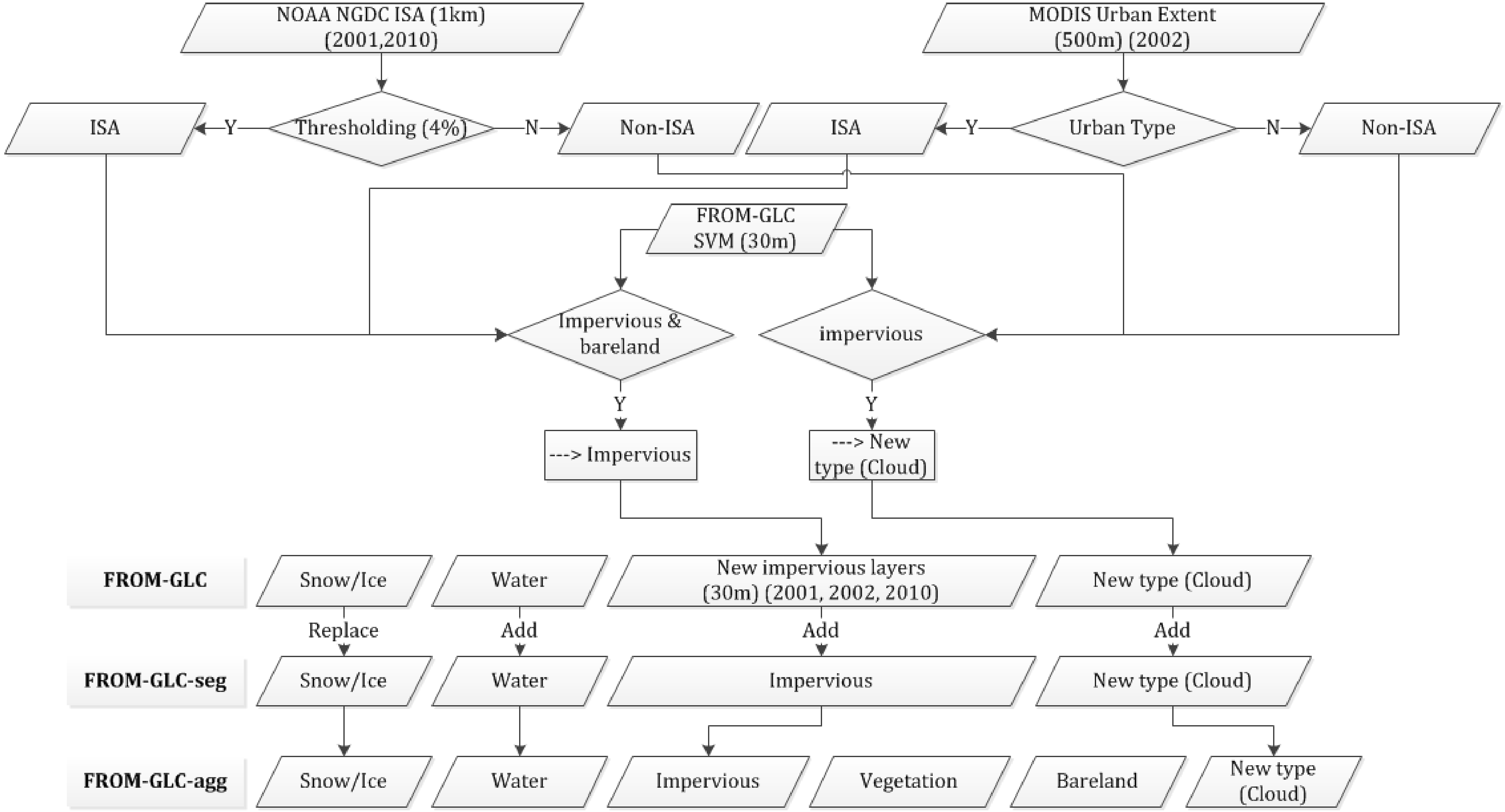

160°W 140°W 120°W 100°W 80°W 60°W 40°W 20°W 0° 20°E 40°E 60°E 80°E 100°E 120°E 140°E 160°E 180°
180° 80°N 60°N 40°N 20°N 0° 20°S 40°S 60°S 80°S
Legend
Nodata
Agriculture
Forest
Grassland
Shrubland
Water bodies
Bareland
Agriculture (temporarily bare)
Snow/Ice

Yu et al., 2013


p199r033
Spain
FROM-GLC
FROM-GLC-seg
p042r034
USA
FROM-GLC
FROM-GLC-seg

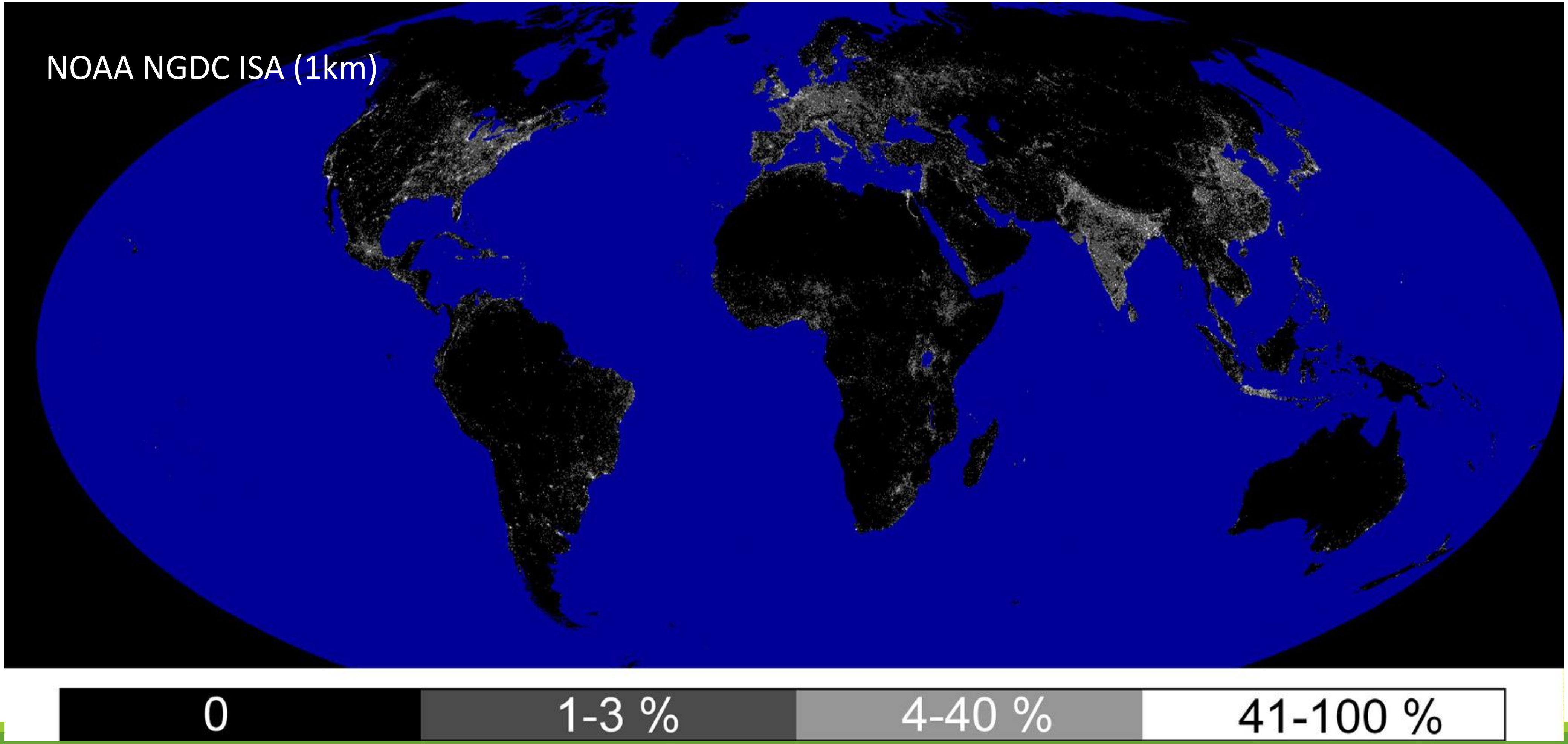
Yu et al., 2013

Map aggregation: FROM-GLC-agg



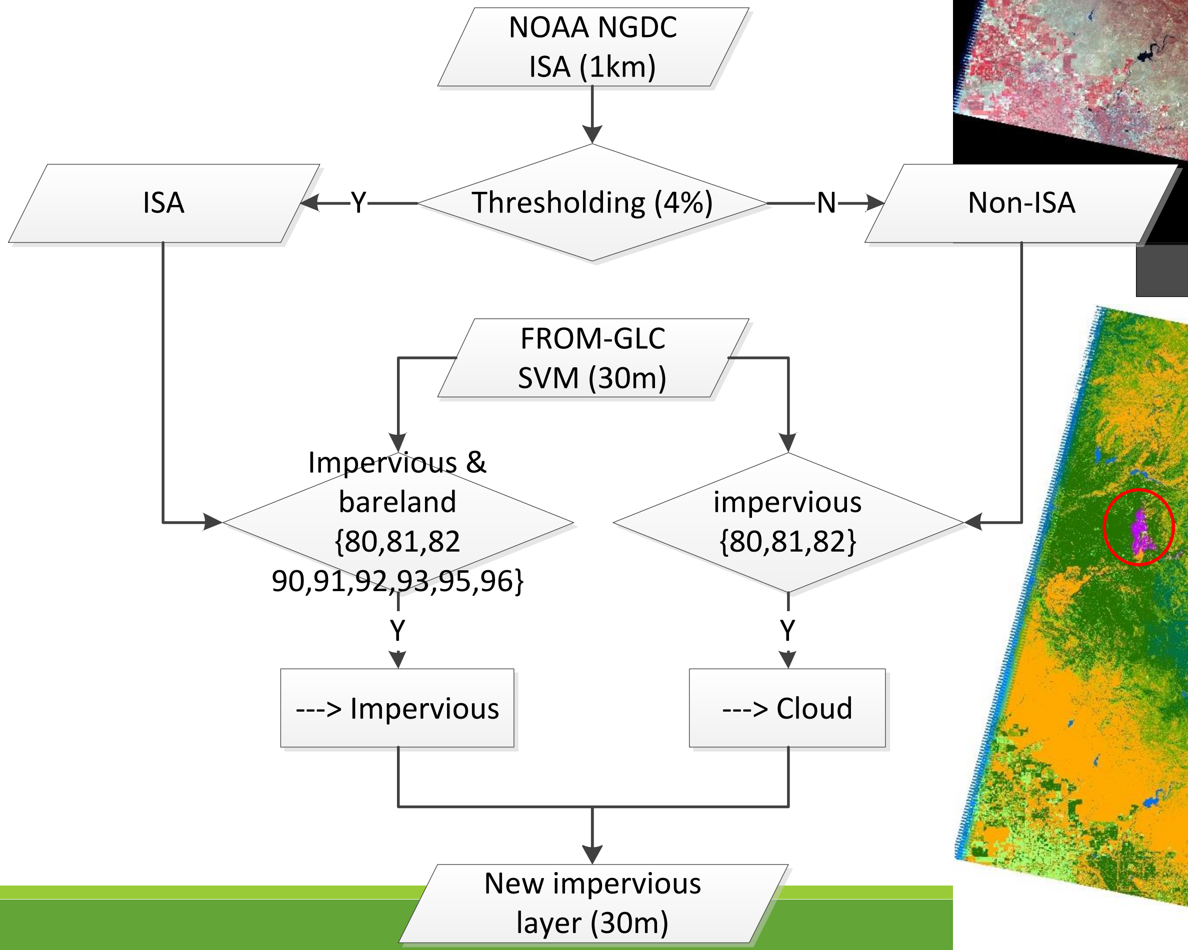
Yu et al., in preparation

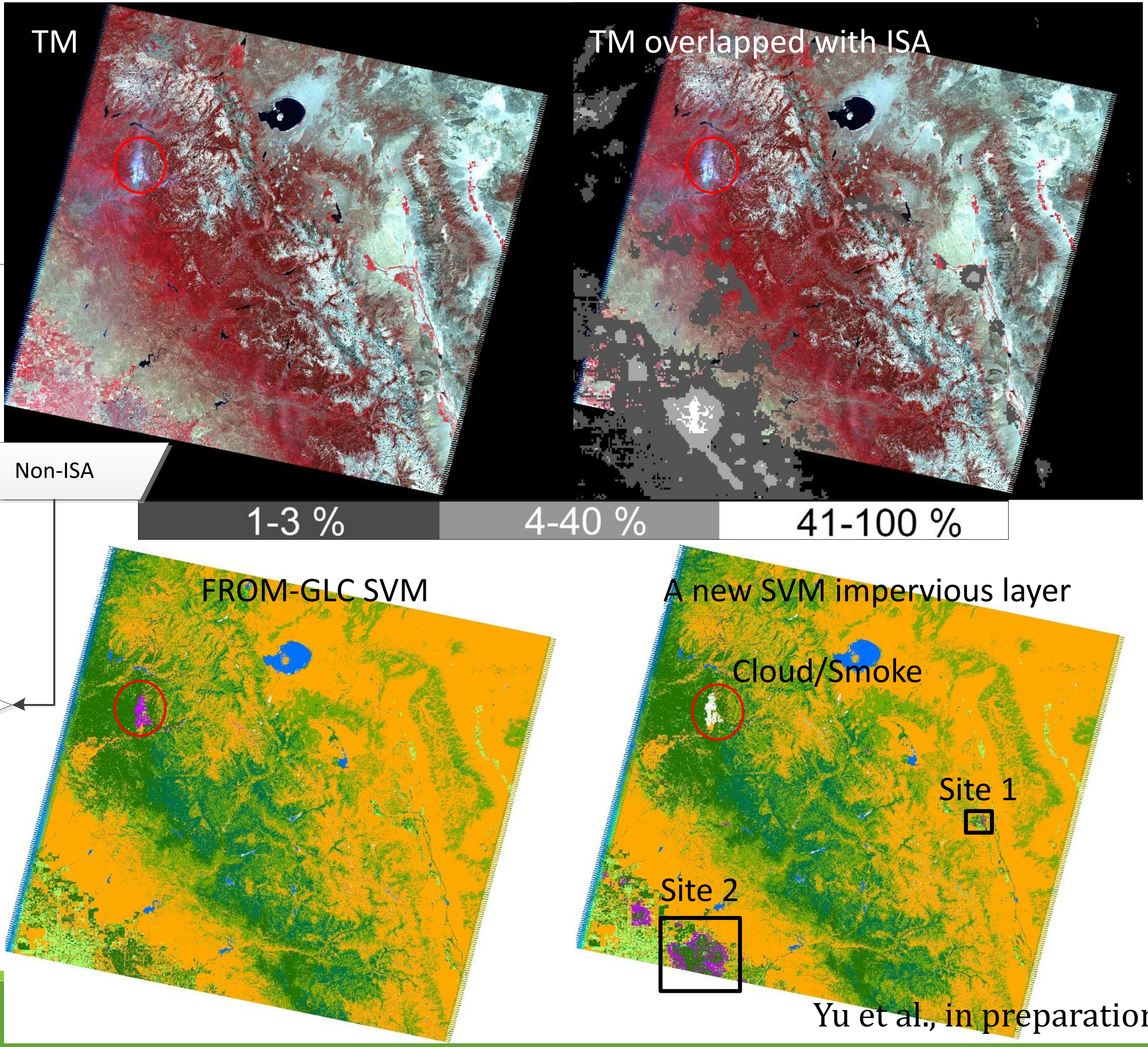
Global impervious surface area (ISA)



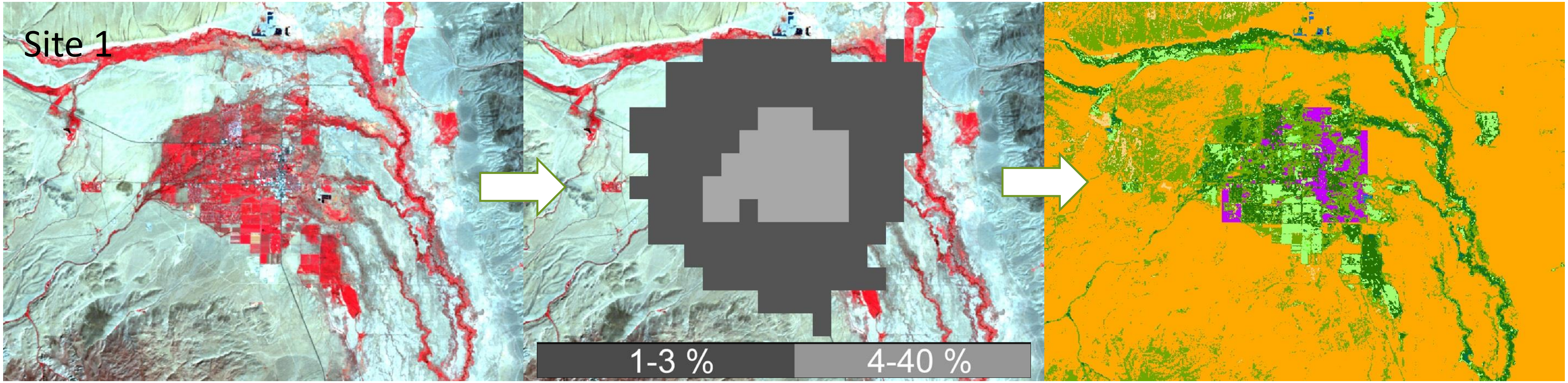
Elvidge et al., 2007. Global distribution and density of constructed impervious surfaces, Remote Sensing, 7: 1962-1979

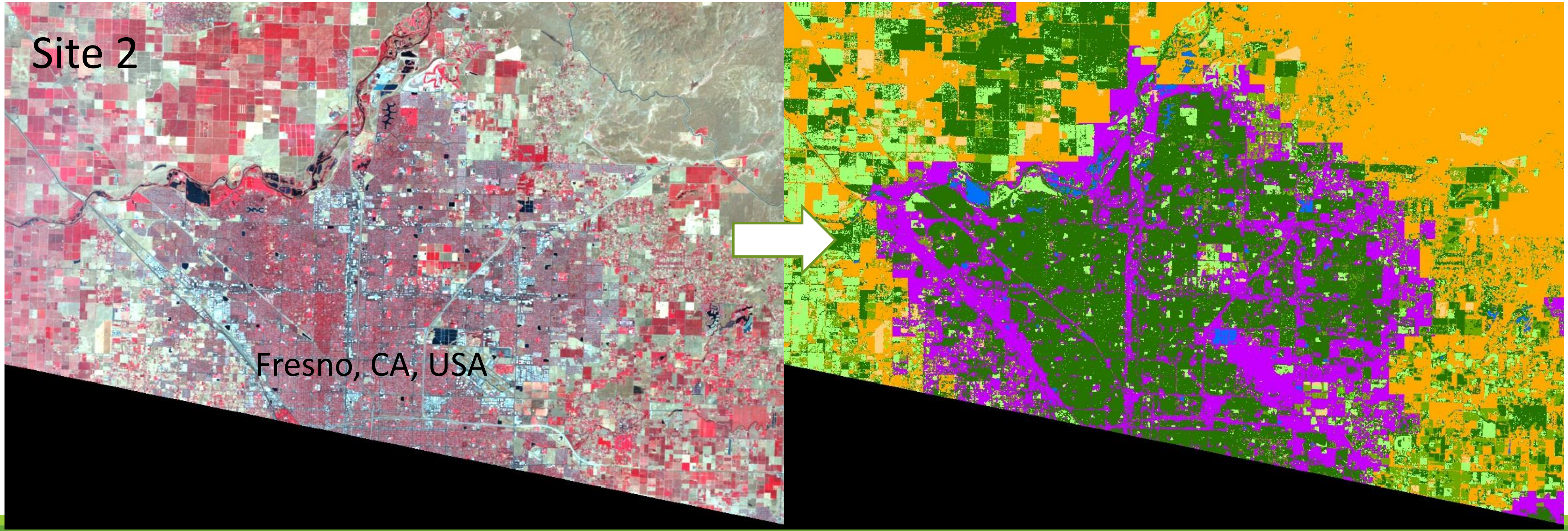
ISA Up-scaling



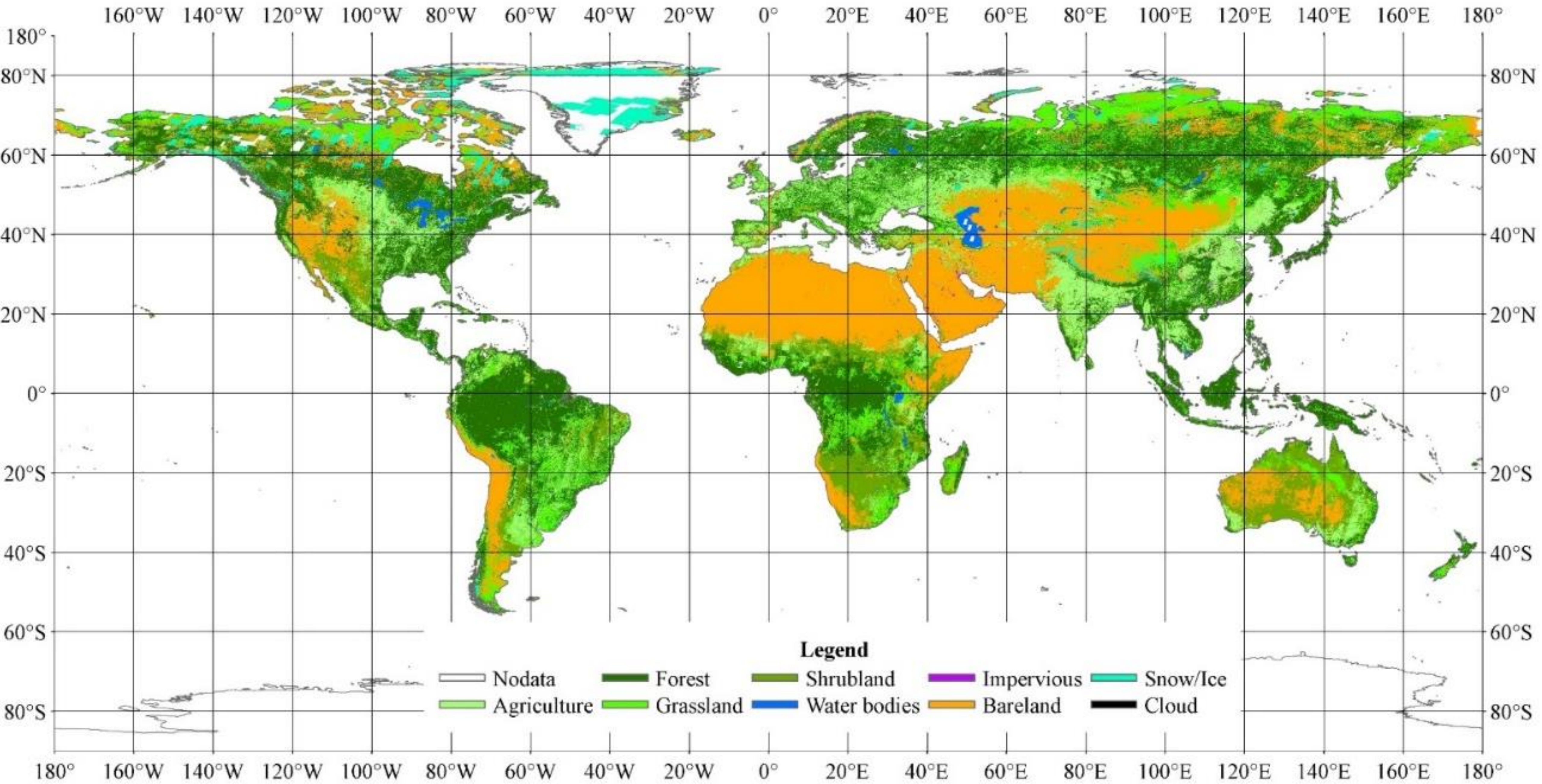


Yu et al., in preparation



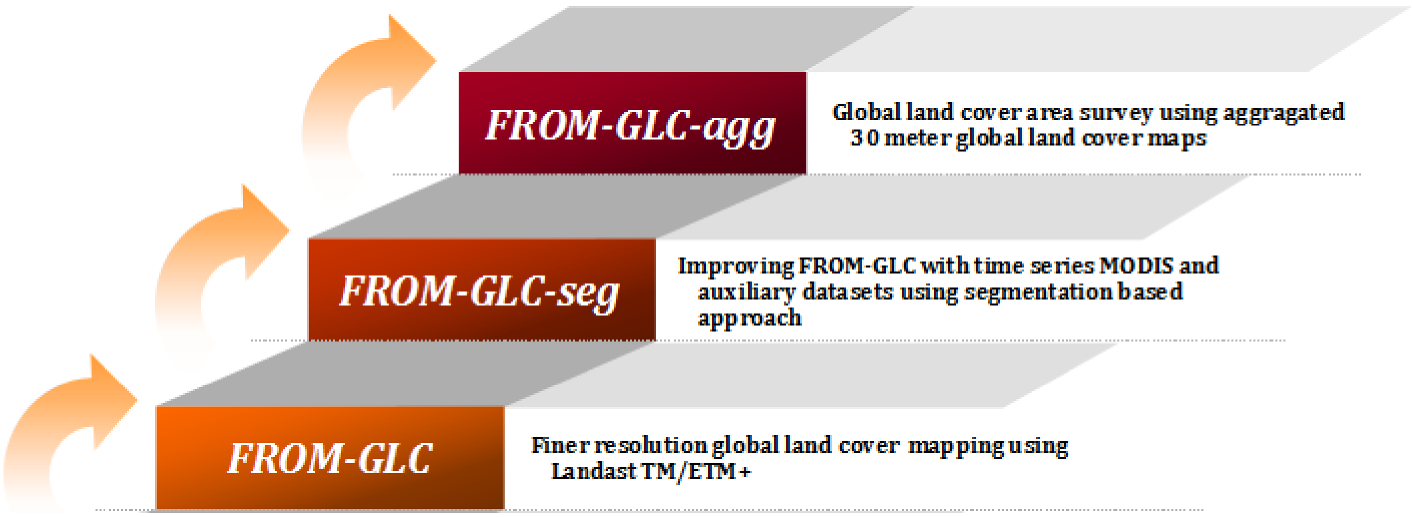


Yu et al., in preparation



Yu et al., in preparation

Three global land cover products



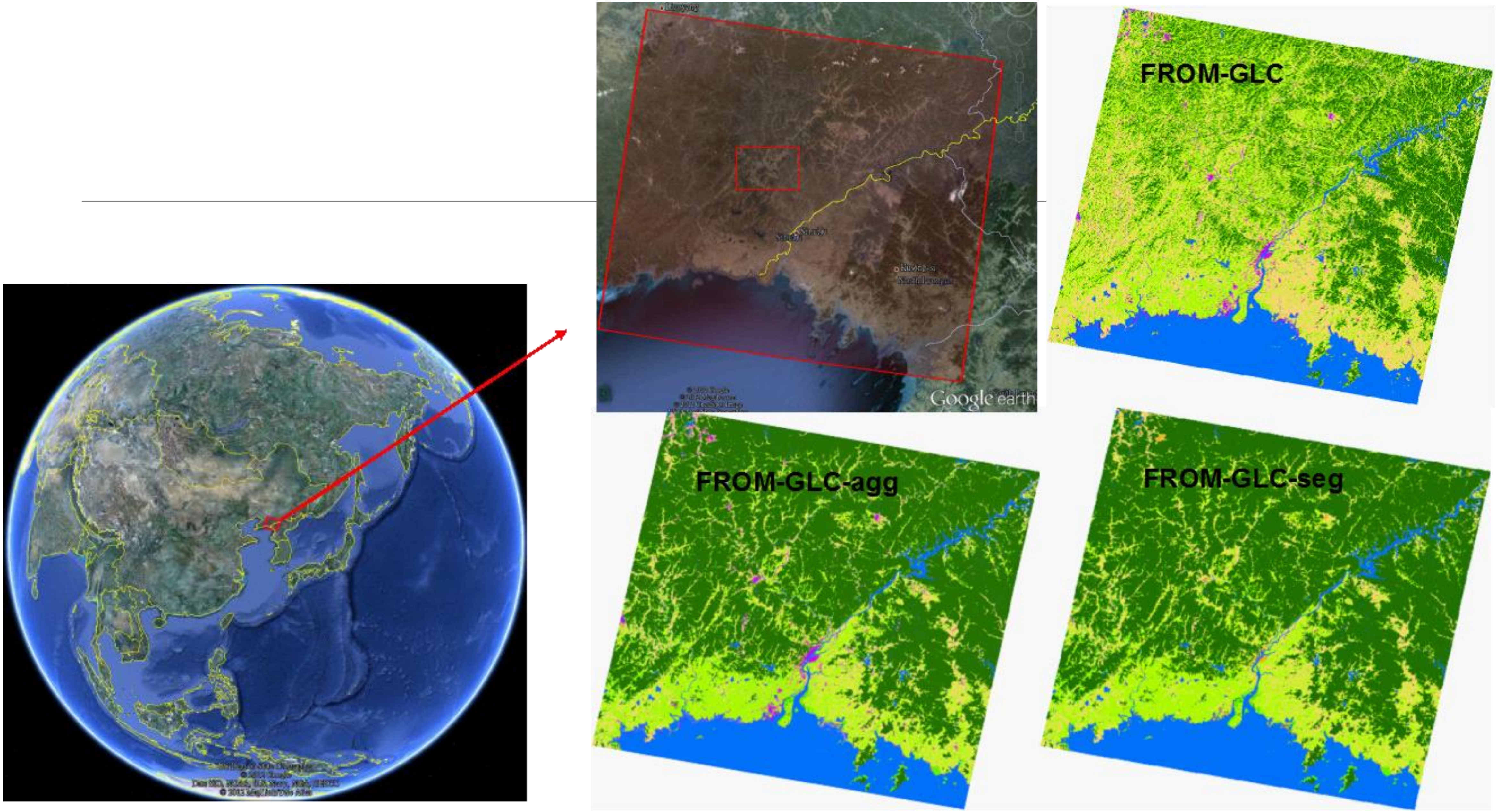
	FROM-GLC		FROM-GLC-seg		FROM-GLC-agg	
OA	63.69%		64.42%		65.51%	
K	0.5429		0.5562		0.5722	
K_{var}	9.2804e-6		9.2137e-6		9.1341e-6	
CI	[0.5370,0.5489]		[0.5502,0.5621]		[0.5663, 0.5781]	
	UA (%)	PA (%)	UA (%)	PA (%)	UA (%)	PA (%)
Cropland	43.24	37.59	*55.21*	**67.63**	**57.60**	*66.62*
Forest	**80.16**	77.10	79.13	**80.09**	*80.07*	*79.06*
Grasslands	**53.66**	34.18	52.43	**34.57**	*53.14*	*34.42*
Shrublands	**49.11**	34.73	*48.89*	**38.45**	48.31	*37.93*
Water Bodies	**82.88**	*88.41*	*72.02*	87.72	69.51	**93.10**
Impervious	34.88	10.53	-	-	**40.59**	**25.00**
Barelands	56.38	**93.45**	*60.64*	91.23	**62.43**	*90.60*
Snow & Ice	*96.54*	**85.94**	80.87	*63.35*	**97.95**	58.58
Cloud	65.82	83.63	-	-	66.97	83.50

FROM-GLC
- Landsat TM/ETM+

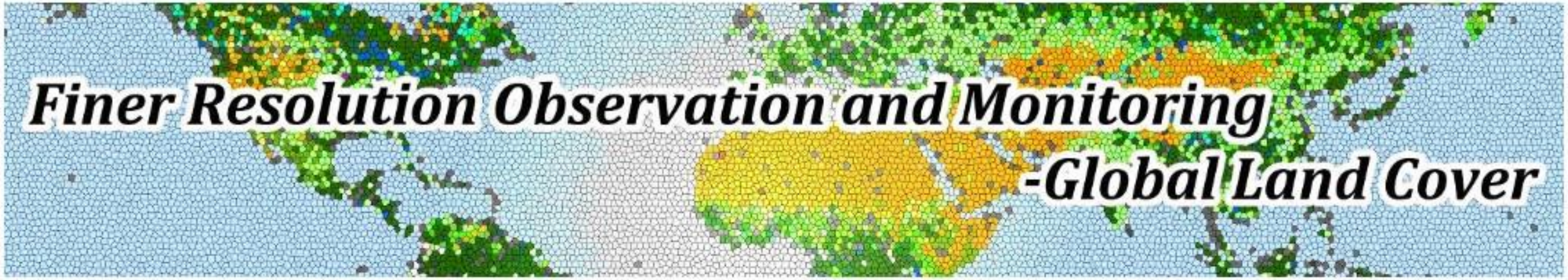
FROM-GLC-seg
- Landsat TM/ETM+, MODIS EVI, Bioclimatic variables, DEM…
- Segmentation based

FROM-GLC-agg
- Aggregation of FROM-GLC, FROM-GLC-seg, and two 1km global impervious products (Elvidge et al., 2007), Schneider et al., 2009, 2010)

Yu et al., in preparation


Google earth
FROM-GLC
FROM-GLC-agg
FROM-GLC-seg

Free access to 30 m land cover maps at http://data.ess.tsinghua.edu.cn



Homepage   Download by MODIS Tile (FROM-GLC)   Download by Path/Row (FROM-GLC)

News

International Symposium on Land Cover Mapping for the African Continent: http://data.ess.tsinghua.edu.cn/ISLandCoverAfrica.html
(will jump to http://www.cess.tsinghua.edu.cn/publish/essen/7774/2013/20130716143808193384006/20130716143808193384006_.html)

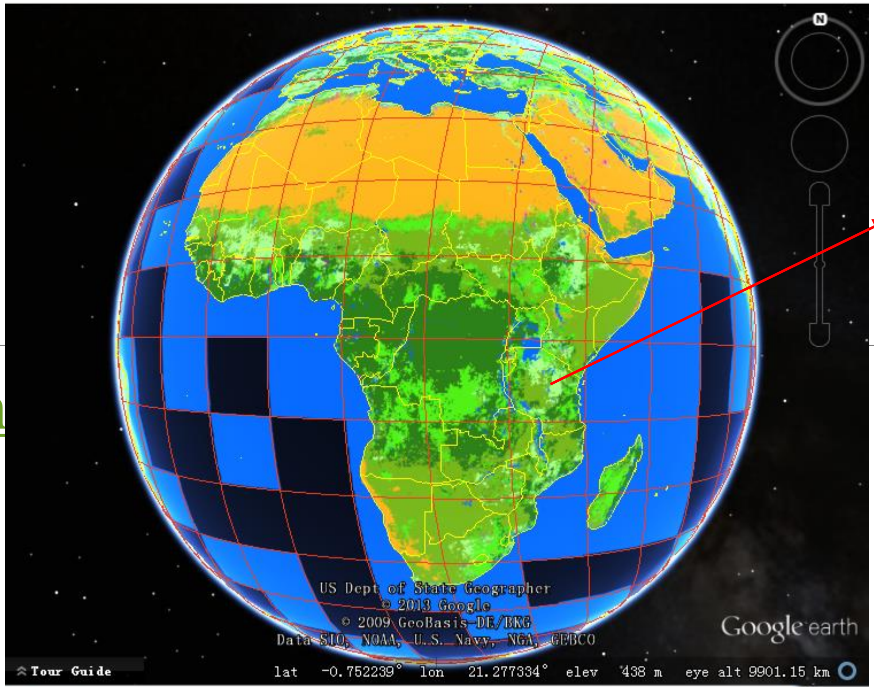
Release of FROM-GLC-agg (08 February, 2013)

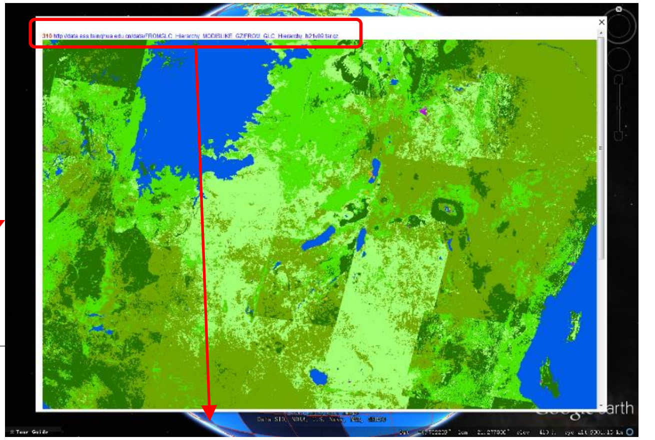
FROM-GLC download web URL: http://data.ess.tsinghua.edu.cn/index.html
FROM-GLC-seg download web URL: http://data.ess.tsinghua.edu.cn/landsat_pathList_fromglcseg_0_1.html
FROM-GLC-agg download web URL: http://data.ess.tsinghua.edu.cn/landsat_pathList_fromglcagg_0_1.html
* If you do not know the MODIS tile number of your area of interest, please click http://modis-land.gsfc.nasa.gov/MODLAND_grid.html to use their spatial query to find it out.
* If you do not know the Landsat Path and Row number, please click http://landsat.usgs.gov/tools_csf.php to use their spatial query to find it out.

Data access

(1) http://data.ess.tsinghua.edu.cn

(2) KML download link





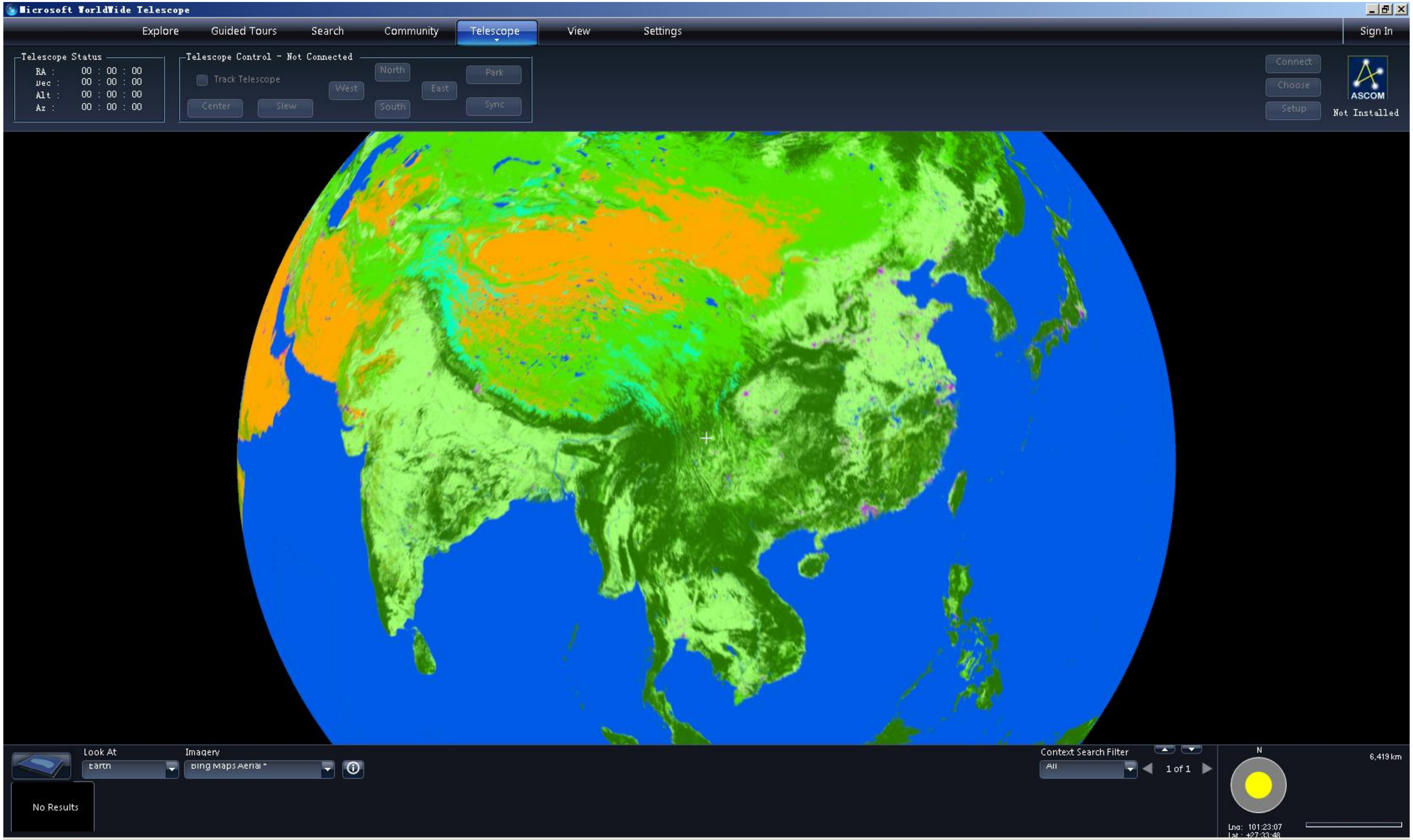
Download link:
http://data.ess.tsinghua.edu.cn/data/FROMGLC_Hierarchy_MODISLIKE_GZ/FROM_GLC_Hierarchy_h21v09.tar.gz

Name	Type	Size
FROM-GLC_30mTile_h21v09_1km_Majority.tif	TIFF image	247 KB
FROM-GLC_30mTile_h21v09_5km_Majority.tif	TIFF image	13 KB
FROM-GLC_30mTile_h21v09_5km_Proportion.tif	TIFF image	1,157 KB
FROM-GLC_30mTile_h21v09_10km_Majority.tif	TIFF image	6 KB
FROM-GLC_30mTile_h21v09_10km_Proportion.tif	TIFF image	339 KB
FROM-GLC_30mTile_h21v09_25km_Majority.tif	TIFF image	3 KB
FROM-GLC_30mTile_h21v09_25km_Proportion.tif	TIFF image	85 KB
FROM-GLC_30mTile_h21v09_50km_Majority.tif	TIFF image	3 KB
FROM-GLC_30mTile_h21v09_50km_Proportion.tif	TIFF image	26 KB
FROM-GLC_30mTile_h21v09_100km_Majority.tif	TIFF image	3 KB
FROM-GLC_30mTile_h21v09_100km_Proportion.tif	TIFF image	8 KB
FROM-GLC_30mTile_h21v09_250m_Majority.tif	TIFF image	4,254 KB
FROM-GLC_30mTile_h21v09_500m_Majority.tif	TIFF image	1,037 KB
FROM-GLC_30mTile_h21v09BaseMap.tif	TIFF image	88,084 KB

(3) Microsoft Research – Worldwide Telescope

(Coming soon…)

http://www.worldwidetelescope.org/webclient/



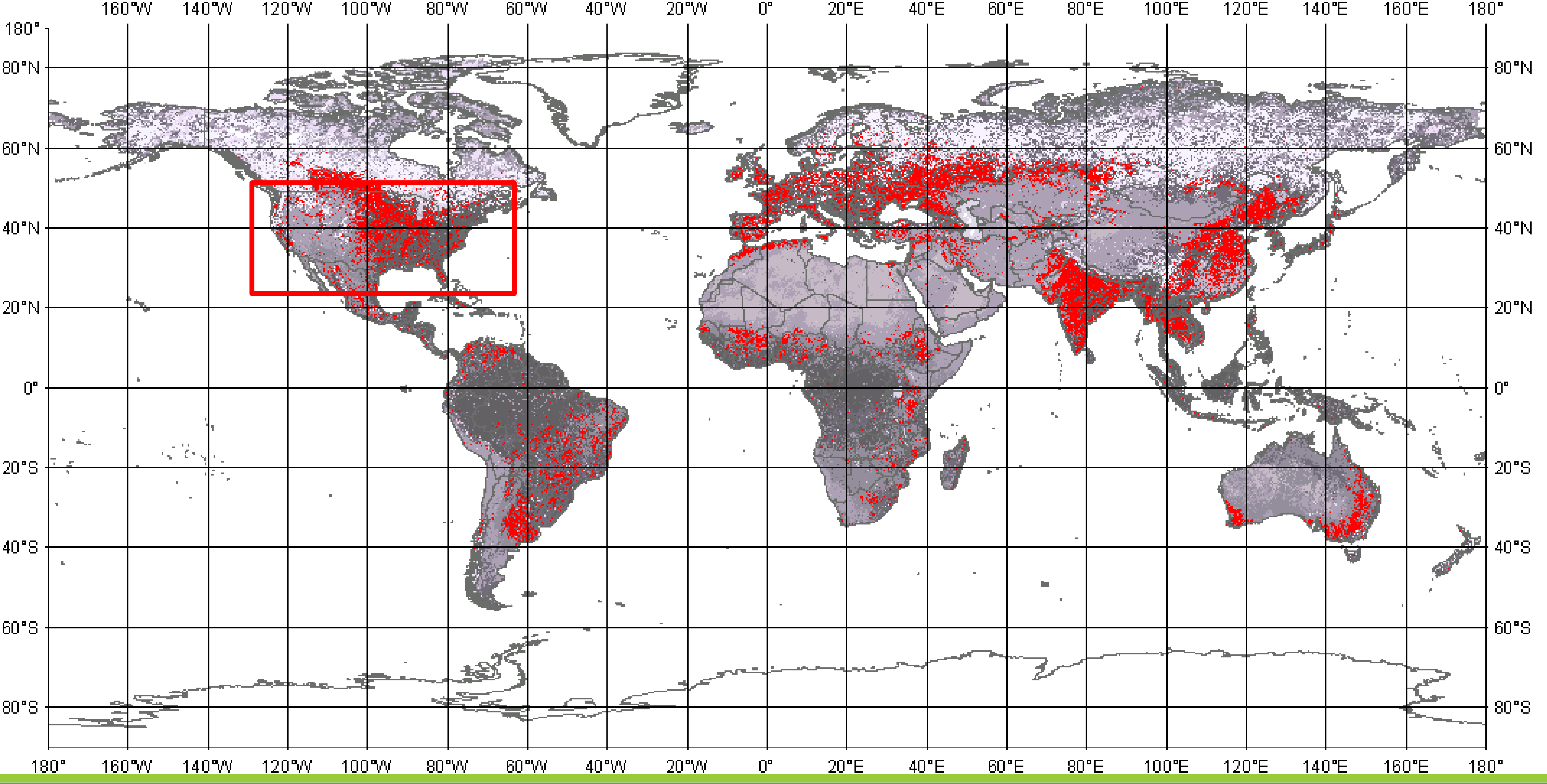
Microsoft WorldWide Telescope
Explore
Guided Tours
Search
Community
Telescope
View
Settings
Sign In
Telescope Status
RA : 00 : 00 : 00
Dec : 00 : 00 : 00
Alt : 00 : 00 : 00
Az : 00 : 00 : 00
Telescope Control - Not Connected
Track Telescope
North
West
East
South
Park
Sync
Center
Slew
Connect
Choose
Setup
ASCOM
Not Installed
Look At
Earth
Imagery
Bing Maps Aerial
No Results
Context Search Filter
All
1 of 1
N
6,419 km

Applications

Global cropland extent

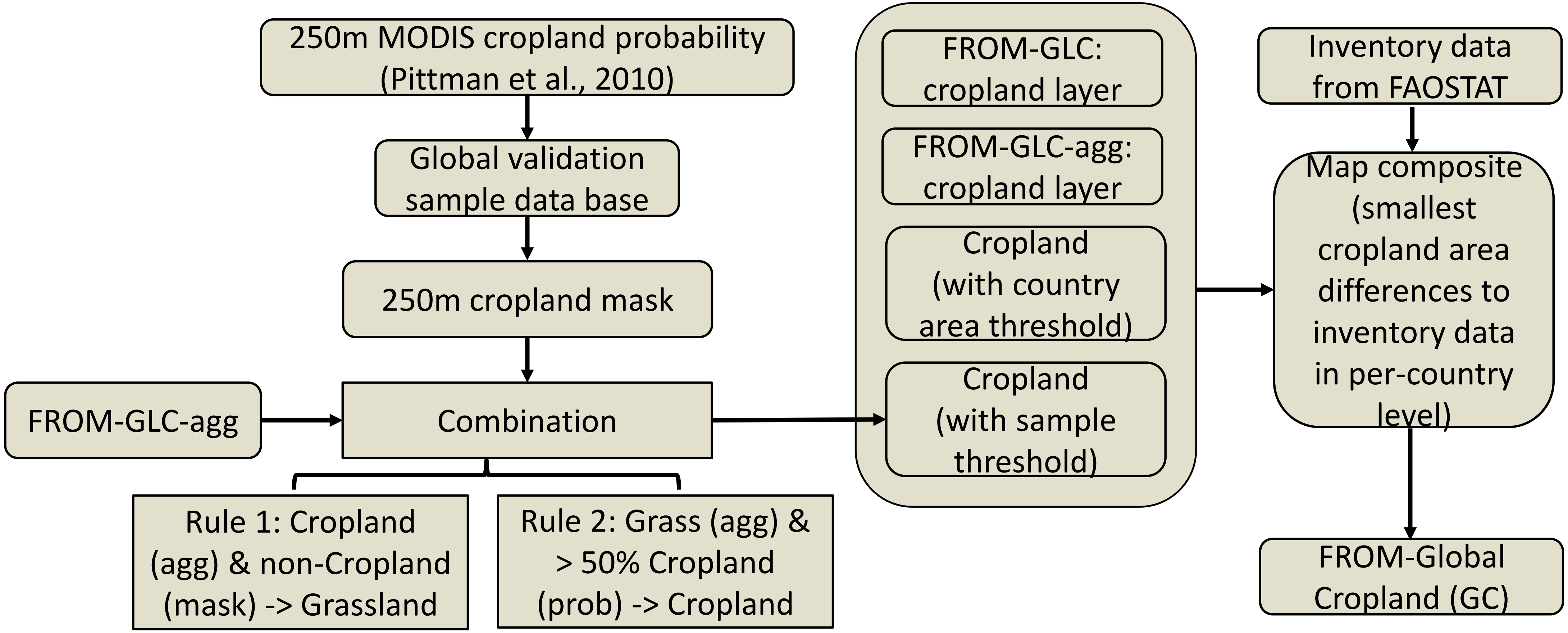
Scale issue analysis

Land cover projection

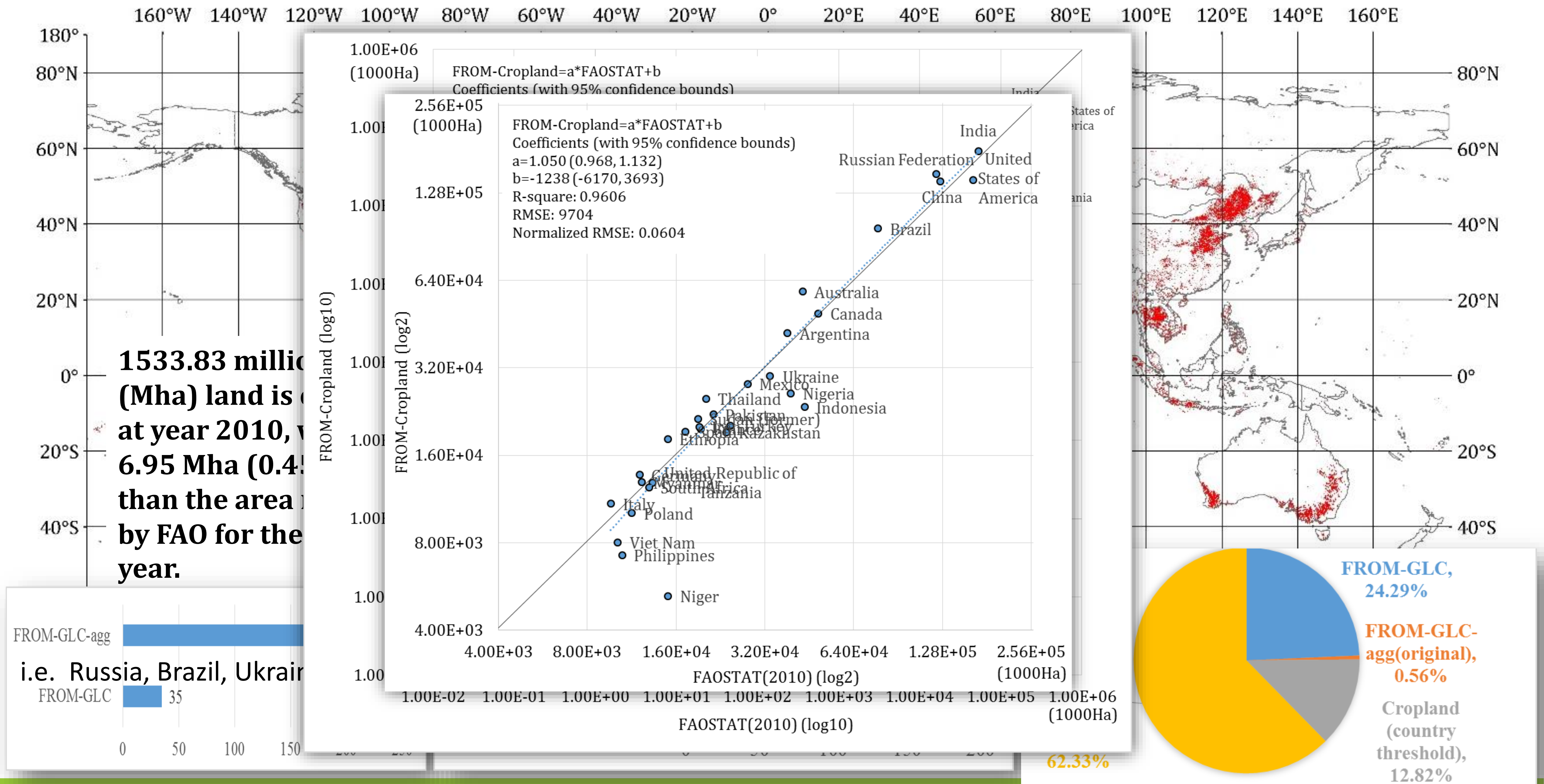


Global Cropland Distribution

FROM-Global Cropland



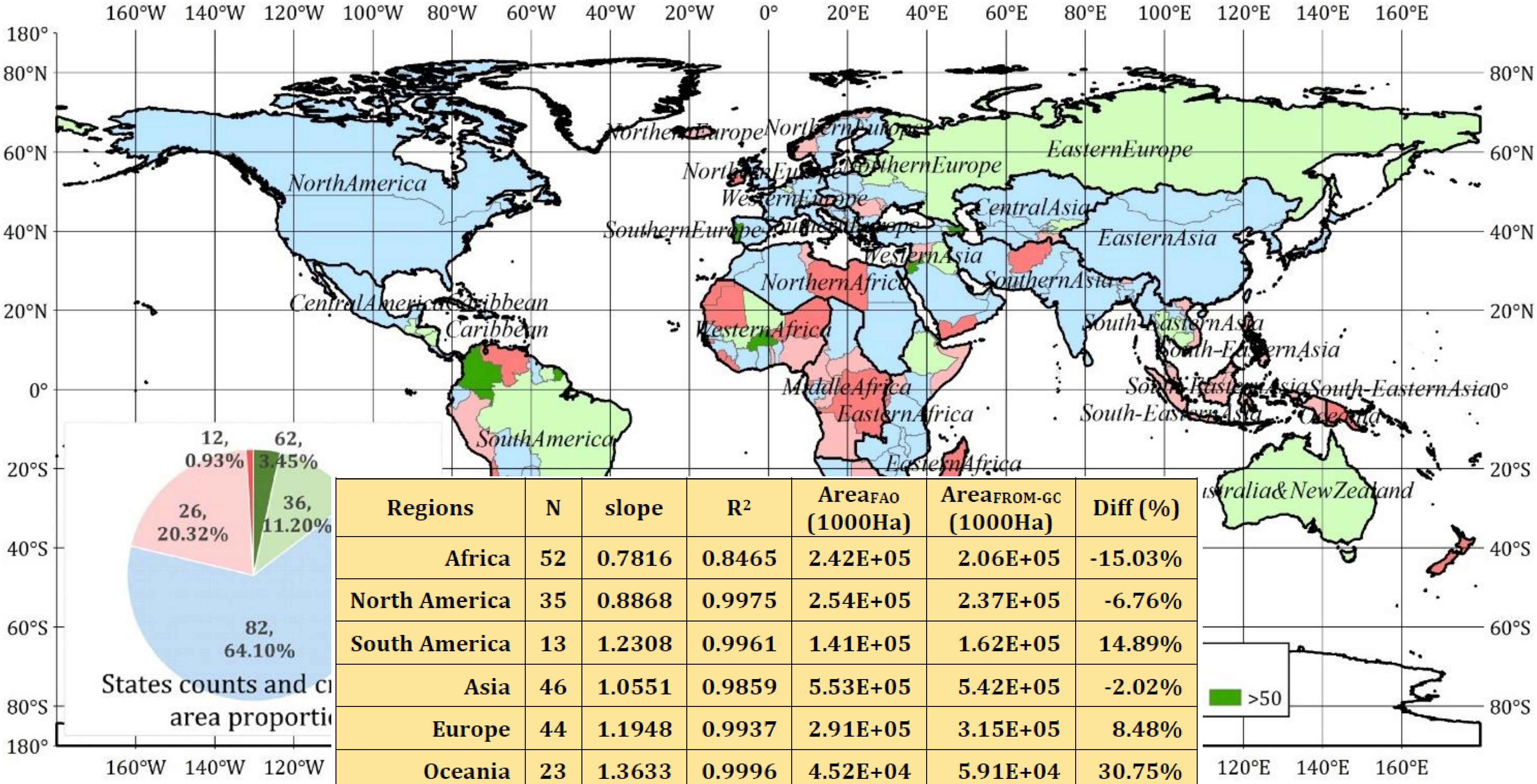
Yu, Wang , Clinton et al., 2013



1533.83 millio
(Mha) land is
at year 2010,
6.95 Mha (0.45
than the area
by FAO for the
year.

i.e. Russia, Brazil, Ukrain

Yu, Wang , Clinton et al., 2013



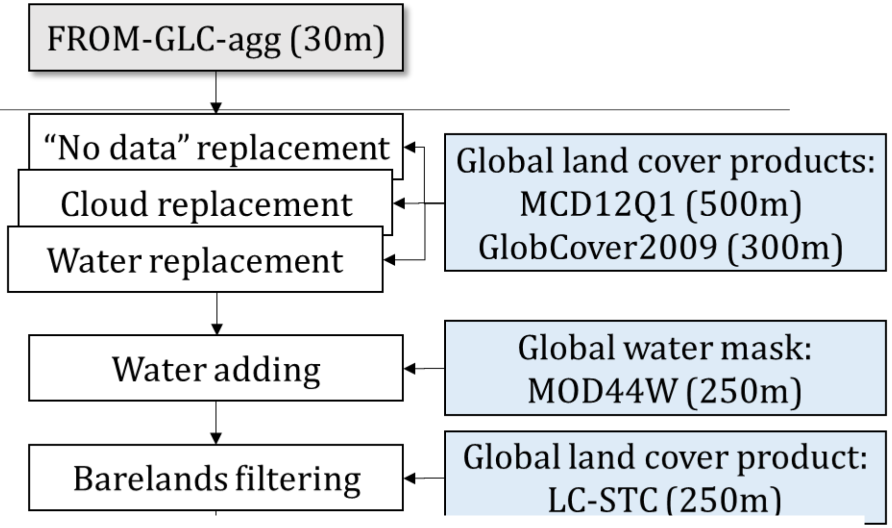
Regions	N	slope	R^2	$Area_{FAO}$ (1000Ha)	$Area_{FROM-GC}$ (1000Ha)	Diff (%)
Africa	52	0.7816	0.8465	2.42E+05	2.06E+05	-15.03%
North America	35	0.8868	0.9975	2.54E+05	2.37E+05	-6.76%
South America	13	1.2308	0.9961	1.41E+05	1.62E+05	14.89%
Asia	46	1.0551	0.9859	5.53E+05	5.42E+05	-2.02%
Europe	44	1.1948	0.9937	2.91E+05	3.15E+05	8.48%
Oceania	23	1.3633	0.9996	4.52E+04	5.91E+04	30.75%

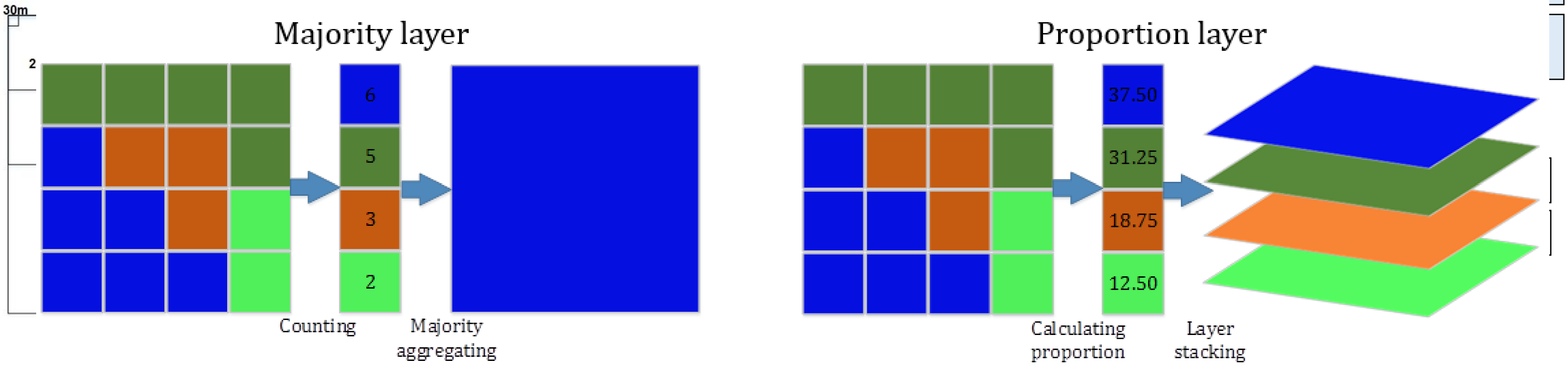
Yu, Wang , Clinton et al., 2013

Scale related biases

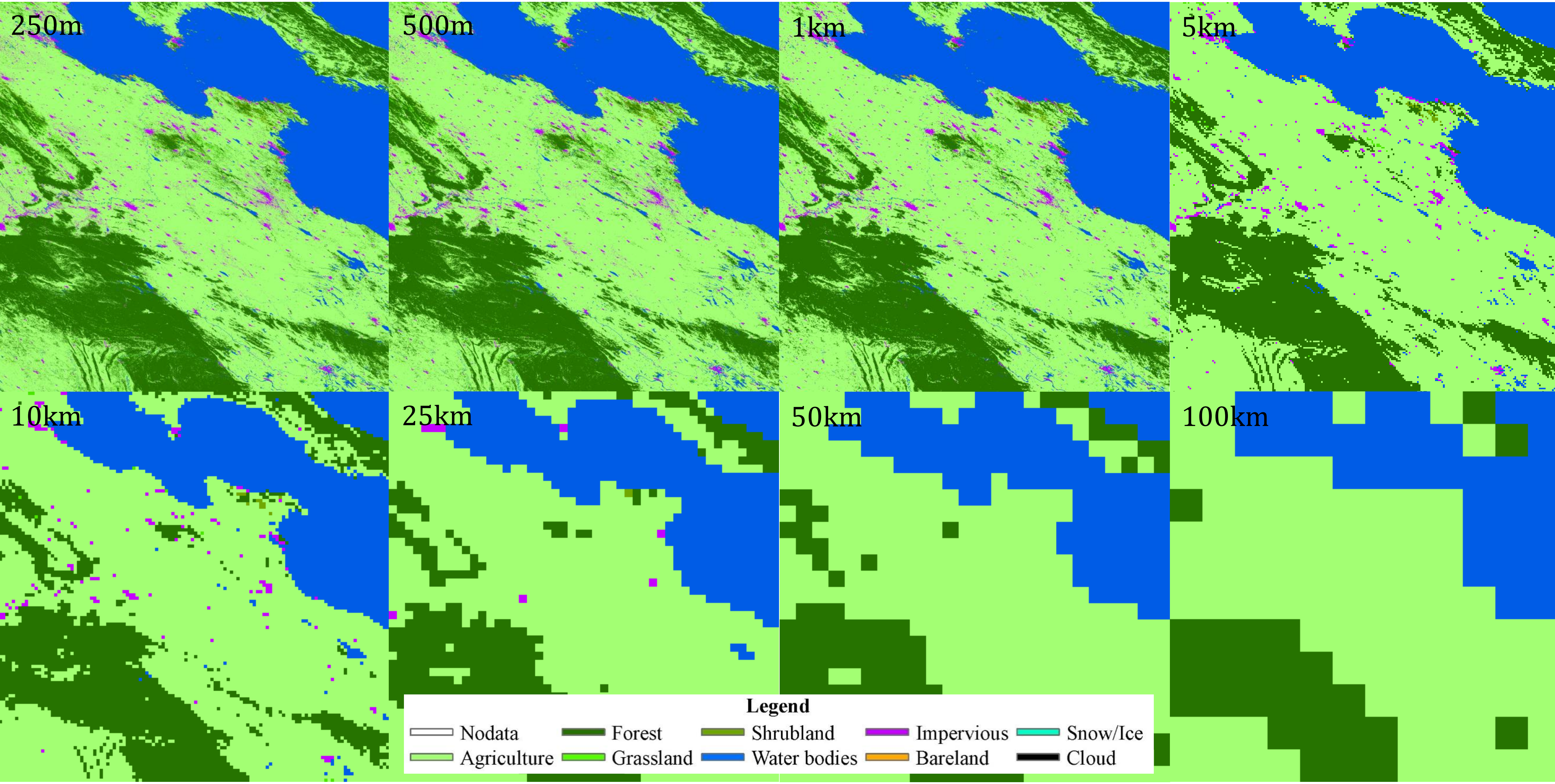
Different applications require land cover maps with different resolution

Explorer the area estimation biases for different land cover types at different resolutions



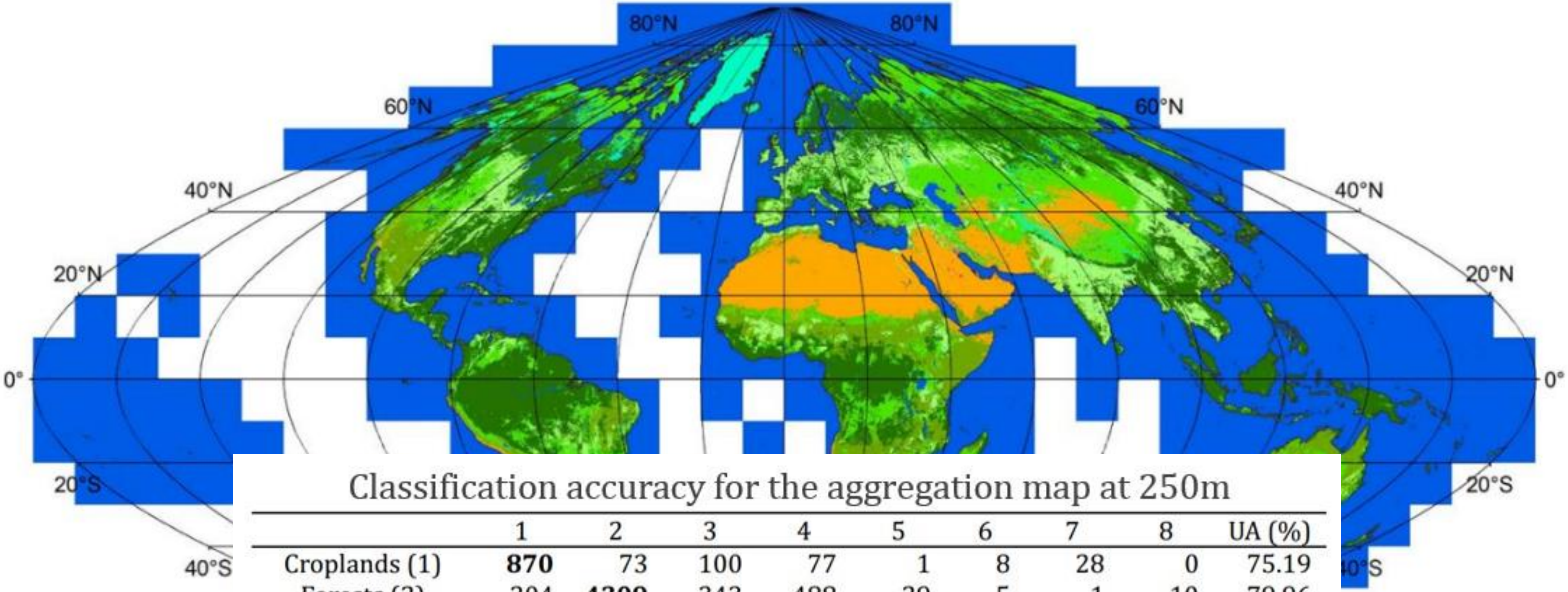


Yu, Wang, Li et al., in review



Yu, Wang, Li et al., in review

Majority aggregation product at 250m resolution

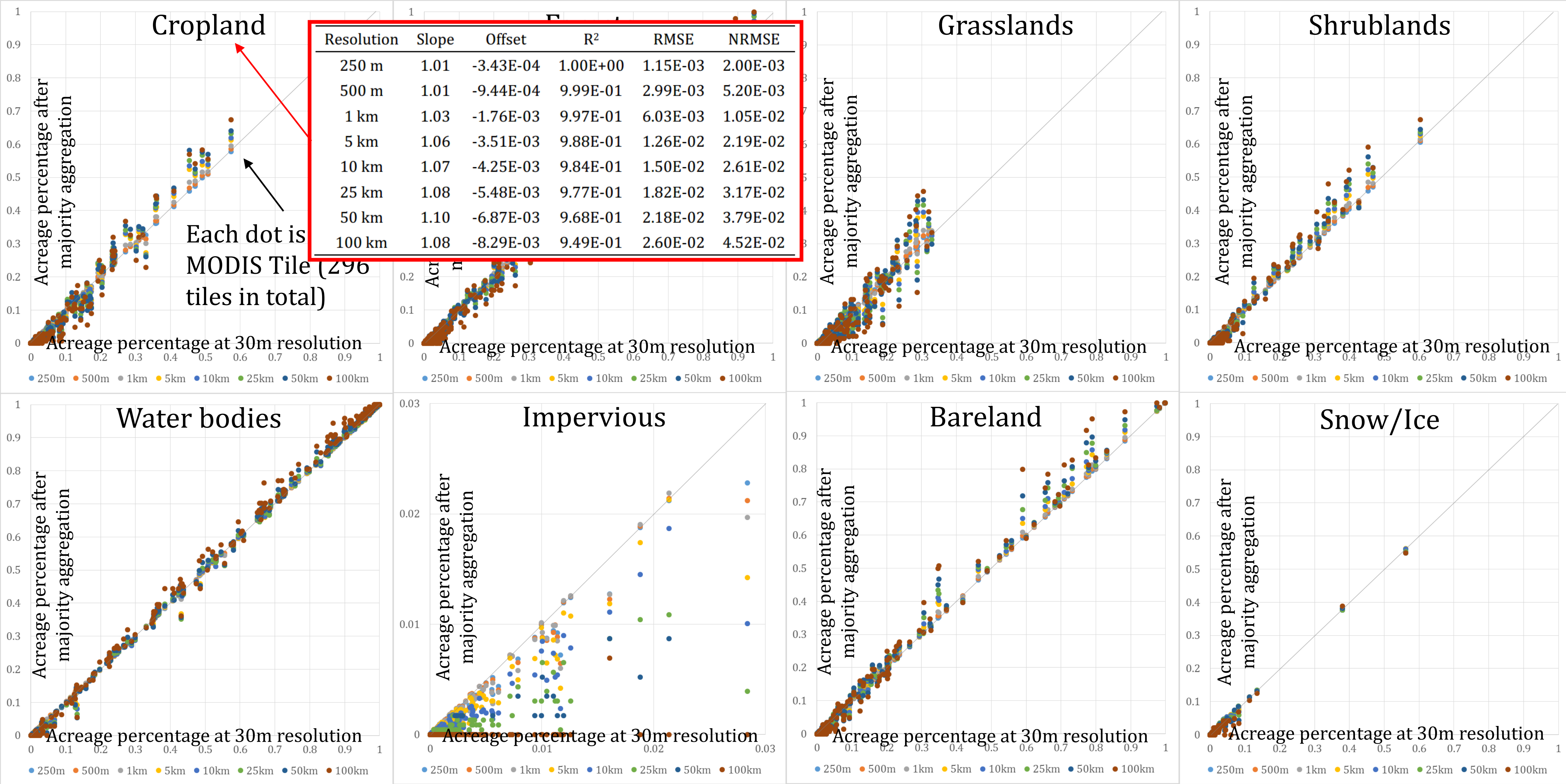


Classification accuracy for the aggregation map at 250m

	1	2	3	4	5	6	7	8	UA (%)
Croplands (1)	**870**	73	100	77	1	8	28	0	75.19
Forests (2)	204	**4309**	343	488	29	5	1	10	79.96
Grasslands (3)	316	248	**1529**	374	34	5	7	8	60.65
Shrublands (4)	130	291	318	**1591**	10	2	2	1	67.85
Water bodies (5)	0	1	0	1	**550**	0	0	0	99.64
Impervious (6)	4	2	2	1	0	**2**	1	0	16.67
Barelands (7)	36	5	325	388	30	20	**2935**	18	78.12
Snow/Ice (8)	0	10	54	6	39	0	0	**87**	44.39
PA (%)	55.77	87.24	57.24	54.37	79.37	4.76	98.69	70.16	**74.54**

Yu, Wang, Li et al., in review

Estimation biases for different land cover types after majority aggregation



Resolution	Slope	Offset	R^2	RMSE	NRMSE
250 m	1.01	-3.43E-04	1.00E+00	1.15E-03	2.00E-03
500 m	1.01	-9.44E-04	9.99E-01	2.99E-03	5.20E-03
1 km	1.03	-1.76E-03	9.97E-01	6.03E-03	1.05E-02
5 km	1.06	-3.51E-03	9.88E-01	1.26E-02	2.19E-02
10 km	1.07	-4.25E-03	9.84E-01	1.50E-02	2.61E-02
25 km	1.08	-5.48E-03	9.77E-01	1.82E-02	3.17E-02
50 km	1.10	-6.87E-03	9.68E-01	2.18E-02	3.79E-02
100 km	1.08	-8.29E-03	9.49E-01	2.60E-02	4.52E-02

Yu, Wang, Li et al., in review

Biases after majority aggregation

Positive: over-estimation, Negative: under estimation;

Dark green: bias less than 1%, Light green: bias less than 5%, Gray: bias less than 10%

	Cropland	Forests	Grasslands	Shrublands	Water	Impervious	Bareland	Snow/Ice
250m	0.53%	0.66%	0.39%	0.57%	0.02%	-11.99%	0.10%	-0.12%
500m	1.32%	1.66%	0.62%	1.72%	-0.04%	-14.10%	0.36%	-0.33%
1km	2.97%	2.54%	1.93%	3.25%	0.03%	-15.07%	0.86%	-0.45%
5km	6.09%	5.22%	3.65%	6.20%	0.41%	-27.79%	2.12%	-0.30%
10km	7.21%	6.45%	3.64%	7.63%	0.58%	-41.88%	2.85%	-0.61%
25km	8.42%	8.18%	2.96%	9.78%	0.81%	-65.61%	4.15%	-1.90%
50km	9.86%	9.87%	2.44%	11.69%	1.00%	-81.31%	5.39%	-2.80%
100km	8.24%	11.40%	3.78%	15.68%	1.17%	-96.85%	7.26%	-4.49%

Biases of majority aggregation layer for Cropland, Forests, Shurblands are larger than 2% when resolution coarse than 5km

Bias of majority aggregation layer for impervious is huge

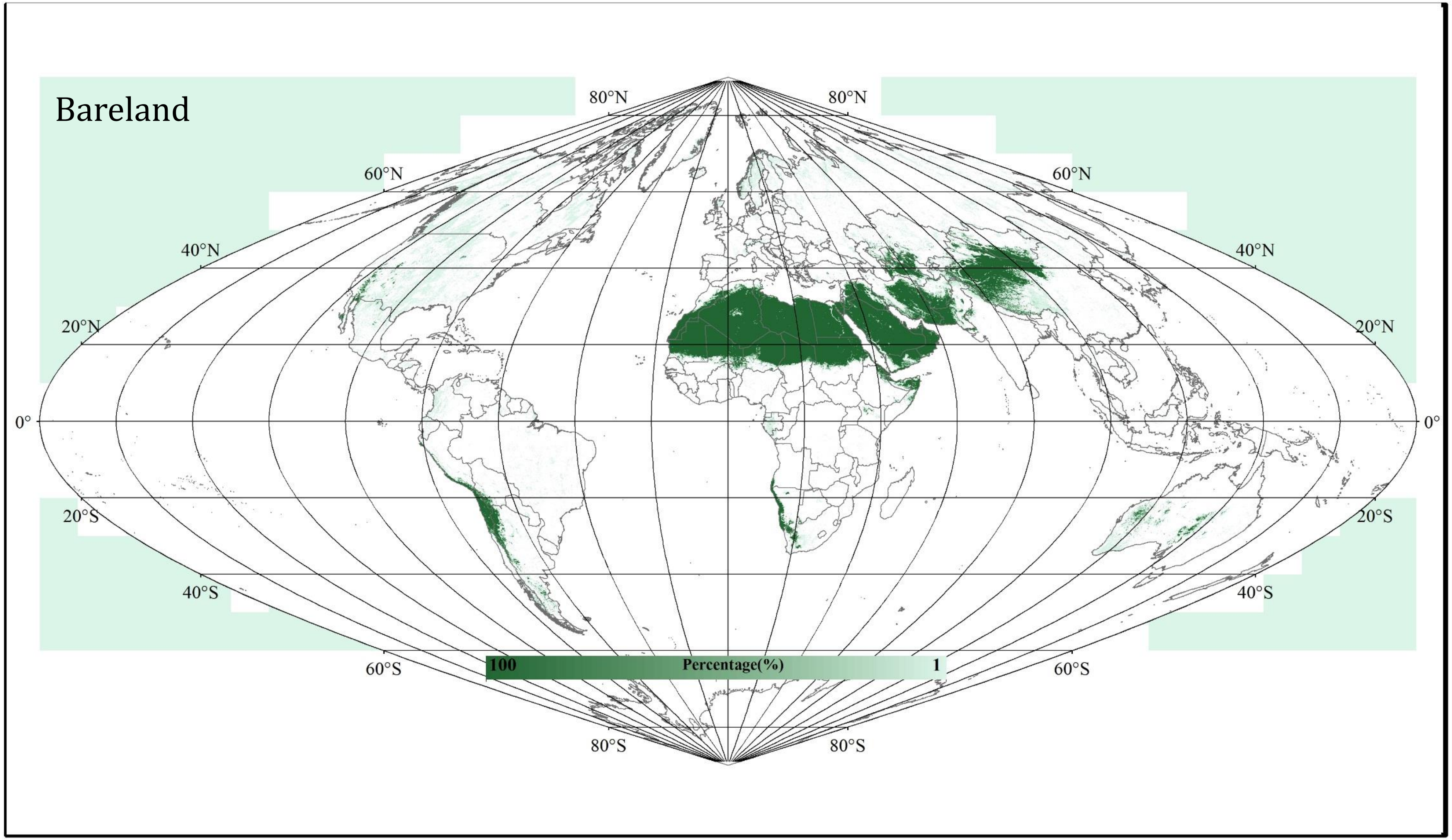
Biases of majority aggregation layer for Grasslands, Water bodies, Barelands, Snow/Ice are samll

A general suggestion:

chose majority aggregation layer for resolution 250m~1km and proportion layer for resolution coarser than 5km

Yu, Wang, Li et al., in review

Proportion Layer (5km)



Yu, Wang, Li et al., in review

Conclusions

Major components for land cover mapping

Global land cover maps produced in 1980s, 1990s, 2000s, 2010s

Area estimation biases related to scale

- chose majority aggregation layer for resolution 250m~1km and proportion layer for resolution coarser than 5km

30 m global cropland map: FROM-GC

- R^2 = 0.9742 (FROM-GC vs. FAOSTAT)
- According to FROM-GC, 1533.83 million ha (Mha) land is cropland at year 2010, which is 6.95 Mha (0.45%) less than the area reported by FAO for the same year

Reading materials

Gong, P., Wang, J., Yu, L., Zhao, Y., Zhao, Y., Liang, L., Niu, Z., Huang, X., Fu, H., Liu, S., Li, C., Li, X., Fu, W., Liu, C., Xu, Y., Wang, X., Cheng, Q., Hu, L., Yao, W., Zhang, H., Zhu, P., Zhao, Z., Zhang, H., Zheng, Y., Ji, L., Zhang, Y., Chen, H., Yan, A., Guo, J., Yu, L., Wang, L., Liu, X., Shi, T., Zhu, M., Chen, Y., Yang, G., Tang, P., Xu, B., Ciri, C., Clinton, N., Zhu, Z., Chen, J., Chen, J. 2013. Finer resolution observation and monitoring of global land cover: first mapping results with Landsat TM and ETM+ data, International Journal of Remote Sensing. vol.34, n.7, pp.2607-2654.

Yu, L., Wang, J., Gong, P. 2013. Improving 30 meter global land cover map FROM-GLC with time series MODIS and auxiliary datasets: a segmentation based approach, International Journal of Remote Sensing. vol.34,n.16, pp.5851-5867.

Yu, L., Wang, J., Clinton, N., Xin, Q., Zhong, L., Chen, Y., Gong, P. 2013. FROM-GC: 30 m global cropland extent derived through multisource data integration, International Journal of Digital Earth.

Q&A