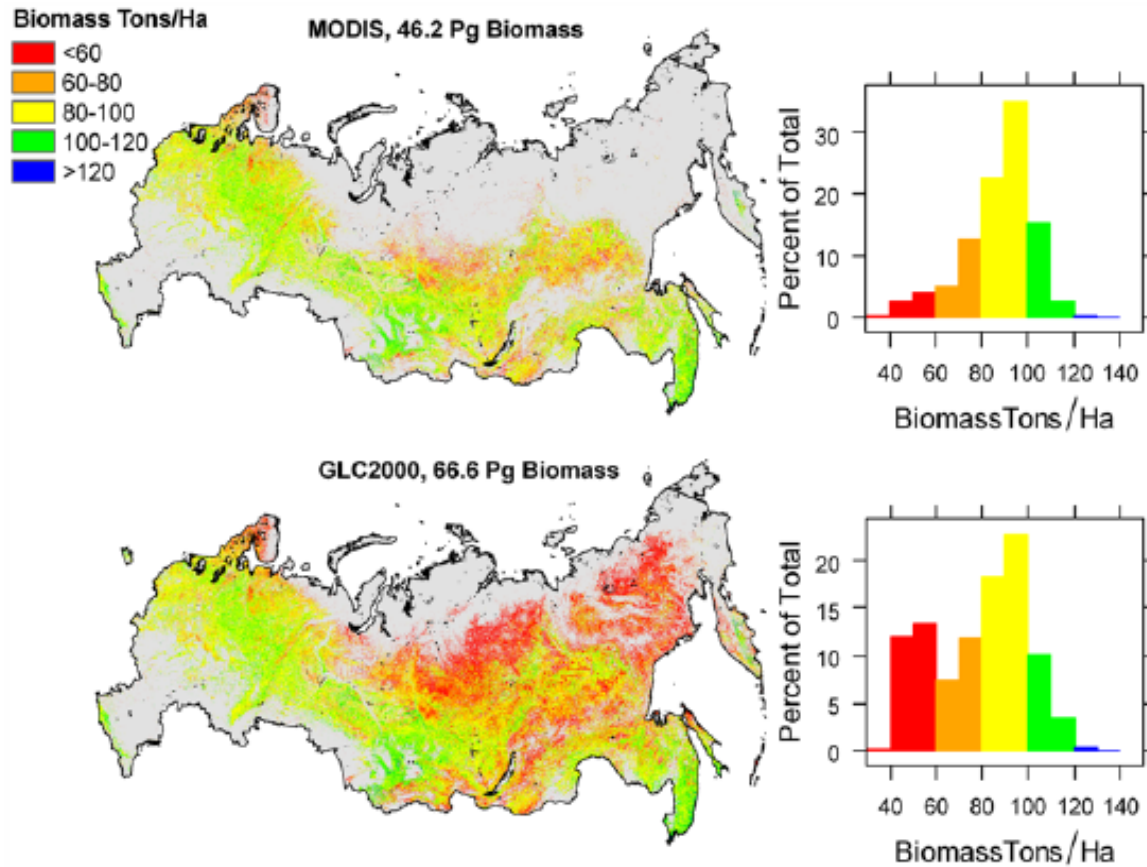


# The future direction for LCLUC validation activities

Olga N. Krankina, Oregon State University  
Curtis Woodcock, Boston University

*with contributions from NELDA Project team  
and GOF-C-GOLD Land Cover Implementation Team*



**Figure 4.** (a) Map of Russian forest biomass as predicted by the MODIS land-cover product (MOD12Q1). (b) Map of Russian forest biomass as predicted by the GLC2000 land-cover product (Bartalev *et al* 2003).

# Introduction

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1. As the land cover community matures, an increasing emphasis on validation and accuracy assessment - a difficult, somewhat unpleasant and surprisingly expensive activity
2. The GOFC-GOLD LC IT has proposed to support the broader community through validation
3. Idea is to collect ground reference data independent of any single land cover product to support validation of many land cover datasets
4. Intent is to supplement and complement ongoing validation activities associated with individual land cover datasets



# Supporting Developments

---

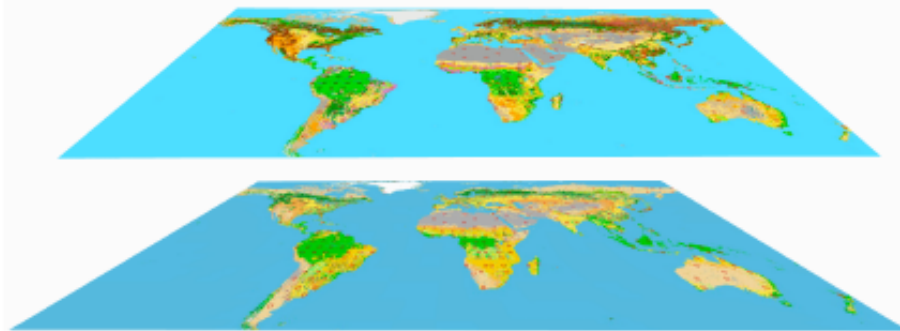
1. Prior experiences with global land cover validation
2. Emergence of LCCS - and its value in promoting consistency in land cover descriptors used in legends for land cover datasets
3. Development of community consensus on “best practices” for global land cover accuracy assessment (CEOS WGC report)

# International consensus on technical issues

## “Best Practices Document”

Strahler et al., 2006

**GLOBAL LAND COVER VALIDATION:  
RECOMMENDATIONS FOR EVALUATION AND  
ACCURACY ASSESSMENT OF  
GLOBAL LAND COVER MAPS**



# A "Living Reference Dataset"

---

A set of validation sites distributed around the globe

Based on high resolution (a few meters) imagery interpreted by regional experts (the regional networks)

Checked annually for land cover change, and updated periodically

Limited set of land cover classifiers

- life form - (trees, shrubs, herbaceous)

- cover

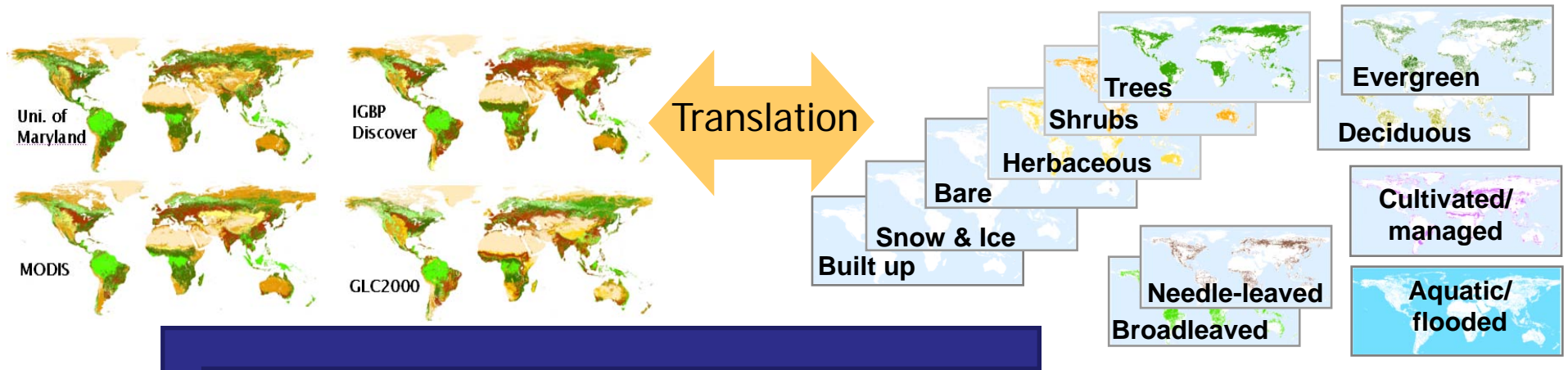
- leaf type

- leaf phenology



# Categories in existing global datasets

# Terminology: land cover classifiers (LCCs)



Translation

## Common classifiers (Terminology standard)

- Classifiers commonly used to characterize land cover worldwide
- i.e. life form & surface type, leaf type & phenology, terrestrial/aquatic

## Generic classes (Thematic standard)

- Basic set of standardized classes based on combination of common classifiers and independent of any cartographic standard
- i.e. broadleaved evergreen trees, herbaceous crops, built up area

## Mapping Categories (Cartographic standard)

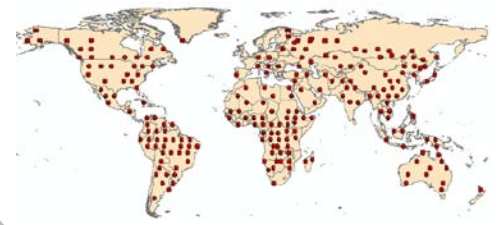
- Application of cartographic generalization (MMU) to generic classes
- Definition of mixed categories or using density thresholds
- i.e. Closed to open (>15%) broadleaved evergreen forest (> 5m) 8



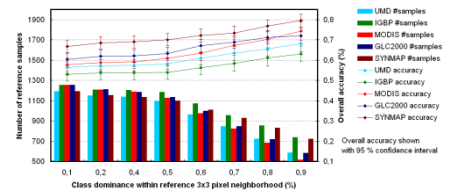
# Thematic standards

- Common classifiers (Terminology standard)**
  - Classifiers commonly used to characterize land cover worldwide
  - i.e. life form & surface type, leaf type & phenology, terrestrial/aquatic
- Generic classes (Thematic standard)**
  - Basic set of standardized classes based on combination of common classifiers and independent of any cartographic standard
  - i.e. broadleaved evergreen trees, herbaceous crops, built up area
- Mapping Categories (Cartographic standard)**
  - Application of cartographic generalization (MMU) to generic classes
  - Definition of mixed categories or using density thresholds
  - i.e. Closed to open (>15%) broadleaved evergreen forest (> 5m)

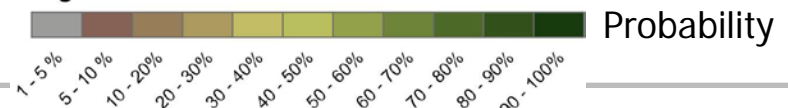
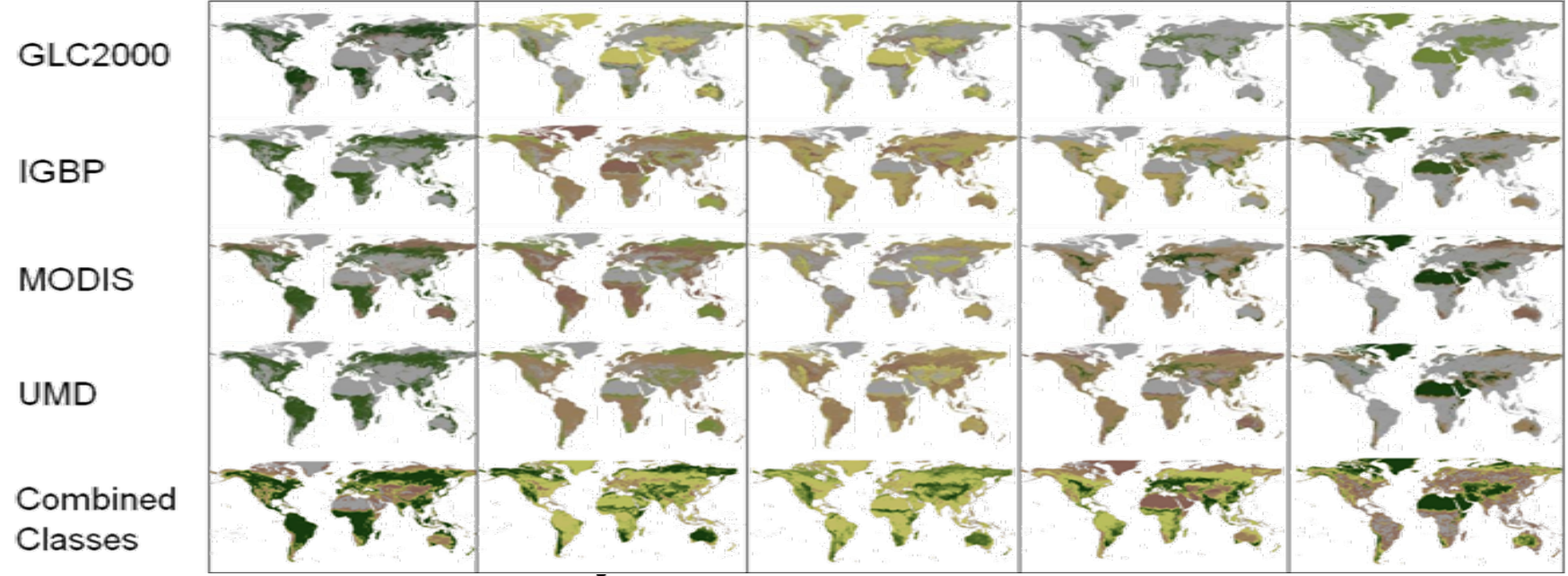
# Reference database (GLC2000)

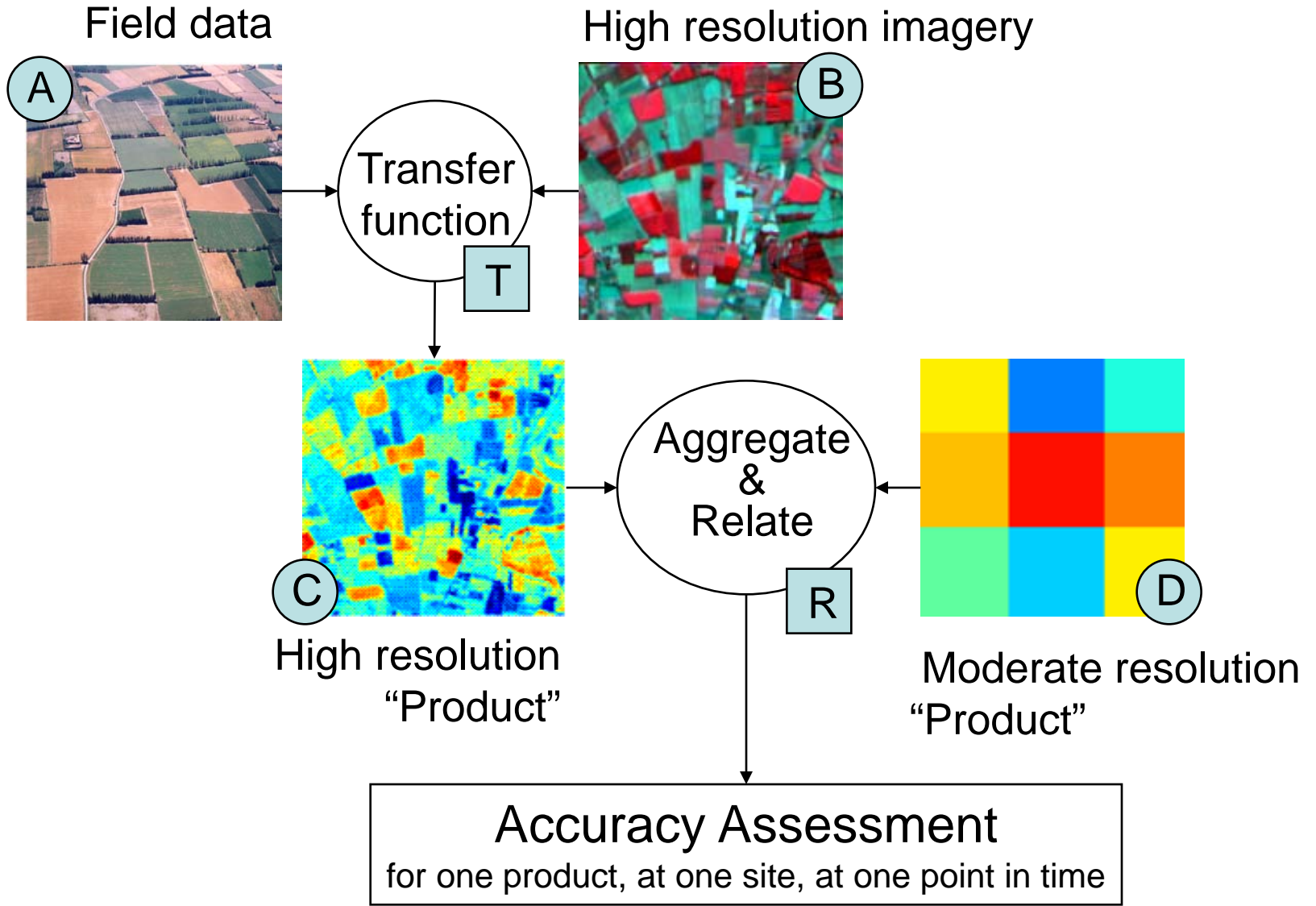


# Comparative validation & assessment



## Trees (>15%)      shrubland      grassland      agricultural cropland      Non vegetated land



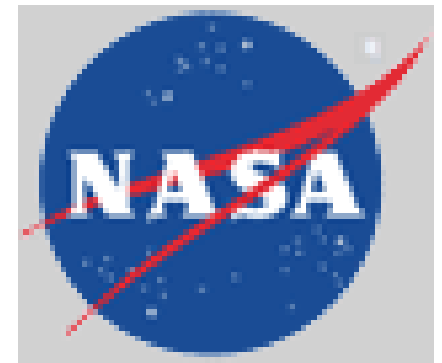


# NEELDA

**(Northern Eurasia Landcover Dynamics Analysis)**

08/04/2009

Olga N. Krankina, OSU



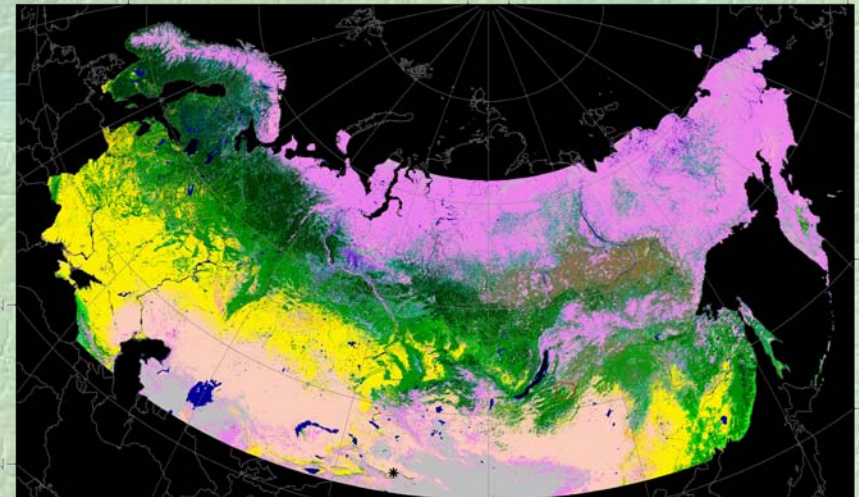
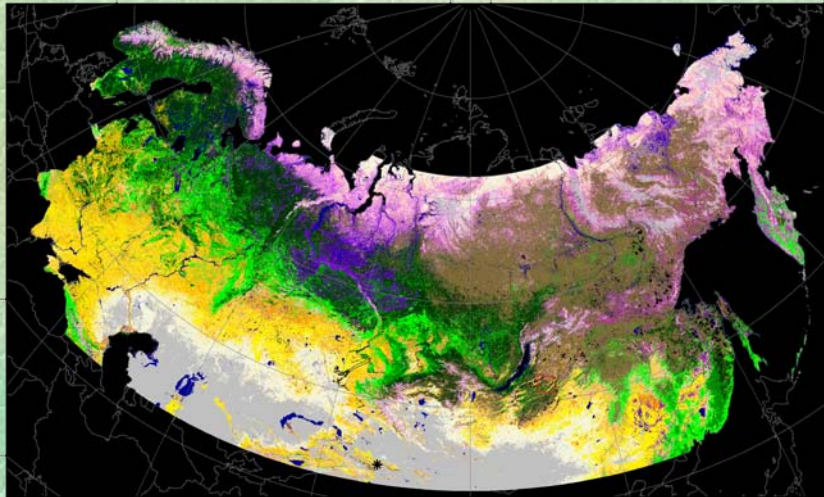
# Approach

- Combine remote sensing data (Landsat, MODIS) and local knowledge of land-cover conditions and change to validate and improve land cover / land-cover change products for Northern Eurasia
  - **establish a set of test sites**
  - **use these sites to validate global and regional land cover / change products**
  - produce a new, updated land cover map for Northern Eurasia based on MODIS data

# Land Cover of Northern Eurasia

## GLC2000

## MODIS-IGBP 2001



### GLC2000 Global Legend

- |   |  |  |
|---|--|--|
| Tree Cover, broad-leaved, deciduous, closed   | Shrub Cover, closed/open, evergreen                      | Mosaic, Cropland / Shrub and/or Herbaceous cover |
| Tree Cover, broad-leaved, deciduous, open     | Shrub Cover, closed/open, deciduous                      | Bare Areas                                       |
| Tree Cover, needle-leaved, evergreen          | Herbaceous Cover, closed/open                            | Water Bodies (natural & artificial)              |
| Tree Cover, needle-leaved, deciduous          | Sparse Herbaceous or sparse shrub cover                  | Snow and ice (natural & artificial)              |
| Tree Cover, mixed-leaf type                   | Regularly flooded shrub and/or herbaceous cover          | Artificial surfaces and associated areas         |
| Mosaic, Tree cover / Other natural vegetation | Cultivated and managed areas                             | NELDA validation site - CH1A                     |
| Tree Cover, burnt                             | Mosaic, Cropland / Tree Cover / Other natural vegetation | Urumqi   |

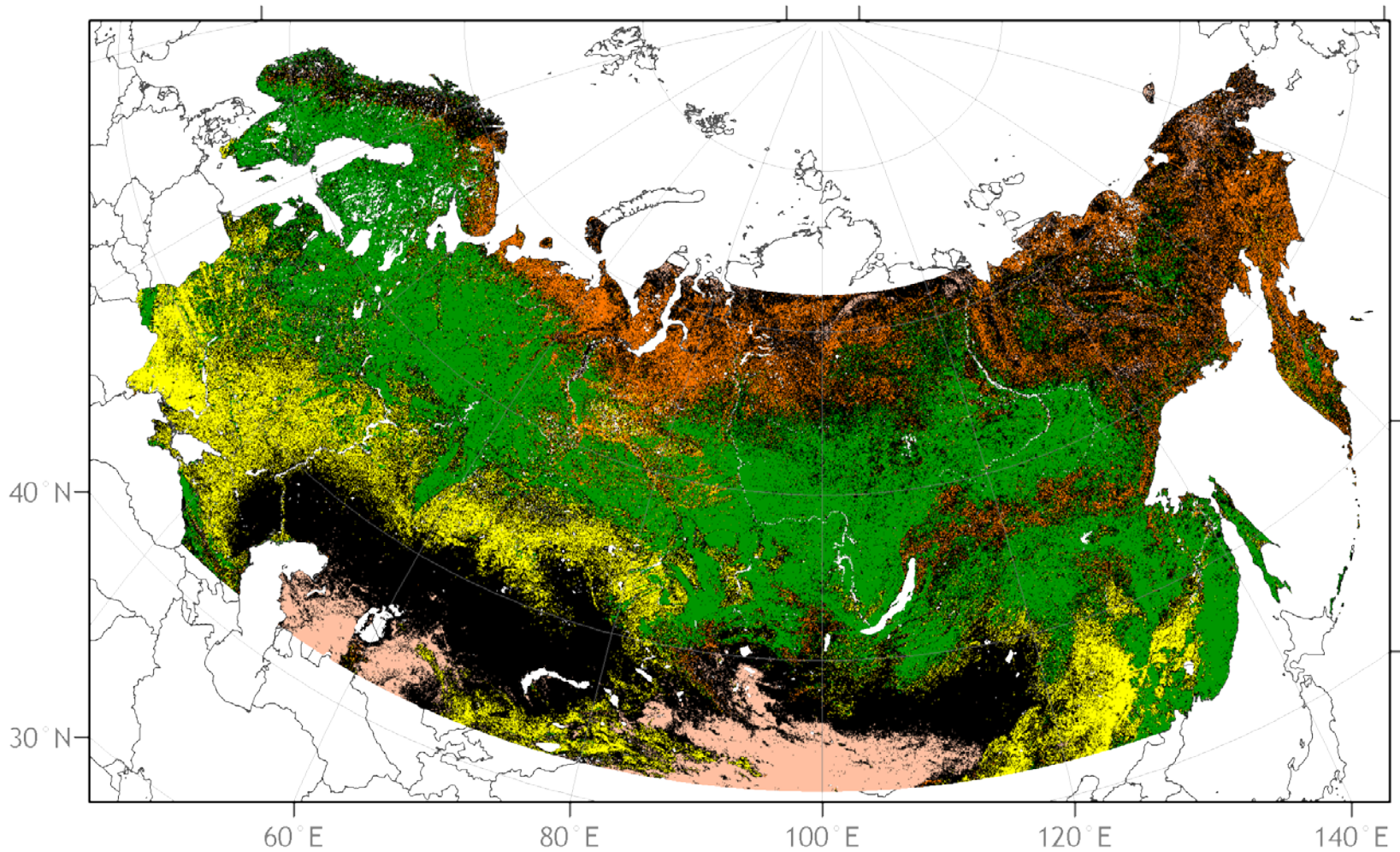
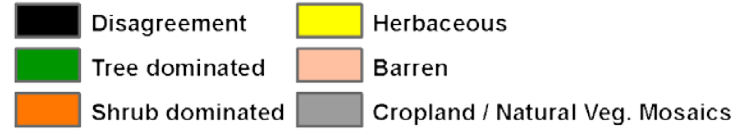
### MODIS-IGBP

- |                             |                            |                                    |                              |
|-----------------------------|----------------------------|------------------------------------|------------------------------|
| Deciduous Needleleaf Forest | Open Shrublands            | Permanent Wetlands                 | Snow and ice                 |
| Water                       | Deciduous Broadleaf Forest | Croplands                          | Barren or Sparsely Vegetated |
| Evergreen Needleleaf Forest | Mixed Forest               | Urbanland Built Up                 | NELDA validation site - CH1A |
| Evergreen Broadleaf Forest  | Closed Shrublands          | Grasslands                         | Urumqi                       |
|                             | Woody Savannas             | Cropland/Natural vegetation Mosaic |                              |
|                             | Savannas                   |                                    |                              |

# Similarity matrix for the GLC2000 and MODIS-PFT legends

GLC-2000.LCCS (rows) MODIS.PFT (columns)		1	2	3	4	5	6	7	8	9	10	11	0
		Needleleaf evergreen tree	Broadleaf evergreen tree	Needleleaf deciduous tree	Broadleaf deciduous tree	Shrub	Grass	Cereal crop	Broadleaf crop	Urban and built-up	Snow and ice	Barren or sparsely vegetated	Water
1	Tree Cover, broadleaved, evergreen	T	T	T	T	ts	th	th	th	tb	tb	tb	lw
2	Tree Cover, broadleaved, deciduous, closed	T	T	T	T	ts	th	th	th	tb	tb	tb	lw
3	Tree Cover, broadleaved, deciduous, open	T	T	T	T	ts	th	th	th	tb	tb	tb	lw
4	Tree Cover, needle-leaved, evergreen	T	T	T	T	ts	th	th	th	tb	tb	tb	lw
5	Tree Cover, needle-leaved, deciduous	T	T	T	T	ts	th	th	th	tb	tb	tb	lw
6	Tree Cover, mixed leaf type	T	T	T	T	ts	th	th	th	tb	tb	tb	lw
7	Tree Cover, regularly flooded, fresh water	T	T	T	T	ts	th	th	th	tb	tb	tb	lw
8	Tree Cover, regularly flooded, saline water	T	T	T	T	ts	th	th	th	tb	tb	tb	lw
9	Mosaic: Tree cover / Other natural vegetation	T	T	T	T	S	H	th	th	tb	tb	tb	lw
10	Tree Cover, burnt	T	T	T	T	ts	th	th	th	tb	tb	tb	lw
11	Shrub Cover, closed-open, evergreen	ts	ts	ts	ts	S	sh	sh	sh	sb	sb	sb	lw
12	Shrub Cover, closed-open, deciduous	ts	ts	ts	ts	S	sh	sh	sh	sb	sb	sb	lw
13	Herbaceous Cover, closed-open	th	th	th	th	sh	H	H	H	hb	hb	hb	lw
14	Sparse Herbaceous or sparse shrub cover	tb	tb	tb	tb	sb	hb	hb	hb	B	B	B	lw
15	Regularly flooded shrub and/or herbaceous cover	ts	ts	ts	ts	S	H	H	H	hb	hb	hb	lw
16	Cultivated and managed areas	th	th	th	th	sh	H	H	H	hb	hb	hb	lw
17	Mosaic: Cropland / Tree Cover / Other natural vegetation	T	T	T	T	S	H	H	H	hb	hb	hb	lw

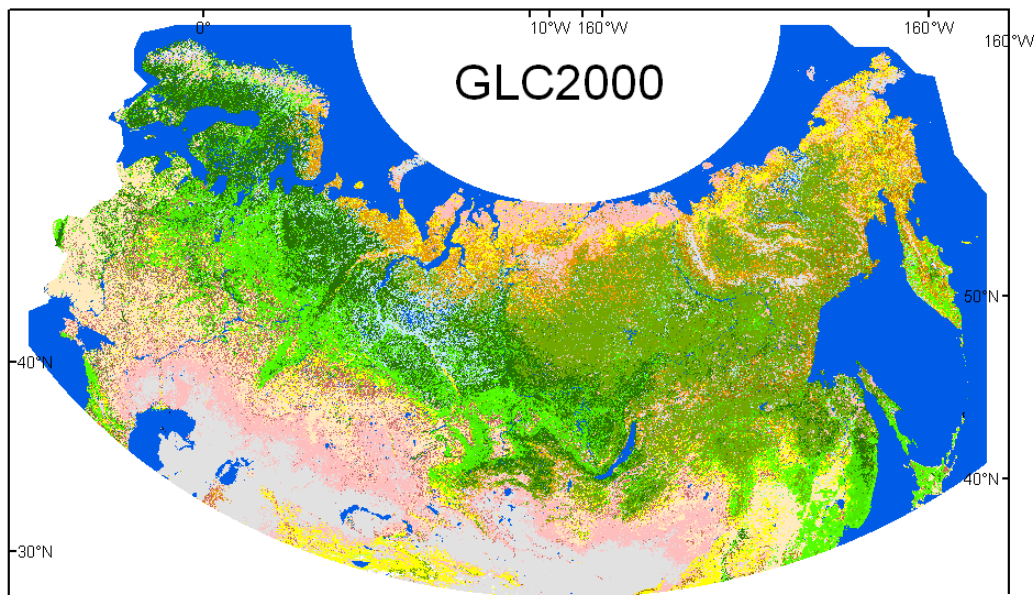
# Agreement in dominant vegetation cover (54%)



# Agreement matrix for GLC-2000 and MODIS.PFT dominant vegetation types excluding water, 1000 km<sup>2</sup>

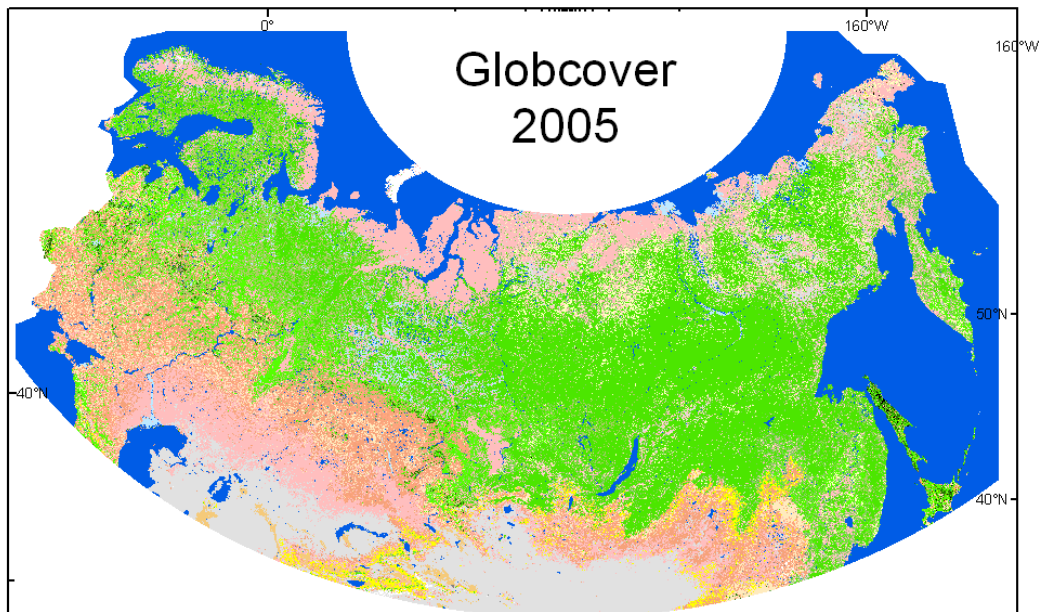
GLC-2000	MODIS.PFT					Agreement
	Tree	Shrub	Herbaceous	Barren		
Tree	2,395	1,697	351	7	4,450	54%
Shrub	200	1,922	105	31	2,258	85%
Herbaceous	24	698	160	34	916	17%
Barren	12	973	64	183	1,232	15%
	2,630	5,290	680	255	8,855	
Agreement	91%	36%	23%	72%		<u>53%</u>





# GLC2000

- |   |   |                              |
|---|---|------------------------------|
| Tree Cover, broadleaved, evergreen          | Mosaic: Tree Cover / Other natural vegetation   | Mosaic: Cropland / Tree C    |
| Tree C over, broadleaved, deciduous, closed | Tree Cover, burnt                               | Mosaic: Cropland / Shrub a   |
| Tree Cover, broadleaved, deciduous, open    | Shrub Cover, closed-open, evergreen             | Bare Areas                   |
| Tree Cover, needle-leaved, evergreen        | Shrub Cover, closed-open, deciduous             | Water Bodies                 |
| Tree Cover, needle-leaved, deciduous        | Herbaceous Cover, closed-open                   | Snow and Ice                 |
| Tree Cover, mixed leaf type                 | Sparse herbaceous or sparse shrub cover         | Artificial surfaces and asso |
| Tree Cover, regularly flooded, fresh water  | Regularly flooded shrub and/or herbaceous cover | No data                      |
| Tree Cover, regularly flooded, saline water | Cultivated and managed areas                    |                              |

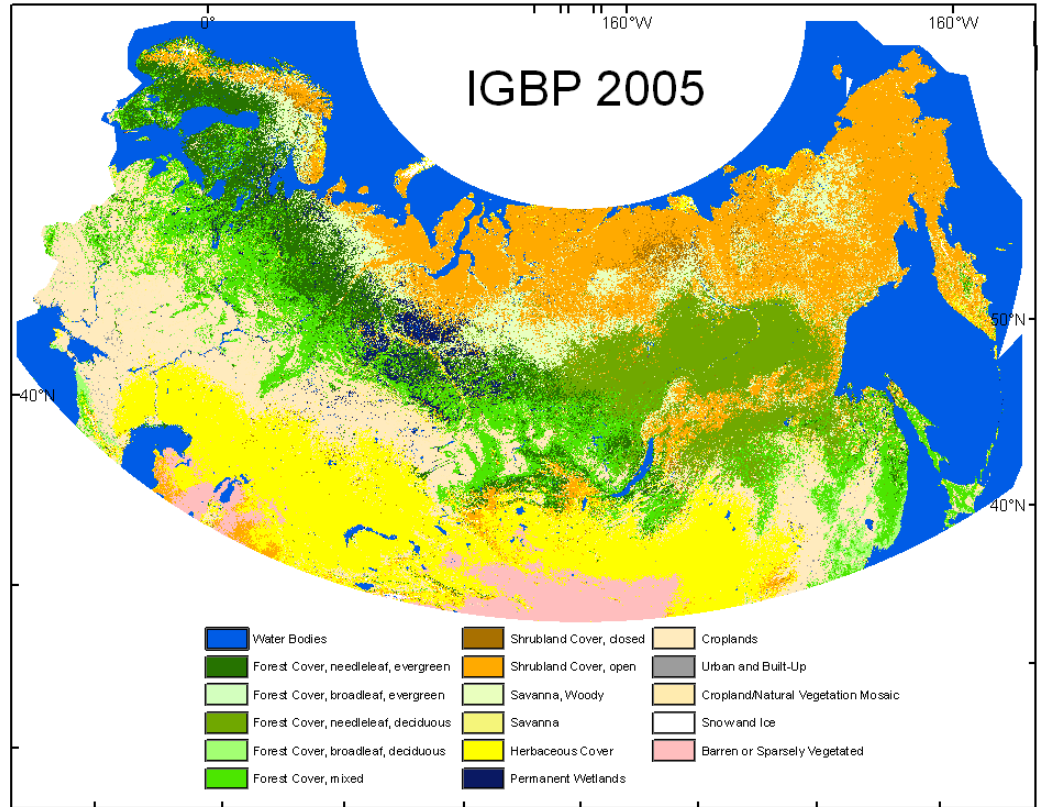
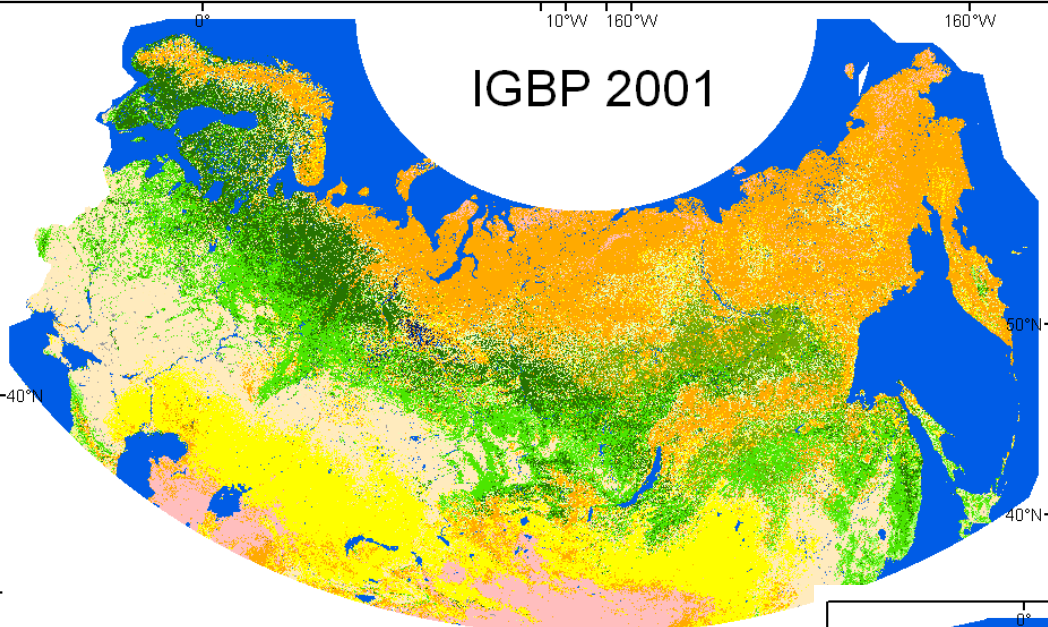


# Globcover 2005

- |  |   |  |
|--|---|--|
| Croplands (Irrigated)                                  | Forest Cover, needleleaved, closed            | Sparse vegetation                                |
| Croplands (Rainfed)                                    | Forest Cover, needleleaved or deciduous, open | Regularly flooded herbaceous or woody vegetation |
| Mosaic: Cropland / herbaceous, shrubland, forest       | Forest Cover, mixed type                      | Artificial surfaces and associated areas         |
| Mosaic: Herbaceous, shrubland, forest / Cropland       | Mosaic: Forest or Shrubland / herbaceous      | Bare Areas                                       |
| Forest Cover, evergreen or semi-deciduous, closed-open | Mosaic: Herbaceous / forest or shrubland      | Water Bodies                                     |
| Forest Cover, broadleaved, deciduous, closed           | Shrubland Cover, closed-open                  | Snow and Ice                                     |
| Forest Cover, broadleaved, deciduous, open             | Herbaceous Cover, closed-open                 | No data  |

4/8/2009

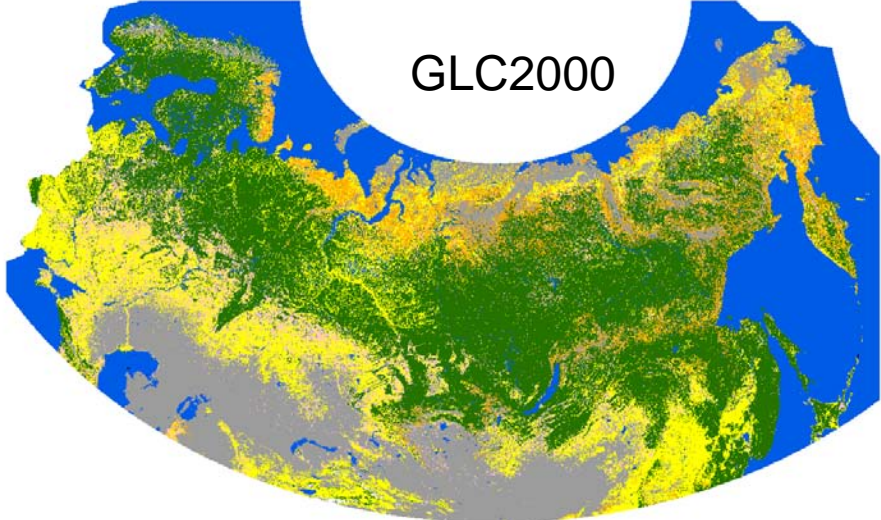
Olga



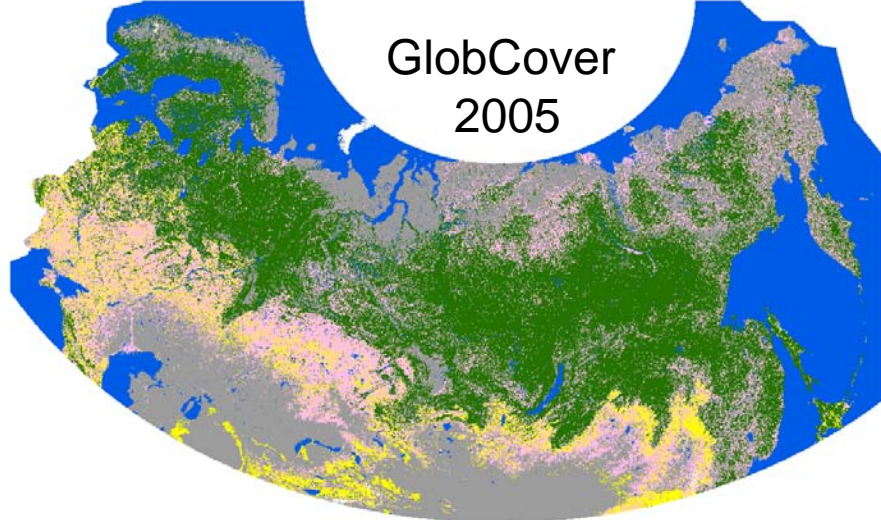
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Olg

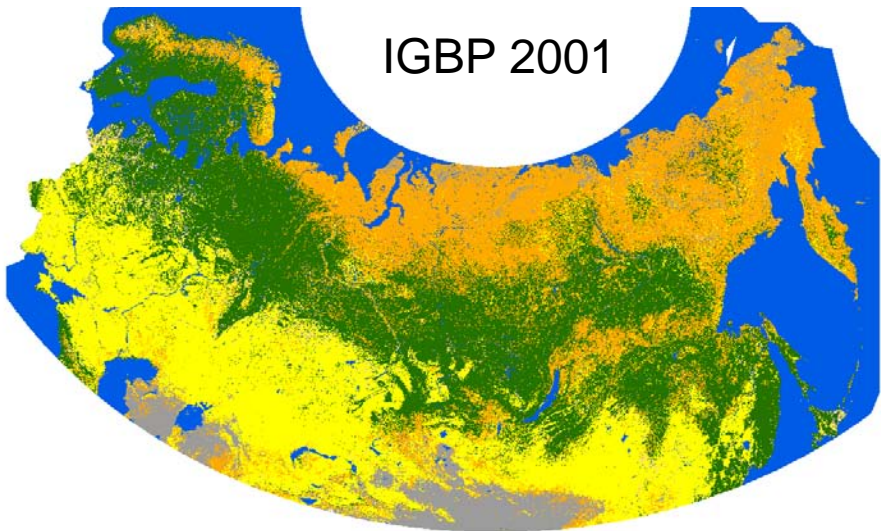
GLC2000



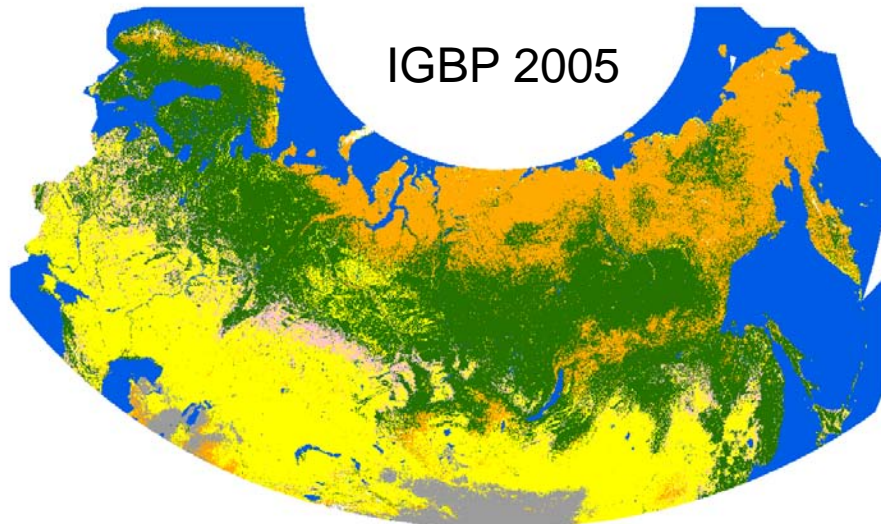
GlobCover 2005



IGBP 2001



IGBP 2005



Tree



Shrub



Herbaceous



Mosaic



Bare

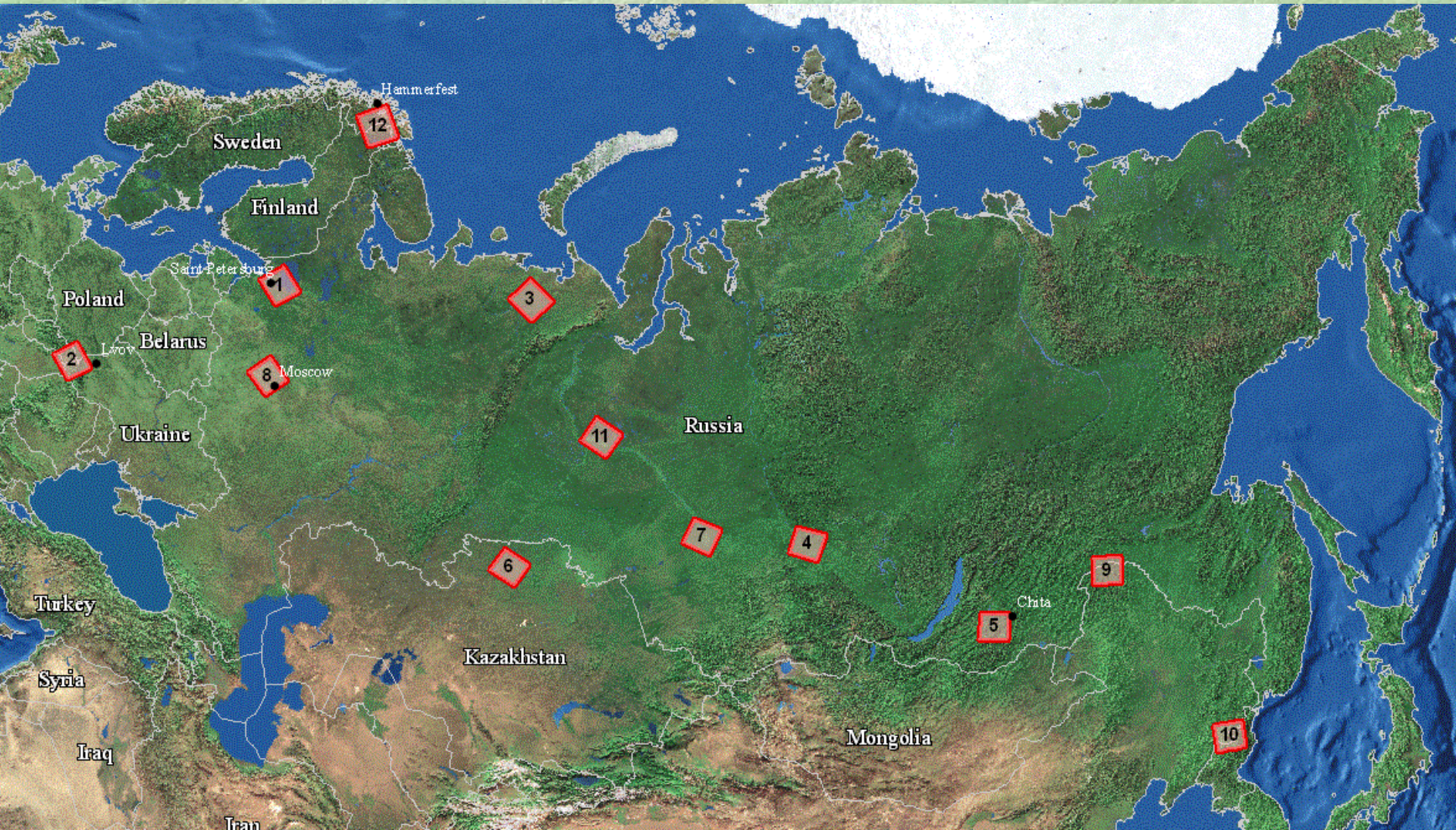


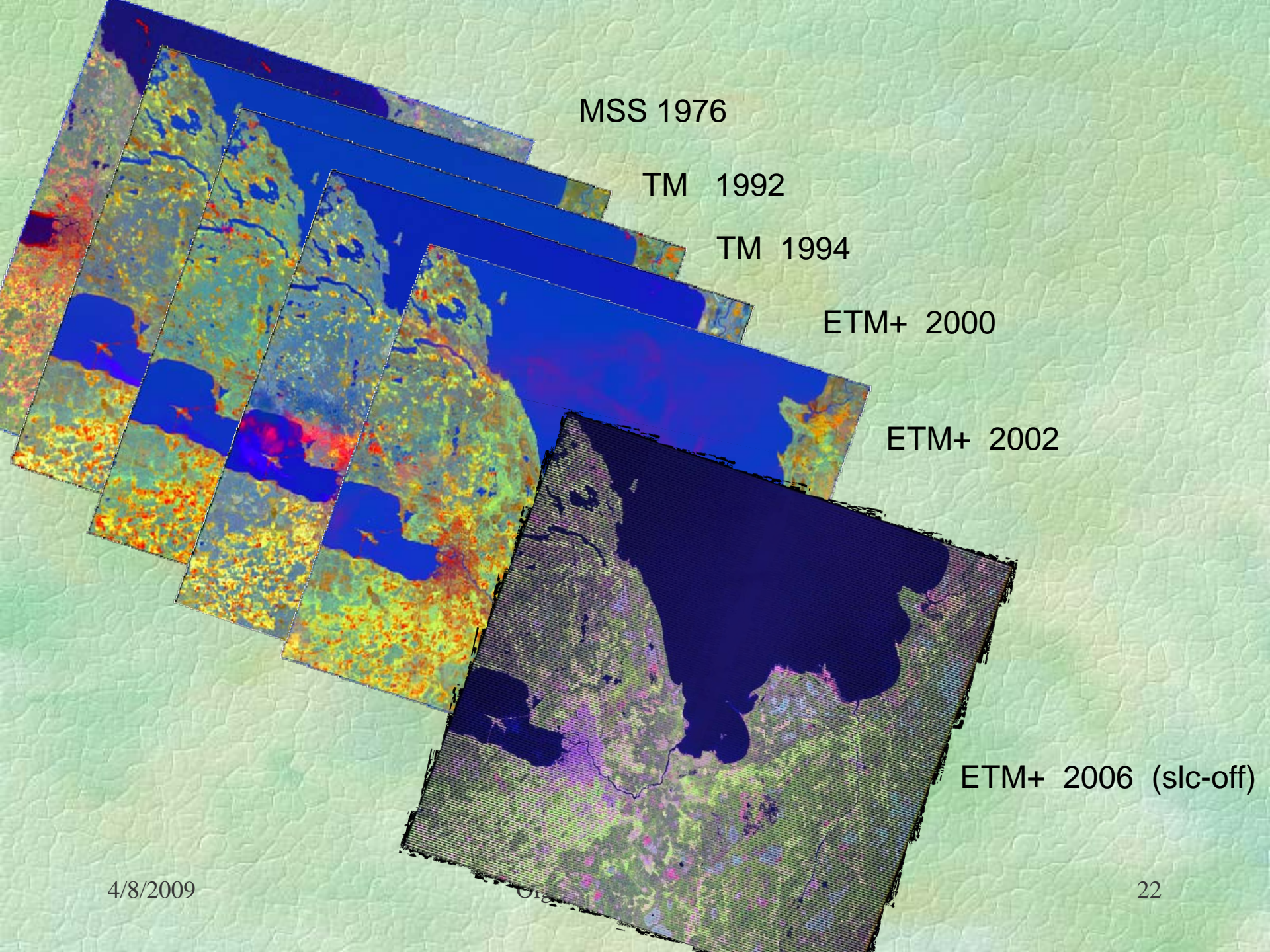
Ice



Water

# NELDA Test Sites





MSS 1976

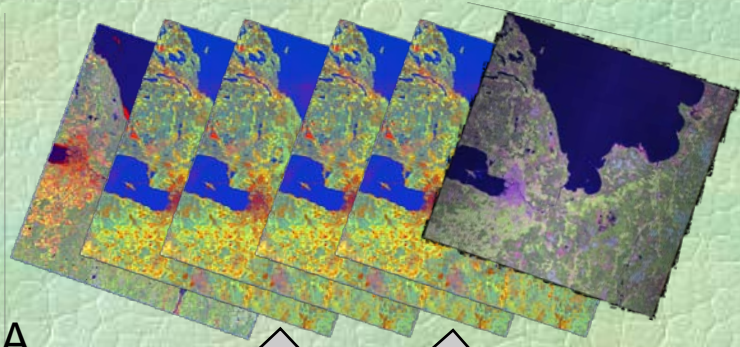
TM 1992

TM 1994

ETM+ 2000

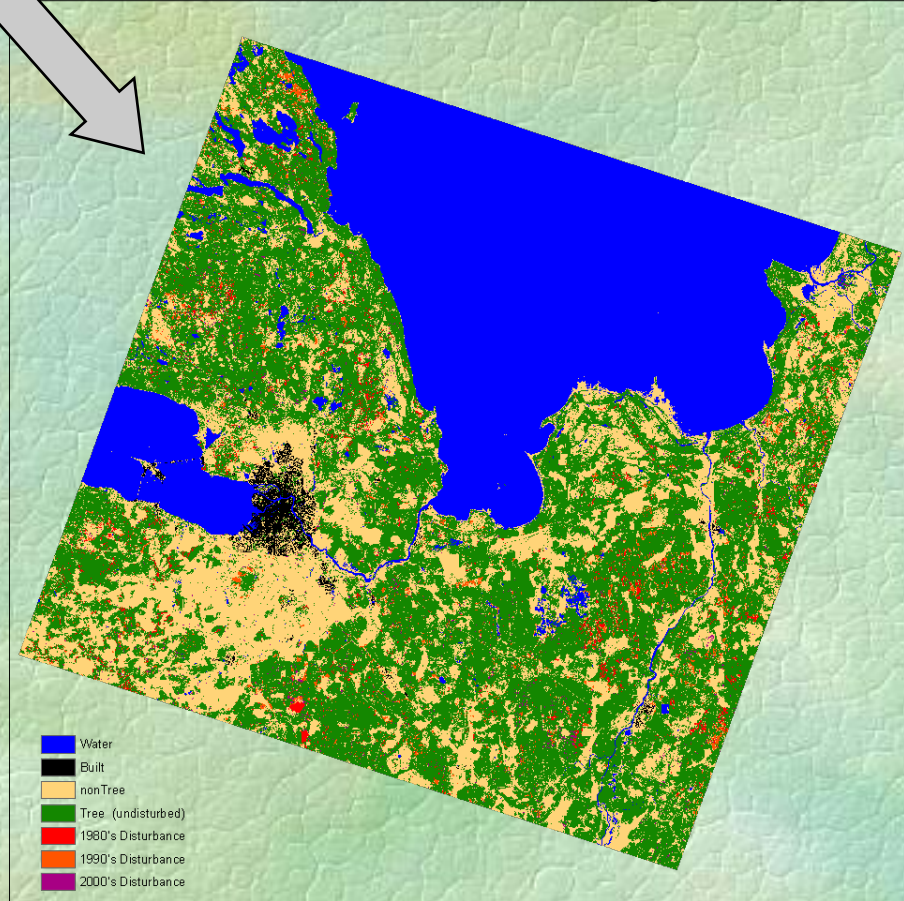
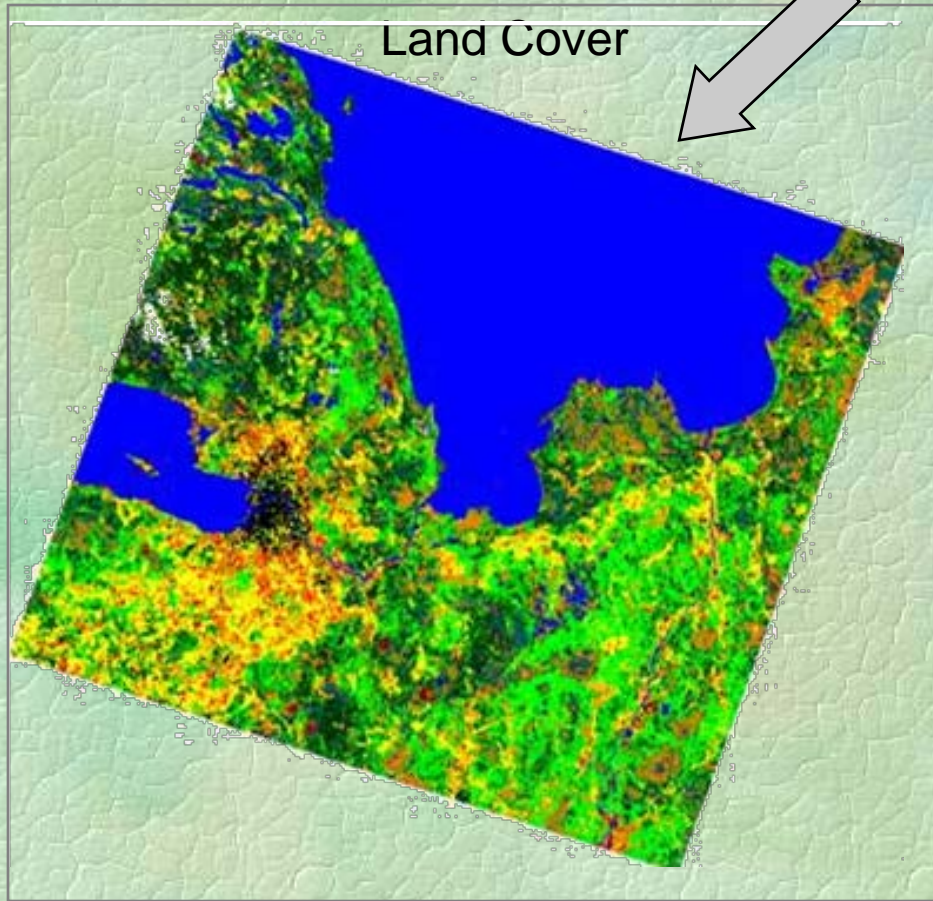
ETM+ 2002

ETM+ 2006 (slc-off)



NELDA  
Land Cover

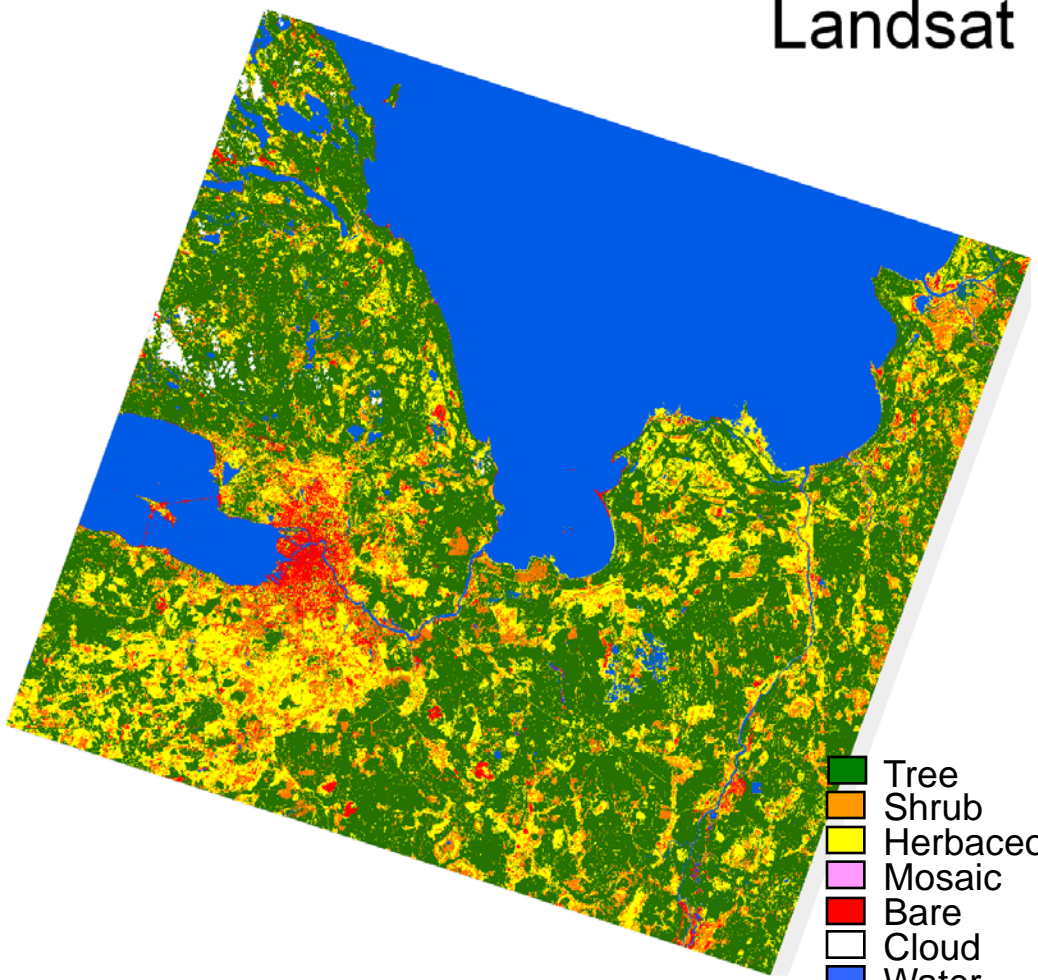
Change Map



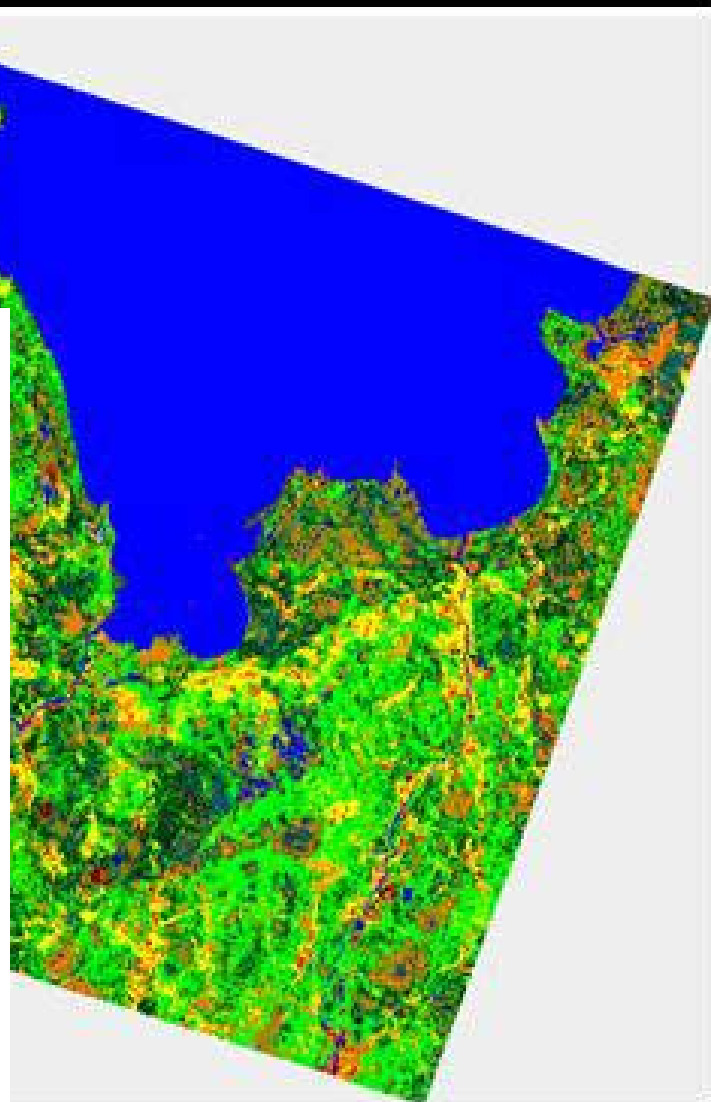
- F:\NELDA\NELDA\_Sites\1\_SrPete\classifications\
  - NELDA\_SrPetersburg\_2002\_Landcover\_Level5
    - (1) Water
    - (2) Bare, Built
    - (3) Bare
    - (4) Bare, Wetland
    - (5) Herbaceous
    - (6) Herb. Wetland
    - (7) Shrub
    - (8) Shrub, Wetland
    - (9) Tree, Needleaved, Evergreen, Closed



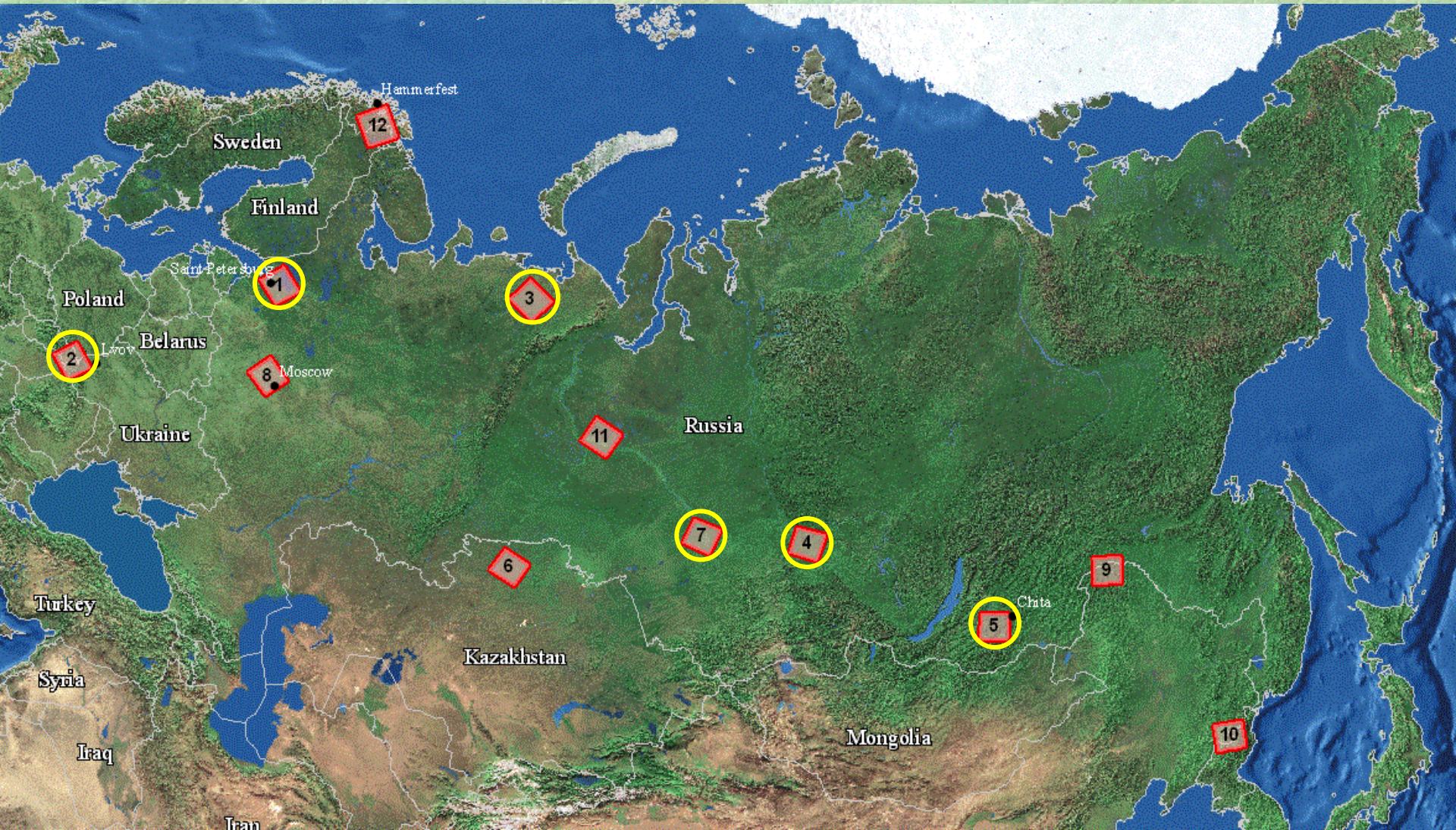
# Landsat



- Tree
- Shrub
- Herbaceous
- Mosaic
- Bare
- Cloud
- Water



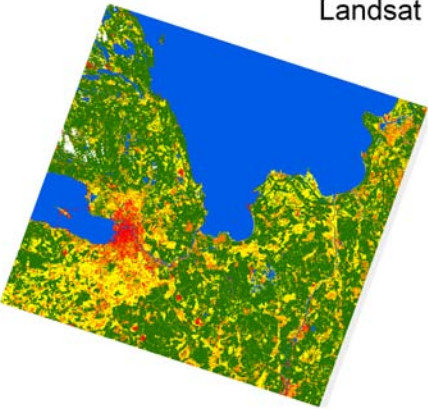
# NELDA Test Sites



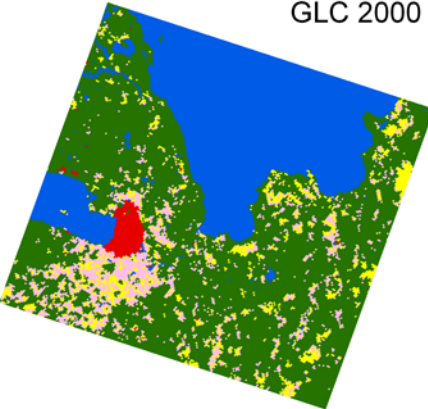


# St. Petersburg

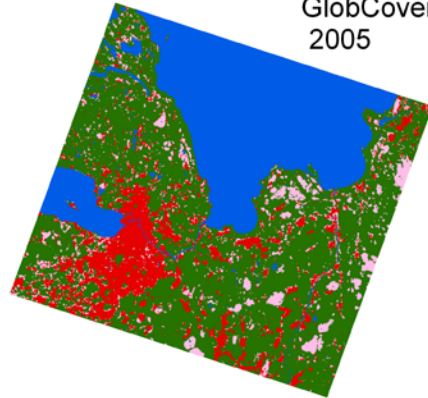
Landsat



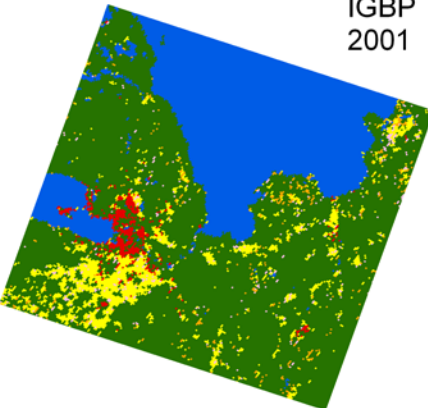
GLC 2000



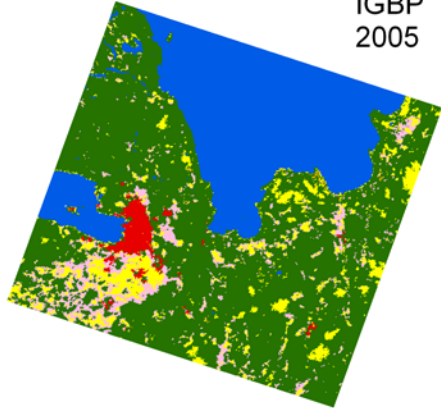
GlobCover 2005



IGBP 2001



IGBP 2005

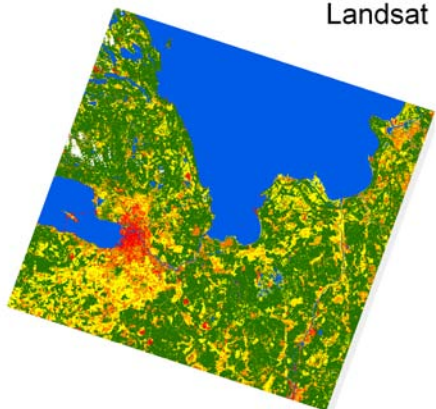


## Approaches to validation

- Visual comparison
- Comparison of class areas
- Confusion matrices
  - % agreement
  - per-class omission/comission errors

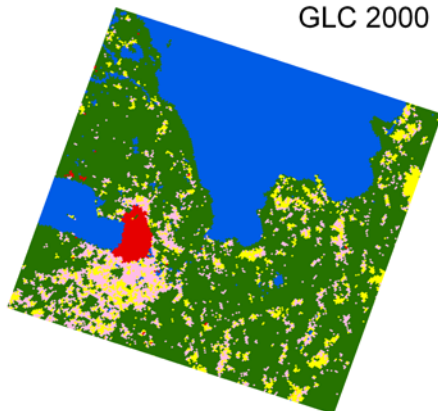
# St. Petersburg

Landsat

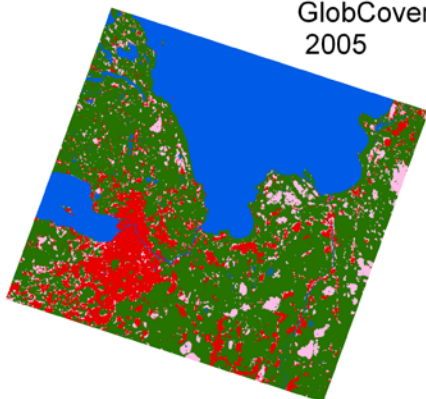


- Tree
- Shrub
- Herbaceous
- Mosaic
- Bare
- Cloud
- Water

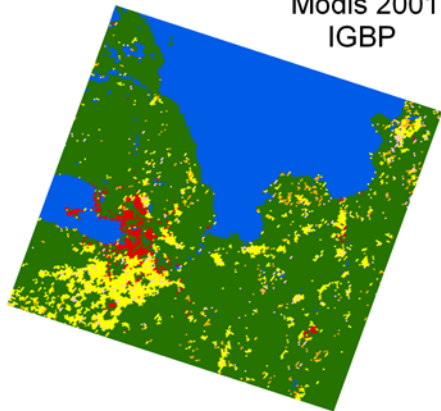
GLC 2000



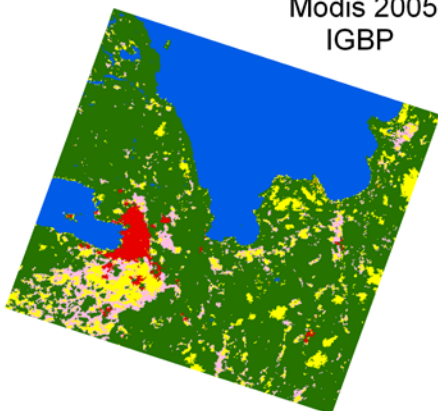
GlobCover 2005



Modis 2001  
IGBP



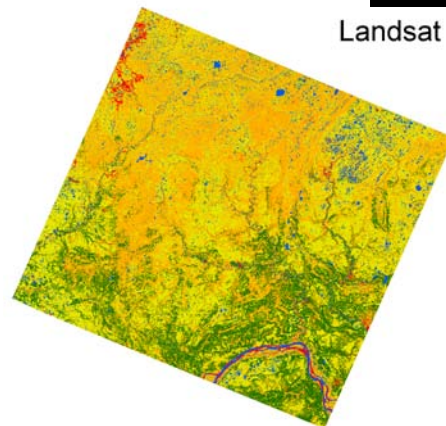
Modis 2005  
IGBP



nki

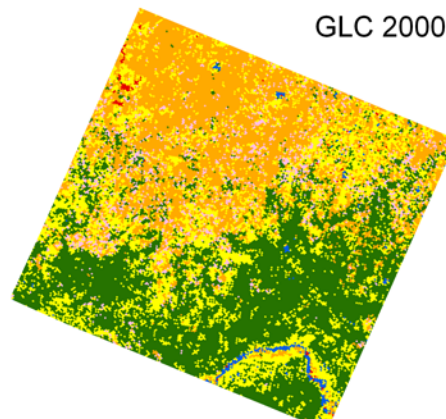
# Komi

Landsat

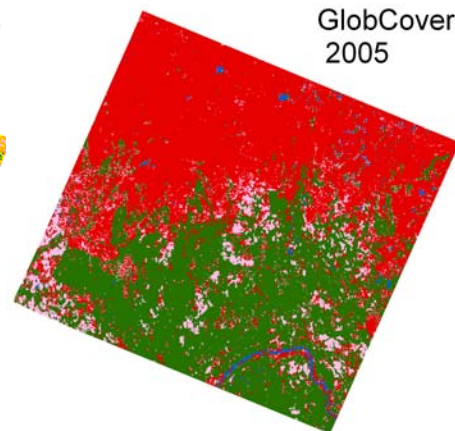


- Tree
- Shrub
- Herbaceous
- Mosaic
- Bare
- Cloud
- Water

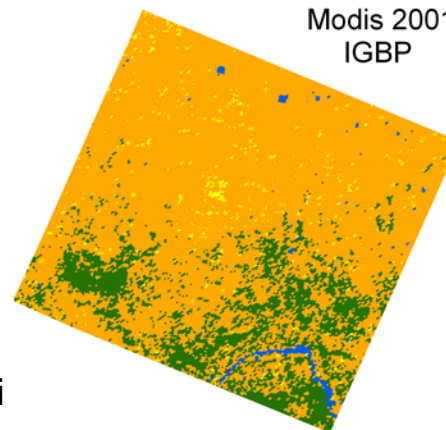
GLC 2000



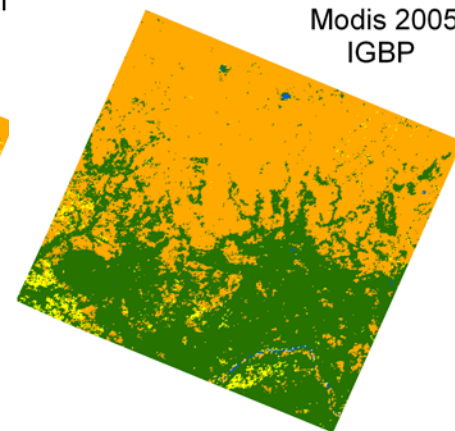
GlobCover 2005



Modis 2001  
IGBP

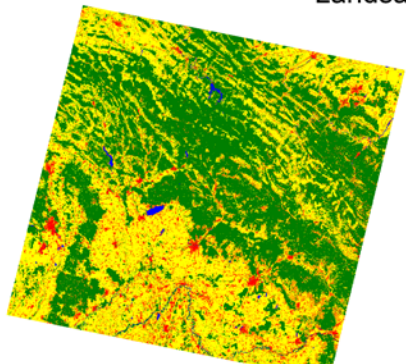


Modis 2005  
IGBP



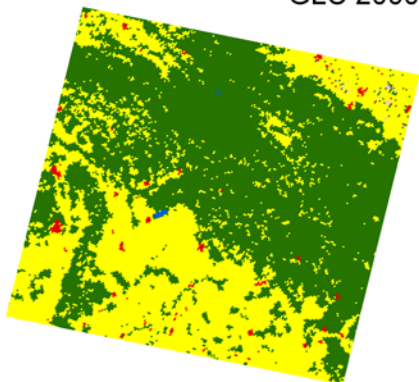
# Carpathians

Landsat

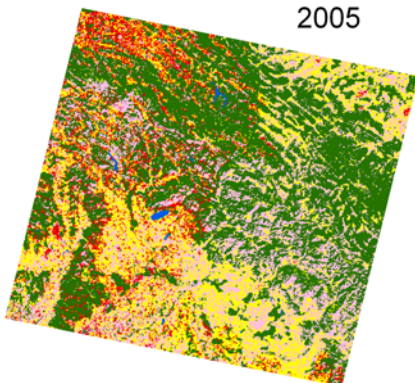


- Tree
- Shrub
- Herbaceous
- Mosaic
- Bare
- Cloud
- Water

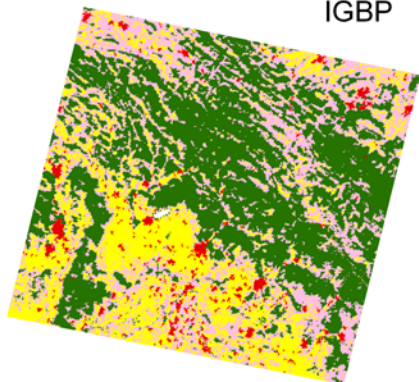
GLC 2000



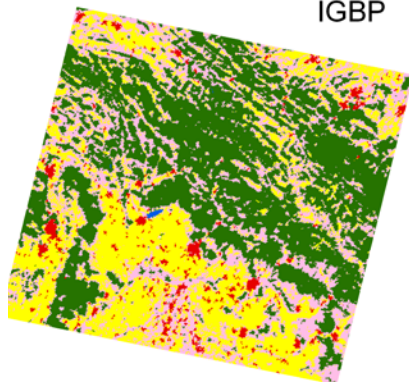
GlobCover 2005



Modis 2001  
IGBP

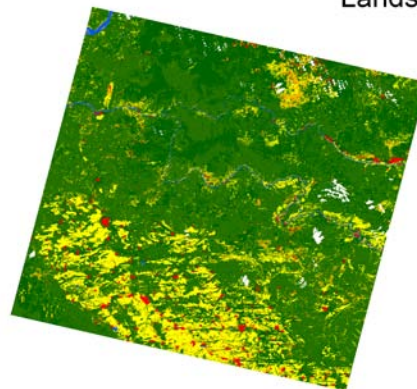


Modis 2005  
IGBP



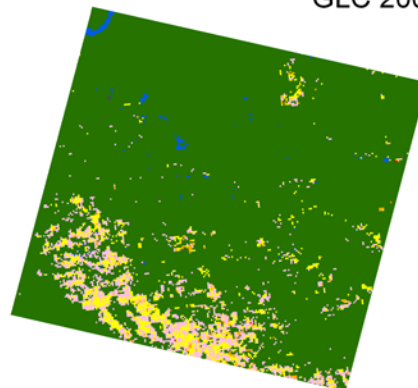
# Priangarie

Landsat

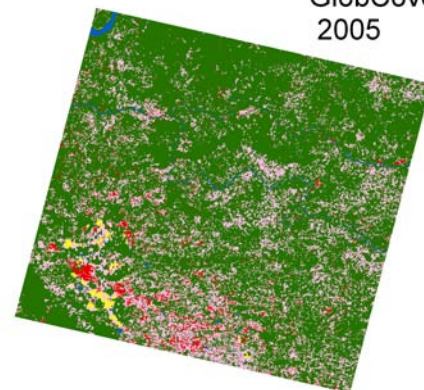


- Tree
- Shrub
- Herbaceous
- Mosaic
- Bare
- Cloud
- Water

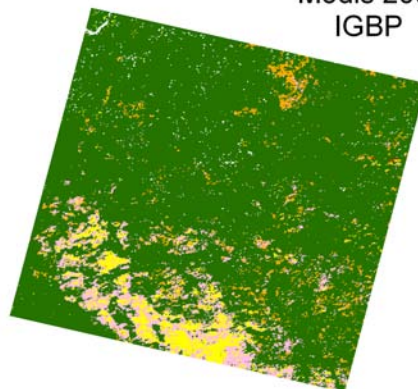
GLC 2000



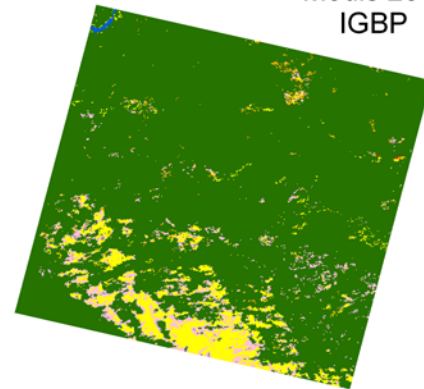
GlobCover 2005



Modis 2001  
IGBP



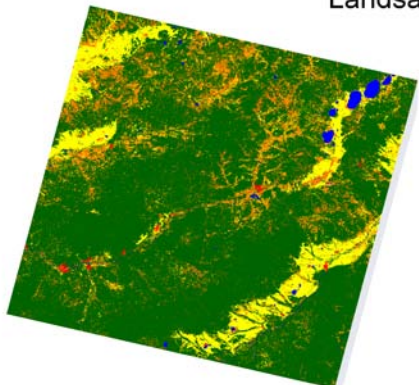
Modis 2005  
IGBP



ink

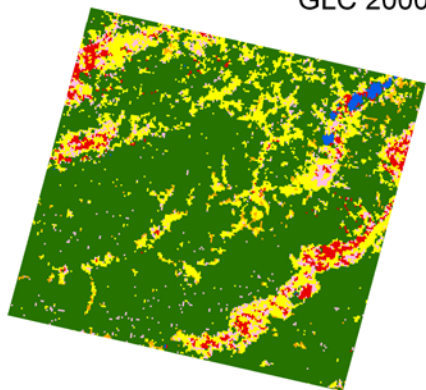
# Chita

Landsat

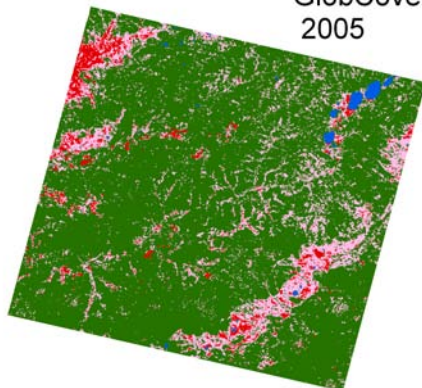


- Tree
- Shrub
- Herbaceous
- Mosaic
- Bare
- Cloud
- Water

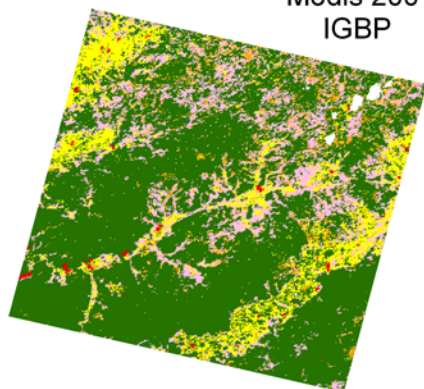
GLC 2000



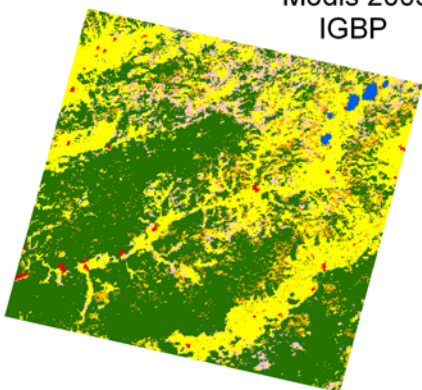
GlobCover 2005



Modis 2001  
IGBP



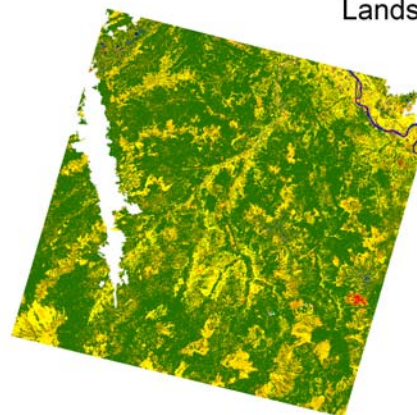
Modis 2005  
IGBP



anki

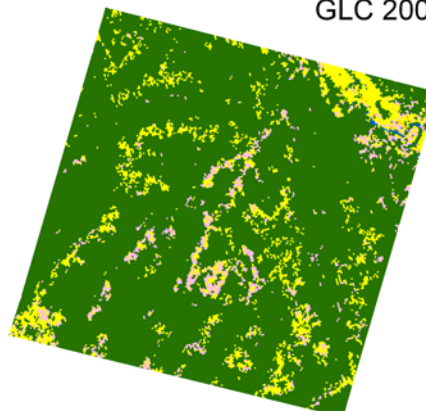
# Vasyuganje

Landsat

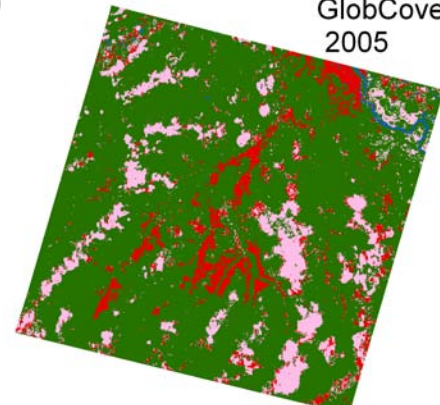


- Tree
- Shrub
- Herbaceous
- Mosaic
- Bare
- Cloud
- Water

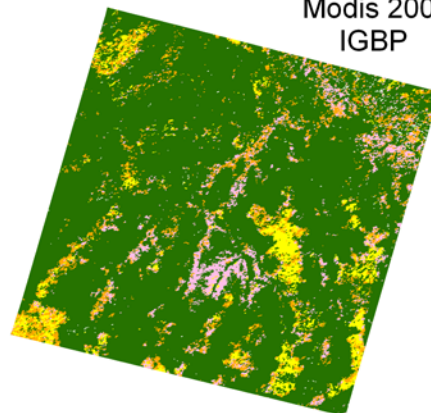
GLC 2000



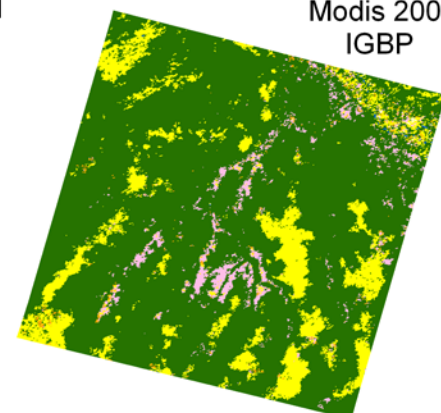
GlobCover 2005



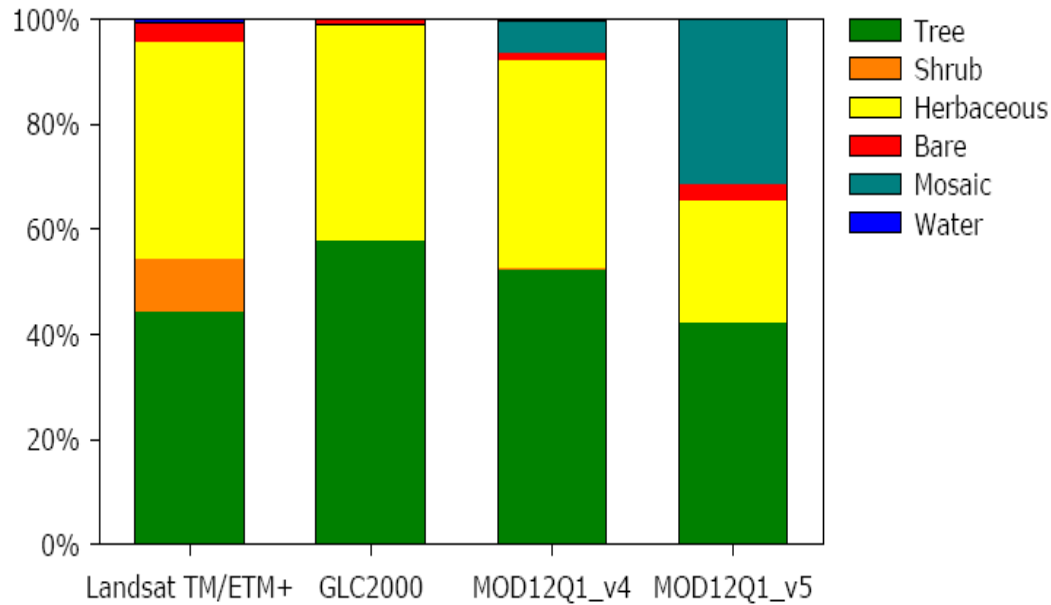
Modis 2001  
IGBP



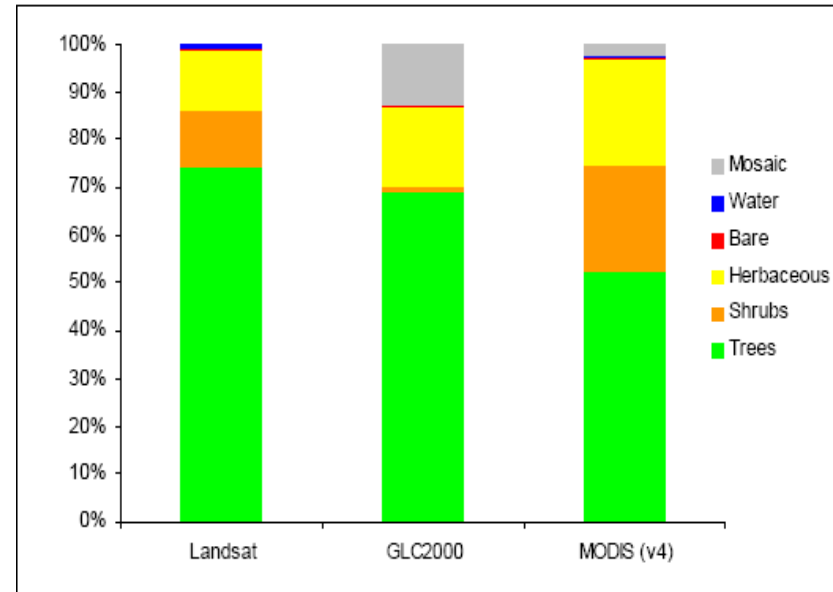
Modis 2005  
IGBP



# Comparison of class areas

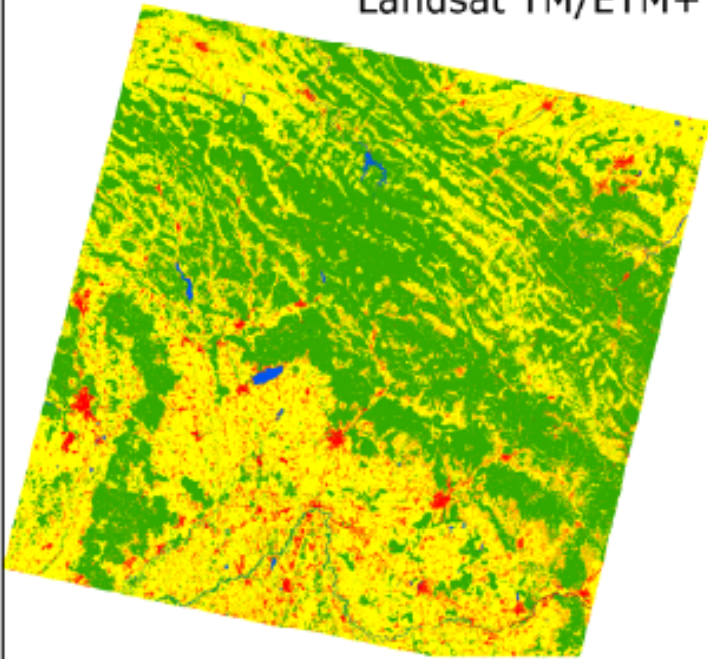


Carpathians

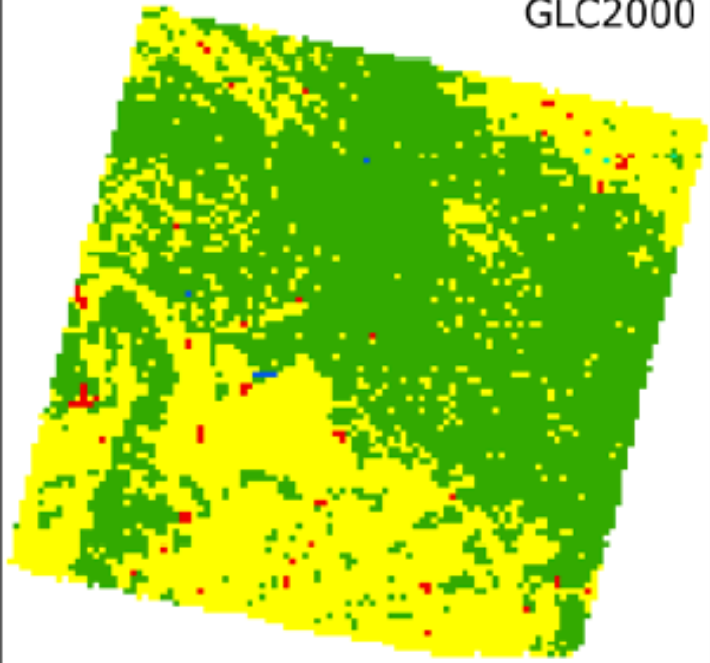


Chita

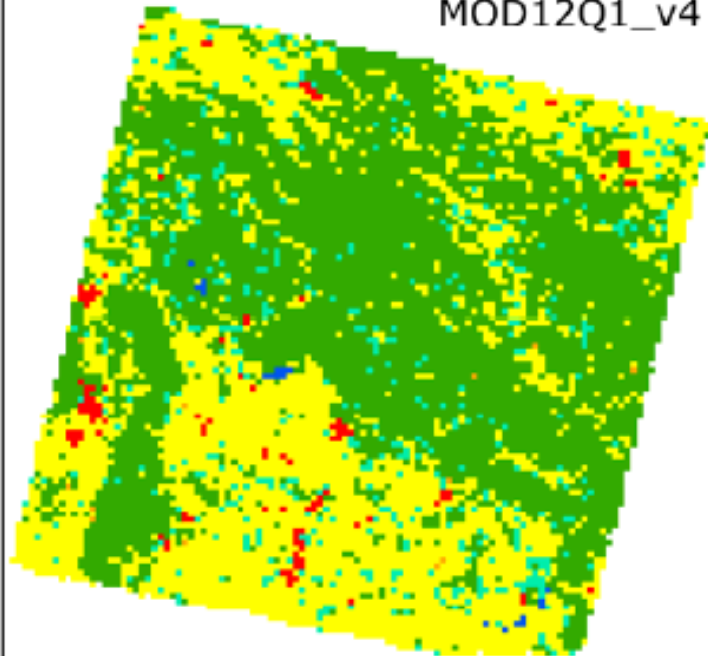
Landsat TM/ETM+



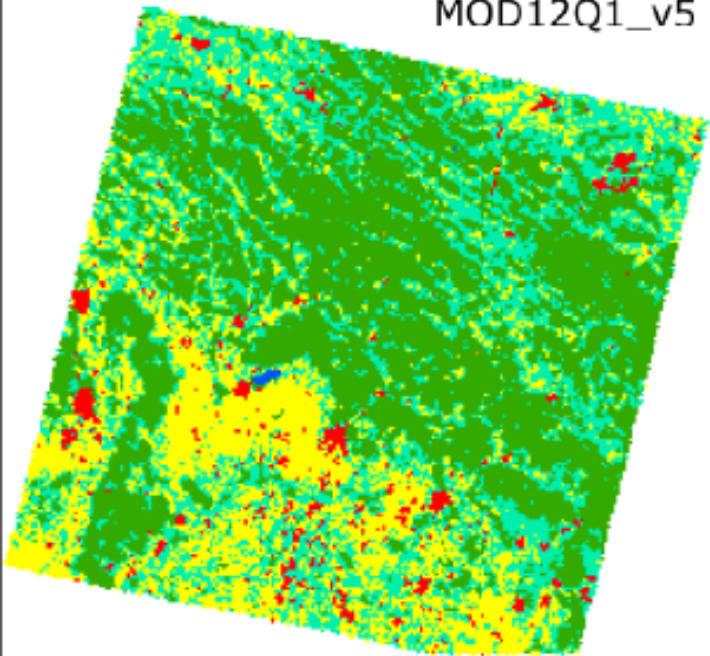
GLC2000



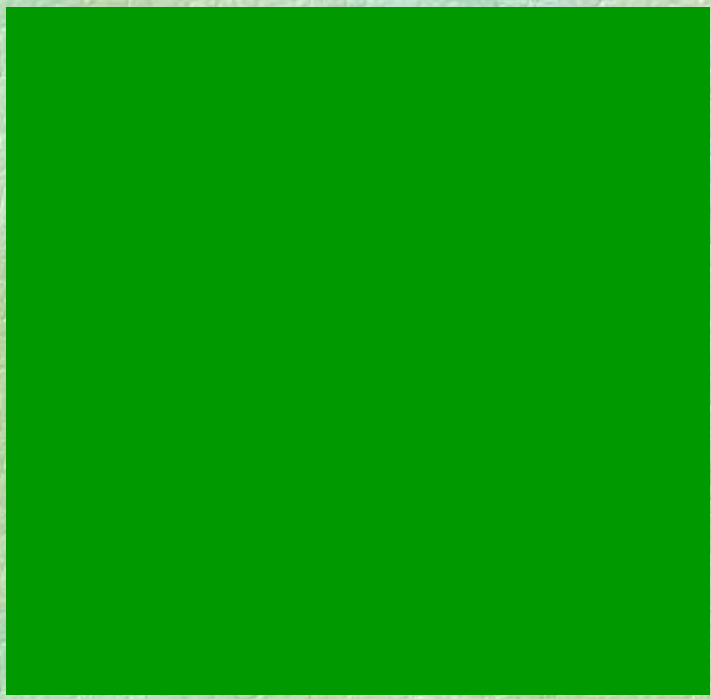
MOD12Q1\_v4



MOD12Q1\_v5

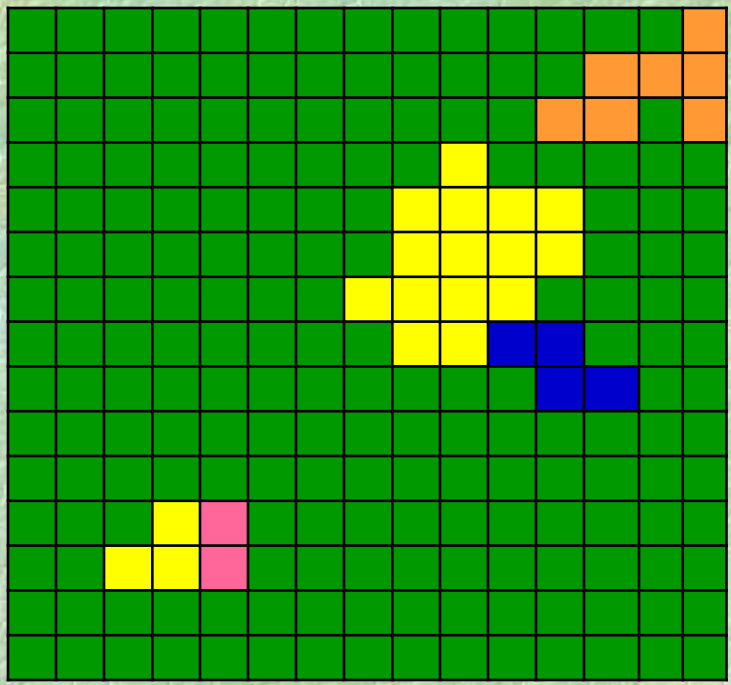


# Deriving confusion matrix: example for one 1 km pixel



1 km

1 km



# Agreement matrix for St. Petersburg site, km<sup>2</sup>

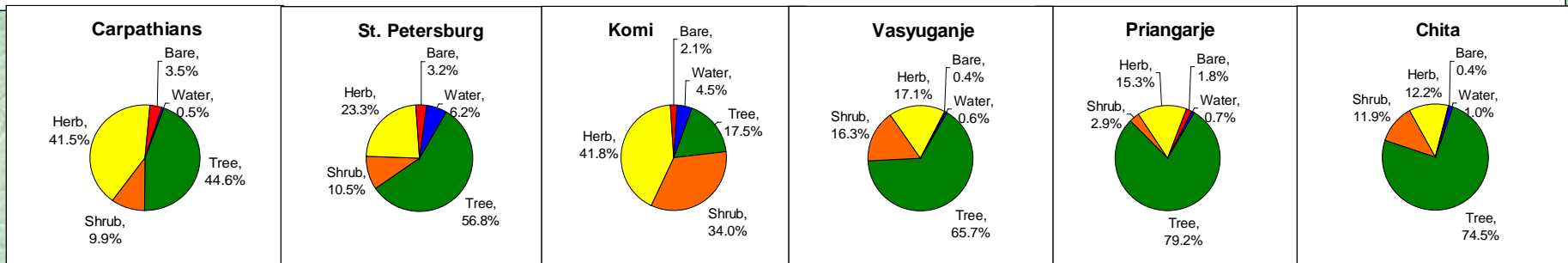
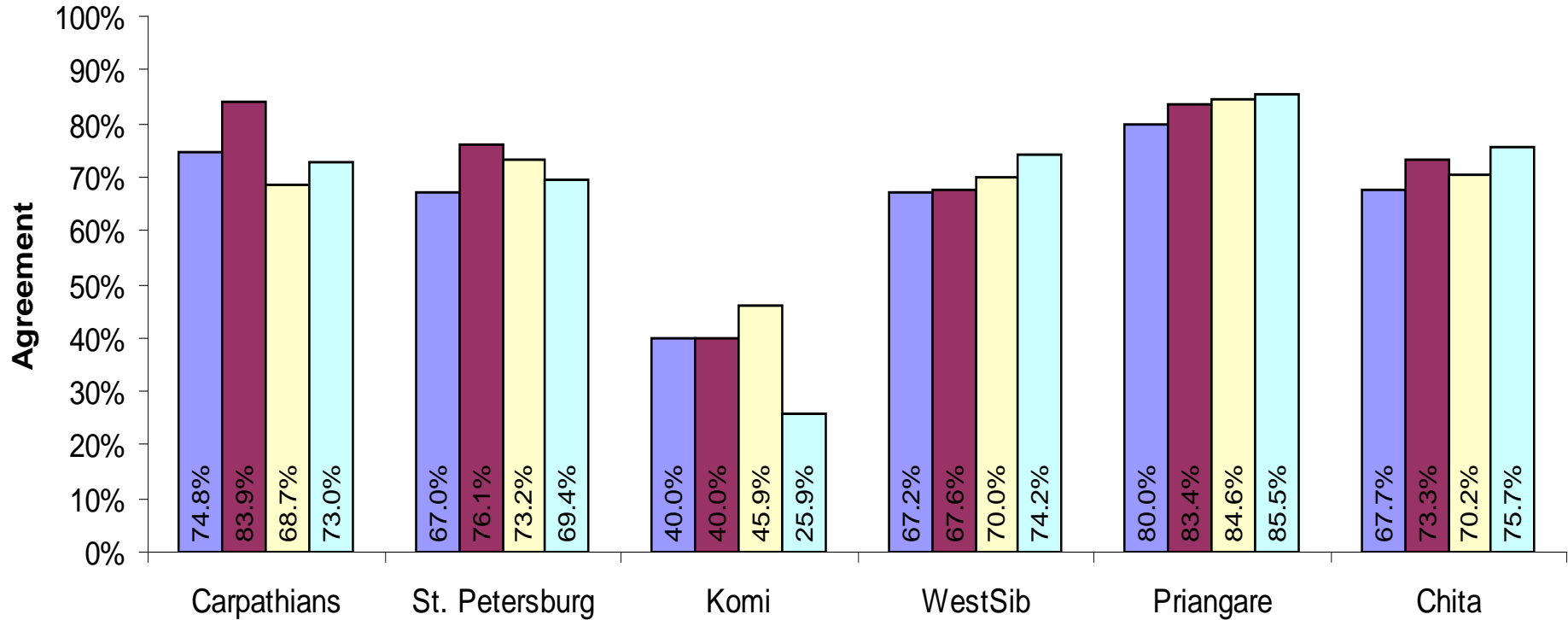
GLC-2000	NELDA land cover (km <sup>2</sup> )					Commission
	Trees	Shrubs	Herbaceous	Barren	Water	
Trees	<b>11,264</b>	1,103	2,635	177	298	4,213
Shrubs	1	<b>2</b>	2	1	0	5
Herbaceous	324	444	<b>926</b>	97	32	1,499
Barren	39	44	96	<b>239</b>	25	404
Mosaics	<b>535</b>	<b>671</b>	<b>1,349</b>	<b>133</b>	33	2,186
Water	167	33	87	47	<b>940</b>	1,107
Omission	1,066	1,194	2,460	517	1,030	

Agreement = 73.2%, Kappa = 50.5%

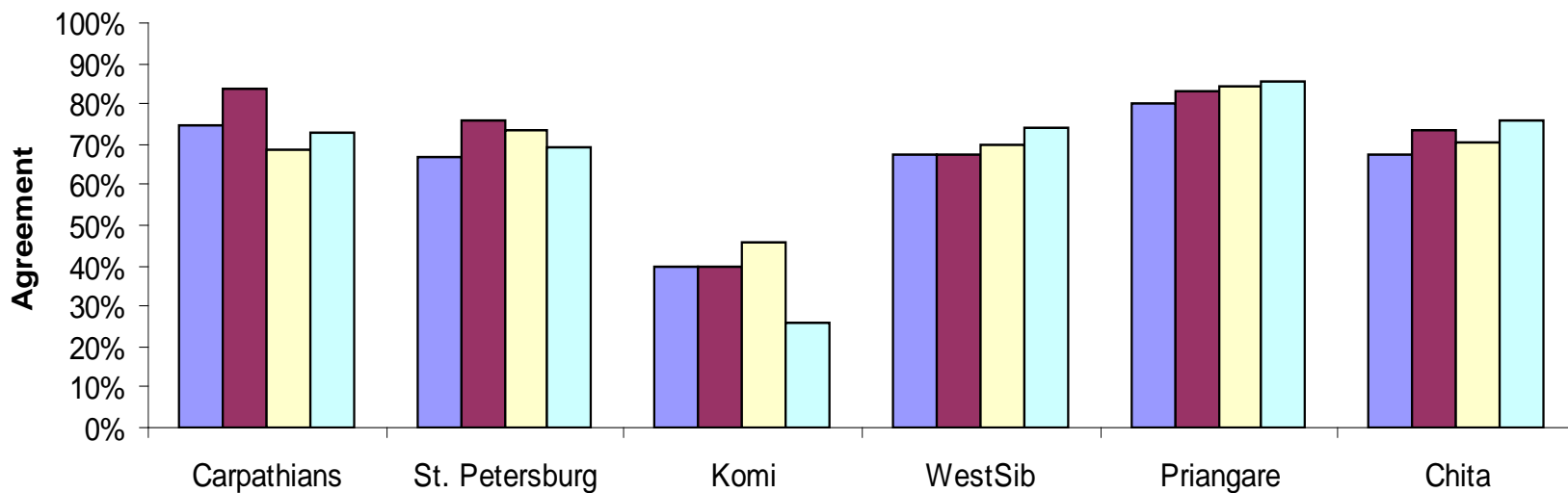


# Agreement of coarse resolution and Landsat-based maps at NELDA sites

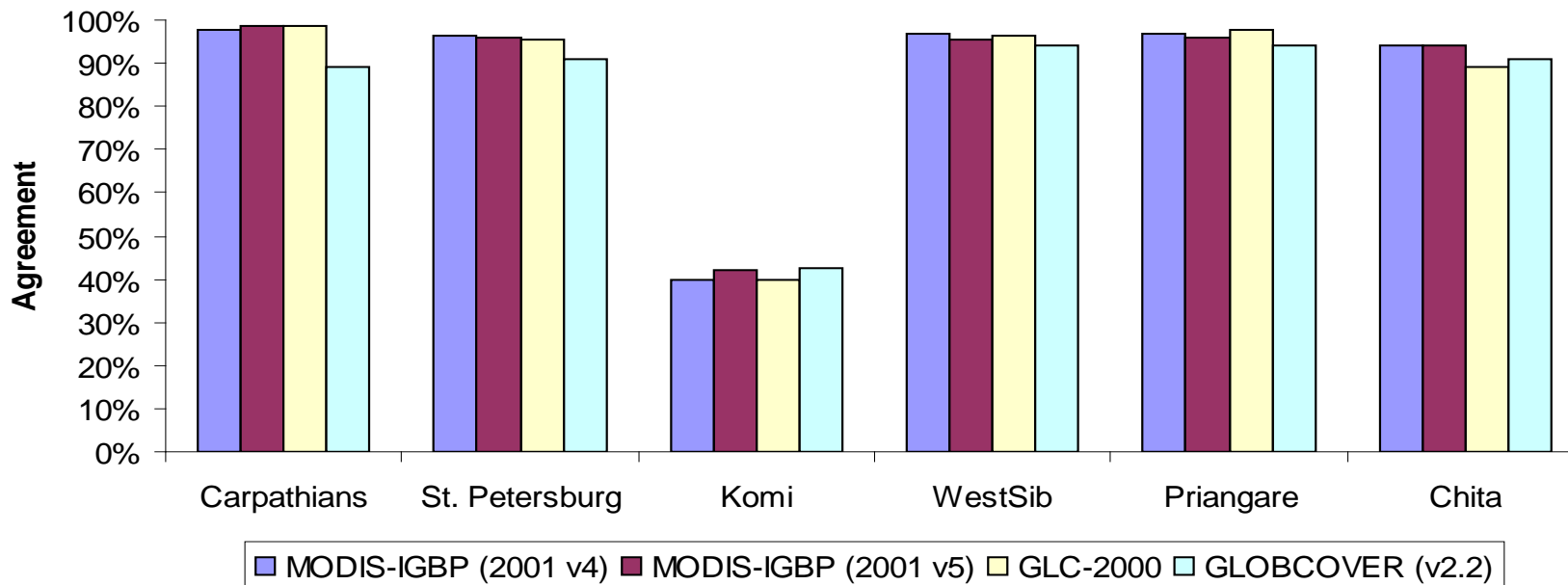
■ MODIS-IGBP (2001 v4) 
 ■ MODIS-IGBP (2001 v5) 
 ■ GLC-2000 
 ■ GLOBCOVER (v2.2)



## All Pixels

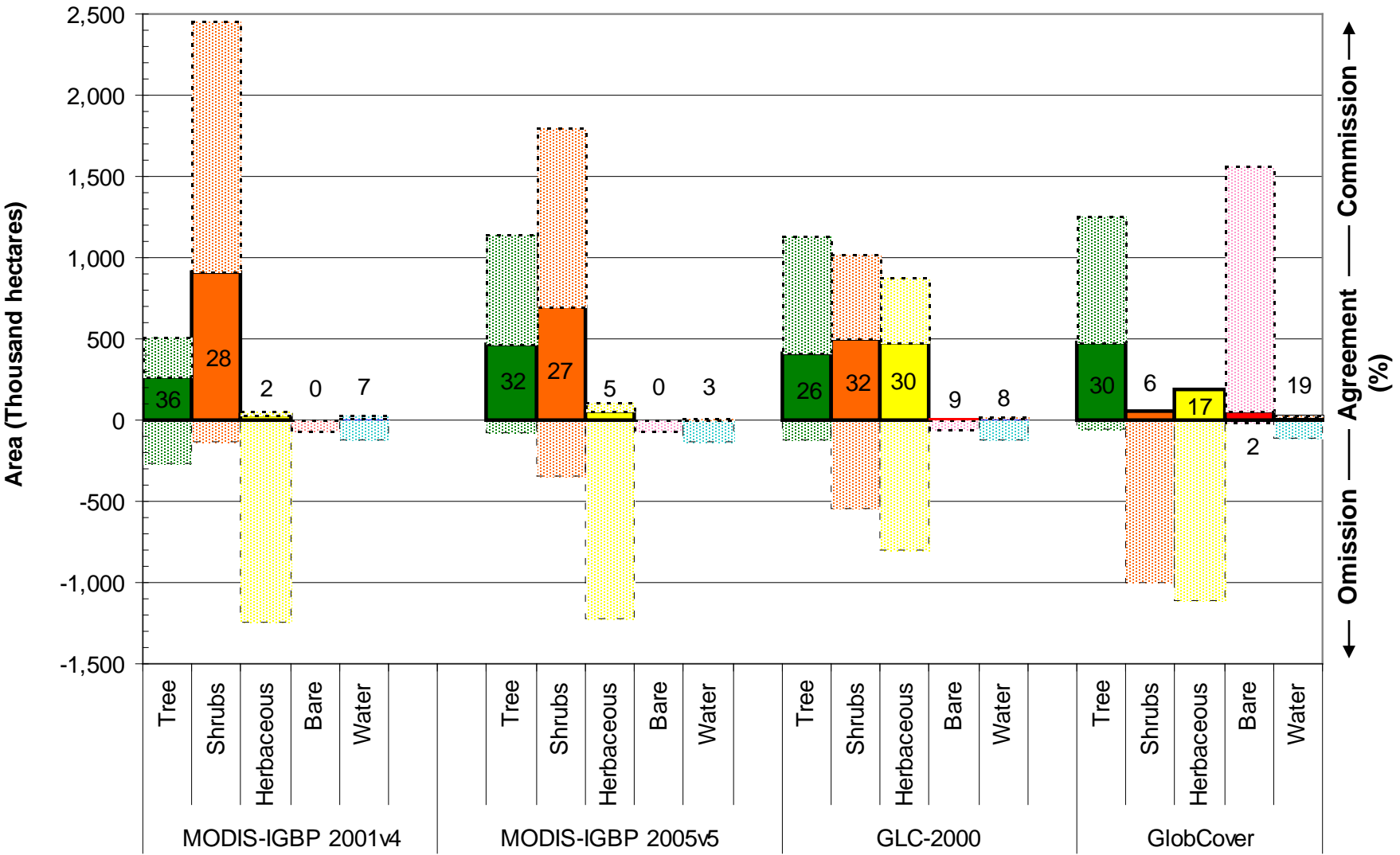


## Pure pixels

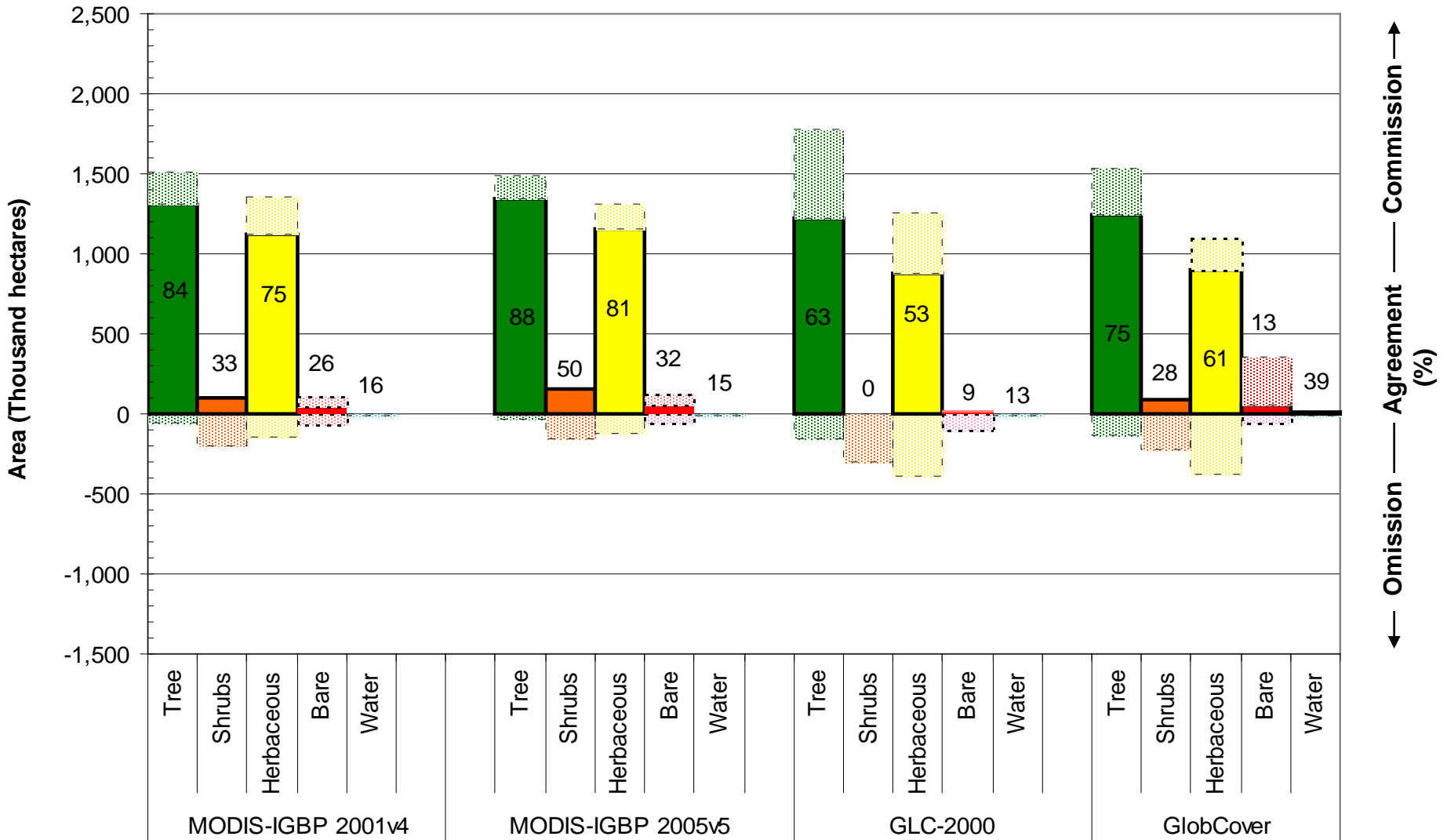


Legend: MODIS-IGBP (2001 v4) (blue), MODIS-IGBP (2001 v5) (maroon), GLC-2000 (yellow), GLOBCOVER (v2.2) (cyan)

# Komi Landsat Classification Comparison to Global Products

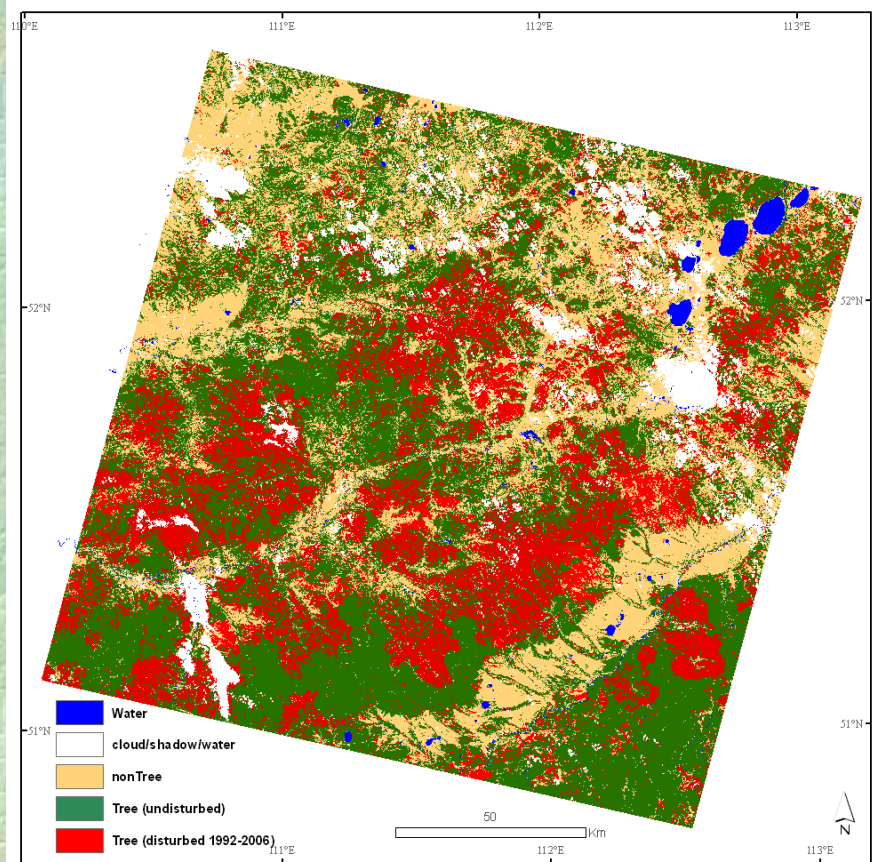
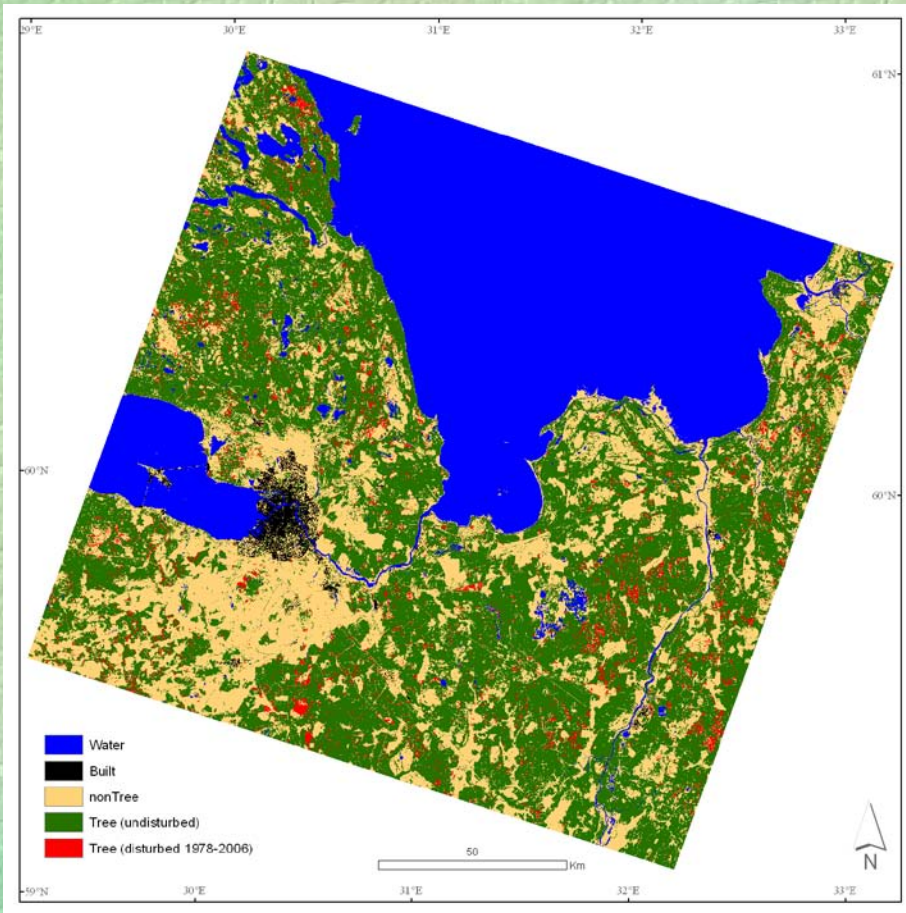


# Carpathians Landsat Classification Comparison to Global Products



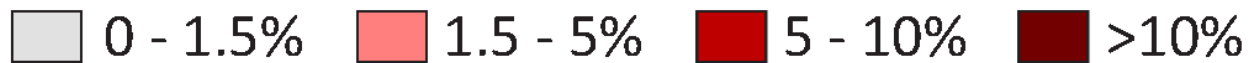
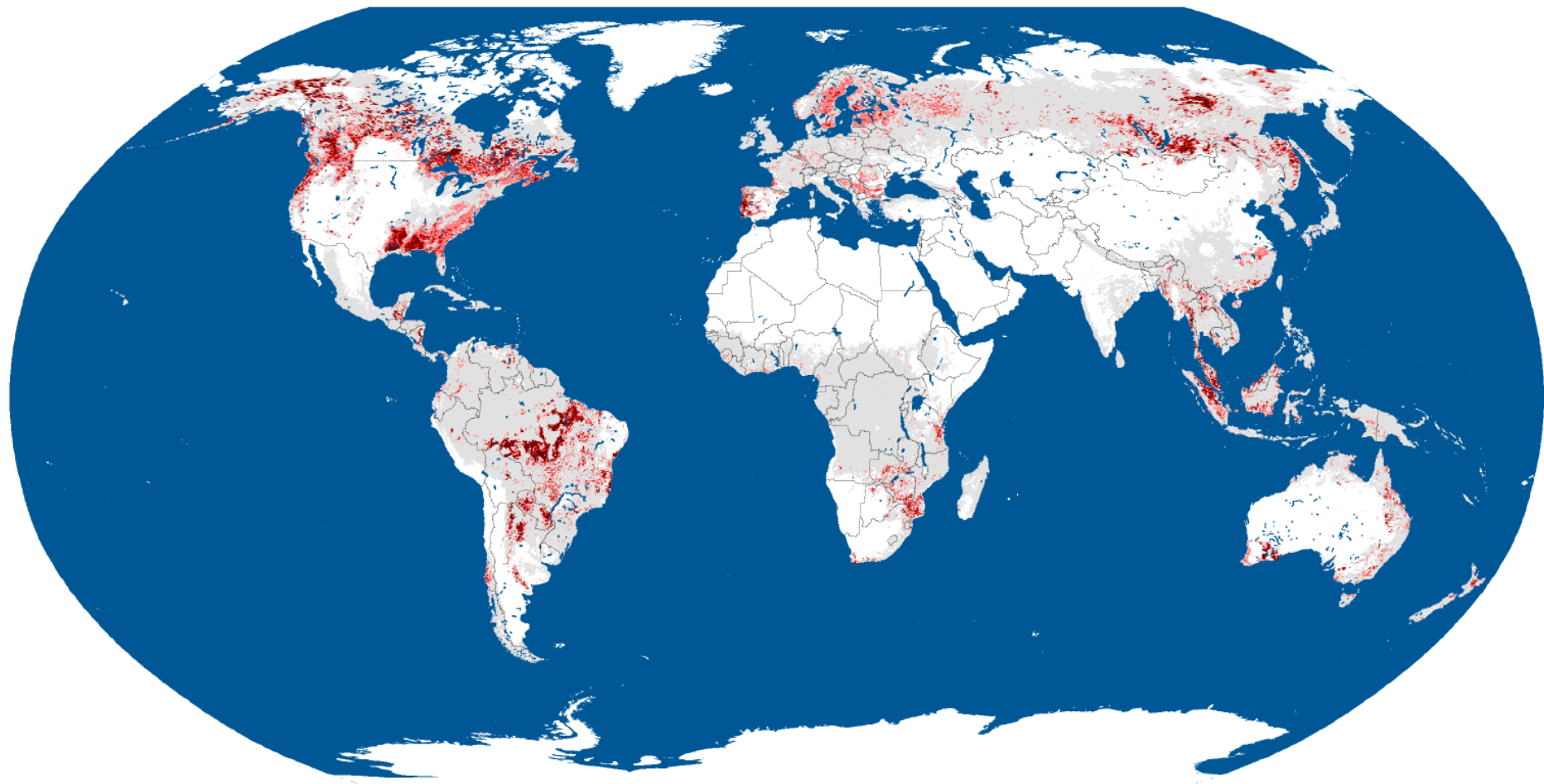
# Take home messages

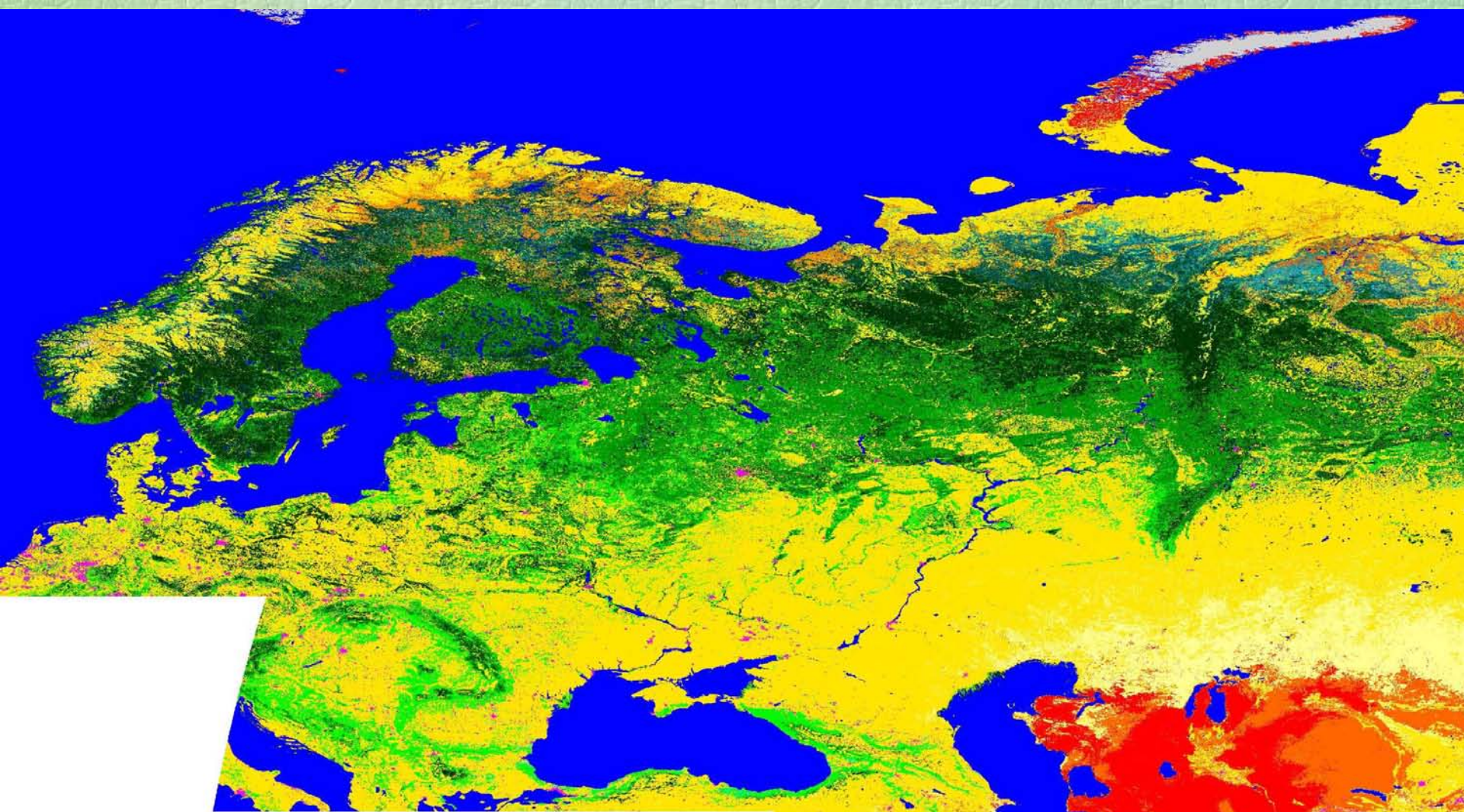
- Map selection matters
- Map performance depends on location and classes of interest















# Percent forest cover loss, 2000 to 2005

## Percent forest cover loss, 2000 to 2005



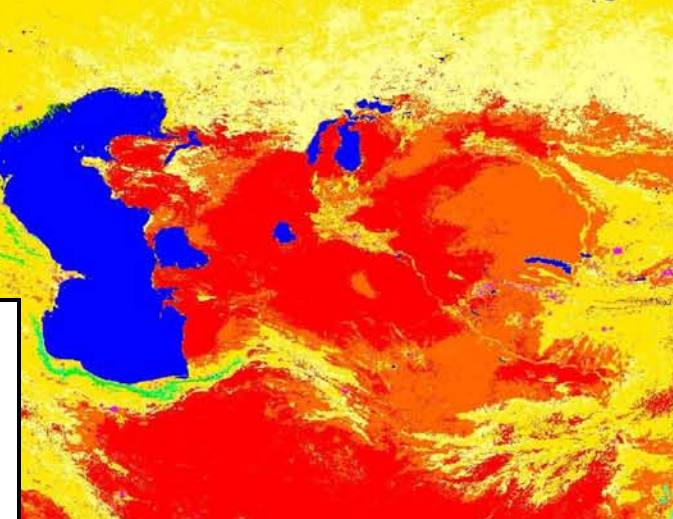


**Vegetated**

- |  |   |
|--|---|
|  Tree Evergreen Needleleaved Closed |  Tree Mixed Closed |
|  Tree Evergreen Needleleaved Open   |  Tree Mixed Open   |
|  Tree Deciduous Needleleaved Closed |  Shrub Closed      |
|  Tree Deciduous Needleleaved Open   |  Shrub Open        |
|  Tree Deciduous Broadleaved Closed  |  Herbaceous Closed |
|  Tree Deciduous Broadleaved Open    |  Herbaceous Open   |

**Nonvegetated**

- |   |
|---|
|  Barren   |
|  Snow/Ice |
|  Water    |
|  Urban    |





# Conclusions

- Validation of LC maps is a pressing need
  - currently activities are very limited
- Community consensus on general framework for global land cover validation and accuracy assessment
  - efficiency of validation network is essential
  - independent of any single land cover product to support validation of many land cover datasets
  - global network with stratification by geographic regions, areas where maps differ, important rare land-cover classes
  - quantitative results to guide users (including error matrix for each map and region)
- Details of validation methods are evolving
  - VCF and land cover change maps
- Expanding the network of validation sites requires community effort



Globe-flower – *Trollius asiaticus*