Pioneering NASA LCLUC Russia Research Projects Mature 1997-2003

Team Significant Results Overview Publication

Kathleen M. Bergen *, Susan G. Conard, R. A. Houghton, Eric S. Kasischke, Vyacheslav I. Kharuk, Olga N. Krankina, K. Jon Ranson, Herman H. Shugart, Anatoly I. Sukhinin, Rudolf F. Treyfeld,. 2003. "**NASA and Russian Scientists Observe Land-Cover and Land-Use Change and Carbon in Russian Forests**, *Journal of Forestry*, June, pp 34-41.

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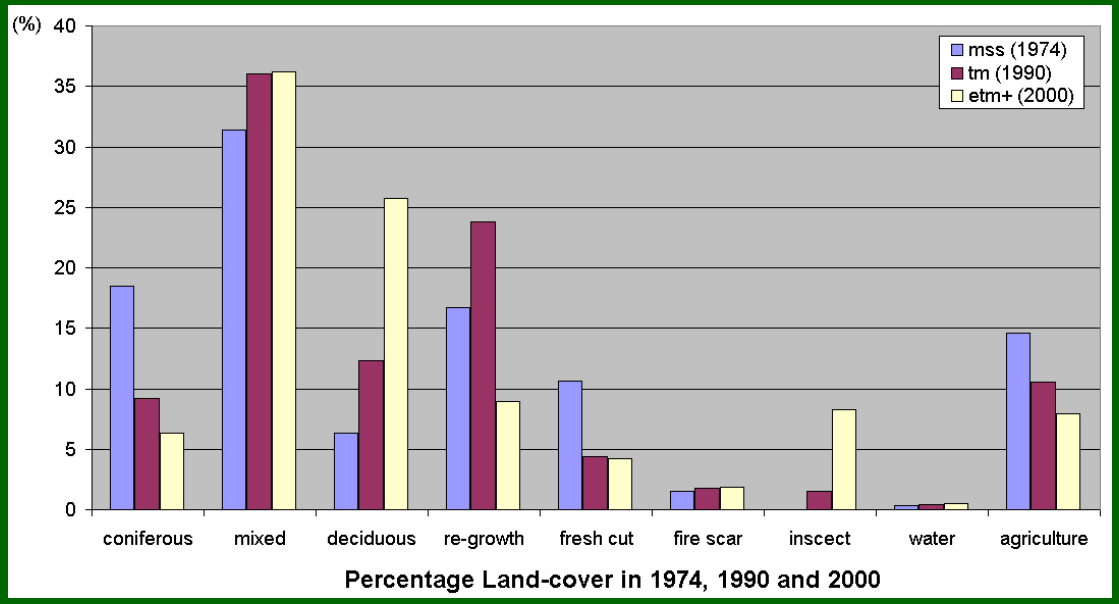
SIBERIAN FORESTS AND SOCIOECONOMIC CHANGE (PI: K. Bergen, U. Michigan)

Change from the state-controlled Soviet Union to a transitioning market economy in 1990's is *already* showing different Land-Use/Cover footprints and these are directly observable and quantifiable by Landsat analysis 1975-2000.

Results in LCLUC book, Chapter 5, Northern Eurasia (accepted).



Landsat-derived statistics 1975-2000 (above) in case study sites show significantly reduced forest harvest and increased collective farm abandonment and insects/fire and re-growth deciduous forests are changing the *amount*, *age*, and *type* of forest on the landscape with implications for carbon storage (IALE 2003).

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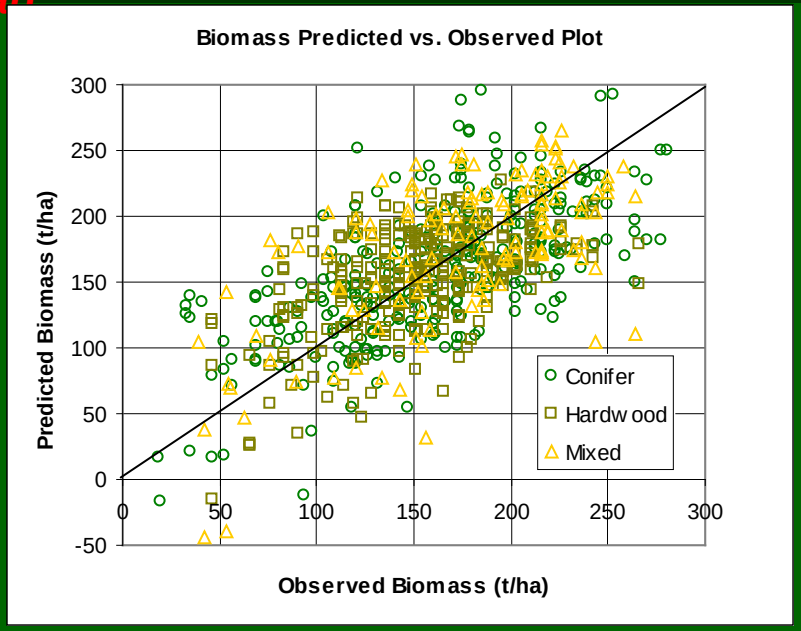
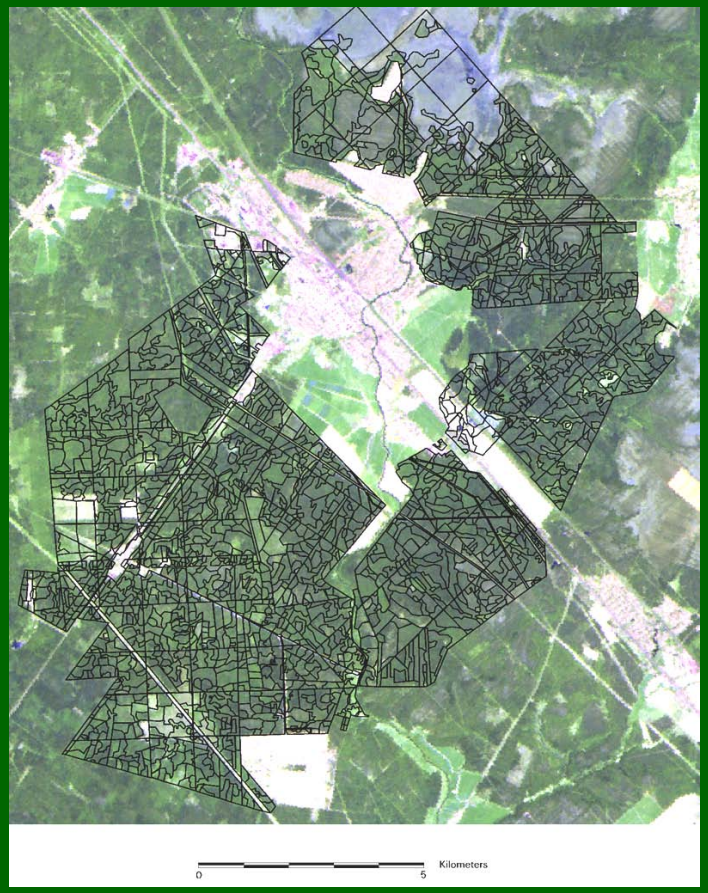
WESTERN RUSSIA CARBON BUDGETS (PIs: O. Krankina, Oregon State University; Richard Houghton, WHRC)

Between 1973 and 1993, time-series Landsat analysis shows C stores in the St. Petersburg region increased from 185 to 250 million tons, or nearly 20%, corroborating models that show a present net carbon sink in northern mid-latitudes. *Book for Springer-Verlag Ecological Studies series (Krankina et al)*





Ground data used to model carbon stores: forest inventory polygons overlaid with Landsat TM image.

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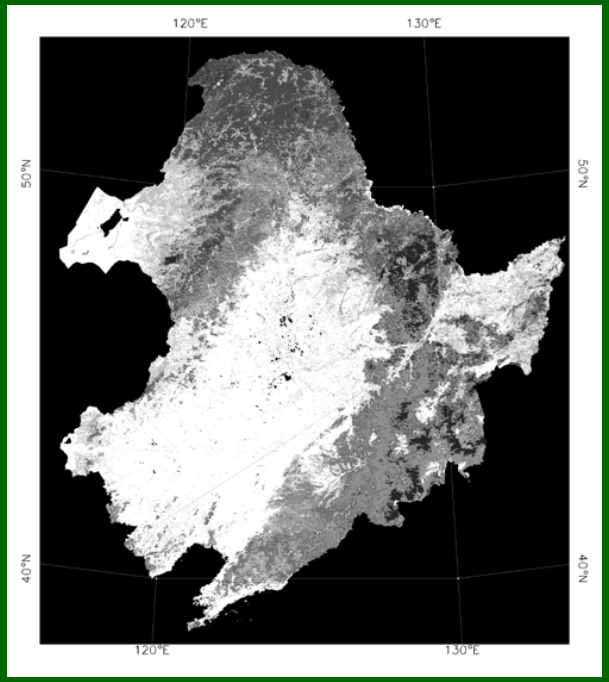
LAND-COVER CHANGE IN NORTHERN CHINA (PI: G. Sun, GSFC)

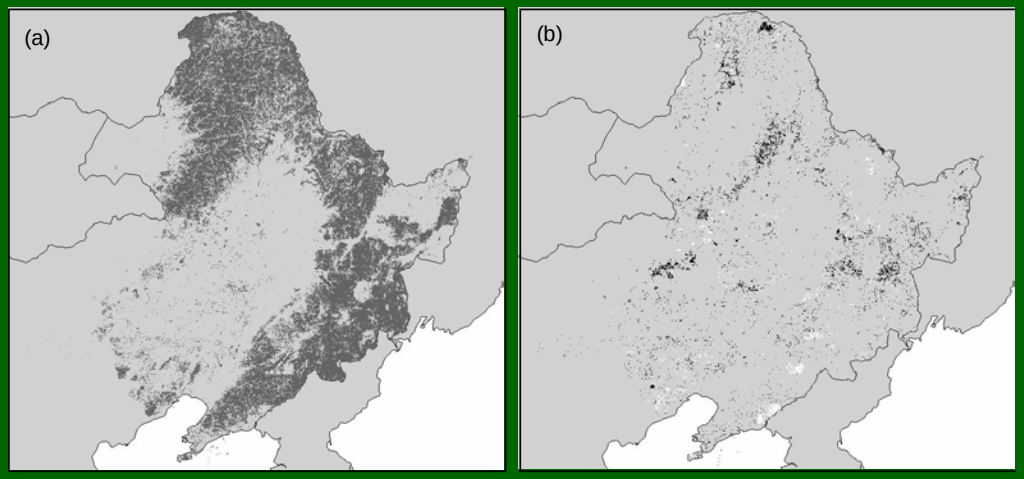
The forests in northeast China have been undergoing dramatic changes during the last several decades. Clearing and fires in earlier decades are now turning towards sustainability management with the National Forest Conservation program. Small declines (0.2% per year) in forest found through remote sensing anlaysis. (LCLUC Book).



MODIS 500 km Land-Cover Classification

Evergreen Needleleaf
Deciduous Needleleaf (Larch)
Deciduous Broadleaf
Needle-broadleaf Mixed
Shrubland
Grassland
Wetland
Cropland
Water

Land-cover classification derived from MODIS NDVI time series.



Forest-cover and change from land-use map analysis of Landsat-5 and Landsat-7 imagery. (a) Extent of NE China forests (dark gray) in 2000 as mapped from Landsat-5 TM data; (b) forest loss (black) and gain (white) calculated by comparing 1990 and 2000 Landsat forest extent maps.

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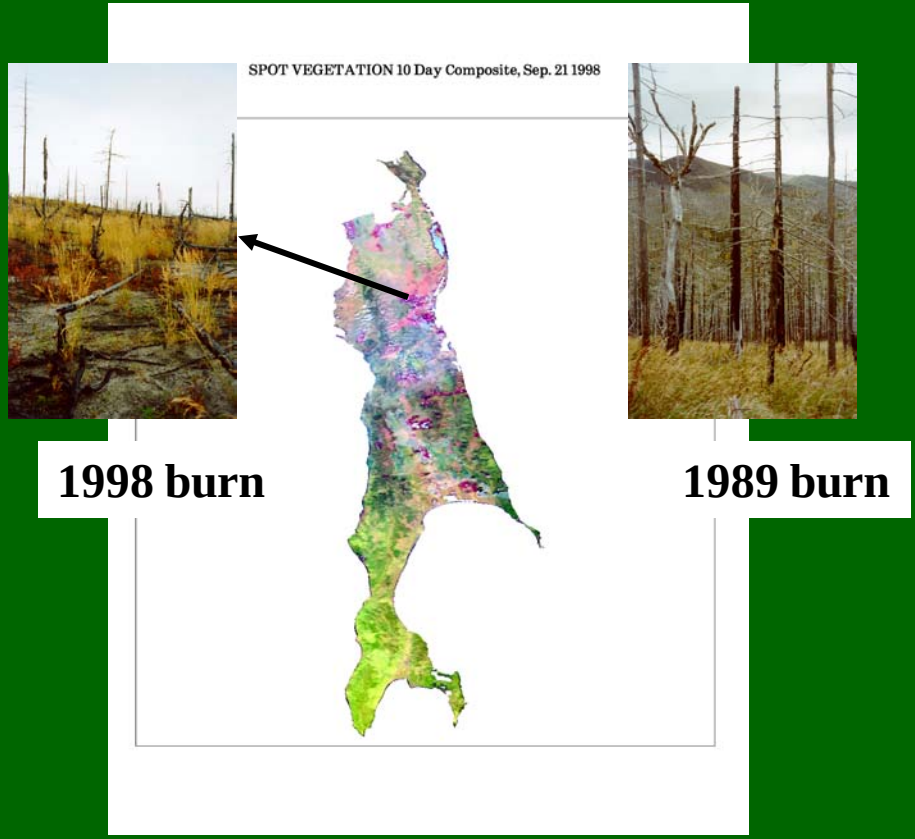
FIRE AND EMISSIONS

Satellite sensors and surface sampling are reducing uncertainties in the role of boreal forest fires in the direct emission of trace gases (CO_2, CO and CH_4). Emissions in 1998 were the source of anomalously high levels of CO and CH_4 (Kasischke and Bruhwiler 2003; Forster et al, 2001). Analysis shows some 15 million ha of boreal forests and peatlands burned in 1998 releasing 188 to 440 Tg of C into the atmosphere (Conard et al in press; Kasischke and Bruhwiler 2002). (PI E. Kasischke, UMD).



SPOT VEGETATION image collected over Sakhalin Island in September of 1998. The 1998 fires are the dark red areas. Large fires also occurred in 1989, with the scars from these fires still being visible in the 1998 satellite imagery as areas of pink.

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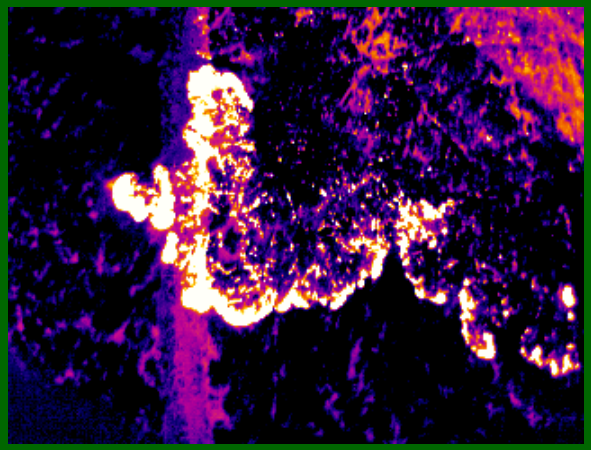
FIRE BEHAVIOR

Results of experimental fires and analysis of concurrent remote sensing data (aircraft, AVHRR, and MODIS) show significant variability in carbon release from fires and emphasize the need to quantify fire severity in addition to burned area to obtain accurate estimates of fire emissions (McCrae et al. 2002). (PI S. Conard, USFS).

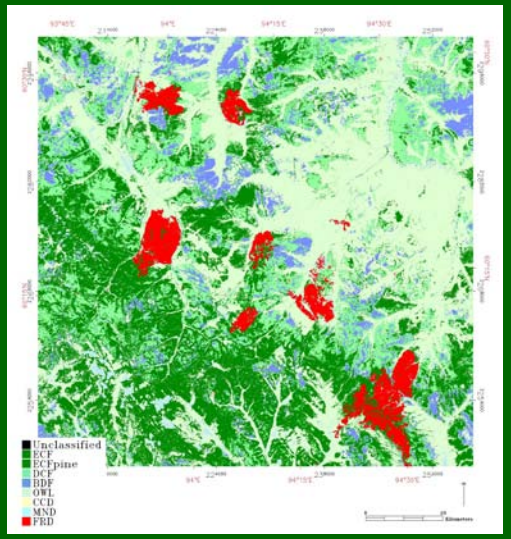
MODIS image of controlled burn in Central Siberian pine forests.



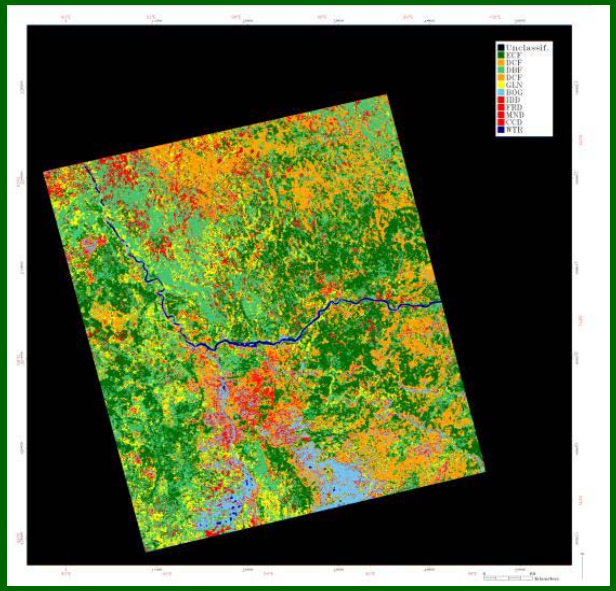
Pioneering NASA LCLUC Russia Research Projects Mature 1997-2003 (K. J. Ranson, GSFC)

NEW REMOTE SENSING METHODS

Remote sensing of Russian land-cover disturbance in Central Siberia shows that the combination of the radar and optical data provided better classification results of land-cover and disturbance of the area than either data type alone and is recommended for ongoing monitoring of disturbance in Siberian forests. (PI J. Ranson, GSFC).



Moderate resolution Landsat ETM+ and ERS/JERS SAR (top figure) and coarse resolution AVHRR and MODIS and RADARSAT ScanSAR (bottom)



Forest Dynamics in the Central Siberian Boreal Forest: Analysis using Statistical Data, Satellite Imagery, and Models

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Goal of this NASA Land-Cover Land-Use Change (LCLUC) Project

- Our goal is to determine the relationship of socio-economic change to land-cover change in Siberian Russia to answer the questions:
  - is the change-over from the state-run Soviet Union to an emerging market economy (1990s) impacting LCLUC in Siberian Russia, and can we observe and quantify the effects of this on the landscape and forest over the several decades 1975-2000?

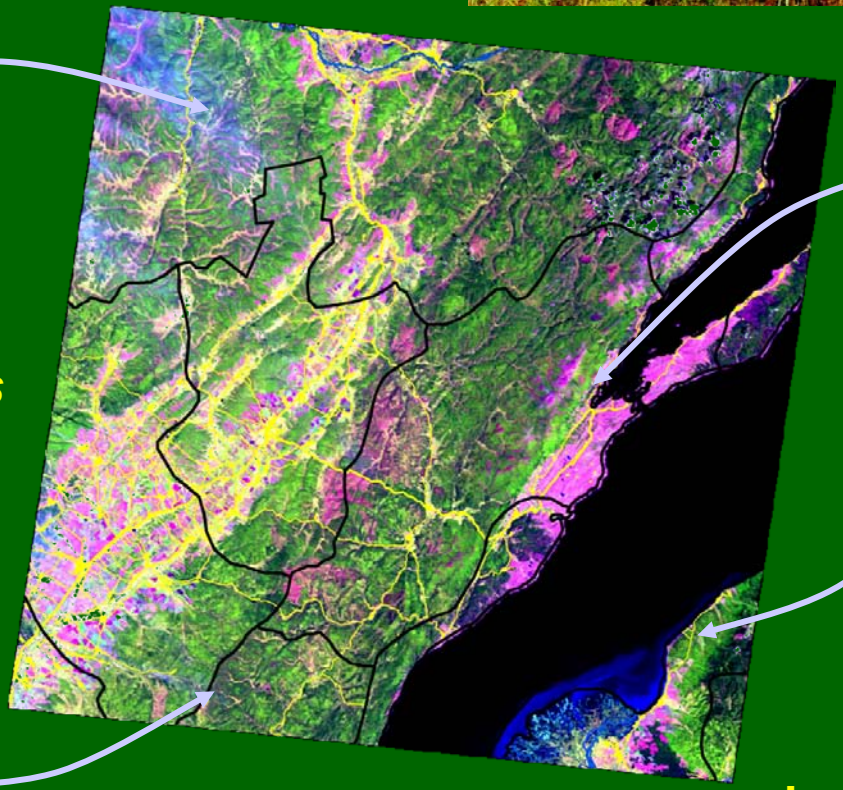
- We are doing this using:
  - time-series Landsat satellite remote sensing data 1975-2000 (UM)
  - time-series Russian statistical data 1975-2000 (UM)
  - forest dynamics models (UVA) & spatial and land-cover change models (UM)
  - and . . .

Scientists at Work in Siberia, really . . .
What it's all about . . .

Forest Types in the Region

Spruce/Fir/ Siberian Pine (*Pinus siberica*)

Aspen/birch

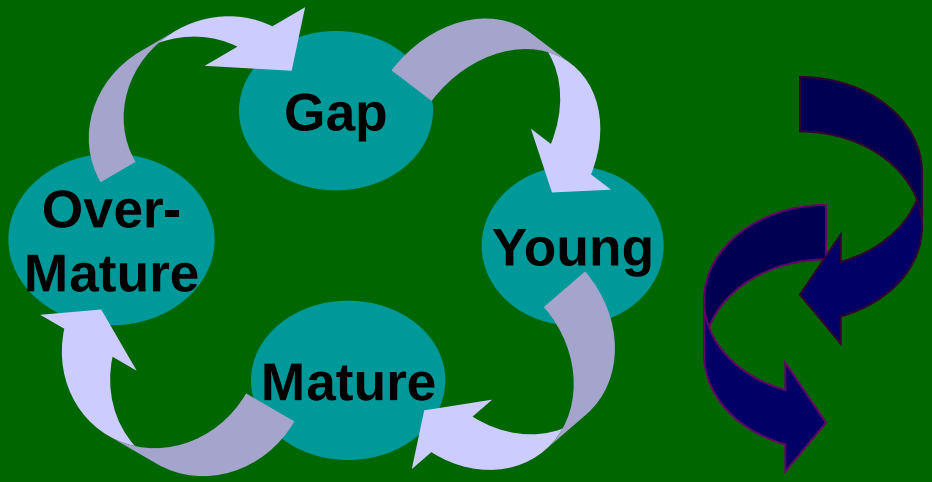


Pine (*Pinus sylvestris*)

Larch

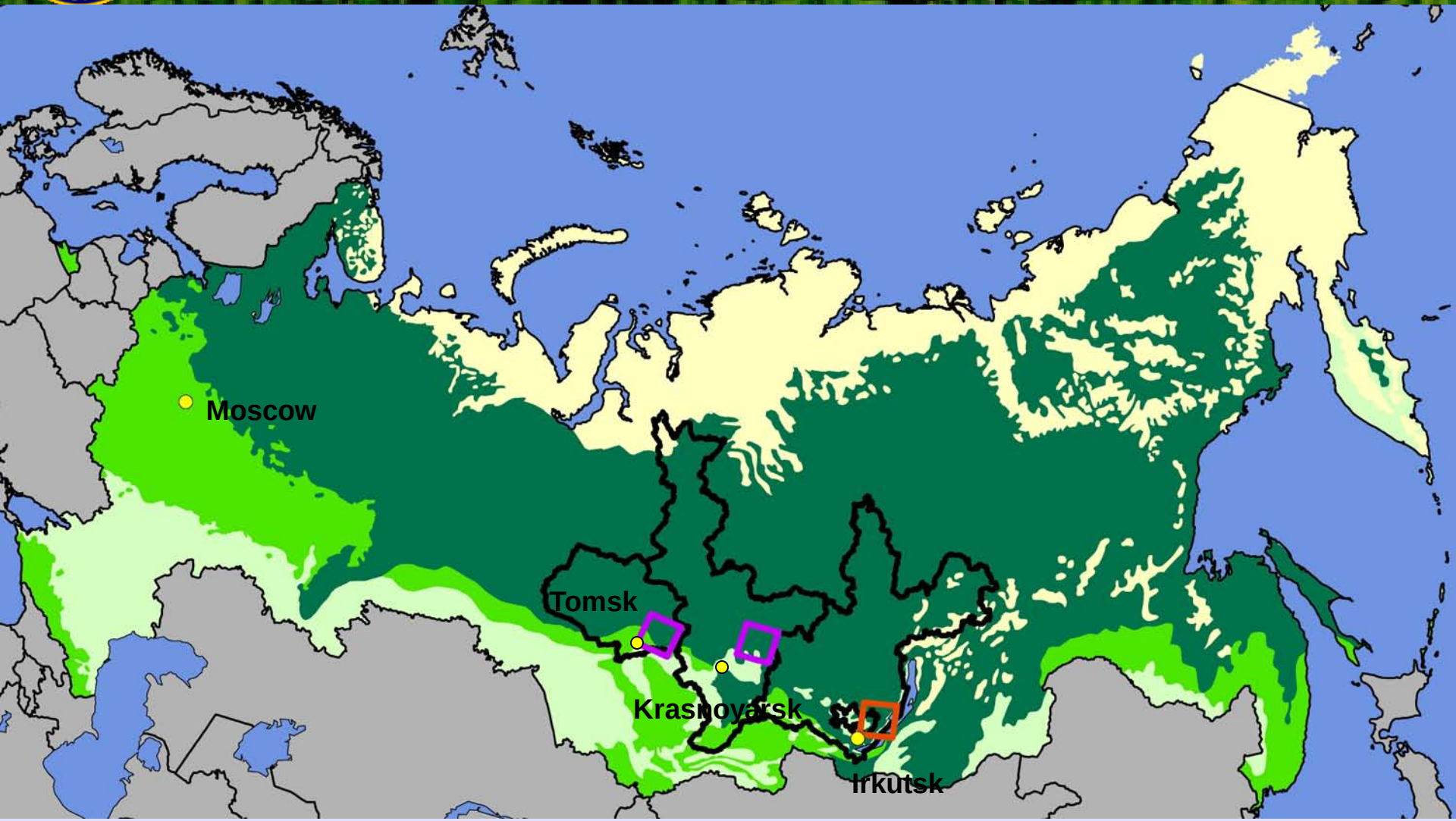
Forest Dynamics in the Region

Forest Succession

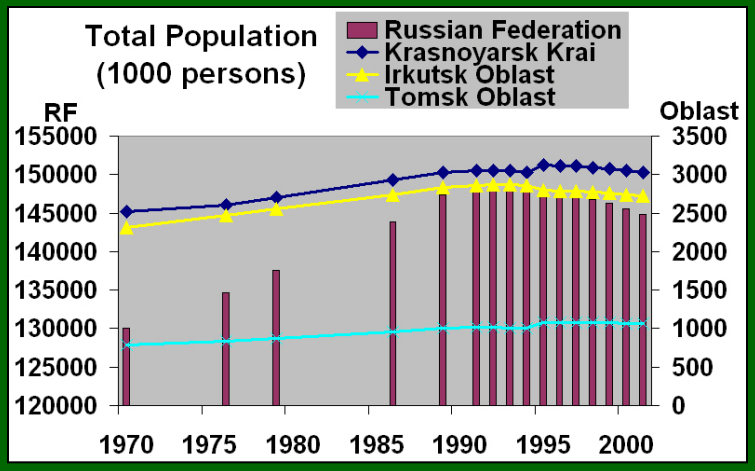


Disturbance:
Fire, Insects and Logging

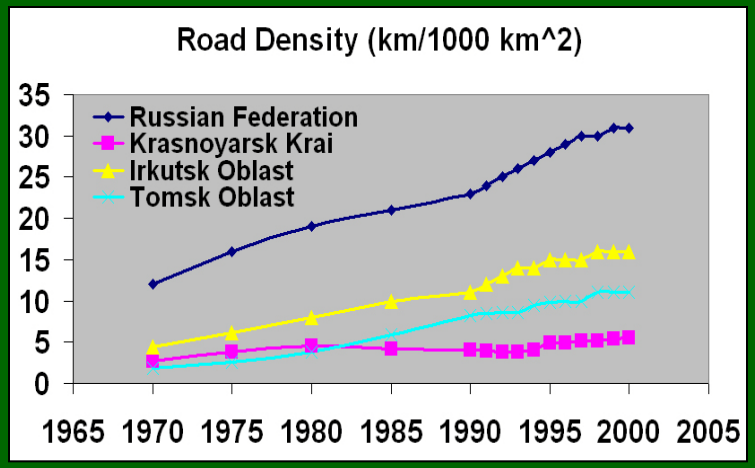
The Study Region in Central Siberia

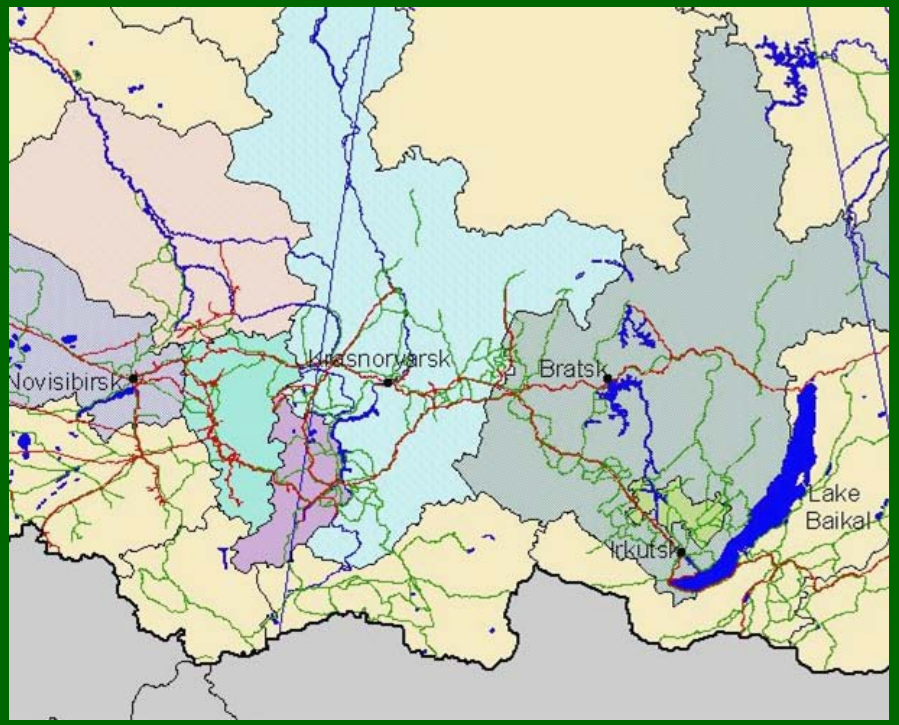


Results of Statistical Analysis



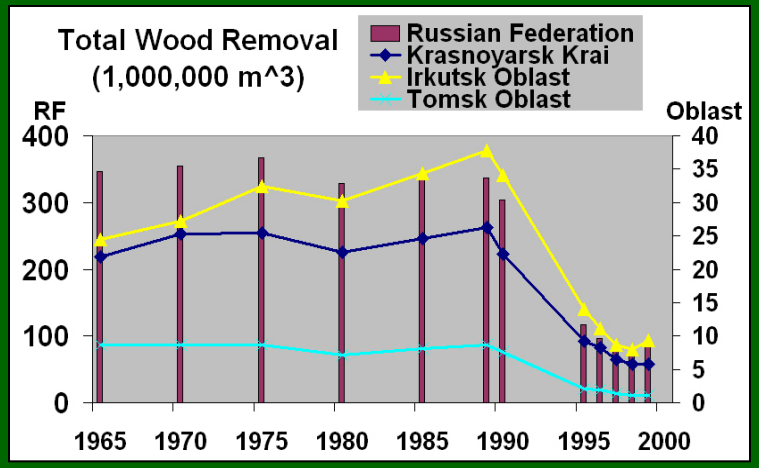
Above: Population in Central Siberia is decreasing slightly, following the same trend as the Russian Federation



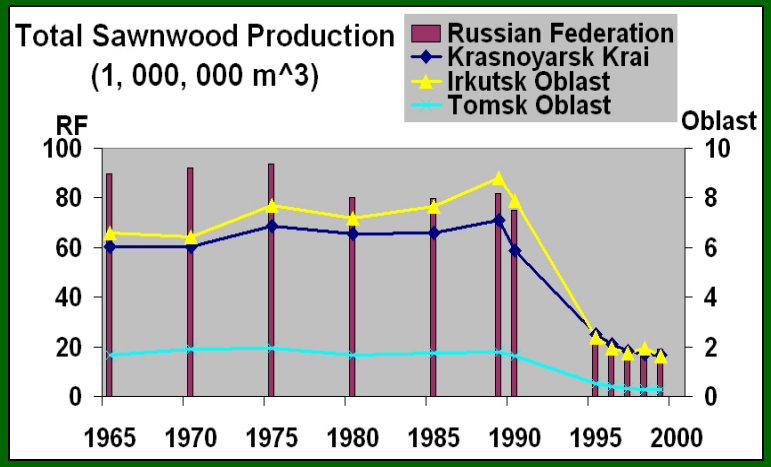


Left: At the same time, some infrastructure in this remote region is increasing

Results of Statistical Analysis



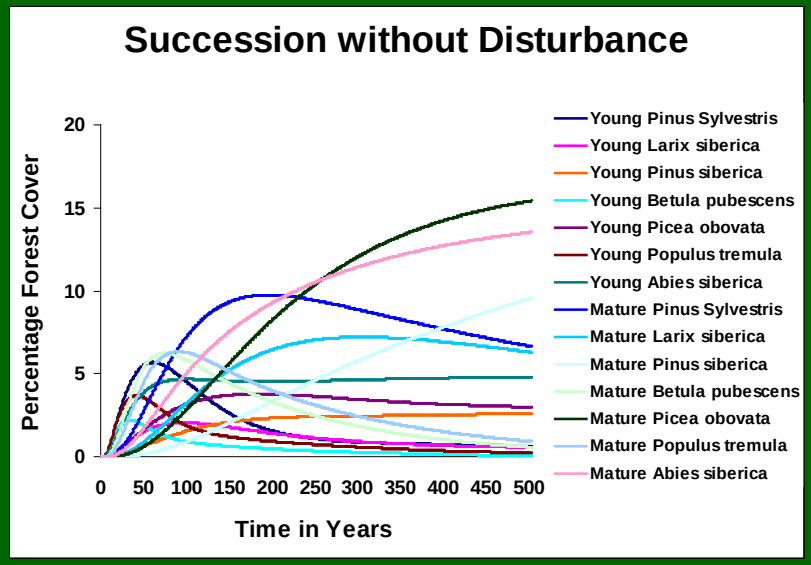
Forest sector productivity, including wood removal (harvest) and sawn wood production decreased dramatically in 1990 (to < 1/4 of former productivity), again paralleling Russian Federation trends

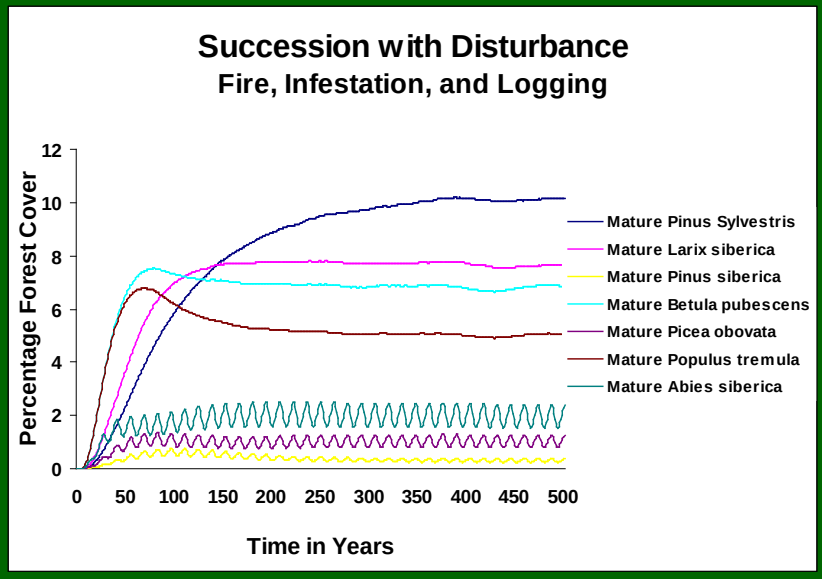


Forest sector productivity has increased very slightly in the past two years

Models

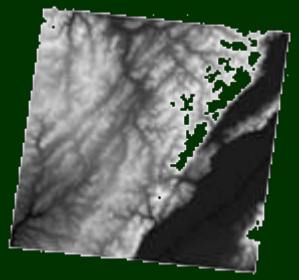
Forest Dynamics (GAP models) parameterized for the species of the Central Siberian region based on prior field studies. Can be run to simulate forest succession in absence of further disturbance (Left) or in presence of different disturbance scenarios (Right).





LOGISTIC REGRESSION ANALYSIS: effects of terrain on land cover

Independent Variables

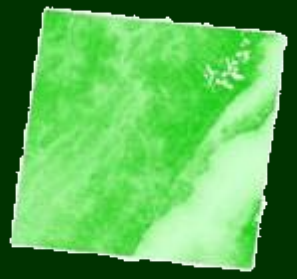


TERRAIN
- **Elevation**
- **Slope**
- Aspect
- Topographic Wetness Index

INFRASTRUCTURE
- **Distance to roads**
- Distance to rivers
- **Distance to Settlements**

LAND COVER
Presence/Absence:
- Coniferous Forest
- Mixed Forest
- Deciduous Forest

Land cover Probability

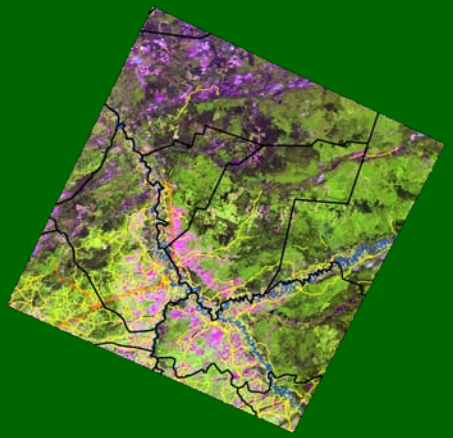


- **Coniferous Forest**
- Mixed Forest
- Deciduous Forest
- Regeneration
- Bogs
- Bogs
- Wetland/Floodland Vegetation
- Burns
- Cuts
- Agriculture

MARKOV CHAIN ANALYSIS: transition probabilities

CELLULAR AUTOMATA: incorporating space into transitions

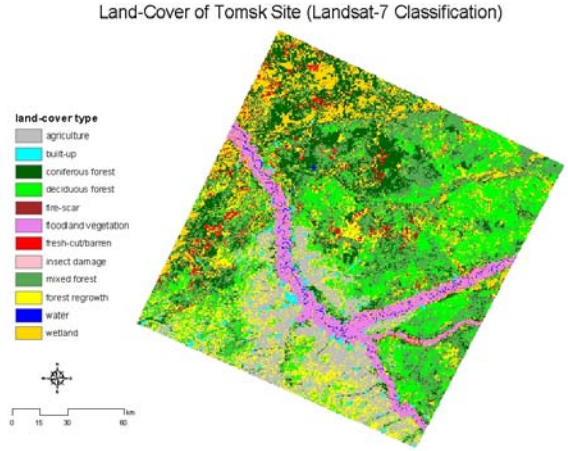
Remote Sensing Analysis
Classification of Land-Cover 2000, 1990, 1975
(all 3 dates plus accuracy assessment completed for each site, only 2000 results shown)

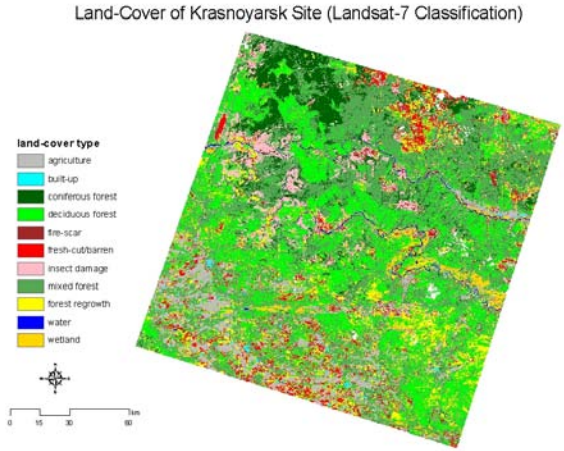


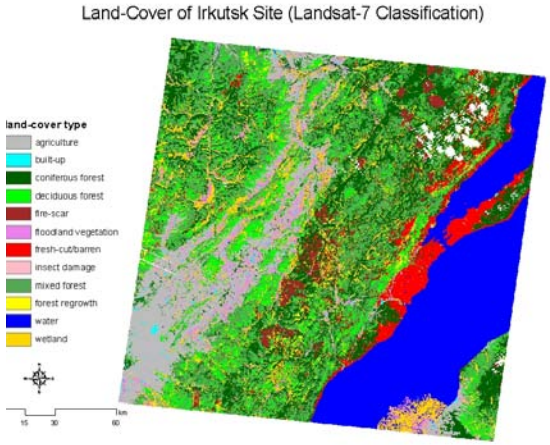
Tomsk
Landsat ETM+ P147R20
7/9/1999 R:5 G:4 B:3

Krasnoyarsk
Landsat ETM+ P141R20
8/18/2000 R:5 G:4 B:3

Irkutsk
Landsat ETM+ P133R23
8/13/2001 R:5 G:4 B:3

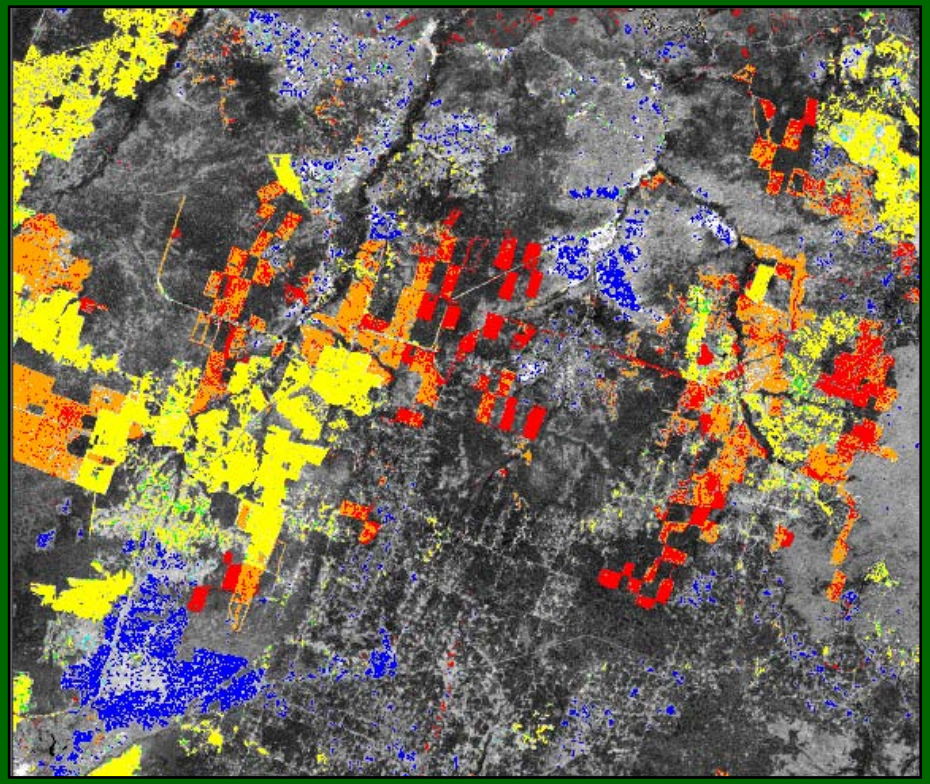






Each case study site is 185 x 185 km Landsat scene footprint

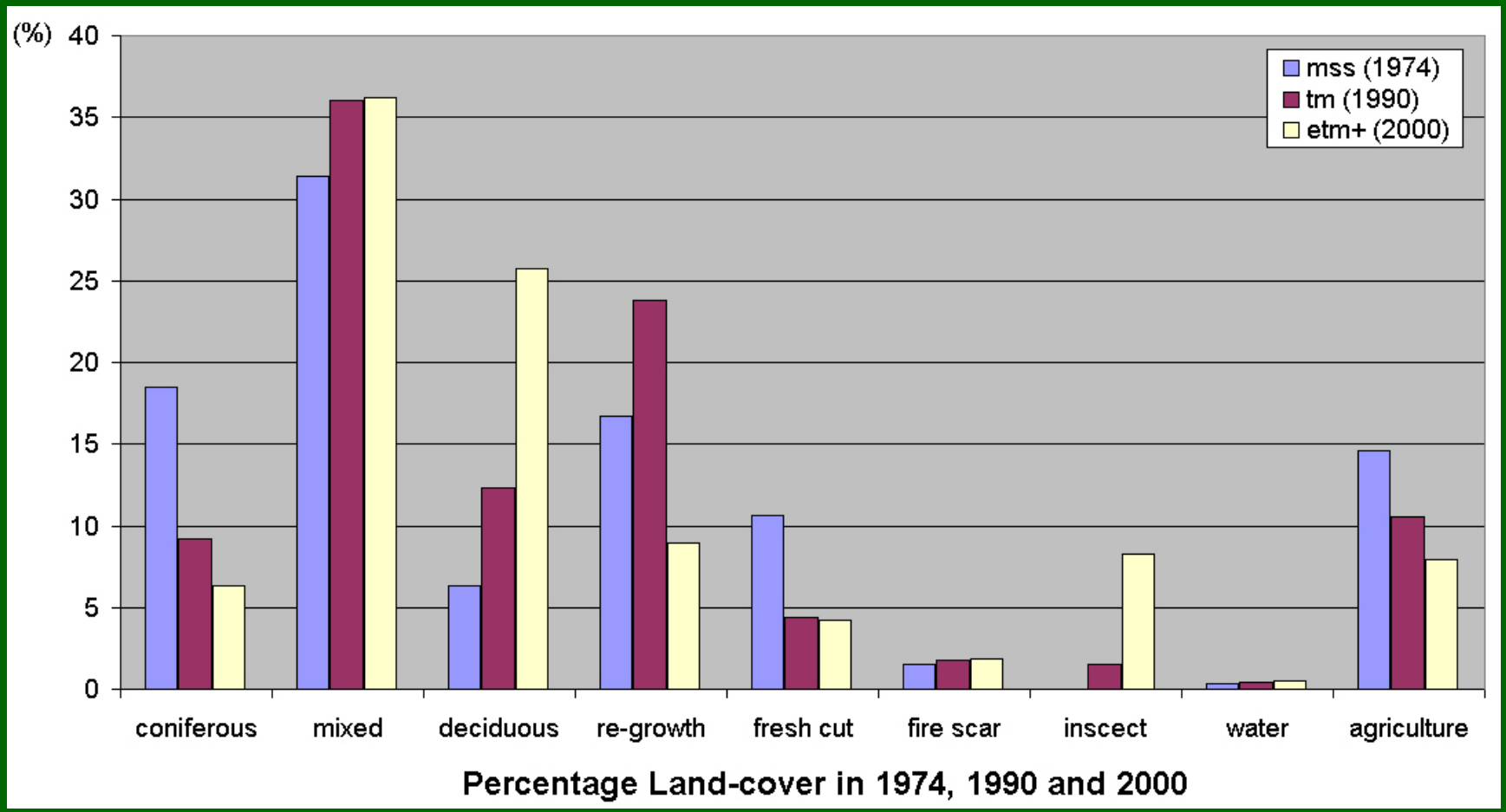
Land-Cover Change Results



3-date categorical change product overlaid on 1999 ETM+ red band.

- Logged before 1975
- Logged close to 1975
- Logged between 1975 and 1989
- Logged close to 1989
- Logged between 1989 and 1999
- Logged close to 1999

Land-Cover Change in the Krasnoyarsk Case Study Site 1974-2000 Results



Overall conclusion: Time-series data, models, and statistics show that the change-over from the Soviet Union to emerging market economy *has* had a significant and observable impact on the landscape of Central Siberia

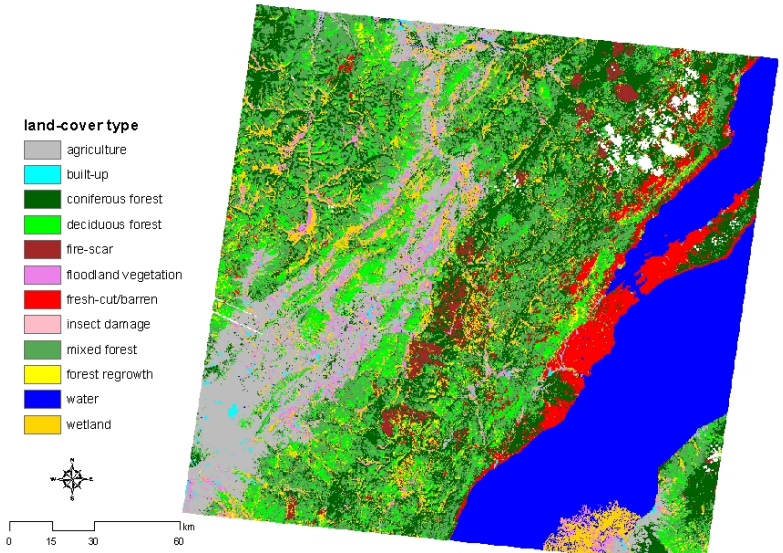
All-Team Conclusions

- **LCLUC project results underscore the need for remote sensing datasets and methods to study land-cover change in areas as geographically vast as the Russian Federation (and Northern Eurasia)**
- **Considerable forest inventory and ecology data, and forest science expertise exist in Russia**
- **Results of research on fire and logging and interactions is contributing to better understanding of the role of Russian Federation forests in the global carbon cycle**
- **The link between forest dynamics and socio-economic factors is now being integrated, methods refined, and results analyzed**
- **The NASA LCLUC projects have fostered growing international collaboration, making it possible for U.S. and Russian scientists to work together to further our knowledge of the influence of land-cover land-use change on the *global* boreal forest**

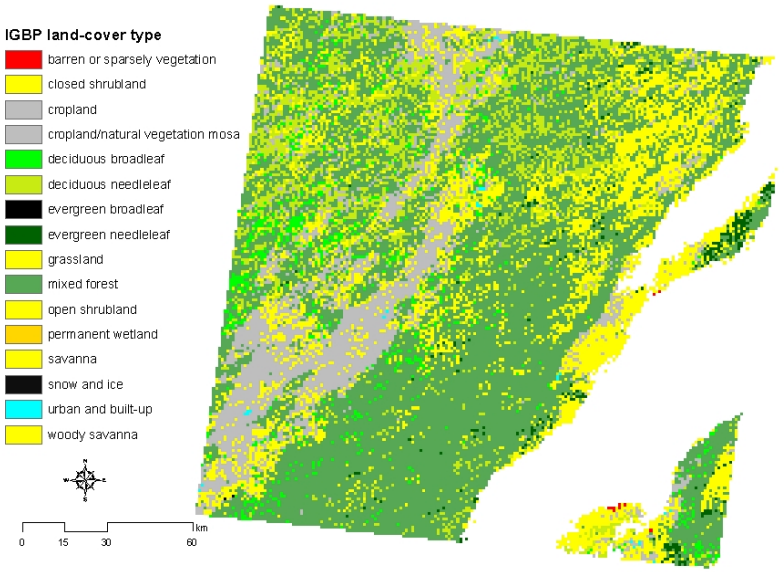
Acknowledgments

- This work is supported by the NASA Land-Cover Land-Use Change Program.
- The authors would like to thank Dr. Garik Gutman (NASA LCLUC) and the Scientists of the Siberian Branch of the Russian Academy of Sciences.
- Alll LCLUC Russia/N. Eurasia Team Members and their staffs.

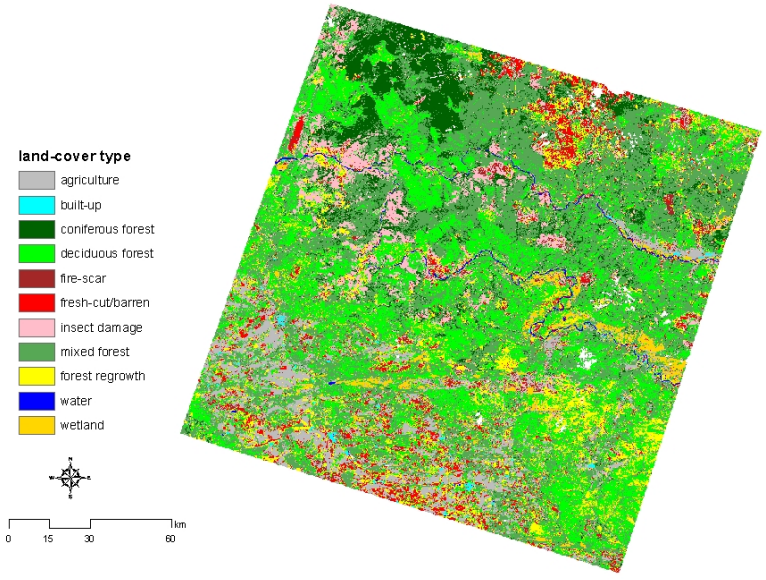
Land-Cover of Irkutsk Site (Landsat-7 Classification)



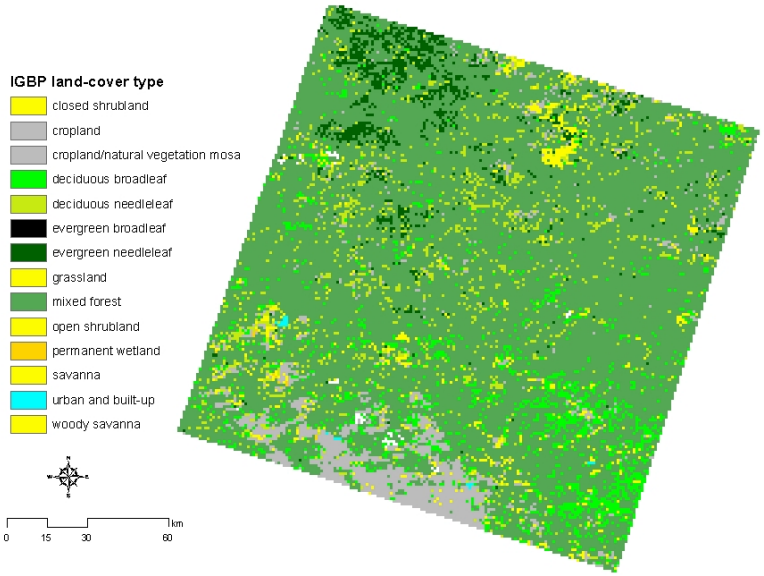
Land-Cover of Irkutsk Site (MODIS LC)



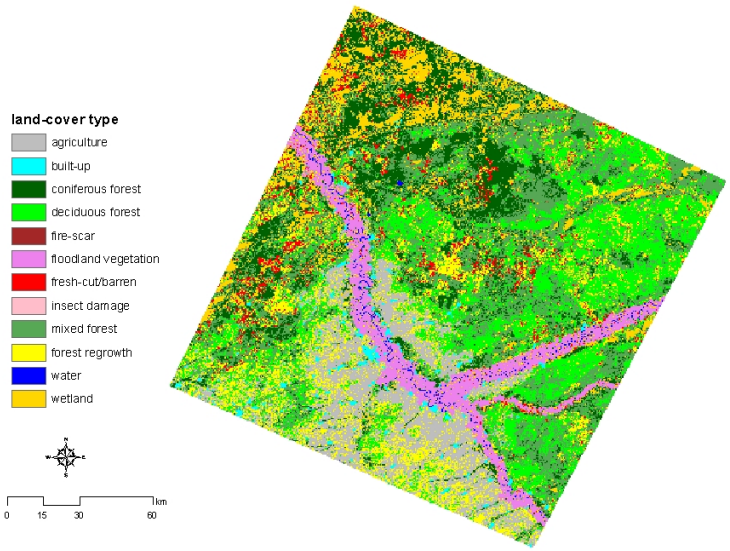
Land-Cover of Krasnoyarsk Site (Landsat-7 Classification)



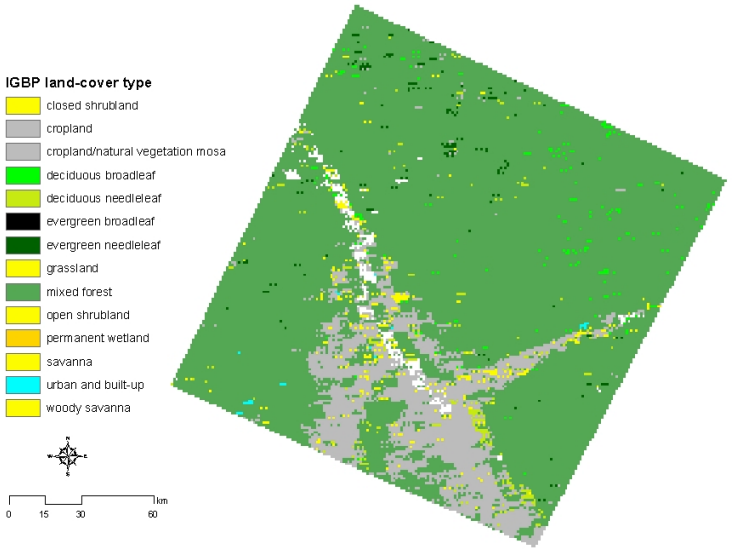
Land-Cover of Krasnoyarsk Site (MODIS LC)



Land-Cover of Tomsk Site (Landsat-7 Classification)



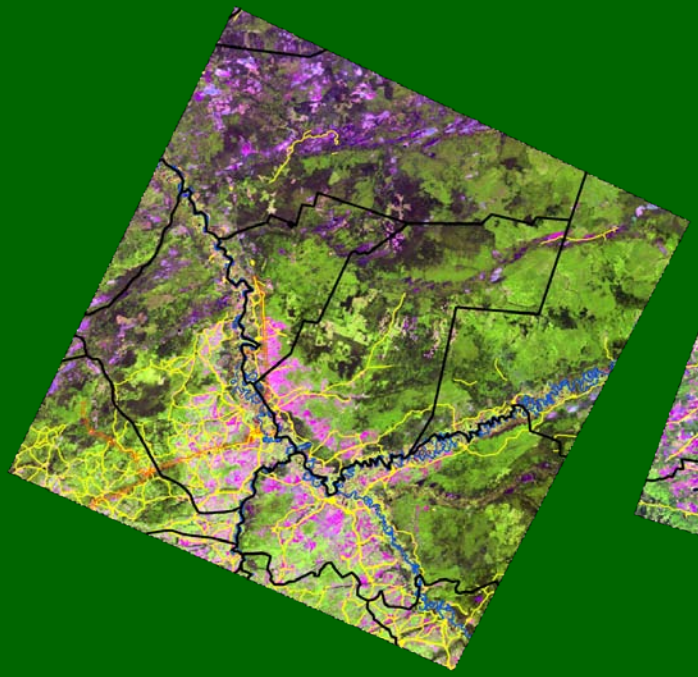
Land-Cover of Tomsk Site (MODIS LC)

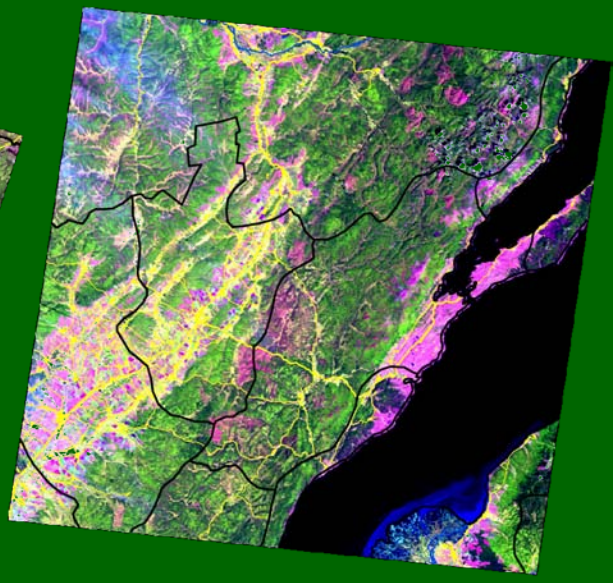


Statistical Analysis

- Russian statistics were gathered and analyzed for the period 1975-2000:
  - For general population and infrastructure trends
  - For forest sector trends
  - Statistics were compiled from Goskomstat of Russia and local/regional statistics were gathered and compiled by project scientists working at the RAS Novosibirsk Institute of Economics
  - Extensive statistics ~1970s to present have been compiled in an Access database

Three Case Study Sites in Central Siberia





Tomsk

Landsat ETM+ P147R20
7/9/1999
R:5 G:4 B:3

Krasnoyarsk

Landsat ETM+ P141R20
8/18/2000
R:5 G:4 B:3

Irkutsk

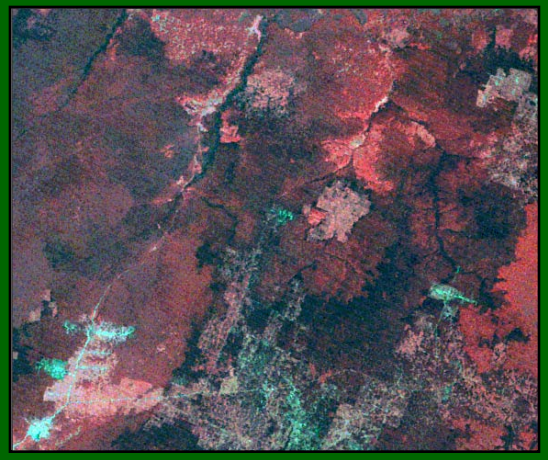
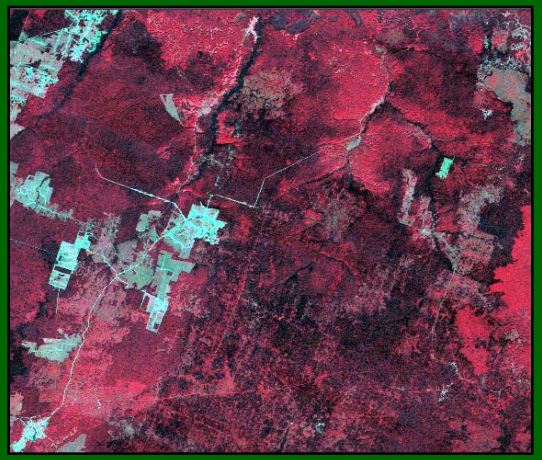
Landsat ETM+ P133R23
8/13/2001
R:5 G:4 B:3

Each case study site is 185 x 185 km

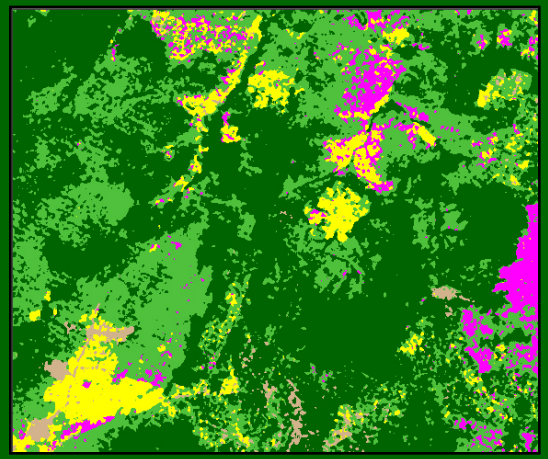
Remote Sensing Analysis

- **Time series Landsat data were acquired, processed, and analysed for land cover and land-cover change**
  - **Three case study sites, each the footprint of a single Landsat scene (185 x 185 km)**
  - **Three time periods (three images) per case study site: 1975, 1990, 2000**
  - **Analysis involved:**
    - **Preprocessing: georectification, cloud-removal, some mosaicing**
    - **Land-cover classification**
    - **Post-classification change detection**
    - **Analysis of results**

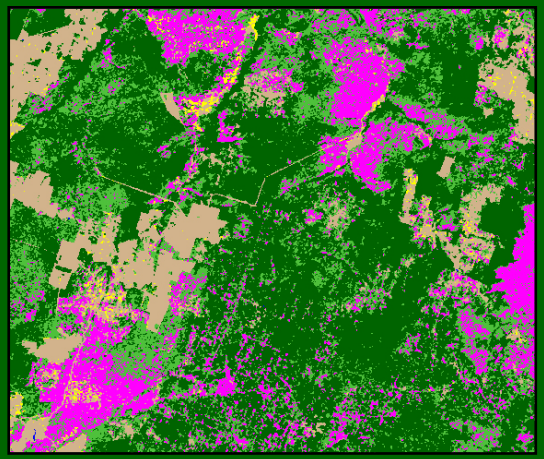
Landsat Change Detection: Close-up

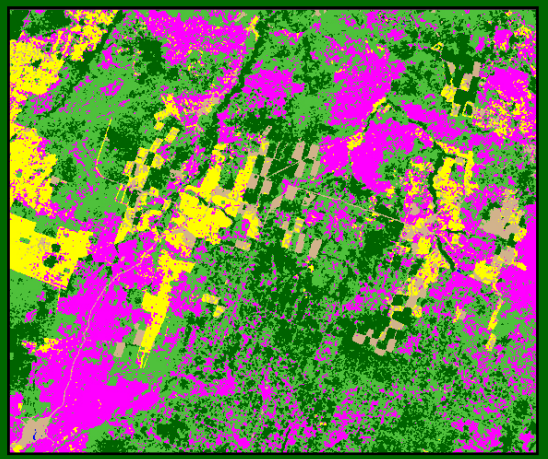

TM false color composite with band 2 in blue, band 3 in green, and band 4 in red.



Classification: August 30, 1975



Classification: Sept. 7, 1989

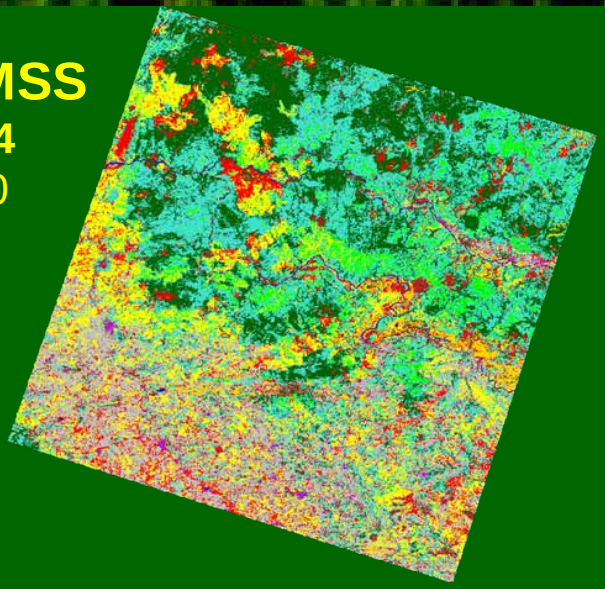


Classification: July 9, 1999

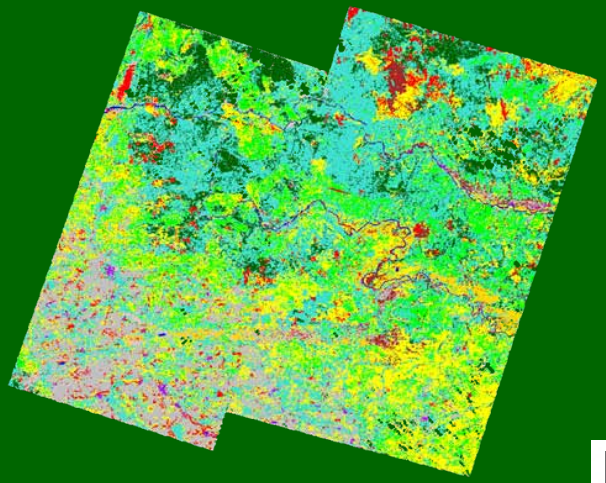
Water
Mature Conifer
Mature Mixed
Mature Deciduous
Pasture/Crop/Regeneration
Bare/Cleared

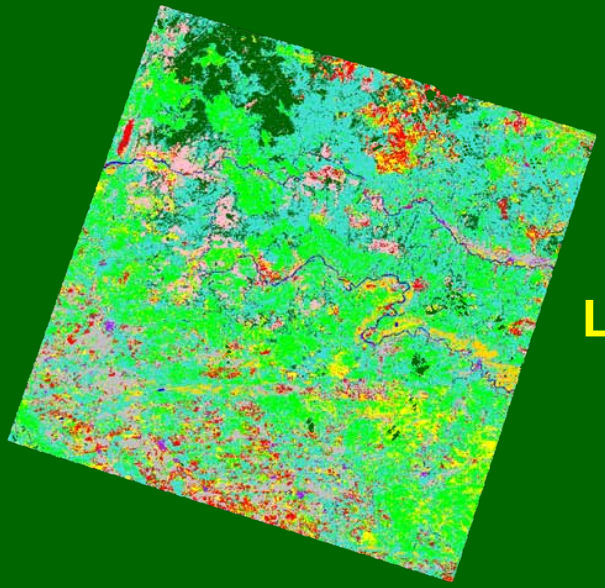
Land-Cover Change in the Krasnoyarsk Case Study Site 1974-2000

Landsat MSS
6/26/1974
P152R20



Landsat TM
7/2/1989 (W)
P142R20
& 7/7/1990 (E)
P140R20





Landsat ETM+
8/18/2000
P141R20

- coniferous
- mixed
- deciduous
- re-growth
- fresh cut
- fire scar
- insect
- water
- agriculture
- wetland
- settlement