

**Progress Report for**

**COMBINED SATELLITE MAPPING OF SIBERIAN LANDSCAPES:  
NATURAL AND ANTHROPOGENIC FACTORS AFFECTING CARBON BALANCE**

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### *Abstract*

Siberia is an immense area stretching from the Ural Mountains on the west to the Russian Far East with total territory similar in size to the continental United States. The Siberian forests are an important source/sink of carbon with total carbon storage in Western Siberia estimated to be 4300 MT, and in Eastern Siberia about 12500 MT. Estimated annual carbon depositions are 20 and 60 MT/yr, respectively. There are a number of factors that affect carbon balance in the Siberian forests. The most important factors are insect invasions, fires, air pollution, logging, and exploitation of mineral reserves. Siberian forests are undergoing changes due to several natural and anthropogenic factors including insects, fires, logging, pollution and mineral exploration. This work is conducted by a team of scientists from NASA, University of Maryland and Sukachev Institute of Forest and will develop and employ methods to map forest type and identify forest disturbances within the Siberian boreal forest using satellite data. This project benefits from a recent study funded by NASA's Terrestrial Ecology Program by incorporating multitemporal RADARSAT-1 data sets into ongoing analyses of combined satellite data. The approach proposed herein is especially suited for areas with frequent cloud cover and long seasonal duration of low solar illumination such as Siberia.

We are developing methods to improve existing mapping capabilities by using standard beam and ScanSAR RADARSAT-1 images to reveal disturbance patterns within landscape classes. This project will develop procedures for detailed assessment of disturbance types with high resolution (~30m) RADARSAT Standard Beam and Landsat 7 data and larger scale mapping with lower resolution satellite data i.e., RADARSAT-1 ScanSAR, MODIS, and AVHRR. Detailed assessments will also consider portions of the taiga-tundra ecotone to determine feasibility of using RADARSAT-1 data for verifying the northward expansion of the taiga forest in response to climate change (Kharuk et al. 1999b). Results will be validated with ground truth available through the Sukachev Institute of Forest in Krasnoyarsk.

The project uses AVHRR, MODIS optical data (1km resolution) and multi-temporal RADARSAT ScanSAR data (0.050 km) to map a 600 X 3000 km area of Siberia currently under study by the International Biosphere-Geosphere Program. The combined use of the two technologies will improve results of previous classification maps (AVHRR only). This map will be tested over areas where detailed ground truth information is available. Areas of known (from existing studies at the Sukachev Institute) and potential change (identified from the satellite map) will be examined in detail using higher resolution satellite sensors (e.g., Landsat ETM+ and RADARSAT standard beam data). The methods use will be tuned to take advantage of new data sources including Alos, and ENVISAT platforms as they become available.

**Keywords:** Research Fields carbon cycle, forest conversion, land cover classification, 2) Geographic Area/Biome, Siberia/Boreal forest 3) Remote Sensing; Radarsat, Landsat, MODIS, IKONOS, ASTER and 4) Methods/scales. Data fusion, local/regional scales.

## **ESE Science Questions**

How are global ecosystems changing?

What are the changes in global land cover and land use, and what are their causes?

How is the Earth's surface being transformed, and how can such information be used to predict future changes?

## **LCLUC related questions.**

a) What are the changes in land cover and/or land use (monitoring/mapping activities)?

Changes in forest cover from fire, insects, logging, mineral exploitation and pollution disturbances and migration of forest species.

b) What are the causes of LCLUC?

Disturbed areas may change to new forest or other vegetation types in response to climate change, ecosystem changes from disturbance, human habitat also impacted by disturbance.

c) What are the consequences of LCLUC?

Change in forest cover changes carbon balance and forest succession trajectories

**Proportion of the themes that are covered in this project:** Carbon 50%, GOFC (mapping/monitoring of forest cover & change detection) 25% , other: Remote Sensing Science 25% , Proportion of Social Science 0%

## **Goals:**

The goal of the proposed project is to produce land cover maps and change maps that can be used to determine the extent and rate of natural and anthropogenic impacts on the Western Siberian boreal forest. Multitemporal RADARSAT-1 data provides a unique perspective to complement MODIS or AVHRR analysis and should enable more detailed and accurate mapping of the disturbances that are under study.

FY01:

Acquire Radarsat ScanSAR and ST4 data requested for Summer 2000, - Data request submitted to ASF May 2001 for multiangle ST beam Radarsat data,

Acquire MODIS, Landsat, ASTER and IKONOS data of selected sites. Coverage of 1999 or 2000 Landsat data obtained for all sites, MODIS coverage for September 8 day period acquired, ASTER order in progress pending agreement, IKONOS data order through SSC data buy.

Conduct field surveys. Two field expeditions conducted by Sukachev Institute of Forest during the summer

Begin to merge data sets and initiate image analysis.

Disseminate Results. Presented some initial results at IGARSS 2001 in Sydney, Australia.

FY02:

Develop procedures for detailed assessment of disturbance types with high resolution (~30m) SAR and Landsat-7 data and larger scale mapping with lower resolution satellite data i.e., MODIS, RADARSAT-1 ScanSAR and AVHRR. Focus on taiga-tundra ecotone sites to determine the feasibility of SAR plus optical data for verifying the northward expansion of the taiga forest in response to climate change. Conduct ground truth studies in selected sites to verify classification results. Publish results.

FY03: Pending

**Timeline: (Accomplishments in bold)**

	FY01				FY02				FY03			
	1	2	3	4	1	2	3	4	1	2	3	4
Order Data												
Radarsat			<b>X</b>				X					
Landsat		<b>X</b>										
IKONOS		<b>X</b>										
MODIS			<b>X</b>	X	X	X						
SRTM						X						
VCL										X		
Data Fusion		<b>X</b>		X		X						
Image Analysis		<b>X</b>							X	X	X	
Field Studies			<b>X</b>	X			X		X	X	X	
Team Meetings				X			X				X	
Publish Results			<b>X</b>					X				X

Bold indicated task accomplished.

**Original approach/method**

Modifications/adjustments made to overcome some problems during the period of performance.

The proposed study is designed to improve the methods of forest mapping in Siberian region for determining the magnitude and rate of change of natural and anthropogenic impacts on Siberian land cover.

Use AVHRR and MODIS optical data (1 km resolution) and RADARSAT-1 data (0.1 km) to map the 600 X 3000 km area.

Evaluate resulting map of boreal cover and disturbance type over areas where detailed ground truth information is available.

Examine in detail areas of known change using higher resolution satellite sensors (e.g., Landsat ETM+ and RADARSAT standard beam).

Determine characteristic features related to forest disturbances using image analysis techniques including decision tree classification and spatial texture analysis.

Evaluate accuracy of results comparing map results with areas of known forest type (from filed. Point-by-point comparison with ground truth map and 2) correspondence of observed spatial patterns. This will be combined into the average mutual information (AMI) index to quantify accuracy of the satellite data generated map.

**Progress for the initial 10 months of the ADRO 2 and LCLUC Programs**

We have acquired Landsat 7 data sets for several of our intensive test sites in Siberia. The data long term acquisition plan seems to be working quite well, as we are able to find relatively cloud free images over our sites of interest. After extensive searching for MODIS data, a single data set was found to be reasonably free of cloud contamination for the period August 28- September 10, 2000. Recent problems with MODIS have been overcome (as of July 2) so good data for the 2001 growing season is anticipated. Radarsat data, acquired in Summer 2000, arrived in late

spring. Early analysis showed the high resolution mode of the ScanSAR is noisy. Smoothing the data to 500m produced a useful data set when combined with MODIS. We are investigating the best smoothing and classification techniques to use with Radarsat data.

Initial analysis was conducted for the Boguchany Fire and Logging Impact site and the Priangare Insect Infestation site. The results showed that Landsat 7 was the best single data type for classifying disturbance type and landcover, but adding radar data did improve identification of certain classes. Smaller scale, regional analysis with MODIS and Radarsat ScanSAR was performed using the areas classified with higher resolution data as ground truth. Figure 1 shows classification results with combined a) Radarsat ST4 and Landsat 7 data and b) Radarsat, JERS and Landsat 7 for Boguchany area. Figure 2 shows resulting classification of Radarsat SWB and MODIS for the larger region using higher resolution classification to train maximum likelihood classifier.

Table 1 presents the percent area classified for land cover types for the two higher resolution data sets and the lower resolution one. It is known from field observations and previous studies that the type and extent of disturbance varies from place to place as illustrated by comparing the Boguchany (primarily fire disturbed) and Priangar'e (insect disturbed) results. The combined results show over 25% of the regional area was disturbed by fire or insects. The next step in this analysis is to check the classification with observations acquired during field measurement campaigns during Summers of 2000 and 2001.

Table 1. Percent area classified

Class	Boguchany	Priangar'e	Region
Conifer	25.1	21.2	27.2
Deciduous	30.3	37.1	22.9
Insect Damaged	0.0	23.3	19.2
Fire damaged	23.8	0.0	8.4
Clear Cut/ Open	20.8	15.0	15.8
Bogs	0.0	3.2	4.9
Water	0.0	0.2	1.6

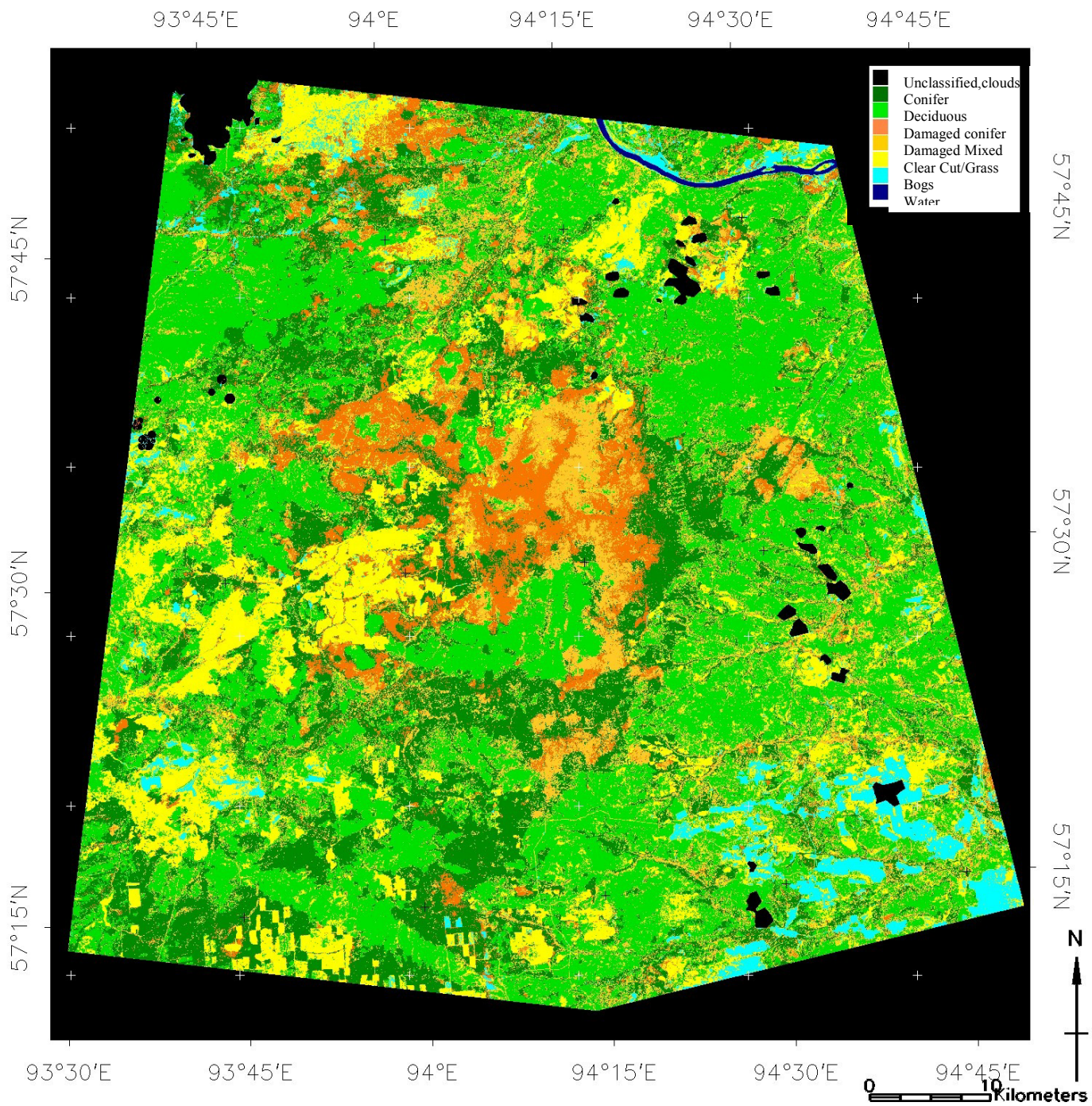


Figure 1a Combined radar and Landsat data classification of insect damaged area in Priangar's area of Siberia.

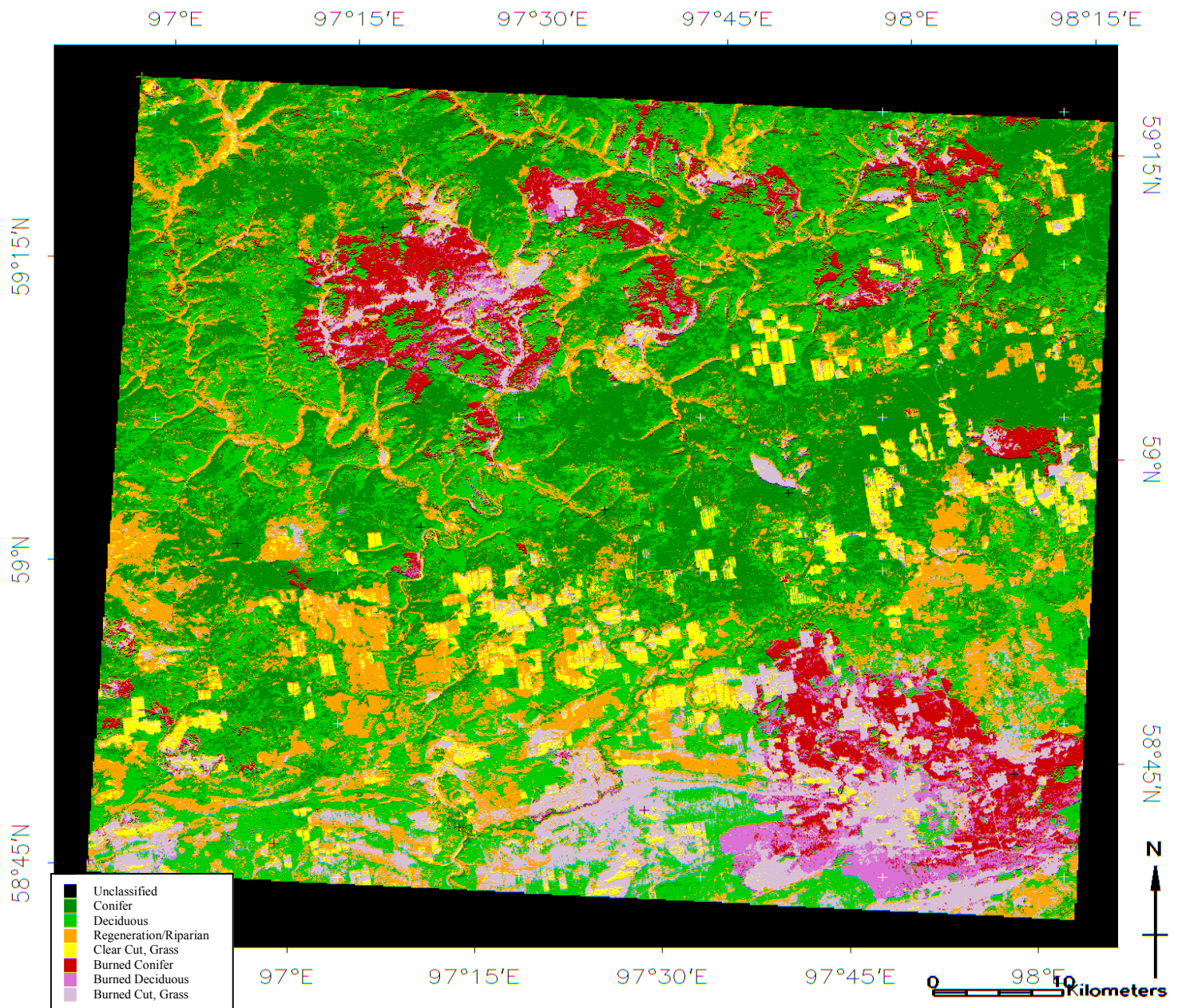


Figure 1b. Classification of Boguchany test site using combined radar and Landsat 7 data.

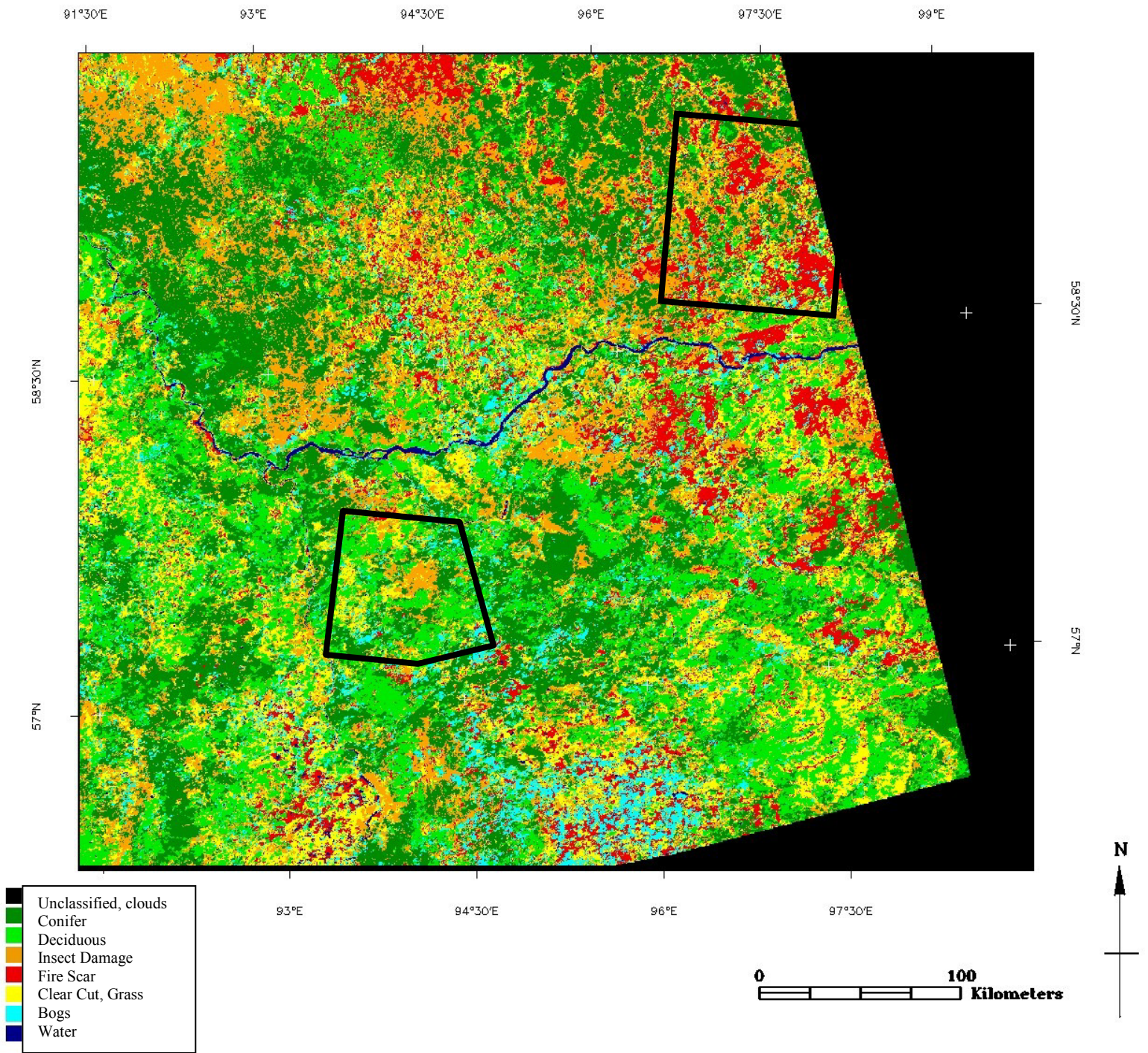


Figure 2. Forest classification of Priangar'e and Boguchany areas with Radarsat SWB and MODIS. Polygons locate higher resolution classified sites shown in Figure 1.