MONITORING FOREST DYNAMICS IN NORTHEASTERN CHINA IN SUPPORT OF GOFC

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ABSTRACT

The forests in Northeastern China have been undergoing dramatic changes during the last several decades due to forest fire, insect infestation, massive logging, agricultural conversion, and afforestation. These changes affect the climate, the ecosystem, the economy and living heritage in the region, and may impact the global carbon cycle.

To monitor the dynamics of the forests in the vast Northeastern China region, we propose to develop an operational forest monitoring system using satellite remote sensing data. The major components of this system will include both standard and enhanced methodologies for forest cover mapping and change detection within a PC-based Geographic Information System (GIS) database. Landsat-7 ETM+ data and ERS tandem SAR data will be used to generate fine resolution forest characteristics base maps for the region. The derived forest cover and change maps will be validated with ground observation data collected at the permanent sample sites already established over the area, and by new field measurements to be collected during the course of this project in concert with our Chinese collaborators.

When the global land cover and land cover change products derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) on the EOS-AM1 satellite (Terra) become available, they will also be used in a preliminary step to locate areas within this vast region where forest changes are occurring. An algorithm similar to that used for creating the MODIS enhanced land cover change products will be used for detecting these areas of forest change. Once the change areas are identified, fine resolution Landsat 7 ETM+ and SAR data corresponding to these geographical locations and time periods will be utilized to characterize the nature/cause of the change(s).

Furthermore, existing forest maps and historical Landsat-5 data will provide the forest status for this decadal time period, and they will be used to map the major forest changes due to natural and human-induced disturbances. Additional fine resolution data from near-term future satellite missions, such as the SRTM and ENVISAT radar sensors, will be requested for test sites within the region to investigate the capability of these data for the extraction of forest structure information. Such information is critical in deriving a better assessment of standing biomass. Thus, we feel that the potential effects of the forest changes on the carbon cycle during this period can be quantified for this region. A test run for predicting forest changes using the database and forest growth models will be performed at selected sites and evaluated in the third year of this project. All of the data sets output from this project, as well as the algorithms employed for this forest monitoring system, will be published and made available to other GOFC partners and other users.

Key Words: GOFC, Forest, Northeastern China, Landsat-7, MODIS, SAR, Regional Monitoring
(The LCLUC RIF web Key word list was not available).

QUESTIONS, GOALS, AND APPROACHES

This project will try to answer the following questions:

- What are the changes in forest cover in NE China during last decades?
- What is the impact of these changes on forest carbon storage in this region?
- What are the causes of the forest cover changes in this region?

The proportion of social science to be used in this project is small – only in the later stage for the last question.

The goals for the first year are (copied from proposal)

- Data collection: Acquire Landsat-7 ETM+ data at test sites and most forested areas in Northeastern China; Collect MODIS data; Collect large-scale forest maps and permanent sample data of test sites;
- Purchase PC ArcView GIS (or ARC/INFO) Workstation and transfer GIS database from IFRIT, China to UMD/GSFC, USA;
- Explore the characteristics of optical and radar signature from various targets, and design classification system;
- Process Landsat and ERS tandem data over test sites including classifications and image mosaic;
- Field trip to China for collaborating work in IFRIT's image processing and GIS labs and field survey;
- Attend LCLUC ST meeting, and send summary material and significant results to LCLUC Web Site.

Original Approach:

- Forest cover classification using Landsat-7 ETM+ and ERS SAR data through three major steps: Data Preprocessing, Forest Cover Classification, and Classification Map Validation.
- Forest cover change detection: MODIS data are first used to detect areas of change at the macro scale. Once identified, fine resolution Landsat-7 ETM+ and SAR data are used to characterize the nature/cause of the changes.
- A PC-based GIS database will host the data and functions for the forest monitoring system. Data and products from this project will be put on the web (http://fir.gsfc.nasa.gov).

Problems:

- Because of the data quality, the ERS SAR data that ESA could provide does not cover the whole region (with many holes between paths). We are trying to acquire JERS-1 SAR data to increase SAR coverage.
- Because of the unique 'MODLAND Integerized Sinusoidal Grid" and no overlap between the data grids (ties), the re-projected MODIS data can not be mosaiced seamlessly.
- Production of a good forest cover map for this region is a huge undertaking (>50 ETM+ scenes). We are looking for more help from the co-I's in China.

Progress

- Data ordering and collection – 31 Landsat 7 ETM+ images over two of the three major forest areas in NE China have been acquired. 8 Landsat-5 TM images were acquired from the Chinese Satellite Ground Station. The 50m pixel land use data at most areas of this region are now in house. The field work in the summer of 2000 resulted in the collection of detailed forest management data for the study sites in Changbai Mountain area. MODIS data were requested and tried for this project.
- Landsat data atmospheric correction, reflectance normalization, mosaicking, classification, and change detection were performed to explore the capability of remote sensing data and for designing a classification system and operational methods. Brief results can be found in our IGARSS2001 paper (attached) on our web site ("results").
- Database and web building – data were processed and put in ARCview and the web site.
- The collaboration with Dr. Sohn at UMBC on comparing classification methods over our test site is progressing, and papers are being prepared.

Conclusion

We have made substantial progress in this project. Major structures (a team, database, and web) are now in place to support our future work.

ATTACHMENT

Monitoring Forest Dynamics Using Multi-sensor Data In Northeastern China

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***Abstract*- To monitor the dynamics of the forests in the vast Northeastern China region, we are developing an operational forest monitoring system using satellite remote sensing data. The major components of this system will include both standard and enhanced methodologies for forest cover mapping and change detection within a Geographic Information System (GIS) database. To rapidly assess forest conditions over the large geographical expanses in Northeast China, Moderate Resolution Imaging Spectroradiometer (MODIS) data are first used to detect areas of change at the macro scale. Once identified, fine resolution Landsat 7 ETM+, and SAR data, are used to generate fine resolution, micro-scale forest maps to characterize the nature/cause of the change(s). This paper describes the project and presents preliminary results in forest classification and change detection in this region.**

I. Introduction

The forests in Northeastern China (Fig.1) have been undergoing dramatic changes during the last several decades due to forest fire, insect infestation, massive logging, agri-cultural conversion, and afforestation. These changes affect the climate, the ecosystem, the economy and living heritage in the region, and may impact on the global carbon cycle.

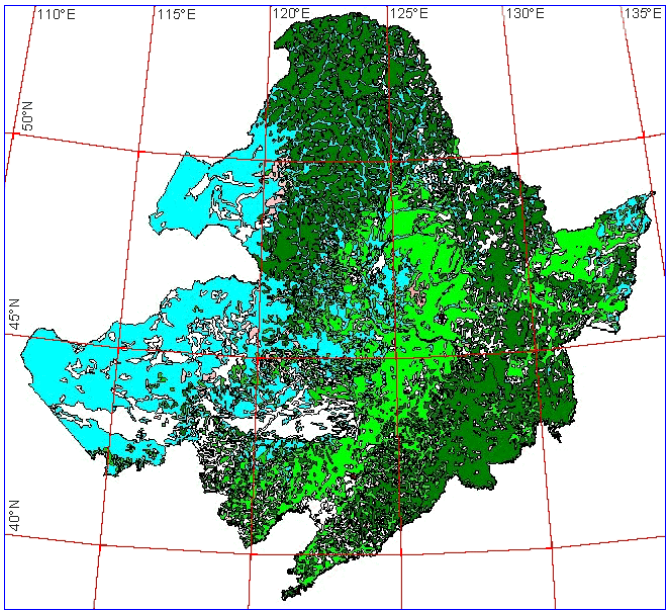

Fig. 1 Northeastern China: dark green – forests

Deforestation in Northeastern China has climatological impacts on regions to its west, including the Inner Mongolia and the Qinghai-Tibet plateau [1]. The scope of the changes is massive, but remote sensing technology can be utilized to provide the information required to more effectively monitor and manage these forests.

This project will 1) develop an updated base map of forest cover by combined use of ERS interferometric tandem SAR data and Landsat-7 ETM+ data. Research emphasis will be placed on the standardization of the classification methods, and the algorithms for deriving forest physical parameters from SAR and ETM+ data; 2) develop operational procedures for forest change detection and analysis by combined use of multi-temporal low spatial resolution optical data from MODIS and high spatial resolution Landsat-7 ETM+ and radar data. This project will contribute to the CEOS Global Observation of Forest Cover (GOFC), and serve as an operational pilot project to provide data for forest cover monitoring and carbon cycle studies.

Preliminary results at two test sites are presented below. One site includes both the Changbaishan Natural Conser-vation, where forests have been protected from disturbance since the 1970s, and the Lushuihe Forest Bureau, where the forests are being actively managed. At a second site, forests are recovering from a fire in May-June 1987, which destroyed nearly 1 million ha of forests.

II. Test Sites

The two sites are:
1) Luoshuihe Bureau of Forestry (42.5^o N, 127.8^o E) and Changbaishan Natural Preserve (42.8^o N, 128.5^o E), Jilin province. Total area of Luoshuihe Bureau of Forestry is 121,295 ha. It has 11000 ha of seed forestry of Korean pine (*Pinus koraiensis*). The total above ground biomass for these stands can exceed 30 Kg/m^2. The other area is mainly covered by mixed plantations (Larch and Poplar) and mixed natural forests (evergreen-needle and broad-leaf deciduous trees). Detailed field data, such as forest type, dominate species, species composition, average age, diameter, height, crown closure, timber volume, stem density, management type, productivity, soil texture and thickness, understory species, etc., updated every year, are now available. Chang-baishan Natural Preserve is located to the southeast of

Luoshuihe Bureau of Forestry. It was started in 1960, but formally established in 1979, and joined in UN MAB Program. It covers an area of 196,465 ha. 86% of the area is covered by forests with average timber volume of 256 m^3/ha. The vertical vegetation zones are distinctive along the slope of Changbai Mountain: from mature mixed broad/needle leaf forests to mountain tundra. This area is prohibited from any human disturbances, with continuous field observations in more than 20 plots and a tower for ecological observations during the last 20 years.

2) Burned area - Location: Mohe Bureau of Forestry (53.1° N, 122.5° E) and Tahe Bureau of Forestry (52.5° N, 124° E), Heilongjiang province. The main forest species are Dahurian Larch (*Larix gmelii*) and Mongolian pine (*Pinus Sylvestris var mongolia*). The total biomass of mature larch forests in this area ranges in 10 – 15 Kg/m^2. There are also some broadleaf forests, such as Asian White Birch (*Betula platyphylla*), David Poplar (*Populus davidiana*), willow tree, Mongolian Oak (*Quercus mongolica*) and Dahurian Birch (*Betula dahurica*). The Xiufeng Forest Farm of Tahe Bureau of Forestry was the starting point of the "forest fire 87." After the fire, large areas of rolling hills were left bare, and soil erosion was severe. The fire also demolished villages and small towns, destroying various establishments in the area. Forests are now regenerating, but various forest diseases and insect infestations have plagued the region.

III. Preliminary Results

A. Database

The images, maps and other spatial data are being processed using ENVI, ERDAS, ARCview, and will be finally converted to the same projection. These data and products will be made available to other users and researchers through the following web address (http://fir.gsfc.nasa.gov).

B. Data Processing

1) Change detection: At the site of Changbaishan Natural Conservation and Lushuihe Forest Bureau, a Landsat 4 TM image acquired on 28 May 1993 and a Landsat 7 ETM+ image acquired on 2 Sept. 1999 were used to detect changes from forest to non-forest in this period. The semi-automatic change detection procedure [2] was used. Significant land cover changes (deforestation) were selected to be training areas using local forest maps. A decision-tree classifier [3] then was used to classify TM and ETM+ images separately and detect changes from combined TM and ETM+ data. In Fig. 2, the red areas are the changed areas detected from the procedure. The upper-left part of the images belongs to Lushuihe Forest Bureau, where trees were cut in the red areas during 1993-1999. The lower-right side of the image is within the Changbai Natural Conservation, so no change (logging) was detected. When the multi-year MODIS data are available, a similar procedure will be implemented to detect the warning areas of the change, followed by use of ETM+ and/or SAR data to locate and analyze the changes.

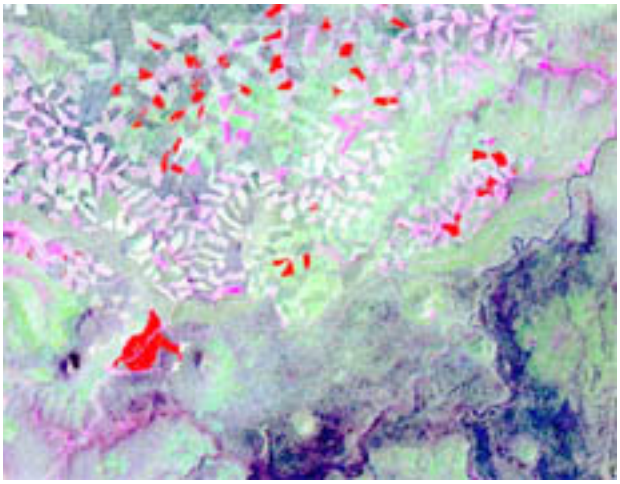

Fig. 2. Areas changed from forest to non-forest (red) during 1993-1999 are overlaid on 1993 TM images.

2) Forest recovery from fire: The second test site is located in Northern Heilongjiang Province, where the 'Moisture needle-leaf forest' is composed of *Larix gmelii* (about 70% of the surface cover in this area), and others such as *Pinus sylvestris*, *Var. Mongolica* and *Betula platyphylla* forest.

Landsat 5 TM images from 1986 to 1995, and Landsat 7 ETM+ images of 1999 and 2000 have been acquired to study the forest recovery after fire. Examples in Fig. 3 show a small area within the fire affected region. The first is a Landsat 5 TM image acquired on 8 June 1987, only a week after the fire was over. The temporal NDVI images on the second row reflect the recovery of forests in the burned area. It can be seen that in terms of NDVI, some burned forest areas are almost fully recovered after 12 years. After the forest maps and field data are collected this summer, a detailed study on the forest recovery, and the capability of remote sensing to monitor these changes will be further examined.

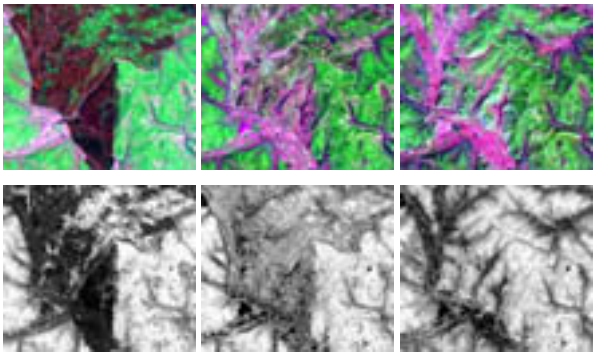

Fig. 3. Top row: L5 TM images of 6/8/87, 6/5/89, and L7 ETM+ image of 9/5/99 (RGB – bands 5,4,2). Second row shows NDVI for each date calculated from images in first row.

3) Forest classification: In our project, the forest cover in Northeastern China will be classified using remote sensing

data from Landsat-7 ETM+ and ERS SAR. Three major steps will be conducted for the classification: Data Preprocessing, Forest Cover Classification, and Classification Map Validation. From the detailed studies and the evaluation of various kinds of classification results, a classification system consistent with GOFC requirements is being developed, and a semi-automated procedure for land cover classification will be designed and documented for this forest monitoring system.

The test site in Changbai Mountain and Lushuihe Forest Bureau was selected to test and evaluate various methods for image pre-processing and classification. The evergreen-needle trees in this area are *Pinus koraiensis, Picea koraiensis, Pinus sylvestris var mongolica,* and *Abies nephrolepis*. Larch (*Larix olgensis*) trees are planted after clear-cutting. There are numerous accompanying broad-leaf tree species including *David poplar, Betula platyphylla, Fraxinus mandshurica, Tilia amurensis*, etc.

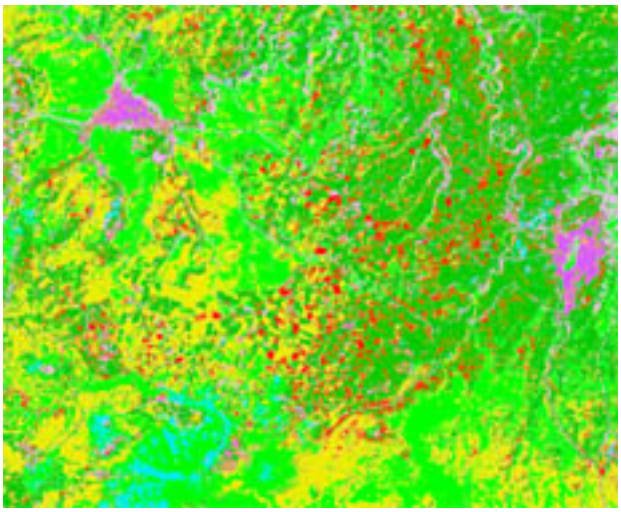

Fig. 4. Supervised Classifications of Landsat 7 ETM+ using 7 bands (2 Sept. 1999) plus a JERS-1 SAR image (7 July 1998): dark green – young evergreen needle, light green – old evergreen needle, Orange – mixed broadleaf deciduous, red – needle-leaf deciduous (larch), purple – build-up area.

Fig. 4 is a classified image using Maximum Likelihood Classifier. A total of 26 training classes were selected. The overall classification accuracy is 94.07%, Kappa coefficient is 0.9351 when 7-bands of ETM+ were used. Adding the JERS-1 SAR channel resulted in an accuracy of 95.08% and a Kappa coefficient of 0.9461. Fig. 5 shows the relationship between timber volume and JERS-1 LHH radar backscattering coefficients. Obviously, the JERS-1 SAR data is not very useful in this case. We will further evaluate other SAR data, such as SIR-C and ERS tandem data, for forest characterization in this area.

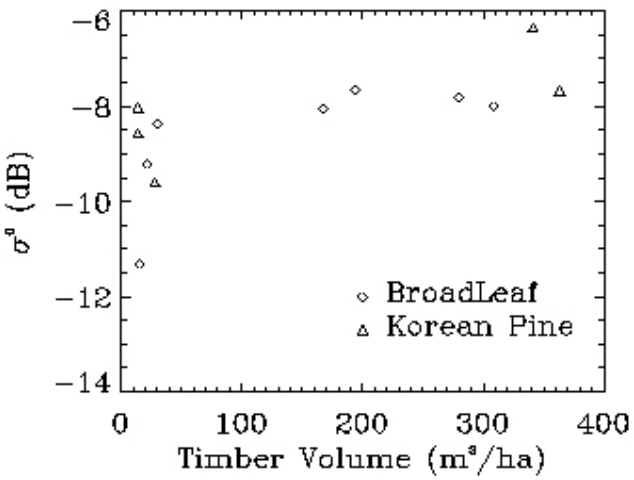

Fig. 5 JERS-1 LHH backscatter vs. forest timber volume

IV. Summary

The forests in Northeastern China have been undergoing significant changes during the last several decades for a variety of reasons. These changes affect the climate, the ecosystem, and the economy in the region. Given the massive scale of these alterations over time, it is speculated that they have had an impact on the global carbon cycle as well. Developing an operational forest monitoring system using satellite remote sensing data is useful, and more achievable now due to new sensors of Landsat-7 ETM+, Terra MODIS and various spaceborn SARs.

Acknowledgment

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