Identification of "hot spot areas" of forest cover changes in boreal Eurasia

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Abstract – An expert consultation was held in 2004 at the initiative of the Joint Research Centre to identify areas of current and potential rapid forest cover change in boreal Eurasia with the characterization of the main drivers of these changes. The resulting "hot spot" regional maps (Boreal European and Siberian regions) are presented in this study. The evidence on which the areas were designated was based on the personal experiences of the contacted experts. Information on potential criteria for an automated delineation and stratification at a broad scale was also collected.

Keywords: Boreal forests, Eurasia, forest cover change.

1. INTRODUCTION and OBJECTIVES

1.1 Rationale for monitoring forest resources in Eurasia

Covering 32% of all forest area, boreal forests are one of the last relatively intact terrestrial biomes and are a critical carbon sink in global climate dynamics. Boreal Eurasia and in particular Russia are endowed with abundant forest resources. Russia alone accounts for over 22 percent of the world's forested area and for 21 percent of the world's estimated standing timber volume. Of the total forested area in Russia, 78 percent is in Siberia and the Far East and 22 percent is in European Russia.

The Joint Research Centre (JRC) of the European Commission is developing methods of forest cover monitoring at global to continental scales. The JRC has already carried out such scientific research over the humid Tropics starting in the mid 1990's, convening a network of 27 partners in the tropical countries. Deforestation "hot spots" in the humid Tropics were identified, involving 30 experts. This exercise was the first step for the determination of deforestation rates (Achard et al., 2002).

We extrapolated JRC's experience to develop a similar monitoring system for the boreal ecosystems of the Eurasian continent. In the long term, we hope to measure change in forest cover in Eurasia and to understand how this change impacts on forest sustainability and on climate change through facilitating carbon emissions. This new monitoring system will benefit from the latest technological advances in Earth Observation. While developing a monitoring method for boreal forests we followed two steps. First, we constructed a continental land cover map for the year of 2000 at a spatial resolution of 1 km (Bartalev et al., 2003). Then the mosaic served as base for identifying areas of rapid change in forest cover, labeling them as "hot spot areas".

The Global Forest Watch (GFW) initiative of the World Resources Institute (WRI) brings together a number of Russian organizations to monitor different aspects of the Russian forest landscape. GFW Russia has developed a protocol for defining and monitoring large areas of insignificant human influence (intact forest landscapes). The protocol uses an stratified approach in which areas with evidence of significant human influence are successively eliminated in inverse order of detectability, using successively finer-scale, remotely sensed information. The method has been applied first to Russia (Yaroshenko et al., 2001; Aksenov et al., 2002), and then to Canada and across the boreal zone.

1.2 Objectives of the study

The primary objective of this study is to identify "hot spot areas" in the boreal forests of Eurasia, i.e. areas of significant forest change caused by logging, fires, mining or other activities.

To reach this objective an expert consultation was held at the initiative of the JRC to collectively identify areas of forest cover change hole boreal zone of the Eurasian continent. The basic task of the group was to locate (on a continental map) areas of current or impending rapid forest cover change in boreal Eurasia and to characterize the main drivers. This consultation was an important step in order to produce a reference data set of identified "hot spot areas" of recent and significant forest cover change. Keeping in mind the continental scale of the approach, the expert consultation was also expected (i) to agree on characteristics for those changes that should be measured and (ii) to state whether this would be possible with present satellite Earth observation techniques.

2. METHODS

2.1 Definition of "hot spot areas" of rapid forest cover change

For the purposes of this study, a "hot spot area" was defined as an area with a high concentration of forest cover change in space, i.e. areas of significant forest change caused by logging, fires, mining or other activities. The study focused on two kinds of hot spot areas: those of ongoing changes within the last 5 years and those where changes are expected to occur in the coming 3 to 5 years.

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Areas with dispersed forest cover change, such as in Sweden, Finland and parts of Russia, were not considered as "hot spots."

2.1 Methodology

Two main tasks were carried out:

(i) Identification and delineation of "hot spot areas"
(ii) Description of change in forest cover

Experts were requested to locate "hot spot areas" on a mosaic of satellite imagery printed at 1:4 M scale. Focusing at the boreal domain, the analysis covered the whole Eurasia. The mosaic was based on satellite data at 1 km resolution from the VEGETATION sensor onboard SPOT-4 (Bartalev *et al.*, 2001) acquired in 1999. One map layer was produced with the delineated "hot spot areas".

We described forest change for each "hot spot", indicating the following: (i) the type and cause of change or disturbance, (ii) the rate of the change (qualitative estimate), and (iii) causes, drivers and the underlying disturbance factors that include fire (type and cause), logging (type), construction of infrastructure, mining, clearing of forest for agricultural purposes, etc. The reported information was compiled in a common database.

Information on potential change indicators was also compiled during the consultation in order to evaluate if such indicators would be retrievable from satellite imagery in a future phase. For example fire-location information, which can be derived from satellite Earth observation data (Sukhinin et al., 2004), would be considered as a potential change indicator. Detection of clear cut patterns in the boreal coniferous forests of north western Eurasia is feasible from satellite imagery of medium spatial resolution (250m), given that the size of the clear cut is larger than about 15 ha (Stibig and Bucha, 2005). The use of such spatial indicators could allow a more automated identification of 'hot spots' in future spatial modelling exercises.

3. RESULTS AND DISCUSSION

3.1 General background on forest cover change during the last 20 years

Human influence on the Russian forest landscape has been growing over recent decades due to logging activities and induced fires. A first indicative map (Figure 1) shows these non-natural forest type changes which occurred during the last 10 to 20 years, mainly replacing coniferous forests (green) by deciduous forests re-growth (red).

Figure 1. Map of forest-type change during last 20 y. in Russia.

This map is based on an initial comparison between an old forest map of URSSS (Isaev et al., 1990) and the vegetation map of Eurasia for the year 2000 (Bartalev et al., 2003). Areas of needleleaf forest that transformed to broadleaf forests were identified. Forest type changes due to fires were excluded based on the visual assessment of Landsat TM imagery of the 1990's.

3.2 Increase of fire frequency

The frequency of fires has increased in recent years particularly in Siberia. Only in Russia more than 7.5 million ha of forests burnt annually over a 6 years period in the late 1990's (Sukhinin *et al*., 2004). It is not yet clear to what extent the increase in fire frequency is a consequence of anomalies in weather conditions or a consequence of disturbances caused by logging or mining. However, the sheer amount of forests burnt in these last years cannot be explained by the natural dynamic of the forest ecosystem, i.e. the natural ecosystem fire cycle which can be as high as 520 years in the case of the central Siberian "dark taiga" (Mollicone et al., 2002). The regions most affected by fires are located in Siberia. In 2002 and 2003, the forests around the Lena River in the central part of the Saha Republic and in the river basins of Kolima and Indigirka, respectively, were most heavily affected (Figure 2).

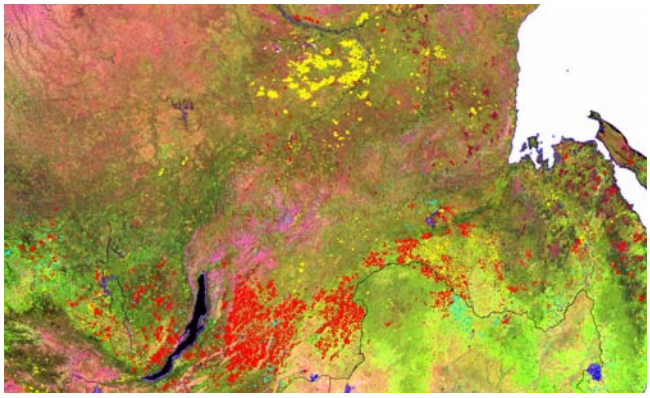

Figure 2. Fire activity during years 2002, 2003 and 2004 in the forest domain of Far East Siberia (from NASA MODIS fire product of University of Maryland)

3.3 Overview of the hot spots types

A general stratification of the 'Hot Spots' into eight main groups or strata could be done at hand of the geographical zoning, the type and the cause of the changes:

1. Logging in the Taiga
2. Intensive logging on the Karelian Isthmus
3. Logging along the Southern border of the Taiga and in the 'Birch belt'
4. Forest conversion for built over area
5. Regrowth of forests in the southern Taiga zone
6. Dam construction sites
7. Conversion of bogs by removing peat & by fires
8. Increase of fire frequency

3.4. Location of hot spots areas

The results of the delineation of the "hot spot areas" were digitized and stored as a unique digital spatial database in a Geographical Information System.

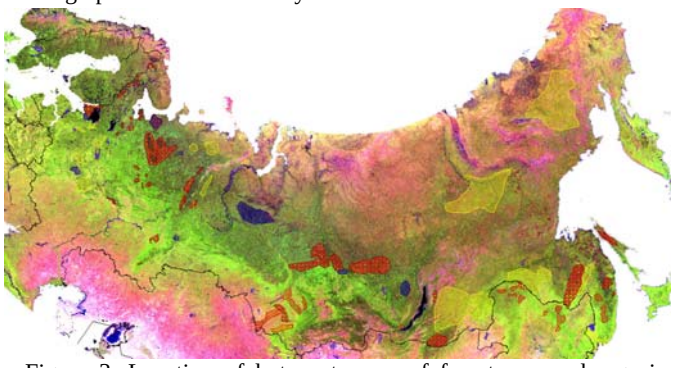

Figure 3. Location of hot spot areas of forest cover change in Eurasia overlaid on SPOT VEGETATION mosaic of year 1999

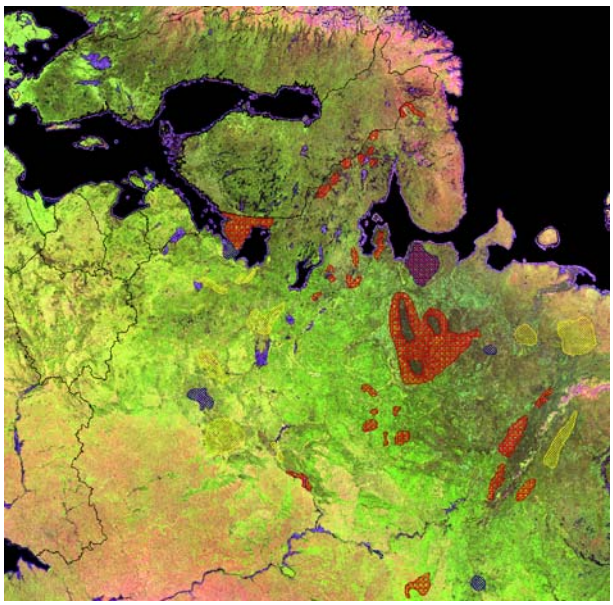

Figure 4. Location of hot spot areas in Western Eurasia

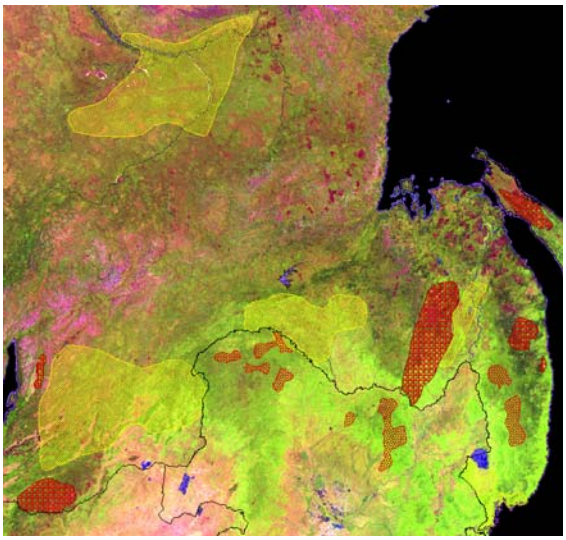

Figure 5. Location of hot spot areas in Far East

The hot spots areas of Eurasia are displayed in Figure 3, the different colors provide a first indication on the dominant change processes:

- Clear-cuts = red,
- Selective logging and intensive forest management = orange,
- Increase of fire intensity = yellow,
- Other processes = blue.

3.5 Synthesis

In the European parts of Russia

- Logging in the boreal coniferous (Taiga) forest affects mainly primary forests with clear cuts of high intensity leading to some loss of forest cover.
- The Southern border of the Taiga and the Birch belt are affected by small-scale logging over large areas with loss of biomass as a cumulative process.
- The intensive logging in the Karelian Isthmus (clear cut and selective logging of northern European type) raises the questions with regard to forest degradation and sustainability.
- Conversion in conjunction with urban sprawl affects mainly the Moscow and St. Petersburg regions.
- The conversion of bogs, mainly located in the south west, is usually occurring on dried peat land and with occasional fires.
- There are a number of areas where the fire frequency has increased, mainly located in the north east and usually in the context of mining.
- Forest regrowth (spontaneous 'afforestation') in the southern Taiga zone is a result of abandoned agriculture. However, this re-growing forest is mainly deciduous and very different from the primary coniferous forests that are harvested further north.

In Siberia, three major groups of hotspot areas have been identified:

- The first major group mainly includes logging activities (clear cuts or high intensity selective logging). The main factors are regular timber harvesting and irregular cutting for public revenue or individual profit in response to growing demand in national and international markets, particularly in China and Japan.
- Degradation is usually a slow process over a number of years. This group of hot spot areas includes large areas affected by fires when their frequency is considered to increase in time. Another process of degradation is pest outbreaks, which are the second factor of forest degradation after fire.
- The increase of forest cover is resulting from spontaneous forest regrowth on abandoned agricultural land. Such afforestation is usually happening in the southern Taiga zone.

For Sweden and Finland, it is considered that their specific forestry management practices do not lead to any particular hot spot area of rapid forest cover change at the country scale, as shown by their national statistical Forestry information. The forest areas have shown little change during a recent past (last 10 years).

Forests of Northeast China are considered in this study although these forests are cool temperate forests. Two main hot spot areas of forest cover change have been delineated although they are characterized by selective logging of moderate intensity. The total forest cover of this region shows an overall trend of slight increase through reforestation.

4. CONCLUSIONS

A group of experts from Russia and from neighboring countries was consulted to locate on a map, areas of current or impending forest cover change and to characterize the main drivers. This approach of assessing forest cover change is rather unconventional but was deemed important as an initial step for developing a new method for monitoring the boreal forest cover of the Eurasian continent.

This consultation with leading forest experts was an important step in order to produce an improved reference data set of identified hot spots areas of recent and significant forest cover change for the international scientific community (Lepers et al., 2005).

The main processes of forest cover changes in boreal Eurasia are the logging activities, with in particular (i) clear cuts and (ii) high intensity selective logging, (iii) increased fire frequency, (iv) other conversion to non- forest, e.g. construction of water reservoirs or transport infrastructures. A positive trend is observed in the southern Taiga zone where deciduous forests naturally re-grow on abandoned agricultural land.

Except for the re-growth in the southern Taiga all other processes lead to the decrease of forest cover (e.g. conversion to non-forest) or to its degradation (e.g. increased fire frequency).

Logging activities are driven by regular timber harvesting and irregular cutting for public revenue or individual profit in response to growing demand in national and international markets, particularly in China and Japan.

The resulting "hot spot" maps of the boreal European and Siberian regions are presented more extensively in a report (Achard et al., 2005). This document has to be regarded as a tentative 'first pass' which will need further improvements and updating in an iterative process. The evidence on which the areas were designated was based on personal expertise, with the understanding that the information upon which it is based will be subject to continuing revision.

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