Detection of Changes in Eurasian Boreal Forest

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Abstract Boreal ecosystems present critical importance in global ecological processes. They are complicated system with great numbers of inner connections and dynamic pattern. The role, which boreal ecosystems play in sustainability of the environment as well as their significant value within forest cover of the Earth, is beyond question.
The influence of anthropogenic activities on the condition of the boreal forests is growing up every year. That is why the determination of zones of current changes and definition of criteria which could be considered as key in the processes of identification such areas, are in a great interest. Besides, it is very important to predict areas where these changes are most likely could happen in next years.

Keywords: Forest cover changes, Boreal forest, Eurasia, Intact Forest Landscapes, biodiversity, conservation, anthropogenic activities.

1. INTRODUCTION

The Joint Research Centre (JRC) past initiatives include projects on identifying “hotspots” in the tropical forest. Experts on tropical forests convened in workshops to map change in tropical rainforest, covering the evergreen rainforest and the monsoon forest of South East Asia, including Northeast India, Bangladesh and Papua New Guinea.

In this project, we aimed to detect areas with significant change in vegetation cover, or “hotspots,” within forest landscapes in the Russian boreal zone and estimate zones of potential changes in next 5 years. To reach this aim we advanced the following objectives:

1. to define the main types of change in forest cover in Russia
2. to map current “hotspots” of change in forest cover that occurred over the last 15 years
3. to estimate and map “hotspots” of change in forest cover in the next 5 years
4. to map density of potential “hotspots”

Because estimating changes for all of the forest of the Russian Federation require an enormous amout of resources and remote sensing data, we identified only those “hotspots” that were on the border of intact forest landscapes (IFL), as determined by Greenpeace Russia and Global Forest Watch (Yaroshenko, A., Potapov, P., Turubanova, S., 2001). Moreover, we assumed that future disturbances would possibly expand into IFL.

2..DATA DESCRIPTION

For this project we used the following data:
1. Landsat-7/ETM+ images – high spatial resolution images with 6 spectral bands.
2. Landsat-7/ETM+ image previews – moderate-resolution browse images sub-sampled from the actual scene data. The image is displayed as a 5,4,3 (RGB) band composite with a standardized 2% linear stretch applied.

Spectral resolution of the both data types described in the Table 1.

Table 1. Spectral resolution of the data

Band*	Preview Landsat-7/ETM+ (250 meters resolution)	Landsat 7/ETM+ images (30 meters resolution)
Band 1	0,63-0,69	0,45-0,515
Band 2	0,75-0,90	0,525-0,605
Band 3	1,55-1,75	0,63-0,69
Band 4	-	0,75-0,90
Band 5	-	1,55-1,75
Band 6	-	2,09-2,35

* - band numbers shows order but not the actual number of the band

Our Landsat data covered the time periods between January 1999 and December 2001. The number of images from different season used in the analysis is described in the Table 2. Most of the data was acquired during summer and autumn.

Table 2. Number of processed images

Numbers	1999 summer	1999 autumn	2000 summer	2000 autumn	2001 summer	2001 autumn
Landsat scenes	36	49	69	22	49	36
Preview of Landsat scenes	79	28	253	38	82	20

In total, we processed 261 scenes of Landsat and about 500 previews of Landsat data. All images and previews were geometrically transformed into the Albers conical equal area projection. Depending on the zone different parameters of the projection were used, Russia’s territory was divided into three zones: European Russia, Siberia, and the Far East. Detailed parameters for each zone are in Table 3

3. DEFINITIONS

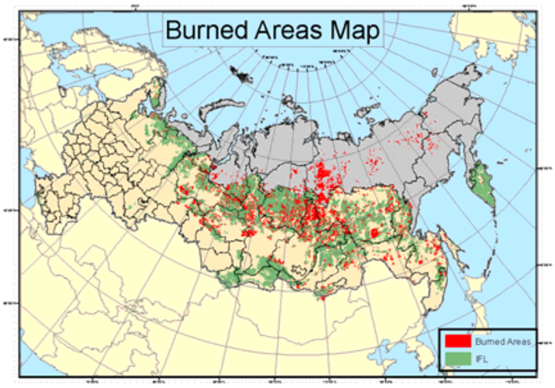
We defined “hotspots” as areas with significant change in vegetation cover as a result of intensive anthropogenic influence. The following types of “hotspots” of change in forest cover were determined:

- burned areas (at least 15 years old)
- intensive forest exploitation (clear-cuts)

- fossil fuel mining (oil and gas extraction, open cast mining, gold mining)
- agricultural development
- other evidence of intensive anthropogenic activities

4. METHODS IN IDENTIFYING CURRENT "HOTSPOTS"

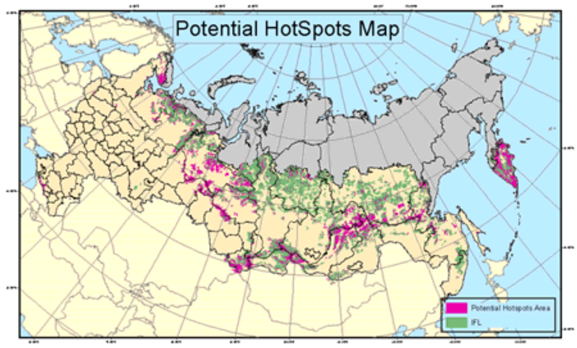
Using Landsat images and image previews, we visually detected the above-listed types of disturbances. To delineate burnt areas we used image previews, while for other types of "hotspots" image previews were not sufficient and we used high spatial resolution images. Working on 1:100,000 scale, minimum size for a change area to be considered was 50,000 sq. m.



5. METHODS IN IDENTIFYING FUTURE "HOTSPOTS"

Changes occurring on the border of IFL are highly likely to expand into the IFL area, mainly because of the being built infrastructure and, consequently, better accessibility compare to those area where infrastructure is absent..
Thus, we aimed to identify those areas of IFL that might be threatened:

1. We calculated the average speed with which "hotspots" expanded into the IFL by selecting several representative areas that significantly changed over the last two or three years and calculating the average speed of "hotspots" growth per year. For clear-cuts this speed was on average from 2 to 5 kilometers per year for model areas. In most cases, "hotspots" grew between two and three kilometers per year and sometimes 5 or more kilometers. Thus, we chose a buffer that was most likely to cover areas of potential change, which we determined to be 5 kilometers. For the mining and agricultural development the buffer size was determined to be 2 and 0,5 kilometers accordingly.
2. Territories of protected areas (zapovedniks and national park) were excluded from the buffer zones.
3. Non-forest areas were excluded from the buffers.
4. Density of the remained polygons was calculated (using moving window of 7,500 meter radius). The resulting map showed density of predicted "hotspots" of change in forest cover.



6. RESULTS AND DISCUSSION

The following results were achieved:

1. We defined the main types of the "hotspots" of disturbances
2. We mapped "hotspots" of current change in forest cover in Russia.
3. We mapped potential changes in forest cover for the next 5 years.
4. We mapped the density of potential "hotspots.

In most cases, "hotspots" on the border with IFL were specific to each region. For example:

- Far East – fresh burned areas (catastrophic fires of the 90s and 70s), logging in mixed conifers and deciduous forests and conifers forests
- East Siberia – burned area in larch forests (burned many times, difficulties in age determination), clear cutting/logging in conifers forests (Angara river area, basin of Baikal, Chitinskaya oblast)
- Northern European Russia (Karelia, Arkhangelskaya oblast) – clear-cutting in coniferous forest
- West Siberia (Tumen region) – mining (oil and gas extraction).

Our methodology presented several advantages and disadvantages. One of the difficulties of working with satellite images is that it is almost impossible to determine the age of disturbances, especially burnt areas as they are susceptible to future fires. For example, it was not clear how to interpret massive areas of larch-forest within the East Siberia territory (Evenkia, Yakutia). On the one hand, fire dynamics of this territory could be treated as natural, however, we also could guess that number of fires on this area increased due to intensification of anthropogenic influence. Additionally, our study area included only changes in forests bordering with or located in IFL. But also, our method was rather time-consuming, because delineation was done manually.

However, to our advantage high resolution images covered all of the study area, and the data for this area was more precise and current, giving us an opportunity to make an accurate estimation.

After analyzing several methodologies (Lillesand T.M., Kiefer RW. “Remote sensing and image interpretation”; Jensen J.R. “Introductory digital image processing”) we concluded that three bands, that are included to Landsat image previews, are most sufficient to detect change. The 5, 4, 3 combination, used in preview imagery composite, provides a great amount of information and color contrast. Healthy vegetation is bright green and soils are mauve. The 5, 4, 3 combination has the most agricultural information. This combination is useful for vegetation studies, and is widely used in the areas of timber management and pest infestation. In addition, this combination is useful in the fire management applications for post-fire analysis of burned and non burned forested areas interpretation.
To our convenience, several previews of Landsat images were available for each footprint of Landsat in the territory of investigation. On average, at least than 2-3 previews obtained in different seasons were used instead of only one full Landsat scene typically available for each footprint. Thus, if using only one seasonal image did not allow detecting changes, there was a possibility to use previews of different seasonal previews. During the analysis, summer and autumn (rarely – spring) seasonal previews were used. In work we did not conduct an additional geometric correction through ground reference points. On average, RMS error with automatic geometric correction was no more than 400 meters for previews and no more than 250 for Landsat images. Taking into account the big scale of the project this accuracy could be recognized satisfactory.

7. OPPORTUNITIES FOR FUTURE WORK

In the future we see several possible streams for this work

- increasing the accuracy of the results - making more precise definition of the changes using only high resolution data
- increasing the study area - delineation of the changes not only on the border with IFL, but for all of the Russian territory
- conducting a change analysis – detection of the changes for different time points (using Landsat mss, tm data) and obtaining the dynamic of changes and possibly, determination the key factors of changes

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