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REGIONAL MONITORING OF FOREST DISTURBANCES AND THEIR POTENTIAL EFFECTS TO CARBON CYCLING

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ABSTRACT: Boreal forest zone is recognized as one of regions greatly influenced by global warming in near future. The forest fire (FF) is considered as one of the main driving factors influencing the forest and its occurrence is supposed to be increased due to climate change in boreal zone. Knowledge about forest fire intensity, occurrence and extent is thus required. In this study NOAA AVHRR satellite is employed for monitoring and assessment of forest fire phenomena. The extensive archive of NOAA HRPT (High Resolution Picture Transmission) of IIS (Institute of Industrial Science, The University of Tokyo) during a period of 1983 to 2001 serve as a valuable source of information required for understanding forest fire dynamics. As an area of interest, the Far East Region (Primorskij and Khabarovskij Kraj and part of China) was selected because of frequent forest fire occurrence and feasible HRPT scene coverage. The goal of this work is to obtain forest fire history (burned area, type and age of burned forest) and description of vegetation succession after fire using satellite product. As a tool for forest fire accounting the HANDS (Hotspot and NDVI Differencing Synergy, Fraser, 2000) algorithm is used because it was designed for boreal environment and performs better than other forest fire detection and monitoring algorithms. For the succession behaviour of fire affected spot the time series of NDVI (Normalized Difference Vegetation Index) and GEMI (Global Environmental Monitoring Index) are analyzed. Using these time series it has been demonstrated that the regrowing burned areas are more vital in vegetation growth due to the fertilization effect in comparing with the unburned areas.

1. INTRODUCTION

In order to fully understand the forest fire phenomena, the precise location, extent and occurrence in time is required. Since a lot of forest fires take place in remote and hardly accessible areas the remote sensing tool seems to be the most appropriate for forest monitoring from the following reasons: data are consistent and their assemblage is easier, the ground truth precise measurements are usually available for only accessible regions and they are not always complete. Even though the forest fire history is very important source of information for vast number of professionals (forest management, global change and carbon cycling community etc.) to get precise fire occurrence in time for given region is very hard even impossible from accessible ground truth data. This study concentrates on creating forest fire history for study region from 1983-2001 using NOAA AVHRR sensor, and the vegetation development of burned areas is described and compared with unburned areas using NDVI and GEMI indices.

2. STUDY AREA

As a study area Primorskij and Khabarovsk regions in Russian Far East and vast forest areas in the northeast China were selected. The area is mostly covered by coniferous and temperate forest. Forest fires occur practically every year. Most of them are caused by human factors and lighting (FIREGLOBE, 2001).

3. METHODOLOGY

3. 1. Vegetation indices

The NOAA AVHRR (Advanced Very High Resolution Radiometer) sensor is used as a main data source for fire monitoring from the following reasons. The first reason is its high temporal resolution (2 – 4 scenes per day are available from our archive); the second is wide observation coverage, which entirely comprises the whole area of interest, and the third is relatively high spatial resolution of 1.1 km in nadir which is appropriate for mapping of most big fires. In order to assess the vegetation state and post fire regrowth condition, two indices derived from AVHRR data sets were used: NDVI (Normalized Difference Vegetation Index) and nonlinear GEMI (Global Environmental Vegetation Index, Pinty 1992). These two indices are described as follows:

$$NDVI = (\rho_2 - \rho_?)/(\rho_2 + \rho_?) \qquad GEMI = \eta(1 - 0.25\eta) - (\rho_1 - 0.125)/(1 - \rho_?) \tag{1}$$

where $\eta = (2(\rho_2^2 - \rho_?^2) + 1.5\rho_2 + 0.5\rho_1)/(\rho_1 + \rho_2 + 0.5)$,

$\rho_?$ is channel 1 (0.58 ~ 0.68 μm) ρ_2 is channel 2 (0.725 ~ 1.10 μm).

From the visual interpretation of images we confirmed that GEMI is less influenced by thin clouds and haze (Table 1) so the future study will be concentrated on using GEMI.

Table 1. Average values of vegetation indexes for different atmospheric conditions for homogenous forest areas 50x50 pixels and two different scenes. Both are allowed to be within the range (-1, 1). Notice the big difference for smoke and thin clouds.

INDEX	Smoke, thin clouds		Clouds		Homogenous Forest (clear sky)	
	August 1998	May 1987	August 1998	May 1987	August 1998	May 1987
NDVI	0.04	-0.05	-0.1	-0.09	0.53	0.04
GEMI	0.33	0.27	-0.21	0.10	0.45	0.28

3. 2. Forest Fire Detection

For the fire detection and burned area mapping the HANDS (Fraser, 2000) method was used because it is most appropriate and most precise. The algorithm consists of two steps. First, the multichannel thresholding is applied for each scene to detect the most probable forest fire places and secondly those places are confirmed by NDVI differencing of pre-fire and post-fire season. The algorithm was developed for boreal environment in Canadian forests. The algorithm was examined on big forest fire in China 1987 (Cahoon, 1994). The detected burned place was used for further analysis using subsequent AVHRR scenes.

3. 3. Post Fire Observation

As a next step of observation of forest fire dynamics a time series data set for some burned and unburned areas was produced. The monthly composites of AVHRR scenes from 1987 till now (using maximum index criterion) were created and the behavior of both vegetation indices was observed.

4. RESULTS

The example of time series of NDVI and GEMI for burned and unburned areas are shown in Figure 1 and Figure 2 respectively. The horizontal axis shows the months and the vertical axis shows vegetation index value. Both plots starts at the time of forest fire event where vegetation decline is recognized. The vegetation index stays lower for several next years compared to unburned place because of little significant coverage which means almost none vegetation index response. After several years the grass and shrub growth increases the vegetation index compared with the unburned plot line and it remain higher due to fertilization effect. This coincides with natural vegetation succession after forest fire (Fire in Pacific Northwest Ecosystems, 2001).

5. FUTURE WORK

The estimation of carbon released during the fire and after the fire will be computed using following (FIREGLOBE, 2001):

$$G = k\,M \tag{2}$$

where
k = 0.5 - constant quotient representing the average content of carbon in forest fuels (FF);
M - mass of burnt FF (t) (product of biomass burned during fire (average 21 t/ha of dry matter) and area)

Evaluation of post fire carbon emission can be computed using:

$$R = k * t * P/ T \tag{3}$$

where
k = 0.5 – quotient of conversion of organic substance mass into carbon
t = 25 – duration of forest regeneration period of burnt-out areas (years)
T = 10 – duration of destruction period do dead trees (years)
P – mass (dry matter) of annual tree mortality after fire (product of phytomass of tree dead organic matter (32 t/ha) and burned area

The total area of burned forest fire for each year was not evaluated yet so the total estimation of carbon released will be computed after finishing whole forest fire history. Also the clear connection of detected regrowth using vegetations indices and biomass regrowth (e.g. carbon sequestration) is under investigation.

6. CONCLUSION

In order to get forest fire history in Far East Region the extensive NOAA AVHRR archive is used. The forest fire detection was performed using HANDS algorithm and succession phenomena was described using NDVI and GEMI vegetation indices. The simple algorithm describing released carbon during and after forest fire is given and will be used after evaluation of total burned area.

COMPARISON OF NDVI FOR BURNED AND UNBURNED AREAS

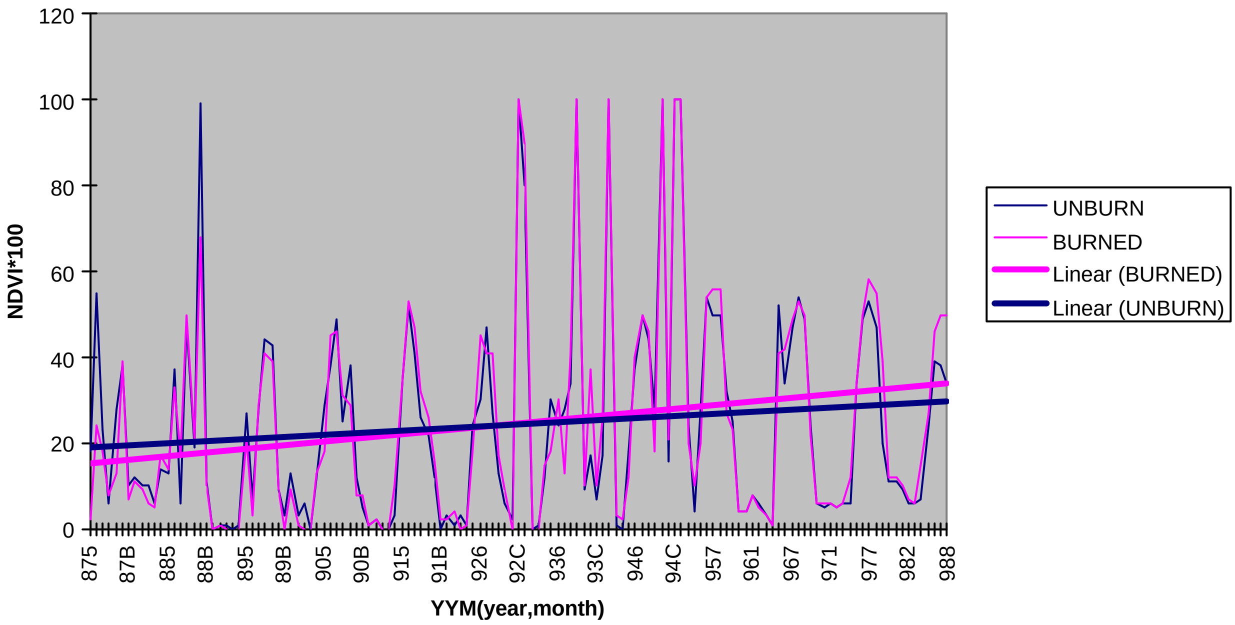

Figure 1. Comparison of NDVI for burned spot (about 4000 km^2) and unburned spot of the same area. The NDVI value increases for the burned area due to fertilization effect of fire.

COMPARISON OF GEMI FOR BURNED AND UNBURNED AREAS

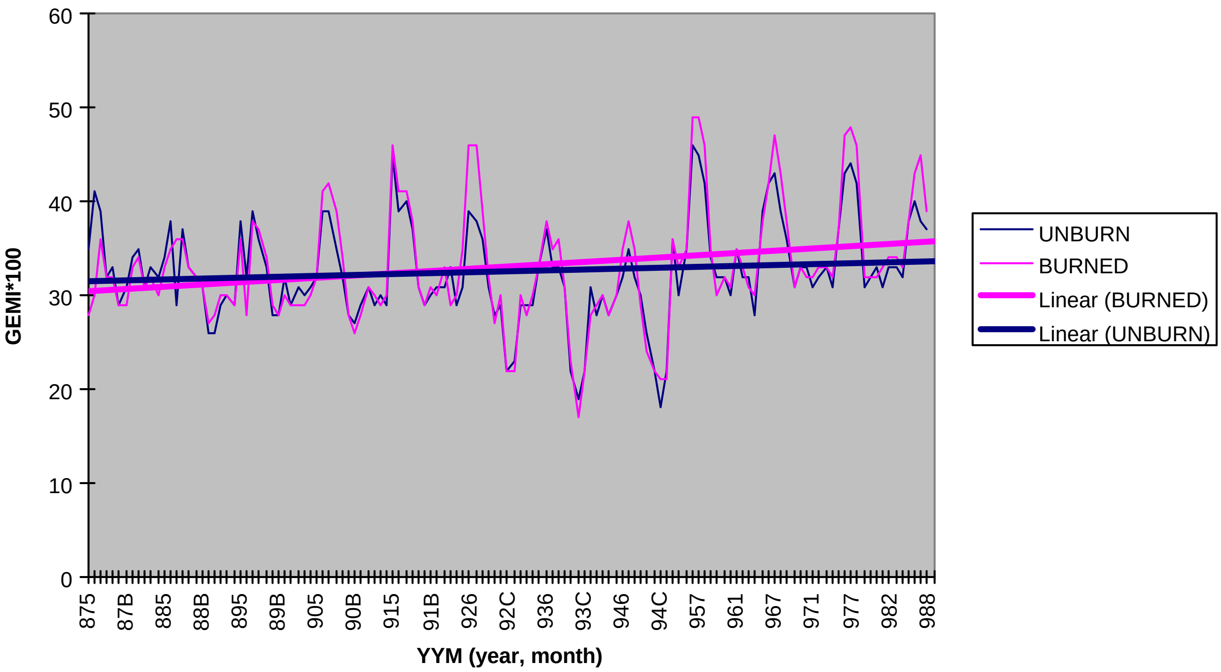

Figure 2. Comparison of GEMI for burned spot (about 4000 km^2) and unburned spot of the same area. The GEMII value increases for the burned area due to fertilization effect of fire.

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