Forest fire categorization using remote sensing method

Małgorzata Mycke-Dominko, Elżbieta Wołk-Musiał

University of Warsaw, Faculty of Geography and Regional Studies, Department of Geoinformatics and Remote Sensing, Warsaw, Poland; dominkom@uw.edu.pl

Abstract. Satellite images are very usefull at determination of forest fire danger rating categories Some studies was taken on miscellaneous images as: LANDSAT, SPOT, IKONOS, NOAA and TERRA ASTER. Solution proposed is to make forest fire danger rating categories refer to forest ranger sub- districts, what gives the forest service greater control over forest fire prevention activities. Forest fire danger assesment was done taking into acount remote sensing indices as the NDVI, TNDVI and others and refered to statistical data. Were specified 3 classes (high, moderate and low fire danger). Study carried out on satellite images acquired by the five satellites provide a very similar final picture.Depending on the units of administration, for which we want to illustrate the phenomenon of forest fire risk category, select the appropriate display. However, for operational services in Poland just enough categorization for forest districts. For this purpose, well suited images from Landsat TM. A detailed map is related to forest districts is derived from images acquired from ASTER TERRA satellite. Images from the NOAA satellites have the advantage, that they can be obtained from a particular day and are the cheapest. At that scale we achieved reliable results. On that basis, we can quickly classify all forest areas for all Poland. Additionally, we can select the images that are made at the time characterized by the typical average weather conditions, and did not come from the extreme and even catastrophic weather conditions.

Keywords. remote sensing, Landsat TM, Ikonos, Noaa, Terra Aster, Spot 4, forest fire, categorization

1. Introduction

Fires are one of the phenomena occurring in the forests..Every year over 100 000 fires break out in European forests. The number of forest fires in Poland is about 10 000 per year.

In 2011 there were 4600 fires in the State Forest area, which is 46% of all fires that swept through the country that year. In non-State forests the number of fires was 5400 In State Forest the average area was 0,2 ha, while in private forests 0,41 ha.

The potential risk of forest fire depends on many factors, such as:

- species composition
- age structure
- average stand (tree height) lub the height of trees
- condition of soil cover
- type of undergrowth
- weather conditions, in particular the size and distribution of rain - mainly in the growing season

Forest fire hazard is also related to people penetrating forests for recreational purposes, especially around large urban agglomerations.

Most fires happen in the early spring months: April, May and during the summer when high temperatures cause a significant drop in the moisture content of forest litter.

The greatest danger of fire is covered by the line of contact between the forest and meadows or where often comes to spring burning grass.

Fire protection of forests is adapted to the category and degree of forest fire risk.

The State Forest has three categories of fire hazard.

I category - high risk of forest fire

II category - medium risk of forest fire
III category - a small forest fire risk

2. Methods

Standard categorization of forest fire risk done in a traditional way is a labor intensive method so studies carried out nowadays use satellite data.

In the method based on Remote Sensing data to designate the categories of fire hazard we use satellite imagery from satellites LANDSAT TM, IKONOS, NOAA, SPOT 4 and TERRA ASTER. The analysis refers to all forests, independent of their owners and the size. It also shows the proximity of these complexes, which is important due to the movement of fire from other lands (especially grassland).

The primary task was to distinguish homogeneous forests (forest fotomorfic units) in terms of spectral reflectance, which have moderately similar features (type of forest habitat, species, stand age, the coefficients humidity). The identification of the so-called "forest fotomorfic units" and correlating them with the fires which have previously occurred in the areas made it possible to identify and classify these units in the three categories of forest fire risk. These categories, in the first stage of the accident, were based on spectral curves for the various fotomorfic units. Spectral reflectance is the result of many factors, including topography, soil and soils on it, soil moisture, land cover, type of vegetation and anthropogenic elements. Wood humidity is the most vital factor conditioning its vulnerability and the origination of fire. Traditionally, one measures humidity of the forest bed, in the satellite method this is the value referred to treetops.

CHARACTERISTICS OF THE AREA UNDER RESEARCH
Location: Radom Plain (Dobieszym Forest Inspectorate)
Wood habitat type: mixed young wood, mixed forest
Prevailing species: pine tree
Average age of tree stand: 40-50 years old
Water conditions: first level of underground waters 5-10 m
Soils: fawn, rusty, podzol
Average temperature of air in the vegetation period: 14 ° C, maximum temperature reaches 36° C.
Average humidity of air: 49.8%.
Average humidity of forest bed: 15.2%.
Precipitation within the vegetation period: up to 500 mm (annual – 650 mm).

CATEGORIES OF FIRE HAZARD BASED ON LANDSAT TM, SPOT, IKONOS, NOAA, TERRA ASTER SATELLITE IMAGES

An unsupervised classification was carried out which allowed for separation of a bigger number of classes and their identification on non-continuous and hardly recognizable areas (mixed coniferous and deciduous types). This classification is also called clustering (cluster creating)

Applied was the of attributing to ISODATA (Iterative Self-Organizing Data Analysis Technique) clusters which uses spectral distances. In this method, to attribute a pixel/a picture element to a cluster one uses a minimum spectral distance.

Also some data was derived from state forest informatic system:

- forestry division (on different levels)
- forest habitat
- age of individual species

- degree of fault tree
- bear habitat
- understorey species
- degree of the forest cover
- tree height
- diameter trees

Works were carried out in several stages:

The first stage was calculating the normalized difference vegetation index (NDVI) for all images. The index was calculated only for forest areas which were located on the numerical map of the Dobieszyn Forest Inspectorate. For each satellite image and for each date, NDVI maps were created. NDVI values from 01 – 1,0 were classified into 18 classes. The most differentiated NDVI values occurred on the map of September, and the most homogenous ones on the map of July.

Then coloured compositions were created out of the chosen channels and submitted for classification. A subsequent stage was analysing spectral values of respective trees in every channel and on each satellite image.

Based on these maps, NDVI values for respective species were analysed. Complexes of deciduous tree stand are quite scattered on this area. Considering the above it was decided to box it in one class independently from its species and age. Coniferous tree stand which creates more dense complexes was classified in three classes:

- Pine tree stands of the age up to 30 years
- Pine tree stands of the age from 30 – 60 years,
- Pine tree stands of the age above 60 years.

Distribution of NDVI values for all classes and images are presented on the charts. The highest NDVI values for all classes occurred in July, while the lowest in September. The differentiation was minimal in May for the pine tree stand. The lowest value applied to pine tree stands of the age between 30-60 years. In July the values were almost the same for all three age classes. In August, pine tree stands of the age between 30 – 60 years had a higher value, while in September the pine tree above 60 years had the value higher than the remaining ones.

Relations between the NDVI value and occurrence of fires on this area according to the age classes was examined.

In the analysis, information about the radiation temperature of the land surface was taken into consideration. The radiation temperature, which the scanner registered was adjusted to the influence of the atmosphere according to the following formula (Karlikowski 1997):

TS = T4 + 2,68(T4 – T5) – 0,4 where:

The radiation temperature of the forest surface

Spectral Channel 4 recording the temperature of the forest surface,

Spectral Channel 5 recording the temperature of the forest surface.

The next analysis consisted of the NDVI values correlated with the values defining the radiation temperature of surface stands, litter humidity and the relative humidity of the air.

After having analyzed numerous fires and the value of the NDVI, the correlation factor was small and amounted to 0.17, while between the TS and the number of fires this ratio was high and amounted to 0.95.

When examining the monthly value of relative humidity, litter moisture, air temperature and radiation temperature of surface stands a very high correlation was found between the NDVI index and the two humidites whereas it was considerably smaller between the NDVI and the air temperatures and the radiation temperature of the surface pine stands.

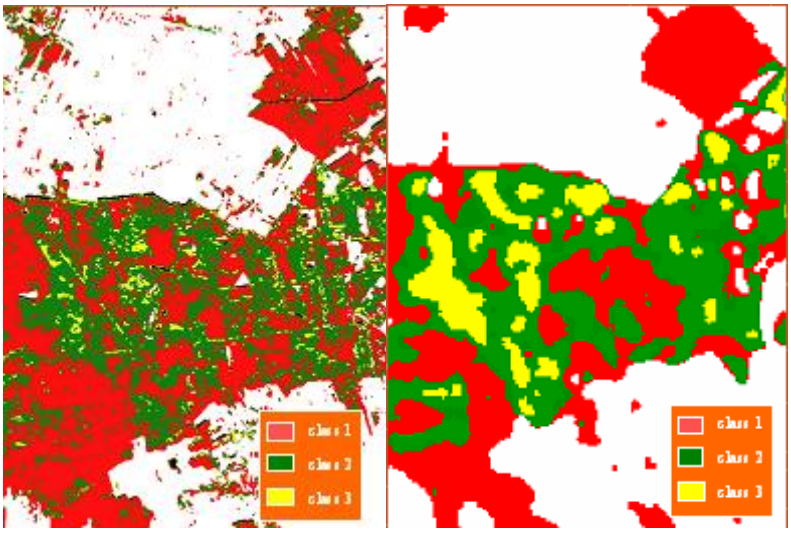

Figure 1. Forest fire hazard after classification derived from Ikonos and Landsat TM

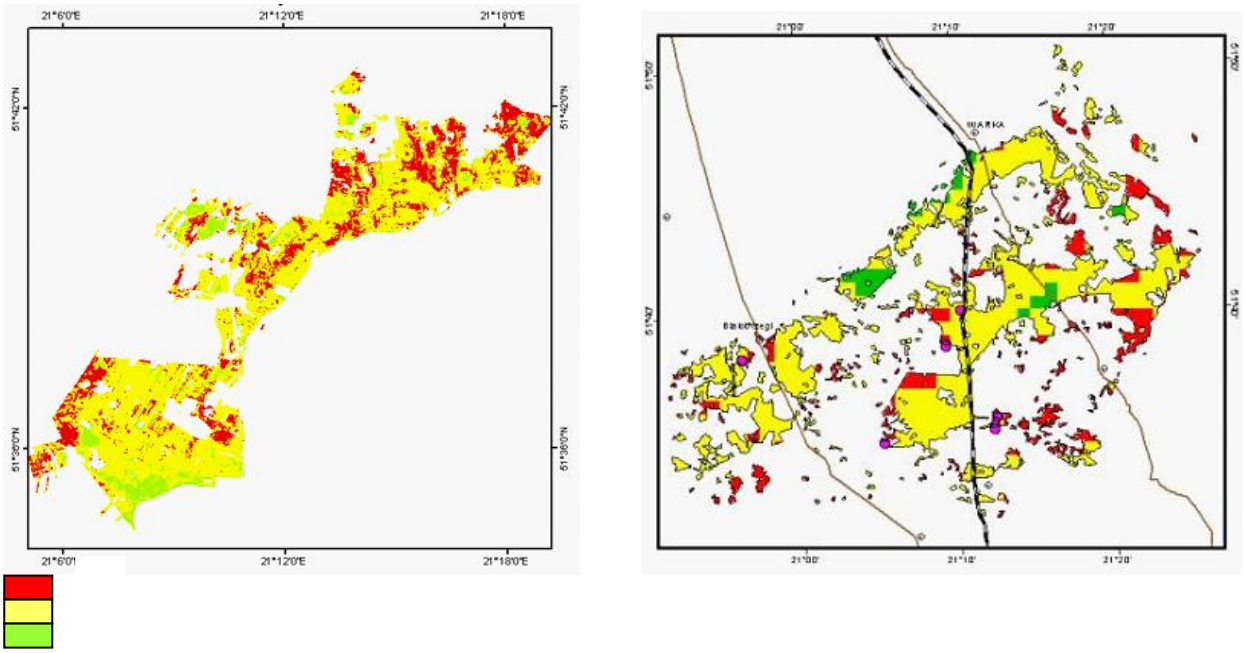

Figure 2. Forest fire hazard after classification derived from Terra ASTER and NOAA

3. Results

The presentation described a study carried out on satellite images acquired by five satellites. They provide a very similar final picture.

Depending on the units of administration, for which we want to illustrate the phenomenon of the forest fire risk category, an appropriate display must be selected. However, for the operational services in Poland a division into categories of fire risks regarding forestry is sufficient enough.

For this purpose, well suited images from Landsat TM, for the final illustration is not as detailed as images from IKONOS and they are more readable for the recipient.
A detailed map is related to forest districts is derived from images acquired from ASTER TERRA satellite.

Images from the NOAA satellites have the advantage, that they can be obtained from a particular day and are the cheapest. At that scale we achieved reliable results. On that basis, we can quickly classify all forest areas for all Poland. Additionally, we can select the images that are made at the time characterized by the typical average weather conditions, and did not come from the extreme and even catastrophic weather conditions.

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