Fire disasters in a wetlands area monitored by remote sensing data

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ABSTRACT: The aim of the project is to use remote sensing data in order to assess damage caused by fire in a wetland area. There are many satellite systems, which provide information on different fire characteristics: location of burned area, duration of active fire, aerosol emissions, etc. Remote sensing data play a significant role in detection and monitoring fires of wetlands and could be the only tool in getting information about burned area when the access to it is difficult. In autumn 2002, fires occurred at the area of the Biebrza National Park, the largest wetlands in Europe. The fire spread to various sites and affected in total almost 3 000 ha. The largest burn scar was located in the central part of the Biebrza National Park in Biele Suchowolskie. In this area the fire destroyed 1 600 ha of wetlands. Fires of peat bogs are dangerous and difficult to stop as they spread under the surface. The fire destroyed natural vegetation on the surface and the thick layer of peat bog. Images from MODIS/Terra satellite were used to estimate the extent of the disaster and the changes in the environment caused by the fire.

1 INTRODUCTION

The Biebrza National Park is one of the largest and the best preserved wetlands in Europe. It covers almost 60 000 ha, and is the largest national park in Poland. The park is located in the northeast part of Poland, close to Byelorussia border. It is divided into three parts: the upper, middle and lower basin of Biebrza River.

The Biebrza National Park is a very beautiful and unique place. The Biebrza River keeps its natural character almost through its entire length. It forms beautiful evolving meanders accompanied by delightful oxbow lakes. Along the river there are widespread marsh areas and meadows, which are flooded in springtime.

Lately drying of marshlands has been observed within the Biebrza National Park (Dabrowska-Zielinska et al. 2002). Dried-up peat and boggy soils are more vulnerable to fire spreading.

In autumn 2002, fires occurred in many sites within the Biebrza National Park and affected approximately 3 000 ha. The largest burned area was located in the central part of the Biebrza National Park in Biele Suchowolskie. In this area the fire destroyed about 1 600 ha of wetlands. Before this area was covered by natural vegetation - natural grass, shrubs and trees.

The fire destroyed natural vegetation on the surface and the thick layer of peat bog. Fires of peat bogs are dangerous and difficult to stop as they spread under the surface. Monitoring and the primary extinction of fire was extremely difficult due to the immense emission of smoke. During the
time of fire, which lasted several weeks, the layer of peat bog was burnt off and the surface level decreased. As a consequence of fire irreversible physical, chemical and biological changes occurred on this area. The range of damage depends on many factors: the species of vegetation land cover before disaster, the depth of peat soil layer, meteorological factors, etc.

Remote sensing data play a significant role in detection and monitoring fire of wetlands and could be the only tool in getting information about burned area due to very difficult access to burned area in the wetlands. There are many satellite systems, which provide information on different fire characteristics: location of the burned area, duration of active fire, aerosol emissions, etc.

2 MATERIALS AND METHODS

MODIS data were used to monitor active fire, range of fire and expansion of the burn scars. The Moderate Resolution Imaging Spectroradiometer (MODIS) sensor is installed on board of NASA’s EOS AM-1 (Earth Observing System) TERRA satellite. MODIS has special channels for monitoring fire with 1 km resolution at 4µm and 11µm wavelengths, with high saturation temperatures of about 500K and 400K, respectively (Kaufman et al. 1998). Seven of its spectral channels from 0.41µm to 2.13 µm wavelength are being used to observe aerosols (including smoke) characteristics over land and ocean (Chu et al. 2002). The new MODIS instrument capability of measuring fire, smoke and burn scars and the ability to broadcast the data directly and to freely disseminate the information in near real-time, makes it ideal for regional monitoring of fire activity and the spread of smoke and other emissions (Kaufman et al. 2003).

![Figure 1. Monitoring of fire evolution on a daily basis using NDVI values. Pixels representing burned areas are very dark (NDVI values below 0.4). Pixels representing healthy vegetation are bright (NDVI values above 0.4). Black lines indicate the area of interest.](image-url)
2.1 Spread of fire monitored by NDVI values

NDVI values were applied in order to monitor spread of fire on the area. NDVI was calculated from band 1 and band 2 of MODIS data, i.e. red (0.62 – 0.67 µm) and near infrared (0.84 – 0.88 µm) bands, respectively. Dramatic changes of NDVI that accompanied the fire evolution are presented in figure 1.

Until August 19 the whole area was covered by the bright pixels (NDVI above 0.4) which represented healthy vegetation. A decrease of NDVI values was observed first on August 30 which meant that healthy vegetation was damaged by the fire. The fire spread quickly and expanded from the west to the east and to the northern part of the study area. On the image acquired on September 25 dark pixels, which represented low NDVI values, covered almost the whole area of interest. Analysis of NDVI values allowed to detect spots of fire, to estimate fire severity and to monitor spreading of fire.

The first spots of fire were also detected by observing emission of smoke, as demonstrated in figure 2.

![Figure 2. The emission of smoke presented on composition formed from MODIS bands 1, 4, 3 for the image of August 30.](image)

2.2 The active fire detection process

Active fire detection was done using 1 km resolution MODIS data, bands: 21 (3.93–3.99 µm), 31 (10.78–11.28 µm) and 32 (11.77–12.27 µm). Figure 3 presents the intensity of fire by surface temperature registered in band 21 of MODIS detector. Bright pixels correspond to the regions with higher surface temperature (above 30 °C). Monitoring temperature distribution between August 30 and September 25 allows us to determine temporal and spatial character of fire phenomenon. On August 30 fire spread on the area corresponding to only six pixels (temperature above 40°C), but it expanded quickly to the neighbouring areas, covering already on September 2 the northern part of the site. On September 25 the whole area affected with the fire had increased temperature, which confirms long-term burning of peat. The analysis of temperature distribution enables to estimate fire outbreak and its extinction.

2.3 The estimation of plant regeneration after fire

The fire of peat bog in Autumn 2002 caused irreversible physical, chemical and biological changes in the environment. Vegetation cover and an upper layer of soil underwent total destruction.

In May 2003 the destroyed area was completely bare of vegetation (figure 4); occasionally water appeared on the ground surface. At that time the adjacent areas, not affected with fires, were covered with green vegetation. Regeneration of vegetation on the areas deeply destroyed is relatively slow.
Figure 3. The active fire detection by the analysis of surface temperature registered in MODIS band 21 at individual dates.

An attempt to estimate the regeneration process was done through the inter-comparison of NDVI values from 4 May 2002, 5 May 2003 and 3 June 2003 (figure 5). In May 2002 NDVI was relatively high (0.4–0.7), confirming the appearance of vegetation, while in May 2003 significant decrease of this index was observed (0.2–0.3), compared to previous years. At the beginning of June NDVI values were still low (0.2–0.4), reflecting lack of vegetation cover.
4 May 2002 5 May 2003 3 June 2003

Figure 5. NDVI values on May 4, 2002, May 5, 2003 and June 3, 2003, correlated with the presence of plants.

The assessment of plant regeneration using MODIS images later in 2003 was not possible, due to the lack of images without clouds. However, it results from field observations, that the first plants started to appear at the end of June. One year after the fire, the burned area was covered by grass and different species of willows and poplars with varying density (figure 4).

3 CONCLUSION

MODIS data are a reliable and quick source of information about fires, especially useful in cases when fires cover an inaccessible area, such as Biebrza marshlands. MODIS data can be used for monitoring the spread of fire, identification of hot spots and the estimation of fire effects. Monitoring of fire disasters comprised:
A. Detection of fire spots and evolution of active fire by using analysis of surface temperature at 4 µm and 11µm wavelength bands.
B. Monitoring of spread of fire by using NDVI values calculated for individual dates.
C. Estimation of post-fire plant regeneration by comparison of NDVI values before fire and some months after it.

REFERENCES