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Identification of grassland transformations due to water regime changes caused by opencast mining applying remote sensing data

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ABSTRACT: Open cast mining activity has always resulted in the ground water table depression in the surrounding areas. This is the reason for progressive heavy degradation of the grasslands communities. To identify these sites, two Landsat images, covering the region of the largest Polish open cast brown coal mine Belchatow, were used. These images were acquired at a ten years interval. To overcome the difficulties connected to the sensor and atmospheric conditions changes, the method of digital image comparison called Percentile Rank Order Differentiation (PROD) was used. The results obtained are in good agreement with field measurements.

1 STUDY AREA

The area of study covers a region surrounding the opencast brown coal mine Belchatow. The coal mine is located in the southern part of the Central Polish Lowlands (figure 1.). The terrain topography is characterized by indifferently diversified relief and inconsiderable altitude differentiation.

Small river valleys and local arable field depressions often comprise marshy ground. These sites are permanently supplied with ground water and seasonally with superficial water (floods or surface runoff). On wetlands, characteristic hydromorphic soils and plant communities were formed. Permanent grassland is the main vegetation type cover on hydrogenic habitats.

The exploitation of brown coal in the opencast mine near Belchatow started in 1975. The excavation now covers 20 km^2 in area and 300 m in depth (figure 2.). The existence of the mine has caused a progressive depression of the ground water table in surrounding areas. The drained expanse has reached over 500 km^2 in 2000.

Deep and long-lasting drainage disturbed natural and agricultural functions of grasslands. Soils and grassland communities undergo progressive transformations which have led to their degradation (figures 3 and 4). The range and the rate of the transformations depend on the former site water regime and the soil type. Vegetation on the mineral soils is relatively resistant to the site water regime changes while different kinds of peat soils grasslands – prevailing on the area under consideration - are very sensitive to these changes.

Identification of hydrogenic habitat transformations and monitoring them by traditional methods is difficult and ineffective, because of the high dynamics of these transformations and their distribution on a large area with generally difficult access. So an attempt to estimate the evolution of green vegetation conditions on the degraded areas using remote sensing techniques has been made.

Figure 1. Study area

Figure 2. Belchatow opencast brown coal mine

Figure 3. Grasslands with natural water regime

Figure 4. Drained grasslands

2 MATERIALS

The type of vegetation communities, plant form, vitality and biomass production are synthetic external indicators of the habitat condition. Because information about all these features can be extracted from the remotely sensed data, it seems to be possible to use satellite images for the identification of areas degraded due to deep drainage.

The field measurements revealed that the most evident distinction between sites with natural water regime and drained ones can be observed in dry periods (Kozlowska *at all* 2000; Dabrowska-Zielinska *at all* 2002). For this study two Landsat TM scenes were selected, acquired in August 21, 1989 and ten years later, on September 10, 1999. Both of them correspond to the highest precipitation deficit periods in the growing season (table 1).

The data sets were preprocessed using Intergraph's Image Analyst and Erdas Imagine Software. Before deriving NDVI values images were geometrically and radiometrically corrected, carefully registered and atmospherically corrected.

On initial examination, the mean spectral responses were calculated in selected test sites. The test sites were localized in the region of strong influence of mining activity. Table 2 shows mean NDVI values in two main classes of grasslands: with natural water regime and drained ones. As can be seen, in August 1989 the difference of index value in these two classes was 20.8 and in September 1999 as far as 60.7, so the degradation of grassland habitats is evidently progressive.

Table 1. Monthly sum of precipitation (mm) for Belchatow region.

Month	Year 1989	Year 1999	Multiyear mean
June	82	263	68
July	57	50	87
August	32	10	67
September	12	22	48

Table 2. Average NDVI values on the test polygons.

Land use class	August 21, 1989		September 10, 1999	
	Mean	St.Dev.	Mean	St.Dev.
Grasslands with natural water regime	151.5	14.0	148.0	18.6
Drained grasslands	130.7	10.6	87.3	23.6

3 METHODS

Remotely sensed change detection studies are based on the fact that natural or induced disturbances in land cover produce detectable variations in the spectral response of ground targets. An effective comparison of digital images consists in seeking the enhancement or isolation of terrain changes apart from any uniform functional differences between the images. Nevertheless, several factors related either to sensor systems – differences in bandpasses, differences in spatial resolution, and variations in radiometric response – or natural conditions – atmospheric scattering and absorption, presence of clouds and cloud shadows, variation in solar irradiance and solar angles, seasonal variation in vegetation phenology and soil moisture – may also affect the

results. Image subtraction, the most common approach to image comparison, require precise registration of images, comparable measurements technology, appropriate scaling and systematic effects of sensor systems monitoring. To overcome these constraints in evaluating grasslands transformations on the study area, the technique of digital image comparison called Percentile Rank Order Differentiation (PROD) was chosen (Wehde 1995).

The relative frequency distribution of image pixel values can be represented by a histogram. Because the histogram is representative of the set of values and population of these values within an image, it defines the image context for any particular pixel. The scene context of a pixel may be defined as the percentile position of its value on the cumulative relative frequency distribution. Such transformation allows two images to be compared on the basis of scene context. When a pixel value changes, the relationship of that pixel to the image (its context) changes, the percentile rank order to which the pixel belongs changes, and the subtraction of two transformed images will capture this change.

In our study, for both Landsat images, the Normalized Difference Vegetation Index, reflecting greenness conditions in the study area, was calculated first. After that, each image was transformed by developing a cumulative percentile look-up table from the image histogram. Regardless of the original image data type and range, the output of such a transformation is an image with values between 0 and 100. Furthermore, the transformed 1989 NDVI image was subtracted from transformed 1999 NDVI image. The resulting pixel values are one byte size, ranging from –100 to +100, which was subsequently arbitrarily scaled within the byte range 0 to 255.

The result of the processing is shown in Figure 5. The output pixel values are scaled and centred on digital 127, so midgray level in the image represents no NDVI changes between the two dates. Order of subtraction results in 1999 increases appearing brighter and 1999 decreases appearing darker. Surface feature changes, improvements or degradations, are evident in the image as the brighter or darker scene components, respectively.

Figure 5. PROD processed NDVI 1999-1989 (scale 1:175 000)

4 CONCLUSIONS

A considerable impact of coal mine exploitation on the surrounding grasslands condition has been found by comparison of multi-date satellite data.

Change detection analysis, based on NDVI values derived for images acquired in dry periods of different years, corresponds well to field observations, indicating the process of grasslands degradation.

Lowering NDVI values can be observed mainly on the periphery of the drained area. Changes of the index values for grasslands in the neighbourhood of the open pit are unnoticeable since they have undergone drainage in the earliest and by the date of the base image acquisition the process of habitats degradation was advanced.

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