USING OF TM DATA AND VHR DATA FOR
RECLAMED AREAS MONITORING USING VEGETATION INDECES

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WG V/6 Visualisation and Animation

Key words: Remote Sensing, VHR data, Ikonos, Environment, Monitoring, reclamation

ABSTRACT

The northern-Bohemia comprises large areas with underground mining and brown coal open-casts. Abandoned open-casts were reclaimed. The reclamation was performed in several possible ways – hydric, forestrial, agricultural. Hydric reclamation can be found in the form of new water basins whose main purpose is to fill in land depressions after excavation, to create new part of countryside and to serve as recreational localities. Agricultural reclamation represents changing of previous open mines into agriculturally used areas. Forestrial reclamation is a creation of new forests whose good growth and sound stand is a measure of successfulness of the reclamation. The age of reclaimed areas varies from more than 30 years up to still reclaimed areas. The methods used for evaluation of these three types of reclamation from TM satellite data series will be presented.

1. INTRODUCTION

The northern Bohemia is heavily touched by mining activities – on and under the surface. Reclamation activities must follow mine closing and are included in the Czech law as a duty of mining companies. Reclamation can be divided into three phases – technical one, biological one and maintaining one. The technical reclamation comprises surface geotechnical and hydrological corrections and improvements of new surface morphology to be stable and suitable for future non-mining using. Stable slopes, appropriate land consolidation, and/or reliable drainage system, transport network (if necessary)

2. STUDY AREA

The area where reclamations is studied, is situated in the northern Bohemia between Erzgebirge Mountain range (forming the frontier Germany – Czech Republic) and the Ohře River. The oldest reclamation is from 1966. Reclamation in certain parts is planned till 2015. The complete area of reclamation is 1416 ha of forest, 920 ha of grassland, 500 ha of agriculture fields, and 160 ha of water surfaces. The landscape is relatively flat with a sparse volcano chain.

3. AGRICULTURAL RECLAMATION

Agricultural reclamation can be characterized by changing land use detectable at least at satellite images from 4-years period. Shorter period could not distinguish agricultural plants with 3-year-old period. Land use classification is the most suitable for evaluation. The yield should be controlled by ground truth data.

represent the first phase. The second – biological phase is a period formed by reforestation, agricultural using, new grassland creation or water basin fulfilling. The project of these two phases are performed by reclamation experts.

The third phase is a maintenance period when reclaimed areas are controlled according to their development compared to their projected developments. This last period ends by handover to previous or new owners. These areas are controlled by reclamation specialists *in situ*.

This project should prove how remote sensing data can be used for evaluation of biological phase and maintenance phase.

4. GRASSLAND RECLAMATION

This reclamation can be evaluated from remote sensing data. Land use classification delineates areas with grass. Development of grassland quality were not determined from processed data (TM Landsat) – because three TM data from 1988, 1992, and 1999 comprise instantaneous data record which can be seasonally influenced – dry grass after long dry period, recovering after important precipitation etc. Usage of remote sensing data can be successfully performed by higher number of image data evaluation within one seasonal period. Three days revisiting of IKONOS is still not sufficient due to frequent cloud and haze occurrence. There are two possibilities of solution. High number of small satellites offering data more than once per day is the first possibility, the second one can be represented by radar data penetrating clouds, haze etc. Polarimetry as method should be used for these tasks.

5. WATER RECLAMATION

This type can be controlled by comparison of water surface quality in different years and water basins size. Water basin size can be derived from water classifications in individual

years. Surface water quality can be detected from comparison of NIR and "green" bands (2nd and 4th bands of Landsat TM and from IKONOS). Similar values (after atmospheric correction) prove similar water quality. However, the water quality state can change very quickly – during one night. This detection is still out of remote sensing data measurements – only large water basins can be found in AVHRR data (NOAA) at least 4 times per day. There are no basins of such size in the Czech Republic.

Slope stability of shores is another proof of good water reclamation. Slope stability/instability detection is quite difficult from TM data. IKONOS will be used for the instability detection. There are more unstable parts alongside large water basin – the Barbora Lake – large open-cast filled by water to play together with its surroundings important role as a recreational area. The instability occurs both in forested shores and out of forest parts.

6. FOREST RECLAMATION

Forest reclamation in the study area occupies 1740 hectares. Deciduous forest is created by 285 hectares, 1395 hectares are covered by mixed forests. Deciduous forests consist of red oak, ash, cherry, birch, lime, maple and others. Mixed forests are formed by already mentioned deciduous trees and by larch, spruce and pine in most cases. The mixture differs from area to area. There are only exceptionally reclaimed areas with one tree type. Size of reclaimed areas varies from tenths of hectare up to tens hectares.

Good reclamation means that planted tree seedlings are sound and grow. Their growth is growing of green vegetation. Vegetation indices are values used for characterizing green vegetation quality and extend. NDVI (Normalized differential vegetation index) is the most often used index for evaluation of vegetation state.

NDVI used for TM data is evaluation of tree groups present on areas of individual pixels whose size is 30x 30 metres. NDVI calculated for IKONOS data is NDVI of individual trees (in case of trees older than about 15 years) when pixel size is 4x4 metres.

6.1 NDVI for forest areas in TM data

Changes of NDVI were calculated as difference between NDVI of two years. Changes were calculated for the period of 10 years – between 1988 and 1998. Following graph shows percentage for reclaimed areas. Reclaimed areas with age above 3 years are
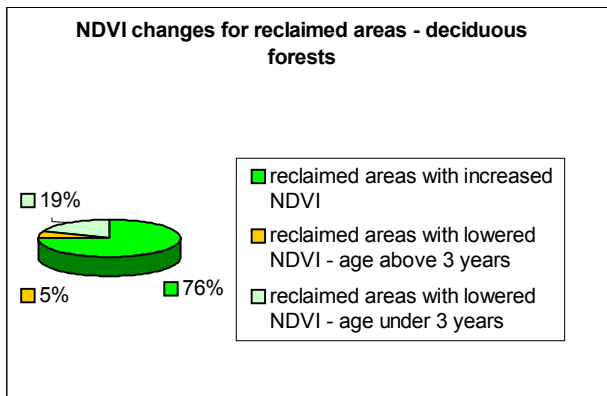

Fig 1. Graph showing changes of NDVI between 1988 and 1998 for deciduous forest where areas with age

under 3 years are areas whose reclamation in the reclamation end year was younger than 3 years
areas whose reclamation were older then three years at the year of reclamation end. Reclaimed areas with age under 3 year area areas whose reclamations were younger than 3 years at the year of reclamation end. Only 5% of reclaimed areas had NDVI (amount of green vegetation) worse after 10 years. Their reclamations were finished in 1970 and 1976.

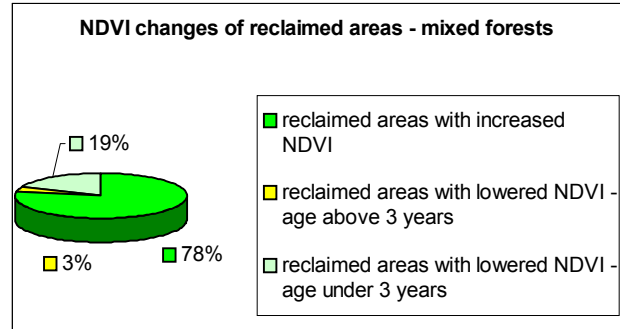Similar evaluations for mixed forests is shown by the following graph

Fig. 2 Graph showing changes of NDVI between 1988 and 1998 for mixed forest where areas whose reclamation whose age in the reclamation end year was lower than 3 years

5 and 3 per cent of reclaimed areas have not shown higher NDVI in their 10 years development. The same situation was in comparison of 4 years changes (1988 – 1992) and 6 years changes (1992 – 1998).

The comparison shown that the period of four years can be used for evaluating reclamation development, tendency showed by this period was the same as that of 6 years and that of 10 years.

6.2 Other vegetation indices in TM data

There more vegetation indices which are studied – RVI, PVI, IPVI, SAVI, TSAVI etc. Their evaluation has not been finished. RVI is the ratio vegetation index which has been used already for many years. Jordan used and defined it in 1969. It is widely used expressing ratio between two band values where highest values are those with green and sound vegetation. The ratio is to eliminate various albedo effects.

$$RVI = \frac{NIR}{RED}$$

(1)

PVI - Perpendicular Vegetation Index - was described by Richardson and Wiegand in 1977. This index expresses differences between soil line and other class values – between soil and vegetation, e.g. According to (Qi et al., 1994), this index is very sensitive to atmosphere state.

$$PVI = \sin\alpha.NIR - \cos\alpha.RED,$$

(2)

where α is angle between soil line and NIR axis.

IPVI is the Infrared Percentage Vegetation Index which was defined by Crippen (1990) who found that the subtraction of the red band value in the numerator was irrelevant, and proposed this index as a way of improving calculation speed. The index values range is between 0 and 1. IPVI and NDVI are functionally equivalent and their relation is expressed by the following equation:

$$IPVI = \frac{NDVI + 1}{2}.$$

(3)

SAVI is the Soil Adjusted Vegetation Index used by Huete in 1988. This index attempts to be a hybrid between the ratio-based indices and the perpendicular indices. Huete found that the isovegetation lines are not parallel, and that they do not all converge at a single point. The index derived from measurements is a ratio-based index where the point of convergence is not the origin. The convergence point ends up being in the quadrant of negative NIR and red values, which causes the isovegetation lines to be more parallel in the region of positive NIR and red values than in the case for RVI, NDVI, and IPVI.

$$SAVI = \frac{NIR - RED}{NIR + RED + L}.(1 + L),$$

(4)

where L is a correction factor which ranges from 0 (very high vegetation cover) to 1 (very low vegetation cover). The most typically used value is 0.5 (intermediate vegetation cover).

The L factor have important influence for the index calculation and its optional choice makes the index "unprofessional" and "more subjective". New index – Transformed Soil Vegetation Index TSAVI was defined by Baret et al. (1989) and Baret and Guyot (1991). This index assumes that the soil line has arbitrary slope and intercept, and it makes use of these values to adjust the vegetation index. This would be a nice way of escaping the arbitrariness of the L in SAVI if an additional adjustment parameter had not been.

The equation for TSAVI is

$$TSAVI = \frac{s(NIR - s.RED - a)}{(a.NIR + RED - a.s + X.(1 + s.s))}$$

(5)

where s is the soil line slope, a is the soil line intercept, X is an adjustment factor which is set to minimize soil noise (0.08 in original papers).

This vegetation indices will be evaluated for individual reclaimed areas, relation to their tree composition, terrain conditions, slope of the terrain and azimuth will be taken into account.

6.3 IKONOS and vegetation indices

The IKONOS data bought for the project are seriously damaged by haze and clouds. The present processing step is oriented to radiometric correction to get data atmospherically corrected.

All indices calculated for TM data will be calculated also for the IKONOS corrected data. This calculation will be used for detailed evaluation of tree species of forest reclamation to determine their individual growth quality.

7. CONCLUSION

The VHR data (IKONOS) will be used for water and forest reclamation evaluation. Their importance is in their high spatial resolution enabling users to work in high spatial detail – to find small element which are undistinguishable at other data types – lines of detailed water network, landslides/unstable areas and to distinguish detailed classes of general classes – tree types in a forest.

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