# Land Cover Changes In Wetland Ecosystem – Case Study Biebrza Valley, Poland

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**Abstract.** The changes in the hydrological conditions and  discontinuance of grass harvesting influenced changes in land cover. The main trend of changes concern increase of shrub land in place of wetland habitats. The aim of this project was to distinct at Biebrza Wetlands area changes in shrub extension in 2001-2010. The study has been performed in optical and microwave images. The following satellite data have been chosen: Landsat.TM, Landsat.ETM+, Terra.ASTER, ERS-2.SAR, ENVISAT.ASAR and ALOS.PALSAR. Optical images from 2001, 2006 and 2010 respectively have been used for land cover classifications. Microwave images have been applied as auxiliary data for classification testing and for examining the changes in backscattering for 2001 and 2008 due to changes in shrub areas. As the results the maps of land cover classifications and biomass changes using NDVI were created. The results give possibilities to improve effective shrub monitoring using additional satellite data which characterize hydrological conditions. The procedure is difficult due to two processes that occurred during considered time 1.Increase of shrub encroachment from 2000 to 2008 and 2.Diminish the shrub area due to mowing the wetlands by Biebrza National Park  Biebrza Wetlands belong to RAMSAR Convention and NATURA 2000. Observation by satellite give the possibility for monitoring and proper management of wetland area and support planning for mowing program which is led in Biebrza National Park.

**Keywords.** Land Cover, Change detection, Satellite images, Wetlands.

## 1. Introduction

Biebrza Wetlands is well known ecosystem in Europe due to rich communities of waders and march birds. The research on Biebrza Wetlands habitats using remote sensing has been carried out in the Institute of Geodesy and Cartography (IGiK) since 2000. The studies concerned estimates of soil moisture changes using radar satellite data, heat fluxes exchange and recently examination of carbon dioxide balance (Rychlik, Dabrowska-Zielinska 2011; Stankiewicz et al. 2004; Dabrowska-Zielinska et al. 2009, 2010). The Biebrza National Park is facing the problem to stop and overturn the succession of shrubs at the fen peat. Succession reduced the amount of breeding waders and other species. To restore the area it is necessary to monitor the area and know how quick the succession proceeds.

The aim of this project was evaluation of shrub encroachment in Biebrza National Park. Variations in hydrological conditions of this area cause the changes in land cover, mainly replacement of inland herbaceous habitats by shrub and sparse woody habitats.

## 2. Methods

Knowledge on biophysical properties of wetlands vegetation retrieved from satellite images enables to improve monitoring of the unique areas, very often impenetrable. The study covers Biebrza wetlands situated in the Northeast part of Poland, considered as Ramsar Convention test site. The research aims at establishing the changes in biophysical parameters due to scrub encroachment. The area is unique in Europe for large groups of fenlands relatively untouched. Natural resources of this area, besides peatlands, are rich variety of flora and fauna. Its close related to specific hydrological conditions. Thanks to its diversity three main groups of habitants were developed: forest habitats, shrubland habitats and inland not-forest habitats (Matuszkiewicz W., 2000). The changes in the hydrological conditions and in land using drainage or discontinuance of grass harvesting influenced changes in land cover. The main trend of changes concern increase of shrubland in place of wetland habitats (Bokdam J. et al 2002).

LANDSAT and ASTER images were the main source of remote sensing data for land cover classification. For classification, the satellite images acquired for three time periods were chosen. The cloudless images from July 2000, 2005 and 2010 have been obtained. These images were derived from: LANDSAT ETM+ 3$^{rd}$ May 2001, ASTER 11$^{th}$ July 2006 and LANDSAT TM 23$^{rd}$ July 2010. LANDSAT data were received from free database GLOVIS, while ASTER data were bought from ESA. The collection of data for land cover change detection should fulfill some expectations. The satellite data should be from the same time of phenological period of vegetation (so the dates of acquisition should be close). Also if possible the images should be from the same sensor. Due to clouds, it was not possible to obtain LANDSAT image for July 2001. However the, ASTER image from the date of 15$^{th}$ July 2001 was obtained for the same area.

ERS microwave images were used as auxiliary data for classification of LANDSAT and ASTER datasets. For year 2001 three ERS images were used: 3$^{rd}$ May, 7$^{th}$ June and 12$^{th}$ July. For the year 2010 four ERS-2 datasets were used: 20$^{th}$ April, 25$^{th}$ May, 29$^{th}$ June and 15$^{th}$ July. In addition, ALOS and ENVISAT ASAR microwave images were used in order to get information about humidity and plant condition. They were applied for comparison sigma values for shrubs and looking for the relation them to classification results based on LANDSAT and ASTER data.

Table 1. Properties of the optical and microwave data used in the study.
VNIR – Visible Near Infrared, HV – horizontally/vertically polarized,
HH – horizontally/horizontally polarized, VV – vertically/vertically polarized

| Satellite | Sensor | Data acquired | Spatial resolution (m) | Bands (number) |
|---|---|---|---|---|
| LANDSAT | TM | 23 July 2010 | 30.0 | VNIR (4) |
| LANDSAT | ETM+ | 3 May 2001 | 30.0 | VNIR (4) |
| TERRA | ASTER | 11 July 2006 | 15.0 | VNIR (4) |
| TERRA | ASTER | 15 July 2001 | 15.0 | VNIR (4) |
| ERS-2 | SAR | 3rd May 2001 | 12.5 | C-band |
| ERS-2 | SAR | 7th June 2001 | 12.5 | C-band |
| ERS-2 | SAR | 12th July 2001 | 12.5 | C-band |
| ERS-2 | SAR | 20th April 2010 | 12.5 | C-band |
| ERS-2 | SAR | 25th May 2010 | 12.5 | C-band |
| ERS-2 | SAR | 29th June 2010 | 12.5 | C-band |
| ERS-2 | SAR | 15th July 2010 | 12.5 | C-band |
| ALOS | PALSAR | 12th May 2008 | 12.5 | C-band, HV |
| ENVISAT | ASAR | 23rd July 2008 | 12.5 | C-band, HH VV |

Table 1 presents all optical and microwave data which were included in this project. LANDSAT and ASTER images were resampled into higher resolution 12.5 meters due to applying ERS-2 images together for classification. Four optical images were atmospheric corrected using ATCOR-2 software. The microwave data were preprocessed using ESA BEAM software, BEST (Basic ENVISAT SAT Toolbox) and ERDAS IMAGINE for backscattering coefficient computing.

At first, for the process of classification, the visual interpretation has been applied. In order to find good results, several approaches were undertaken: standard unsupervised and supervised classification, hybrid classification and also pixel and object methods. All of these methods revealed different time-accuracy ratio. The most common method in researches is supervised nearest neighbor classification (Ozesmi, Bauer 2002). The wetland area is difficult to classifiy due to large influence of humidity on spectral response. Finaly for wetlands classification the object-based method has been chosen. This method was supported with decision tree approach and nearest neighbor classification. The eCognition Developer software has been used.

Process of obtaining information about land cover changes especially in shrubs encroachment was divided in three parts: image classification of land cover classes, GIS analysis and post-classification comparison and finally assessing vegetation indices.

For land cover classification the object-based method was elaborated. Scheme of image classification is presented in figure 1. Classification process was set in few steps. Each step began from image segmentation adjusted to classified land cover class. Next image samples for classified land cover form were collected and finally nearest neighbor classificator was executed. For sample collecting basic field information about land cover has been used. Different features, like NDVI, soil moisture were used to divers the land cover classes. Only for few classes the threshold method was used in order to obtain better results.

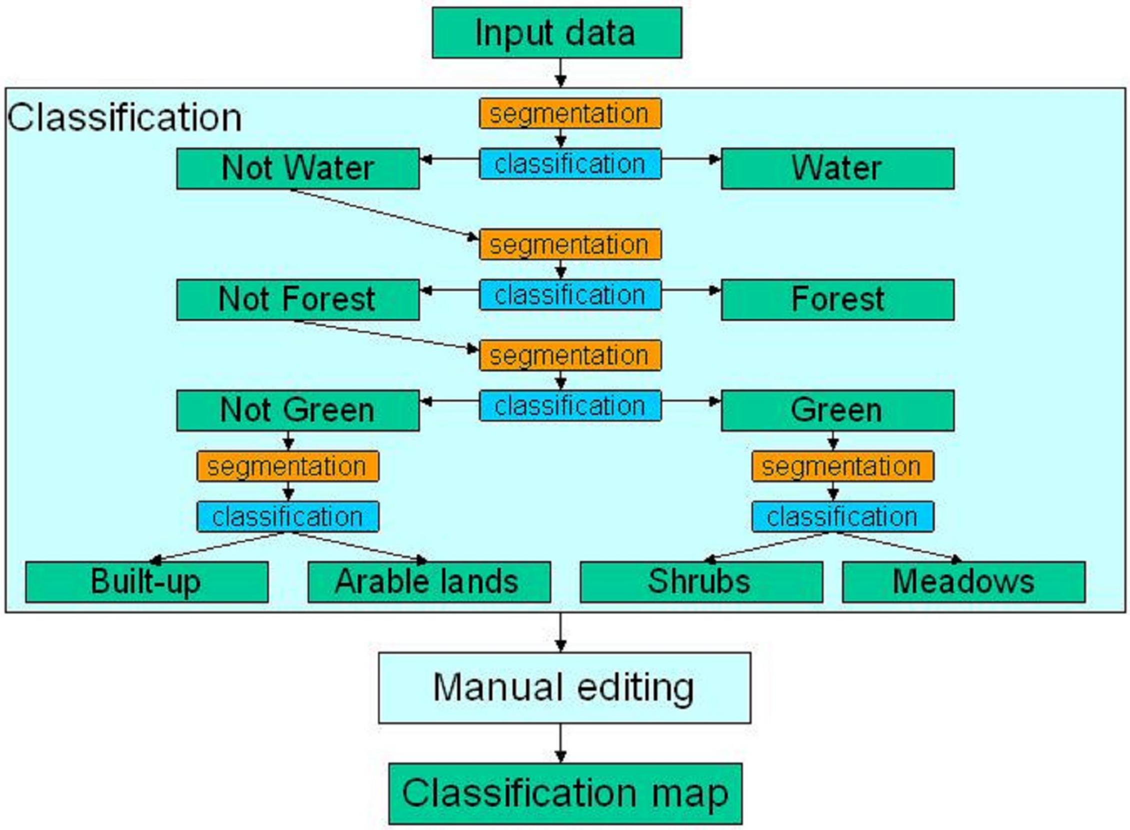


Figure 1 . Flowchart of the classification scheme

According to classification scheme the separate classes were recognized in following sequence: water rivers, water bodies, forests. Next, the residual area was divided in two temporal classes: green and not green areas. These classes were reclassified. From green class it could be possible to obtain shrubs and meadows. From not green class it was received built-up areas. Last residual area was classified as arable lands.

In order to improve the results, the half-automatic and manual editing has been done. The main importance in this process was to correct errors between meadows and arable lands and between forests – shrubs classes. In this case LANDSAT and ASTER composite bands were very useful to interpret shrub lands and to eliminate errors due to under- or overestimation. It clearly showed inherent problem of minimizing the errors related to the methodologies and classification approaches. Independently of weather conditions and time of registered image, there are difficulties in effective distinction of shrubs within marshlands.

## 3. RESULTS

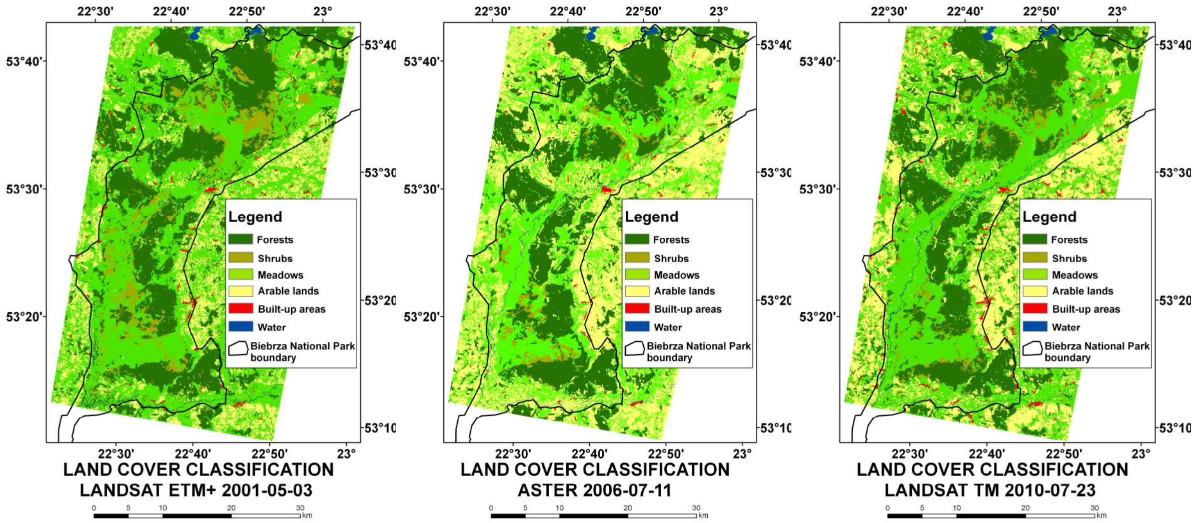


Figure 2: Object-based image classification results of LANDSAT ETM+ 2001 (left), ASTER 2006 (middle) and LANDSAT TM 2010 (right).

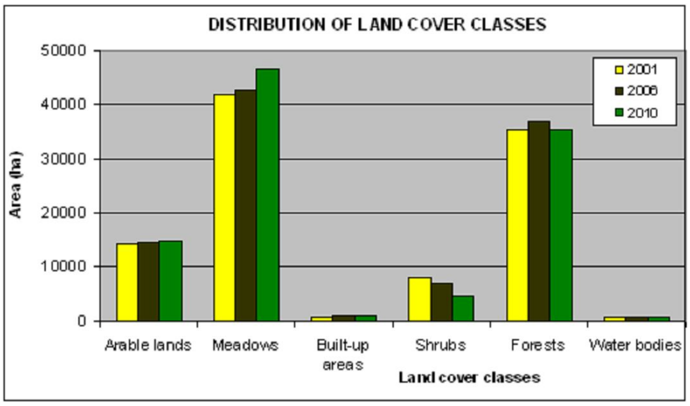


Figure 3: Distribution of land cover classes derived from 2001, 2006 and 2010 classification maps.

For the process of land cover analysis, three classification maps were used. The maps were obtained from classifying 2001 LANDSAT ETM+, 2010 LANDSAT TM and 2006 ASTER images (Fig. 2). To simplify the analysis, the classification results were aggregated into six main classes: water bodies (rivers and lakes), forests, shrubs, built-up areas, meadows and arable lands. The overall distribution of land cover classes in each of analyzing year is shown in figure 3.

Regarding the analysis, the forest cover showed an increase of 1500 ha between 2001 and 2006, while it decreased by 500 ha between 2006 and 2010. Shrub cover was the largest in 2001 and it decreased gradually from 8150 ha to 4764 ha in 2010. Meadow cover showed large increase by 5500 ha between 2006 and 2010. Arable land cover increased gradually by 1600 ha between 2001 and 2010. Built-up areas and water body’s covers were still on the similar level in each of analyzing year. The decrease in shrub area between 2001 and 2006 occurred. We assume that the grown shrubs (mostly birch) were included into the forest area which increased. The mowing of the wetlands occurred mostly in 2009 and 2010. Therefore there was noticed large increase of meadows area.

In order to difference shrub from other classes, LANDSAT and ASTER NDVI images were used. Figure 4 depicts NDVI values for each of land cover classes for 2001, 2006 and 2010 respectively. Looking at these box plots, shrub cover was easy to delineate from forests in 2001 (Fig. 4a) and from meadow pixels in 2006 (Fig. 4b). NDVI in May in 2001 was rather high due to the beginning of the season and good moisture conditions. June in 2006 was dry (low NDVI values for each of the class), whereas year 2010 characterized with the high water level in Biebrza National Park and relatively high NDVI values (Fig. 4c). In general NDVI of shrubs in all three images was low.

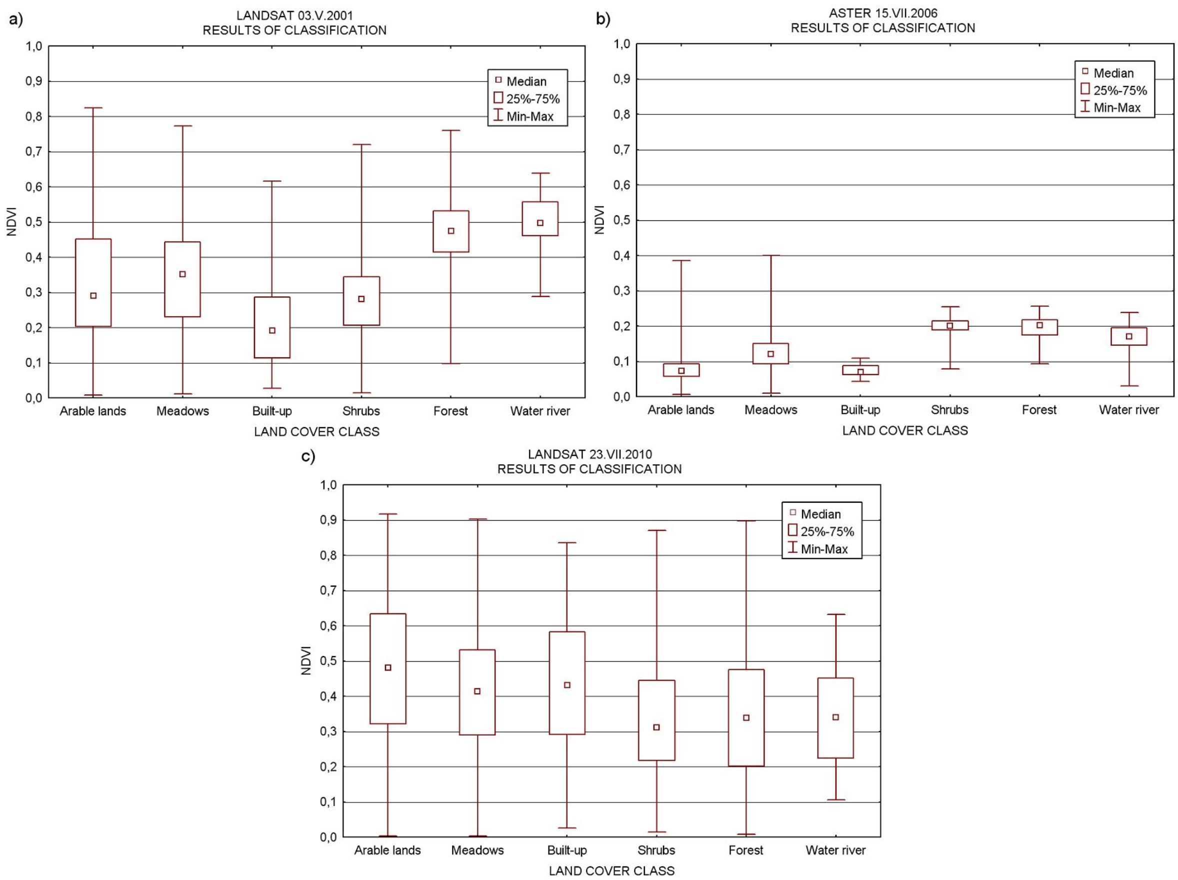


Figure 4: NDVI box plots for six land cover classes derived from 2001 LANDSAT ETM+, 2006 ASTER, 2010 LANDSAT TM.

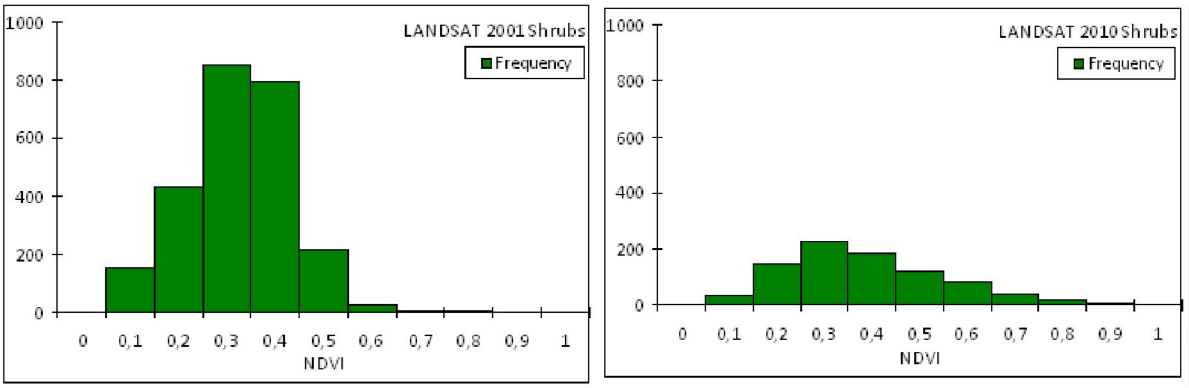

Figure 5: Frequency distribution of NDVI over shrub class from 2001 LANDSAT (left), 2010 LANDSAT (right).

Figure 5 depicts frequency distribution of NDVI values over shrub lands. It is easy to observe major 0.3-0.4 NDVI value for its cover for year 2001 and 2010. The histograms can explain shrub cover changes. Although shrub cover showed decrease in frequency distribution of NDVI in 2010 comparing to 2001. Decrease of shrubs area could be explained by the process of mowing program (LIFE), which is lead in Biebrza National Park getting towards renaturalisation of wetlands. By the other side, the rest of shrubs from 2001 could be grown up and be classified to forest in 2010.

For further analysis of the research, 2001 ERS-2, 2008 ALOS and 2008 ENVISAT images were used. To analyze relation of backscattering coefficient with six land cover classes, radar images were preprocessed. The land cover classes were derived from former LANDSAT classifications. The image from May 2001 of ERS-2 was used for classification of the area and for 2008 ALOS and ENVISAT images were used.

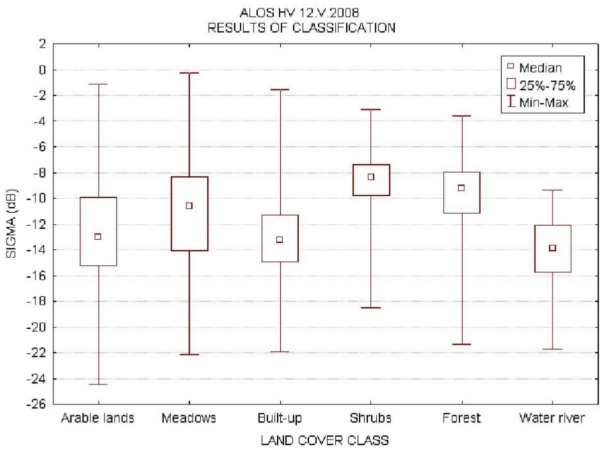

Figure 6: An example of 2008 ALOS sigma signal (dB) box plots for six land cover classes.

Figure 6 shows example of backscattering coefficient values over six land cover classes, derived from 2008 ALOS. The signal values can be useful to differentiate shrubs from forests or meadows. Although high variations of signal values for these classes, median clearly shows specific value for each captionlong2001 and 2008. Although the shrubs characterized lower values in 2001 (ERS-2), it was easy to observe rising signal values in 2008 (ALOS as well ENVISAT). The higher values in 2008 (-10 dB, -9 dB) could be interpreted by occurring still robust shrubs with high roughness texture growing up into the forest.

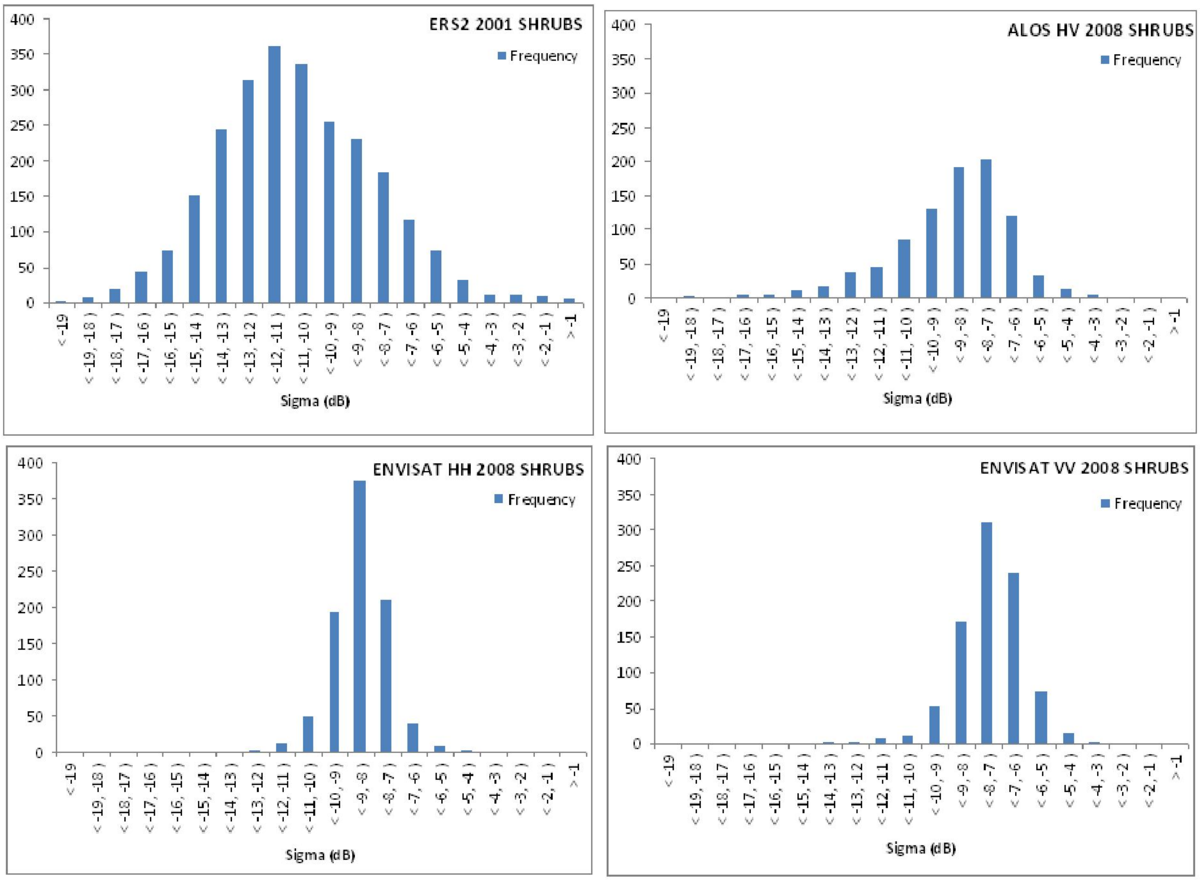


Figure 7: Frequency distribution of Sigma (dB) over shrub class
from ERS-2, ALOS HV, ENVISAT HH, ENVISAT VV.

## 4. CONCLUSIONS

The results of this study can be used in planning to mow shrubs and evaluating vegetation conditions based on satellite images. Applying of various remote sensing data, like the fusion of optical and microwave data could be more useful and give better understanding in relation between shrubs - forests - meadows. The figure 8 presents the example of differentiation of shrubs in Ławki Marsh, in southern part of Biebrza National Park. Some areas of shrubs in 2001 were grown up and classified to forest in 2010. And in other way meadows which were bordered with forests in 2001 were reclassified to shrubs in 2010. There are a few possibilities in changing processes. Some of them could be effect of human activities or of specific nature changes like overgrowing wetlands and development of shrubs.

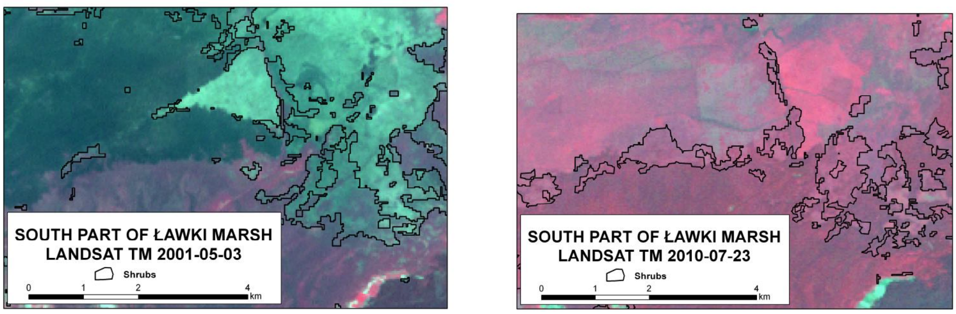


Figure 8: Example of shrub differences between 2001 and 2010 over Ławki Marsh (Biebrza).

The soil-moisture, biomass or LAI measurements taken from many points in terrain over all types of vegetation classes could be helpful information to differentiate shrubs. The extracted soil moisture data will be interpolated over whole scene of Biebrza National Park for the further analysis.

Next interesting approach which could be applied to monitor shrubs is RGB-NDVI composition method (Njomo 2008). For this study, three other LANDSAT ETM+ images: were taken: 15th May 1988, 16th May 2000 and 5th June 2010. For each LANDSAT scene NDVI was computed. All three NDVI images were composited in RGB, where 1988 NDVI image was assigned to blue channel, 2000 NDVI to green channel and 2010 NDVI to red channel. IsoData unsupervised classification for RGB-NDVI composite image was applied. In final result it was obtained 30 classes which were visually interpreted and aggregated into 11. Figure 8 shows results of the classification.

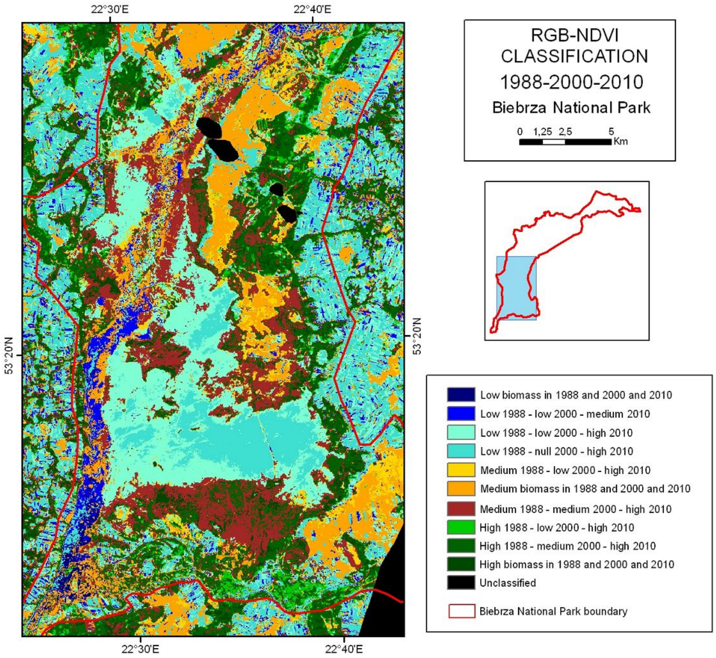


Figure 9: RGB-NDVI classification over part of Biebrza based on LANDSAT ETM+ images.

Sigma signals from microwave images observed for shrubs in the same time-period for analyzed years coincided with decreasing or increasing values. It is likely that prevailing shrubs density or scattering was a major cause of shrub classification. In general, the auxiliary data like three-band composite images and continuously monitoring the area using high temporal images is the proper way to delineate the shrub changes. The relationship between LAI, biomass, soil moisture and backscattering coefficient will be applied with high temporal / spatial resolution images and for proper evaluation of shrubs/forests/meadows classes.

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