OBJECT-BASED CHANGE DETECTION ANALYSIS FOR THE MONITORING OF HABITATS IN THE FRAMEWORK OF THE NATURA 2000 DIRECTIVE WITH MULTI-TEMPORAL SATELLITE DATA

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ABSTRACT:

Multi-temporal and multi-sensor satellite information can supply valuable information about vegetation species, especially in the context of biodiversity. Main focus of the presented project CARE-X is the development of a remote sensing technology for the European monitoring of NATURA 2000 areas. For this type of monitoring, information about the structure and composition of the existing vegetation within a growth period are required. With temporal very high resolution (TVHR) satellite data, such as RapidEye and TerraSAR-X, the optimal dates for a highly effective utilization of acquired images for the monitoring of different vegetation types and habitats can be identified. The study area "Döberitzer Heide" is situated in the Federal State of Brandenburg (north-east Germany). The main habitats are heathland, dry grassland, and wetland, forming a heterogeneous small scale mosaic of vegetation types.

In a first step the land-use and specific habitats within this site and the surrounding area were segmented and classified with five RapidEye images from the vegetation period of 2009. Simultaneously, intensive field spectral measurements took place. First results show that the main land-use classes related to the NATURA 2000 monitoring can be detected with an accuracy of above 0.85. The classification results improve when scenes of August and September are included. The terrestrial spectral measurements show a good accordance with the reflectance of the RapidEye images. Moreover, different vegetation types relevant to the NATURA 2000 monitoring can be separated temporally. In further research the field measurements will be transferred to the multi-temporal RapidEye images using the phenological profile of different vegetation types.

1. INTRODUCTION

Remote sensing considerably contributes to the detection of vegetation structure and composition in the context of biodiversity and nature conservation. Depending on the investigated plant communities, imagery of either high spatial, high temporal, or high spectral resolution is most relevant to enable their differentiation (Förster et al., 2009). The detection of habitats and vegetation communities in the context of biological diversity is one of the most frequently addressed topics in remote sensing studies of high spatial and spectral resolution (Ivits, 2008; Im and Jensen, 2008). However, the changes in the seasonality of plants are significant. Therefore, multi-temporal approaches could be utilized to include the information about seasonal vegetation development. Annual time-series can indicate seasonal trends in vegetation while the comparison of inter-annual data can reveal annual to decadal phenological variability. For field mapping, recurring natural phenomena, such as bud burst, flowering, fruit maturity, or leaf colouring can be observed and combined to a phenological calendar that differentiates phenological seasons (Englert et al., 2008). Observations of the spectral behaviour of vegetation can provide more continuous information about the phenology (O'Connor et al., 2008).

Main focus of the presented project CARE-X (Change Detection Analysis for the Monitoring of Biodiversity in the Framework of the NATURA 2000 Directive Utilizing RapidEye and TerraSAR-X Satellite Data) is the development of a remote sensing technology for the European monitoring of NATURA 2000 areas to fulfill the obligations of the EU commission for the member states. NATURA 2000 sites cover approximately seven per cent of Germany. The EU Habitats Directive (council directive 92/43/ECC) requires a standardized monitoring of the habitat types and a reporting every six years. For this reason, an operational, objective, economically priced and as far as possible automated application is required.

2. STUDY AREA

The study-site for the project is situated in the north-eastern part of Germany. It encloses the nature conservation heathland area "Döberitzer Heide" and the surrounding area situated west of Berlin (see Figure 1). Due to its former long-term military use, it was protected from fragmentation and transformation into agricultural land. It is now a rich mosaic of wood, heathland, sandy grassland, mesophile grassland, seminatural humid meadows, wetland and wasteland.

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Recently, a large-scale wilderness project was started within the "Döberitzer Heide". The goal of this project is the landscape management with large grazing mammals (European bisons, red deer, Przewalski horses) to preserve and increase the structural diversity of the area against succession and to protect rare species. Due to remaining munitions and the introduction of the large animals, remote sensing seems to be the only suitable method for an area-wide monitoring of landscape development.

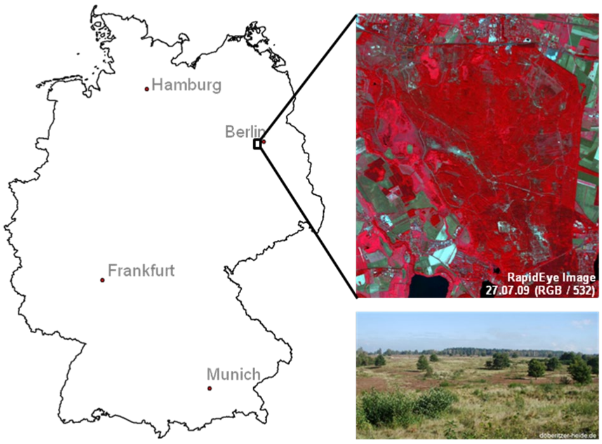

Figure 1. Study Area "Döberitzer Heide"

3. DATA AND METHODS

3.1 Field Spectral Measurement

In order to achieve sufficient phenologic information that can be linked to satellite images, field spectroscopy is required. The spectral reflectance has to be acquired in cloud-free conditions. Therefore, a weekly sampling of different species during the vegetation period (April to October) was intended for field measurements, but there were gaps due to the weather conditions.

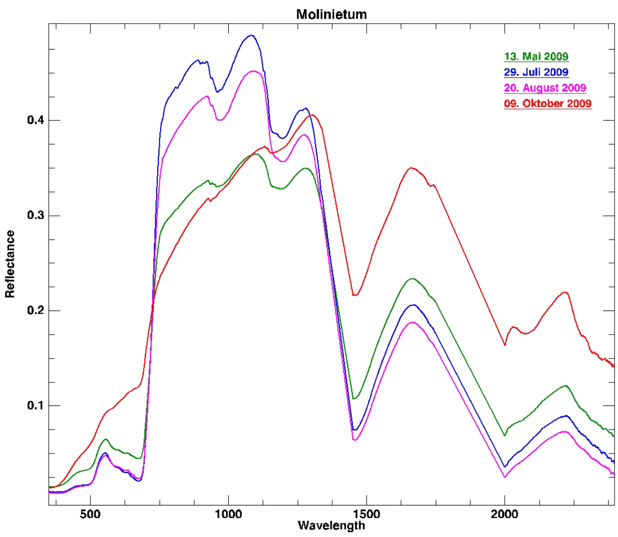

Figure 2. Spectral Measurements of *Molinietum* Vegetation from May to October 2009

Between 2007 and 2009 a set of approx. 80 test areas were measured with an ASD FieldSpec Highres. Besides others, the measurements concentrated on the plant communities tall herb fringe communities, molinia meadows, and phragmitis habitats (see example of Figure 2). 23 days of field spectra acquisition could be accomplished in 2009. Due to cloud coverage no measurement was possible in all weeks during the vegetation period. The spectral and temporal reflectance information of the reference areas can be fed into a data base.

3.2 Satellite Data

For the multi-temporal approach of this study, RapidEye imagery was acquired during the vegetation period of 2009. RapidEye is a German five satellite constellation launched in August 2008. The system acquires images in five spectral bands: Blue (440-510 nm), Green (520-590 nm), Red (630-685 nm), Red Edge (690-730 nm) and Near Infrared (760-850 nm) with a spatial resolution of 6.5m (see Figure 1 for an exemplary image).

Five images (24.5. / 27.7. / 16.8. / 20.9. / 9.10.) were applicable with cloud free conditions. The scenes were ordered as L1B data, radiometrically calibrated, but without ortho-rectification and resampling from the original ground sampling distance of 6.5 m to 5 m. Subsequently, the images were georeferenced with a QuickBird image and local cadastral information of the authoritative topographic cartographic information system. Moreover, the scenes were atmospherically corrected using ATCOR2 (Richter, 1997).

3.3 Land-Use Classification Method

To restrict the possible sites of NATURA 2000 habitats, a land-use classification was performed as a first step. The satellite data have been processed with a multi-scale segmentation method (Benz et al., 2004) by using an object-oriented approach with the software eCognition (Baatz and Schäpe, 2000) in the Developer 8.0.1. version. The segmentation parameters were set to scale parameter 50 (medium object size 7.6 ha). The homogeneity criteria were defined as 0.1 for SHAPE and 0.5 for COMPACTNESS.

Ten land-use classes could be defined with the focus on vegetation classes relevant to NATURA 2000 monitoring. Besides basic classes such as urban, water, deciduous/coniferous forest, and agriculture this includes dry grassland (NATURA 2000 code 62xx), humid meadows (64xx), open sand and heathland (40xx), as well as bogs/mires (7xxx). 120 trainings areas (segments) were chosen from field mapping as well as from the biotope map of the region (acquired in 2004) and evaluated for possible changes of land-use type before the utilization in the classification process.

The set of images was classified with the nearest neighbor algorithm including the spectral mean of all bands. To evaluate the optimal date for a potential data acquisition in the following years, the classification was repeated for all available image dates (see Table 1). The resulting land-use map was validated using 366 randomly selected polygons of the biotope map. It required a minimum overlap of 99 % between selected polygon and the classified segment. Additionally, the selection of a validation polygon was restricted to a minimum size of 0.1 ha.

3.4 Phenological measurement

The derived land-use classification (see 3.3) can be used to evaluate the areas of potential habitats. In a second step, a phenological library was developed to transfer the temporal field spectral to the information of the satellite scene for the possible habitats.

For this purpose the field spectra measurements are reduced to the wave lengths of the RapidEye images with the spectral response function of the sensor. For these bands, phenological profiles were extracted that provide a two dimensional reference of a wavelength band (e.g. from 690 to 730 nm) for a growth period. The phenological profile for a certain vegetation type will not only consist of an optimum graph, because each type has different development stages at the same time due to growth factors such as aspect and soil type. Hence, a certain spectral upper and lower limit defines the possible occurrence of a vegetation type. These variances can be derived from the variability within the terrestrial measurements (see example in Figure 6).

The phenological profiles have to be transferred to the RapidEye sensor. Therefore, transfer functions between the profile and the reflectance value of the satellite image have to be defined and validated. These functions depend largely on satellite specifications as well as the phenological date of the year, specified by the DWD (German Meteorological Service) or with data from the MODIS sensor. The transfer functions allow to assign a pixel or object to a spectral value of a specific vegetation type. Thus, an area wide classification based on a phenological library can be performed for the specified habitats at each time of the year within the growth period, even though there will be limited success in dates that were defined as non-optimal for separation.

4. RESULTS

4.1 Land-Use Classification Method

The land-use classification was performed for 31 different combinations of RapidEye images (see Table 1). Figure 3 shows an exemplary result for the classification including all available RapidEye scenes.

The accuracy assessment resulted in an overall Kappa Index of Agreement (KIA) between 0.75 and 0.88 (see Table 1). The best outcome was achieved using the scenes of August 16th and September 20th. When including the images of these two dates the overall KIA increased throughout all classification runs. This accounts for classifying with just one scene (results 1 to 5 of Table 1) as well as for combined results. Classification runs including the scene of the September 20th result in a higher average accuracy of 0.84 compared to the average accuracy of all classifications (0.82).

24.5.	27.7.	16.8.	20.9.	9.10.	overall KIA	heath-land	dry grass-land
■					0.75	0.86	0.85
	■				0.79	0.85	0.90
		■			0.82	0.86	0.86
			■		0.86	0.91	0.85
				■	0.80	0.95	0.85
■	■	■	■	■	0.85	0.86	0.85
■	■				0.78	0.85	0.85
■		■			0.78	0.86	0.86
■			■		0.82	0.86	0.85
■				■	0.75	0.85	0.85
	■	■			0.82	0.95	0.85
	■		■		0.84	0.95	0.85
	■			■	0.81	0.98	0.86
		■	■		0.88	0.86	0.85
		■		■	0.81	0.86	0.85
			■	■	0.85	0.95	0.85
■	■	■			0.81	0.86	0.85
■	■		■		0.83	0.91	0.85
■	■			■	0.78	0.85	0.85
■		■	■		0.84	0.86	0.85
■		■		■	0.79	0.86	0.85
■			■	■	0.81	0.86	0.85
	■	■	■		0.86	0.86	0.85
	■		■	■	0.84	0.95	0.85
	■	■		■	0.81	0.86	0.85
		■	■	■	0.85	0.86	0.86
■	■	■	■		0.84	0.86	0.85
■	■	■		■	0.82	0.86	0.86
■	■		■	■	0.84	0.86	0.85
■		■	■	■	0.84	0.86	0.85
	■	■	■	■	0.86	0.84	0.84

Table 1. Classification results of the different temporal combinations (visualized in grey) between the 24.5. and 9.10.2009

Comparing the accuracy of single classes, it can be observed that classes with a higher temporal variability, such as agriculture, have a higher variance of classification results. Moreover, the accuracy of these classes increases when including more scenes.

Table 1 shows exemplarily the results of two classes relevant to NATURA 2000 classification. Heathland and dry grassland achieve stable accuracies above the average of the overall classification (0.84 to 0.95). However, for these classes a multi-temporal approach is of limited effect. The results of single scenes are comparable to the results of combined classifications. Furthermore, for the acquired images no trend for a certain image to result in higher accuracies could be observed.

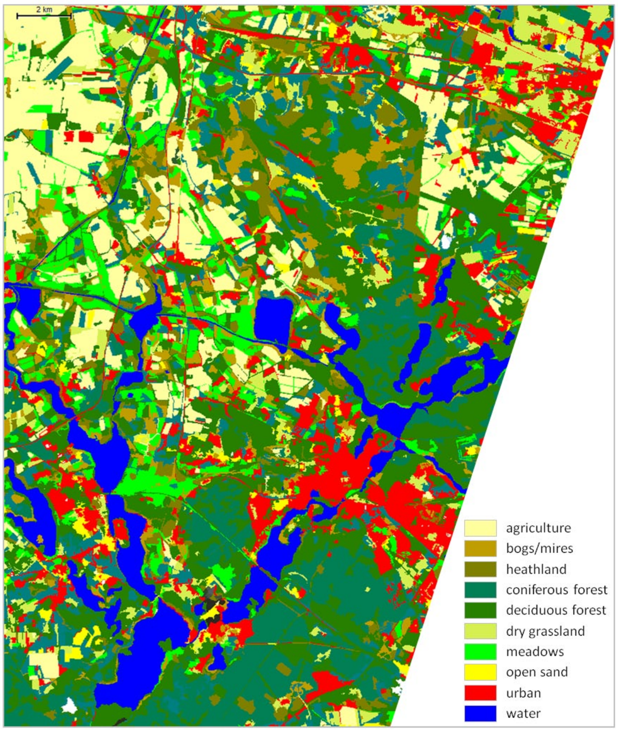

Figure 3. Land-use classification of the combination of five RapidEye images of the Döberitzer Heide and its surroundings

4.2 Phenological measurements

The results of the repeated field measurement from May to October 2009 are shown in Figure 4 for the example of *Molinietum*. The spectral reflectance of the field measurements is very similar. However, there is a smaller increase between red edge and near infrared in the RapidEye imagery. This could be due to the fact that the times of acquisition are differing up to 20 days.

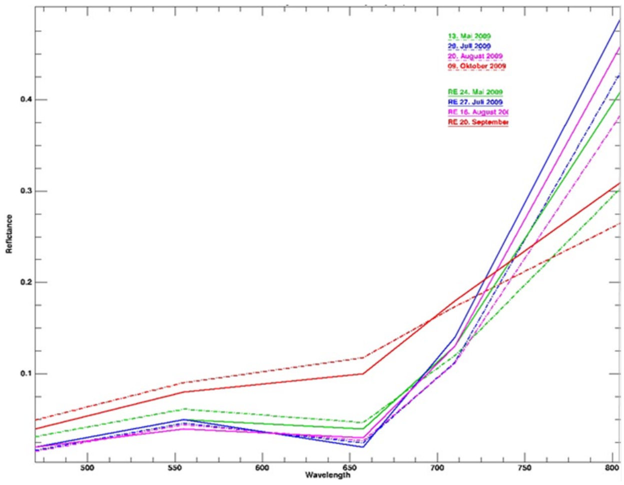

Figure 4. Exemplary comparison of atmospherically corrected RapidEye reflectance and field spectra for *Molinietum*

Since the purpose of the concept of phenolocigal libraries is to compare different phenological profiles, the NDVI of the field measurements between vegetation species was compared. Figure 5 shows the example of *Molinietum* and *Phragmitetum*. It is obvious that there is a possibility of differentiation of these two vegetation composites in May.

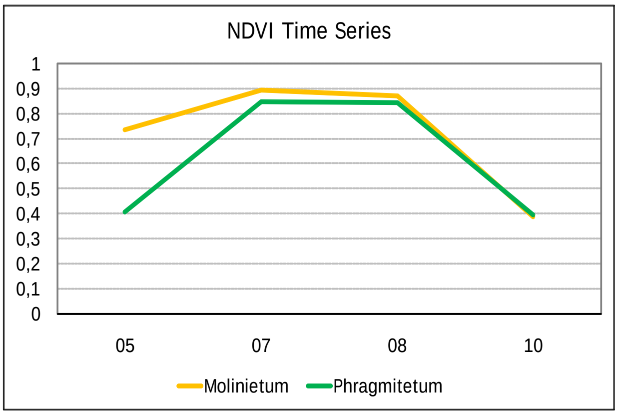

Figure 5. Comparison of the NDVI for terrestrial measurements between *Molinietum* and *Phragmitetum*

The possibility to differentiate vegetation species is restricted by the variability of the spectral signal due to diverse water availability, soil type, and species composition. Therefore, first tests of the change in the terrestrial measured signal were derived. Figure 6 shows the varying NDVI between the months May and September for the example of *Molinietum*. While the variance is less distinct for May and September, increasing differences in the index occur in June to August.

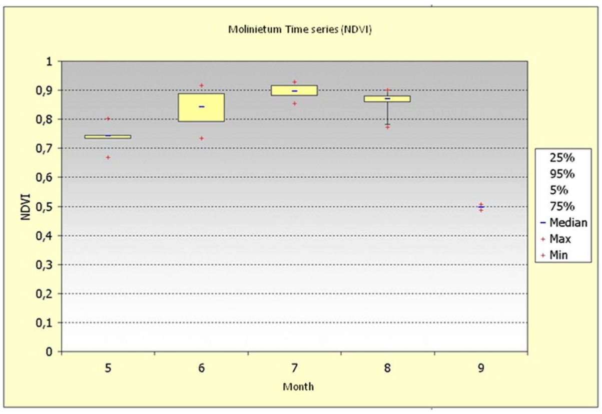

Figure 6. Variability of measurements of the NDVI for terrestrial measurements of *Molinietum* between 2007 and 2009

5. DISCUSSION

The method developed within this study can be divided in a standard land-use classification to detect potential areas relevant for NATURA 2000 monitoring and field measurements which could be used in combination with the multi-temporal spectral signal of the sensor RapidEye.

For the land-use classification the results show that an overall accuracy up to 0.88 was possible. Especially the images acquired in August and September lead to an increase in accuracy. This might be due to the major land-use changes such as harvest (agriculture) and mowing (meadow) within these months. The main land-use classes related to the NATURA 2000 monitoring can be detected with an accuracy of above 0.85. Hence, the method could be used to reduce the search criteria of monitoring areas within a monitoring of a biogeographic region. Additional, it might be an advantage that the results were relatively independent from the date of acquisition. However, these results were derived for only one year and could largely vary with different acquisition dates and transferred to another region.

The field spectral measurements show a good accordance to the reflectance of the RapidEye images. Moreover, different vegetation types relevant to the NATURA 2000 monitoring can be separated temporally. In contrast, for the test case of *Molinietum* the high variability of the measurement within the summer months seems to be challenging when separating different vegetation types. Nonetheless, especially in phases of relatively stable measurement results such as May and September, the possibility to differentiate species seems to be higher (compare Figure 5 and 6). Consequently, image acquisition during the foliation and senescence of the vegetation is most promising for NATURA 2000 monitoring.

6. CONCLUSIONS AND OUTLOOK

The presented study shows the potentials of very high temporal resolution (VHTR) satellite data for the monitoring of land-use and vegetation with specific focus on NATURA 2000 monitoring. Object-based classification methods can be of use for detecting potential regions for the monitoring. Future research on the combination of multi-temporal terrestrial and satellite measurements can potentially improve the results and transfer punctual terrestrial information about vegetation compositions to area-wide classifications.

Repeated spectral measurements (so called phenological measurements) can be used similarly to spectral libraries for imaging spectroscopy classification. Therefore, an adaptation of recent techniques for imaging spectroscopy (e.g. support vector machines) for a multi-temporal classification might be useful. Moreover, the evaluation of the red edge channel of the RapidEye sensor for potential additional information is a future purpose of the project.

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