USING TERRASAR-X AND RAPIDEYE DATA FOR CHANGE DETECTION IN WADDEN SEA AREAS

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ABSTRACT

The tidal areas of the oceans are important transition zones between terrestrial and marine ecosystems. In contrast to the non-marine surface of the earth, access to the tidal lands such as the Wadden Sea along the North Sea coast is often difficult. For this reason, remote sensing offers important monitoring tools. In this study, a new change detection approach is presented, adapted to the Wadden Sea and RapidEye satellite data. It is based on a decision tree approach and uses spectral characteristics in combination with GIS Information, neighbourhood connections, textures and shapes of objects. The spectral characteristics are derived from field visits and radiation spectrometer measurements. The extent of the Wadden Sea area is determined by using available GIS Information. For vegetation, the SAVI and different texture measurements are used. Mussel beds are located by neighbourhood analysis and texture. In a first step, the image taken at date one is classified using the decision tree method. For the second image taken at date two the decision tree is extended based on the first classification. After classification of the second scene the detected changes are calculated and displayed. This approach is fully automated: no manual input is necessary for classification and change detection. The method is transferable to other areas and other scenes in the Wadden Sea of Lower Saxony. The results show an accuracy of over 70 per cent.

INTRODUCTION

The Wadden Sea of the North Sea is the tidal area along the coast, an important transition zone between terrestrial and marine ecosystems. In June 2009, the Wadden Sea was awarded an UNESCO world natural heritage status. In contrast to the land surface of the earth the access to the Wadden Sea is often difficult due to the tides and an unstable underground. Therefore, remote sensing offers important tools for detecting and monitoring of the Wadden Sea. Area-wide information on sediment, macrophytes, mussels and phytoplankton parameters can be derived from multi-spectral images [1]. In addition, with the development of new hyperspectral imaging systems, more accurate class distinctions are possible [2], as long as a sufficiently high spatial resolution is present [3].

In addition to passive optical sensors, active remote sensing sensors such as radar have been used for the systematic monitoring of the coastal area [4]. A big advantage is that radar operates nearly independent of daylight and cloud cover, thereby ensuring a reliable source. Morphological information about the surface of the Wadden Sea can be acquired with high accuracy using airborne laser scanning systems to obtain information on the Wadden Sea topography [5].

Previous experiences with multispectral sensors of medium spatial resolutions (10 m to 30 m) showed that high-accuracy classification has hardly been possible, especially for sediments, mussel beds and macrophytes [6]. Difficulties lie, for example, in the distinction of sea grass and macro algae. For sediments, the distinction between sand and mud flats is already possible, but there are still problems in the differentiation of silt and mixing areas, especially if the sediment is influenced by water. A similar problem occurs in the classification of mussels when they are covered by water or vegetation, such as brown algae. In order to obtain accurate information about the spectral properties of different surfaces, a calibration with terrestrial spectrometer of high accuracy (ground truth) is often essential. Also, the suitability of texture features for characterization of mussel beds or sediments [7] in high-resolution image data has to be studied and is presented in this paper.

As all recording systems have certain advantages and disadvantages, there is no agreement which sensor could deliver the best possible differentiation of classes in the Wadden Sea. Objective of this paper is to show the possibilities of RapidEye image data by using a hierarchical classification approach followed by subsequent change detection.

STUDY AREA AND DATA SETS

Satellite data

Data from the satellite constellation RapideEye has been used in this study. The satellite constellation Rapideye was launched on August 29, 2008. It acquires images at a spatial resolution of 6.5 m and resampled to 5 m. The Rapideye constellation consists of five earth imaging satellites that contain identical sensors which are equally distributed in a sun-synchronous orbit with an altitude of 630 km. This satellite system is especially suited for the monitoring of geographic areas such as the tidal lands of the Wadden Sea, because due to its 5-satellite constellation it offers a potential revisit cycle of 24 hours. In comparison to other satellites such as the single-satellite constellations Landsat or SPOT, the probability of recording a scene during low tide has significantly improved. In addition, the sensors provide a swath width of almost 80 km. This allows, for example, the recording of the east coast of the Schleswig-Holstein North Sea in one pass. Each RapidEye satellite has five bands: blue (440-510 nm), green (520-590 nm), red (630-685 nm), red edge (690-730 nm) and near infrared (760-850 nm) and records the data with a radiometric resolution of 12 bit.

Study area

The test area is located near the island of Norderney in the North Sea. This area is part of the German Wadden Sea, which gained UNESCO world heritage status in June 2009. Figure 1 shows the Rapideye image of this area in the band combination near infrared, red, green. Most affected by the tides is the area between the island and the mainland. Along the north and south coast of the island dry sand is predominant. A mussel bed is located in the center of the intertidal flat south of the island but is hardly visible in the RapidEye image. Salt marshes are distributed along the coast.

METHODS

For classification of the RapidEye images, we developed a hierarchical approach (Fig. 2). As first step, a mask for the coastline is applied. We made use of the coastline feature from the Opentstreetmap Project because it presents the highest accuracy compared to other available data sources in Germany. In the next step, the water in the image is identified using a threshold in the near infrared band. In future analysis, a digital elevation model (DEM) derived from Laserscanning data should be used to model the water level with very high accuracy. Segments are then built from the water class. The segments should have at least 30 Pixel to avoid misclassification, otherwise the class is changed from water to unclassified. The next step involves the use of the Modified Soil Adjusted Vegetation Index (MSAVI) for the differentiation between vegetation and non-vegetation [8]. In comparison to the better-known NDVI (Normalized Difference Vegetation Index) and the standard Soil Adjusted Vegetation Index (SAVI), the MSAVI shows a better visual discrimination between the observed objects. The results of the MSAVI are normalized to 8 bit using a standard 2-σ deviation stretch.

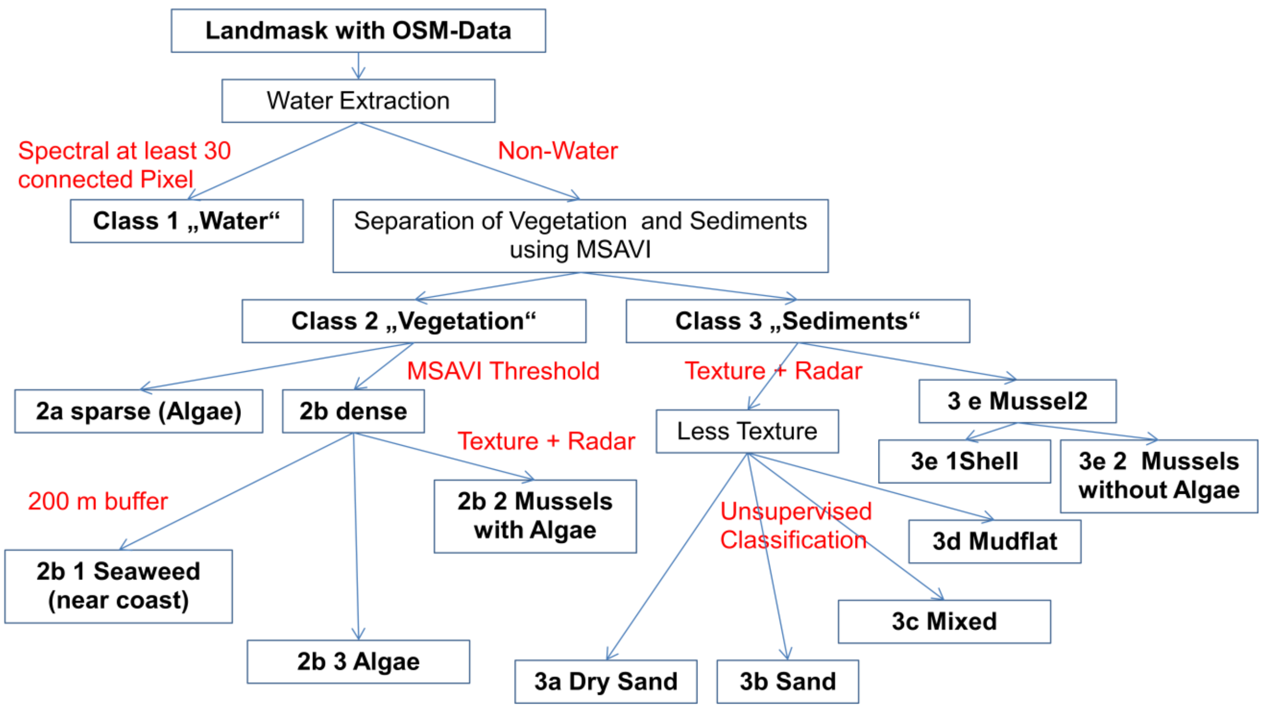

Figure 2: Decision tree for classification of Rapideye data.

This dataset is thresholded using 4 different fixed thresholds from ‘no vegetation’ to ‘dense vegetation’. The thresholds could be transferred to other scenes. The vegetation is also segmented. Using the distance to the coast and the size of objects, salt marshes could be classified. Sparse vegetation is classified without any extra criteria.

To extract mussels, a texture filter is applied. The texture filter is a standard deviation filter in a 3 x 3 pixel window. We make use of the standard deviation because it provides better results than other texture filters such as variance, energy or homogeneity. To avoid the effect that borders of the tidal rivers are also classified as mussel beds we define a buffer for the water areas. Young mussel beds are often not visible in the optical data, therefore we use radar data to classify these young mussel beds. Figure 3 shows a young mussel bed in a TerraSAR-X radar image recorded on 18th of October 2009 in high resolution spotlight mode (1m resolution) on the left () and the same subset in a RapidEye Scene recorded on the 25th of April 2010. The buffer for water is also used here. The roughness of the mussel bed has the highest values in comparison to other land cover in Wadden Sea areas. Finally, using thresholds for MSAVI, texture filter and object size the mussel areas are extracted. For the remaining vegetation and the sedimentation an unsupervised isodata classification is used [9]. The vegetation is only separated by different amount of coverage. For sedimentation five different classes can be extracted.

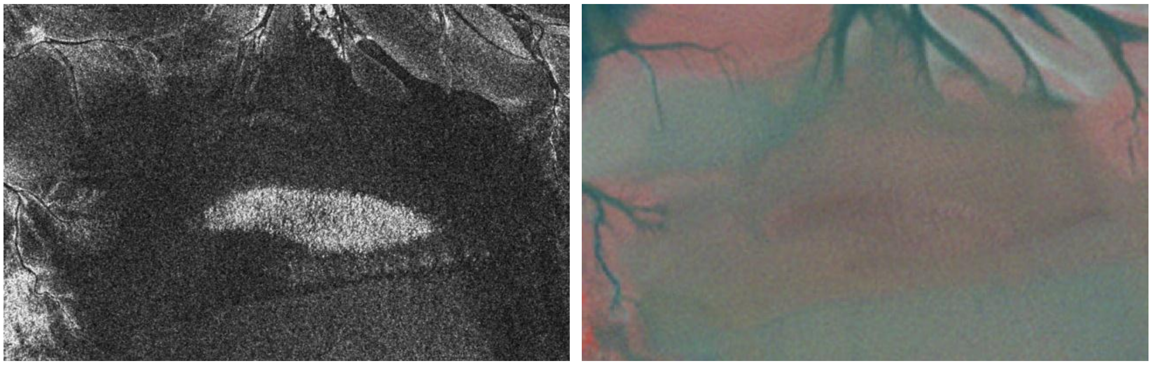

Figure 3: A young mussel bed in a TerraSAR-X image recorded on October 2009 (left) and in a RapidEye image from April 2010. The mussel bed is only visible in the radar image.

CLASSIFICATION

The classification results for RapidEye are shown in Figures 4 - 8 for five different dates. The tidal rivers in the Wadden Sea stand out clearly (blue). One problem is the different water level in the scenes. The different water level represents no change, because the tidal lands are under water twice a day. Therefore these 'pseudo changes' are ignored in our analysis. Dry sand (yellow) is always classified in the north of Norderney and in two images also in the south, due to lower water level. Salt marshes (dark green) are found only on the coast and on the side of the island that faces the Wadden Sea. The vegetation (light green) can be found through the entire Wadden Sea, however, the location of the vegetation is not stable. The reason is that algae are not connected to the sediment. Between the coast and islands large sediment banks exist. Predominant in the sediment is sand (light brown). The detection of sediment is mainly influenced by water. Mudflat has the lowest reflection, but if sand contains a high amount of water, the reflectance is similar to the reflectance of mud. In 2010 (Fig. 4 and Fig. 5) sand is dominant. In 2011 (Fig. 6, Fig. 7 and Fig. 8) it is mixed sediment. If this is indeed a change or is just due to different water content has still to be verified. Unfortunately, ground truth data are only available in 2008 and 2009. The next campaign is planned for 2013. The accuracy of the classification for mussel beds and dry sand can be confirmed by visual inspection. The mussel beds show very little change throughout the multitemporal data sets.

CHANGE DETECTION

A post classification change detection is then applied to the five classified scenes. Table 1 shows the amount of pixels detected within each specific class. From 2010 to 2011, mussels show a general increase. However, due to storms and the colder in the wintertime, some of the mussel beds are destroyed. There will probably be an increase of the mussel bed extension next spring. The salt marshes have also increased. Classification of the sediments is strongly influenced by the different water content and therefore change detection figures are very inaccurate. It looks like sand shows a decrease, whereas mudflats and mixed sediments show an increase. The vegetation is very mobile, Algae swim on and in the water and change their location; therefore there is no clear trend visible. They are often related to mussel beds, because they can connect to the mussels.

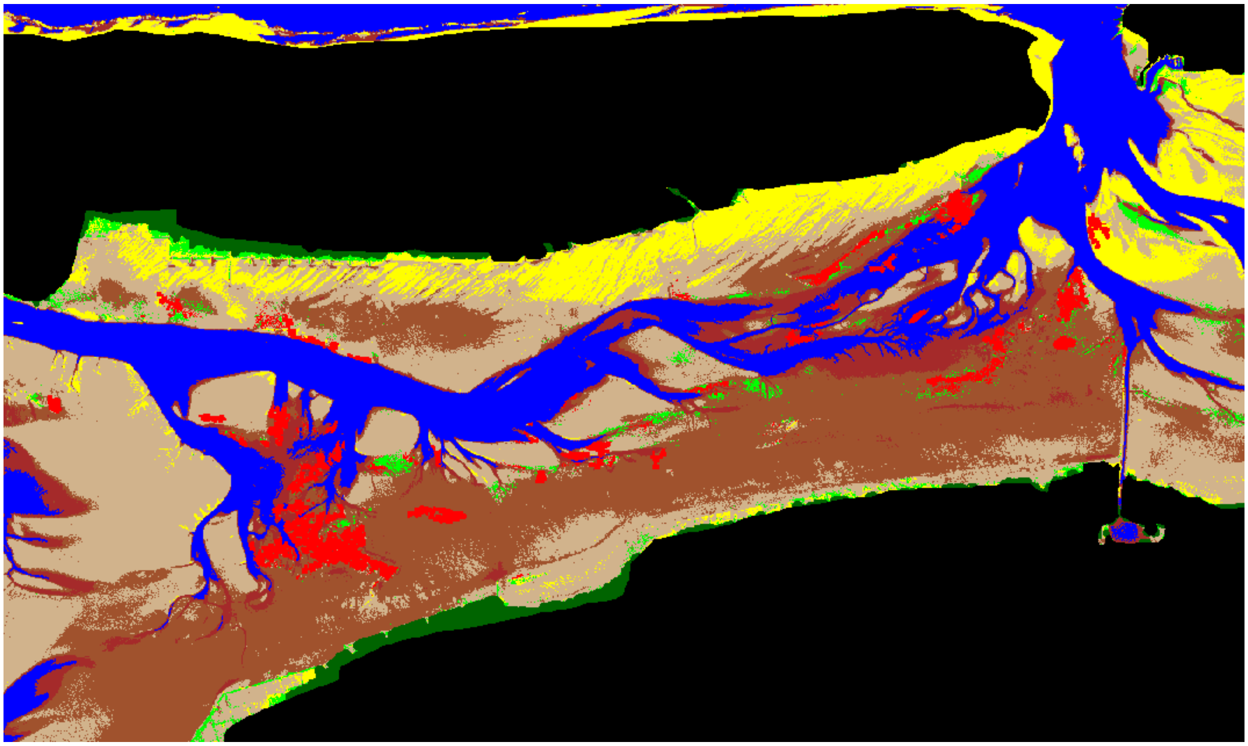

Figure 4: Classification result of RapidEye data recorded on the 25th of April 2010

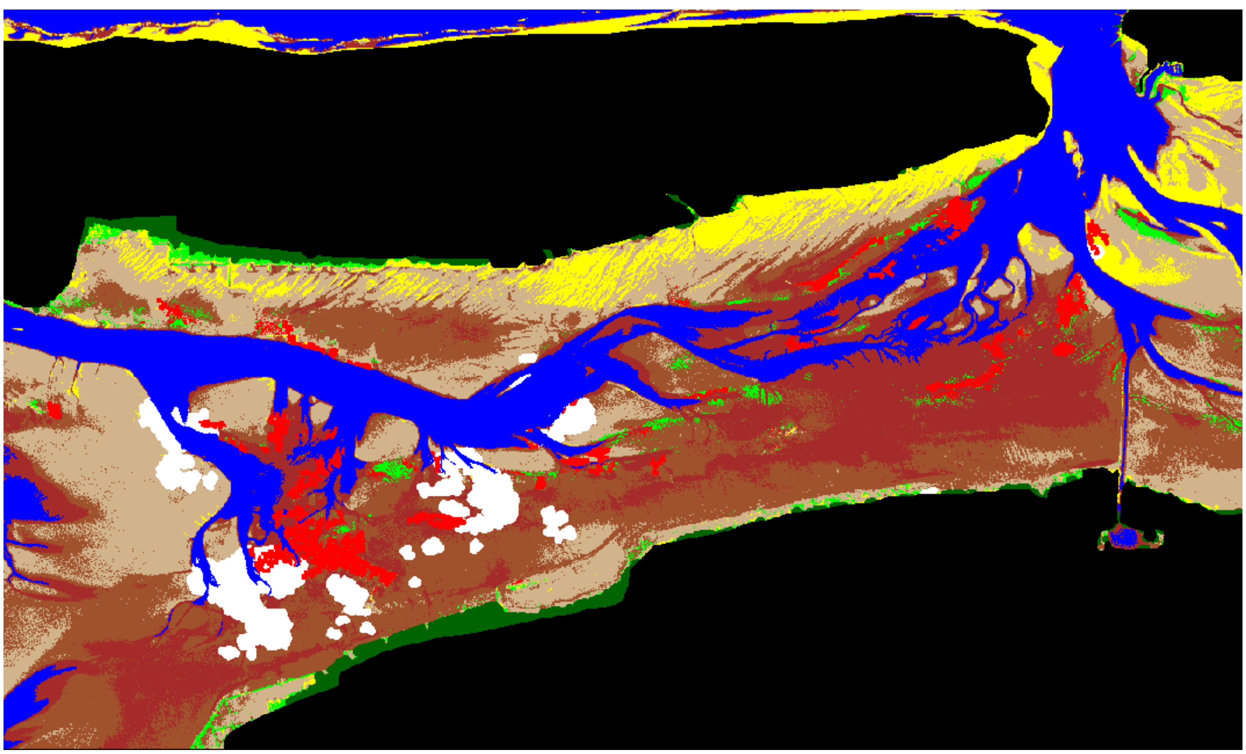

Figure 5: Classification result of RapidEye data recorded on the 7th of September 2010.

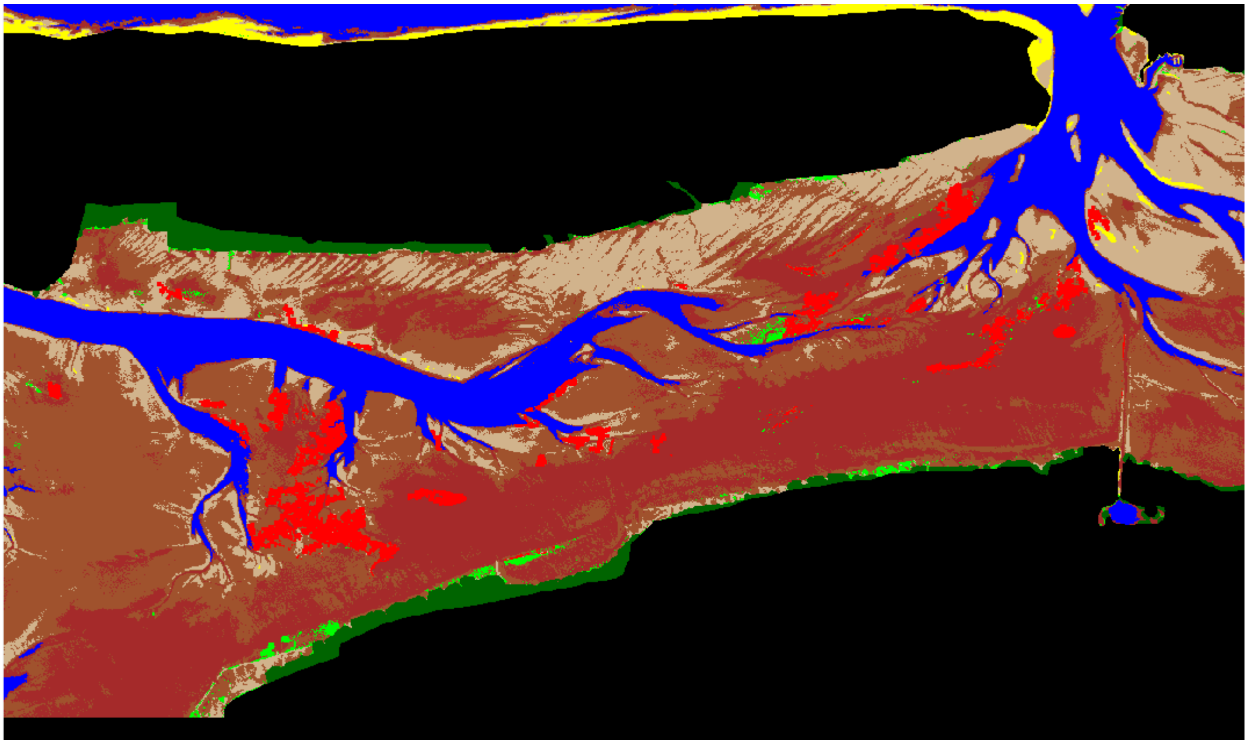

Figure 6: Classification result RapidEye data recorded on the 27th of June 2011.

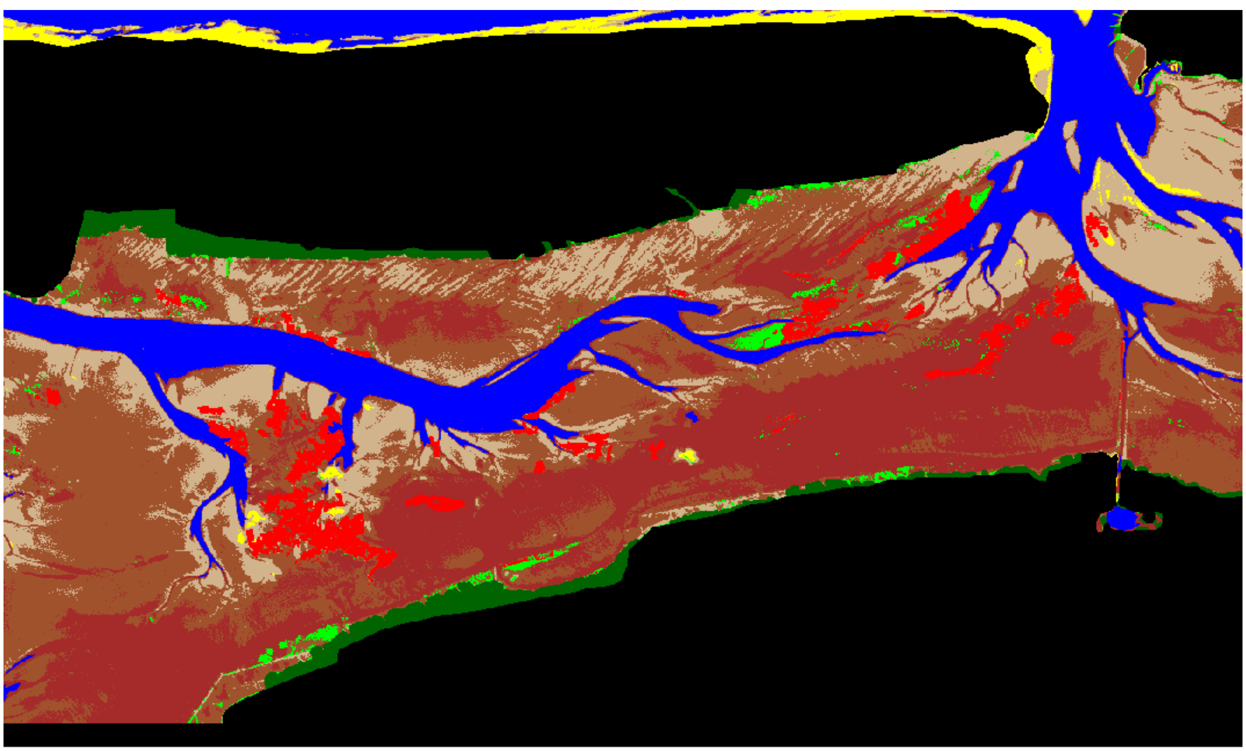

Figure 7: Classification result of RapidEye data recorded on the 11th of July 2011.

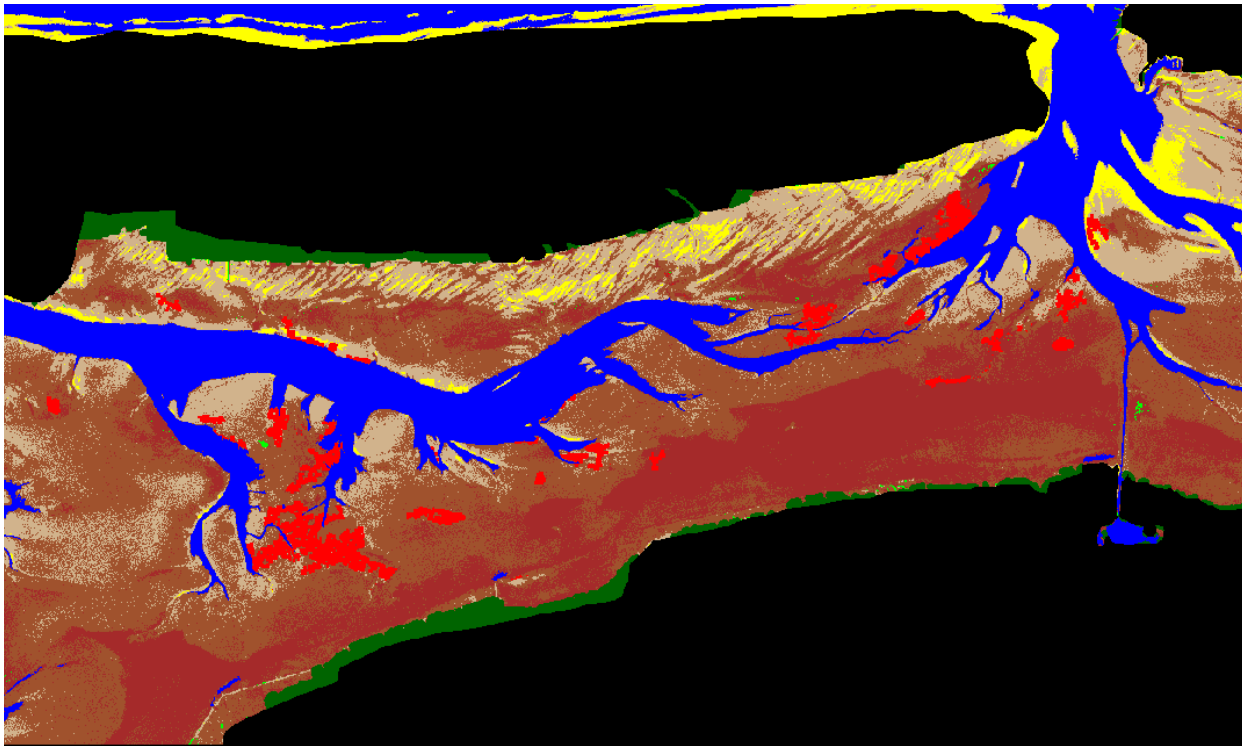

Figure 8: Classification result of RapidEye data recorded on the 22nd of October 2011.

Table 1: Amount of Pixel relating to this class.

Recording date	2010/04/25	2010/09/07	2011/06/27	2011/07/11	2011/10/22
Mussels	60316	60000	70335	78315	54954
Salt marsh	46735	46741	70079	71783	69902
Mudflat	149805	280150	579855	532605	418780
Mixed Sediment	564870	492490	703891	700323	738933
Sand	599419	450509	316997	344563	339608
Vegetation (Algae)	33962	33367	14025	24410	1845
Dry Sand	218652	151700	37257	46809	97666

CONCLUSIONS

Radar data is combined with electrooptical data to better identify mussel beds, because young mussel beds are hard to detect in electrooptical data alone. The decision tree that was developed for tidal land classification from RapidEye and TerraSAR-X data showed great improvements over standard techniques such as maximum likelihood (ML) classification. Nevertheless, the algorithm will still have to be improved. The next steps will involve the development of an advanced decision tree for a broader range of change analysis (e.g. environmental, phenological change in the Wadden Sea). It will also be tested in different study areas as well as on different data sets. For a more accurate calculation of the water level a DEM created by LIDAR should be used. The detection of mussel beds and salt marshes seems very accurate. Due to the different amount of water in the images at the time of their acquisition the classification of sediments becomes complex. In future analyses we will use an unmixing approach to better discriminate between the sediments and to determine the amount of water.

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