Tidal flats, megaripples and marsh: automated recognition on aerial images

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ABSTRACT: Intertidal areas in estuaries are highly dynamic and ecologically important. Here we present a novel method for automated recognition of saltmarsh, pioneer vegetation, megaripples and plane bed from aerial photographs and bathymetry. Results are compared with manual classification. The two methods agree for about 73% of the whole area, and 95% for (partly) vegetated areas. The distinction between the bare bar surface classes is more difficult and often vague due to the existence of gradients and temporal transitions. The distinction between (nearly) plane sand bed and megaripples does not improve much with the use of slope and slope variation calculated from bathymetry, but further improvements may be possible with data derived from stereo photography. Nevertheless, the high degree of agreement shows that the automated method is highly promising for application to large systems such as the Wadden Sea.

1 INTRODUCTION

Intertidal areas in estuaries are ecologically valuable, but their dynamics are poorly understood because they are determined by complex interactions between:

- shallow flow over tidal bars with large bedforms,
- sand-mud sedimentation with macrobenthic bioturbation effects,
- disposed sediment advection following fairway maintenance, and
- saltmarsh.

The most striking characteristic is the spatiotemporal variation in surface properties in close proximity. While saltmarsh has been studied extensively, understanding of the tidal flats is limited because these large areas are difficult to access for fieldwork and difficult to model numerically because of the shallow flows and continuous drying and wetting.

The intertidal surface area in the Western Scheldt is protected by law (e.g. Natura 2000), but it is under threat of reduction. Since large-scale fairway dredging has been conducted, the channels deepened and the bars accreted, so that bar margins steepened and the intertidal area has reduced, which is mitigated by shoal margin disposal strategies. To gain system behaviour understanding and monitor these important areas, Rijkswaterstaat developed a manual methodology of biogeomorphology with protocols for mapping from aerial photography and fieldwork for the entire system (Bouma et al. 2005). An automated method would be beneficial for efficient and objective application to other tidal systems, including the much larger Wadden Sea.

Our objectives are 1) to explore whether a semi-automated classification using Object-Based Image Analysis (OBIA, Addink et al. 2012) and a ruleset produces similar maps as the manual classification, and 2) to study spatial extent and temporal change of megaripples and flats.

2 METHOD AND RESULTS

After extensive testing the following novel method was developed (Douma et al. 2018). Tiles of merged false-colour aerial photographs were segmented to yield a few tens of thousands of objects with a minimum degree of spectral heterogeneity. We developed a ruleset in eCognition to classify the objects into seven classes (Figure 1). Main steps are illustrated in Figure 2. Vegetated surfaces were recognised through a ratio between near-infrared and red reflection: the Normalised Difference Vegetation Index. The bare surface was further classified on the basis of brightness, object shape and context (neighbouring objects). For present conditions and the entire system the total computation time is 24 hours.

The automated classification based on the ruleset produces a similar map as the visual method. The total surface areas of the classes are fairly similar (Figures 3,4,5). For saltmarsh areas including partially covered areas the agreement is about 95%, where differences arise due to objectified thresholds for partial cover and the detail in the boundaries in the automated method. However, the total area of perfect agreement between the manual and automatically produced maps is about 73%.

Most of the disagreement between the maps occurs in the bare surface classes that were difficult to distinguish. We tested whether the use of bed slope and variation thereof calculated from bathymetry improved the classification of the bare surfaces (Figure 6). However, this added megaripple area corresponding on both maps, but also added low-energy and high-energy plane shoal areas to the megaripple class in disagreement with the manually drawn map. Visual inspection shows that the boundaries between sand flat and megaripples are sometimes poorly recognised in the automated method.

Map inspection and field site visits show that all three possible transitions between megaripples, high-energy plane bed and low-energy plane bed occur. The nature of the transitions varies. In some cases there appear to be relic megaripple fields, sometimes covered by mud (consisting of clay and silt). Another frequently occurring transition occurs due to the migration of a sand body, covered in megaripples, onto a low-energy tidal flat. Clearly, further study of spatiotemporal transitions on intertidal flats are needed.

3 CONCLUSIONS

Object-Based Image Analysis of aerial photographs of intertidal areas allows fast automated mapping of biogeomorphology that corresponds well with visual interpretations for about three quarters of the surface.

While two-dimensional bedforms are fairly well detectable by automated methods on bathymetries, the recognition of three-dimensional megaripple fields in complex intertidal areas remains challenging.

Spatial and temporal transitions have various causes and natures that need to be unravelled, and that are reflected by differences between visual and automated mapping.

4 ACKNOWLEDGEMENTS

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5 REFERENCES

Addink, E.A., Van Coillie, F.M.B., and De Jong, S.M., 2012. Introduction to the GEOBIA 2010 special issue: From pixels to geographic objects in remote sensing image analysis. International Journal of Applied Earth Observation and Geoinformation 15, 1-6.

Bouma. H., de Jong, D.J., Twisk, F. and Wolfstein, K., 2005. Zoute wateren EcotopenStelsel (ZES.1) voor het in kaart brengen van het potentiële voorkomen van levensgemeenschappen in zoute en brakke rijkswateren. Report of Rijkswaterstaat RIKZ/2005.024.

Douma, H., Addink, E.A. and Kleinhans, M.G., 2018. Verkenning productie Geomorfologische Kaart met behulp van Object Based Image Analysis. Universiteit Utrecht, Departement Fysische Geografie, report for Rijkswaterstaat CIV.

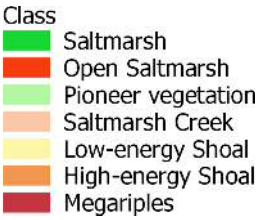

Figure 1. Biogeomorphology classes with map legend.

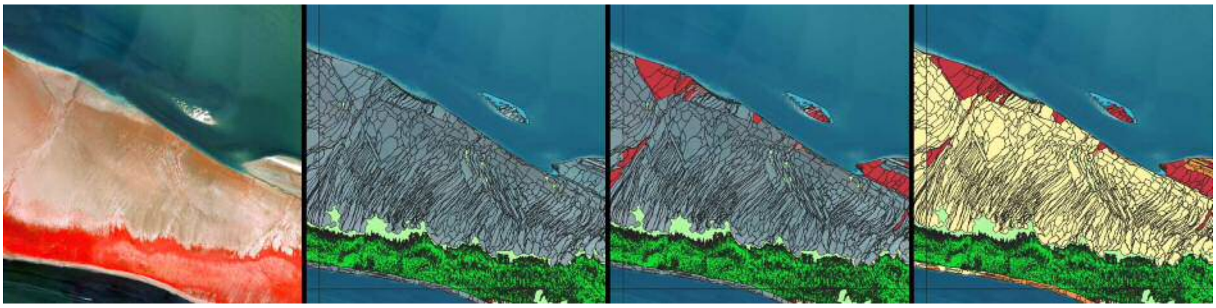

Figure 2. Main steps in the classification: (stretched) aerial photograph; vegetation, megaripples (includes height information), bare surface classes.

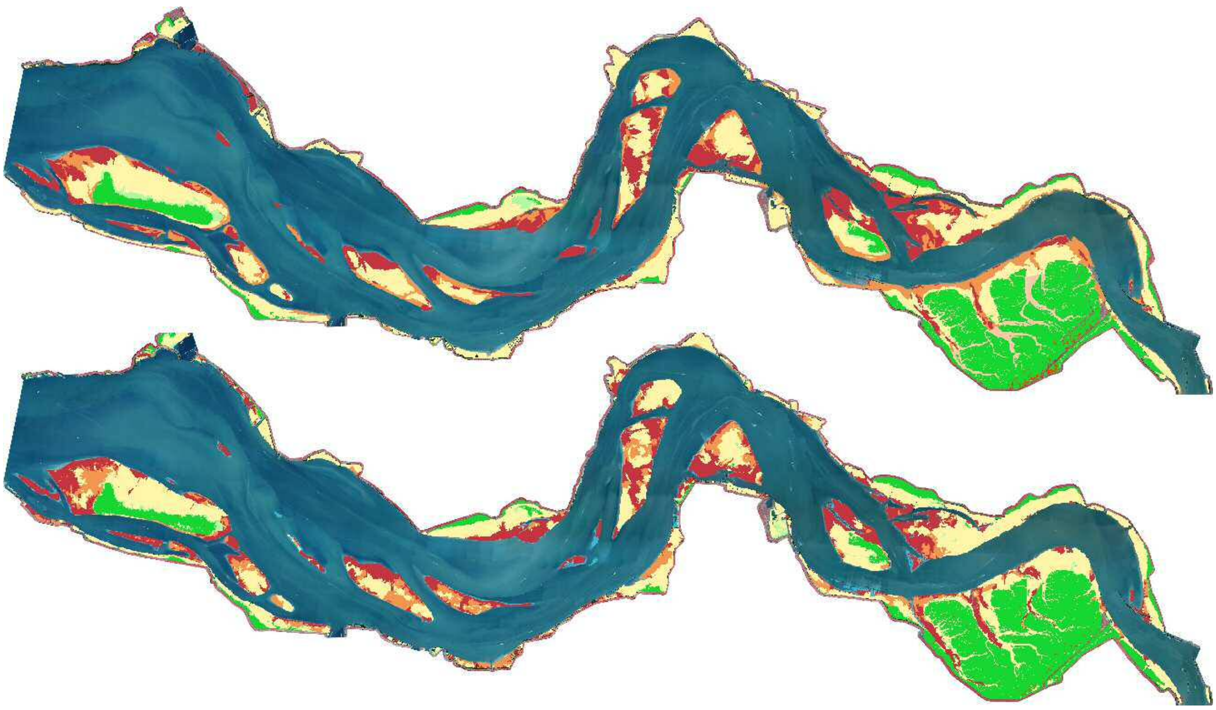

Figure 3. Maps of the Western Scheldt (Netherlands) classified automatically (top) and manually (bottom).

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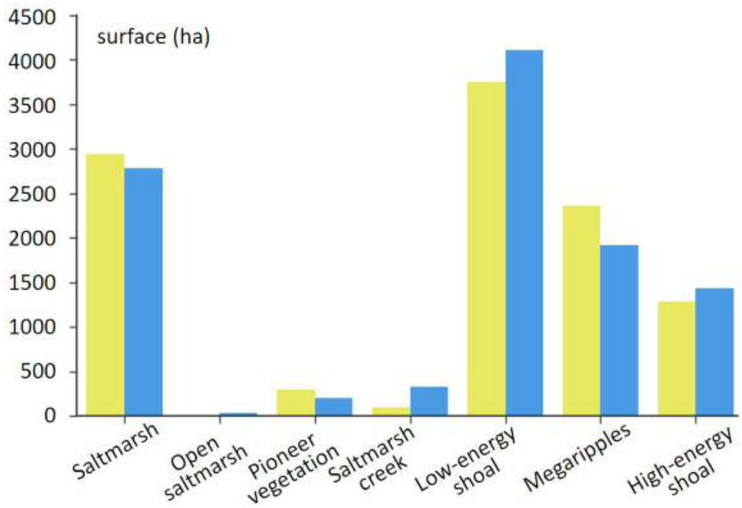

Figure 4. Total area per class in 2016 for the manual (yellow) and automatic (blue) classification including elevation data.

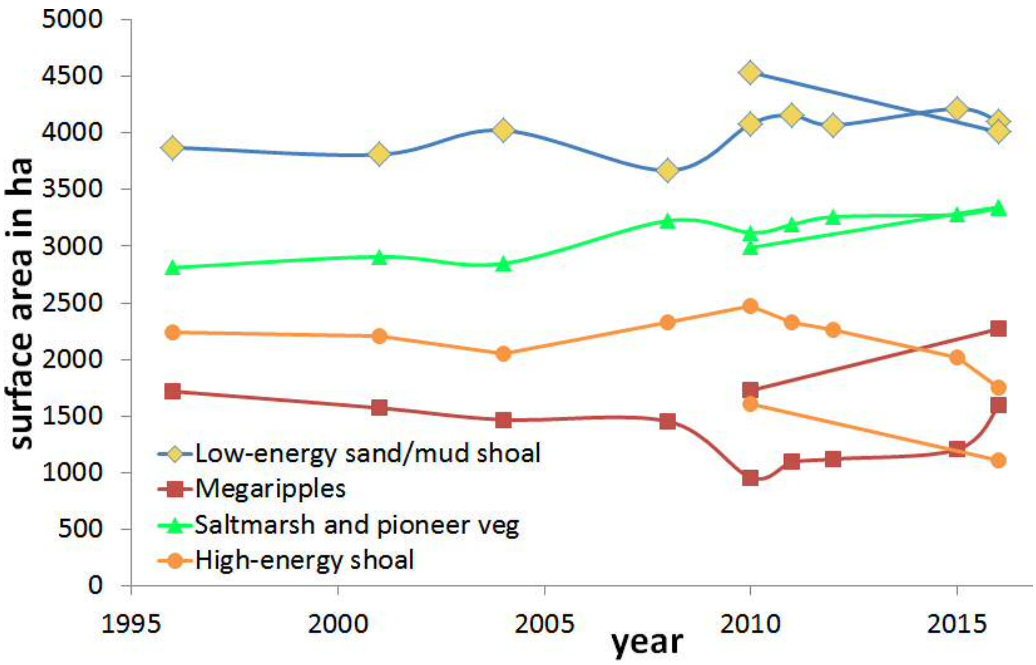

Figure 5. Development of surface area. Straight lines with points at 2010 and 2016 are from the automatic classifications presented here.

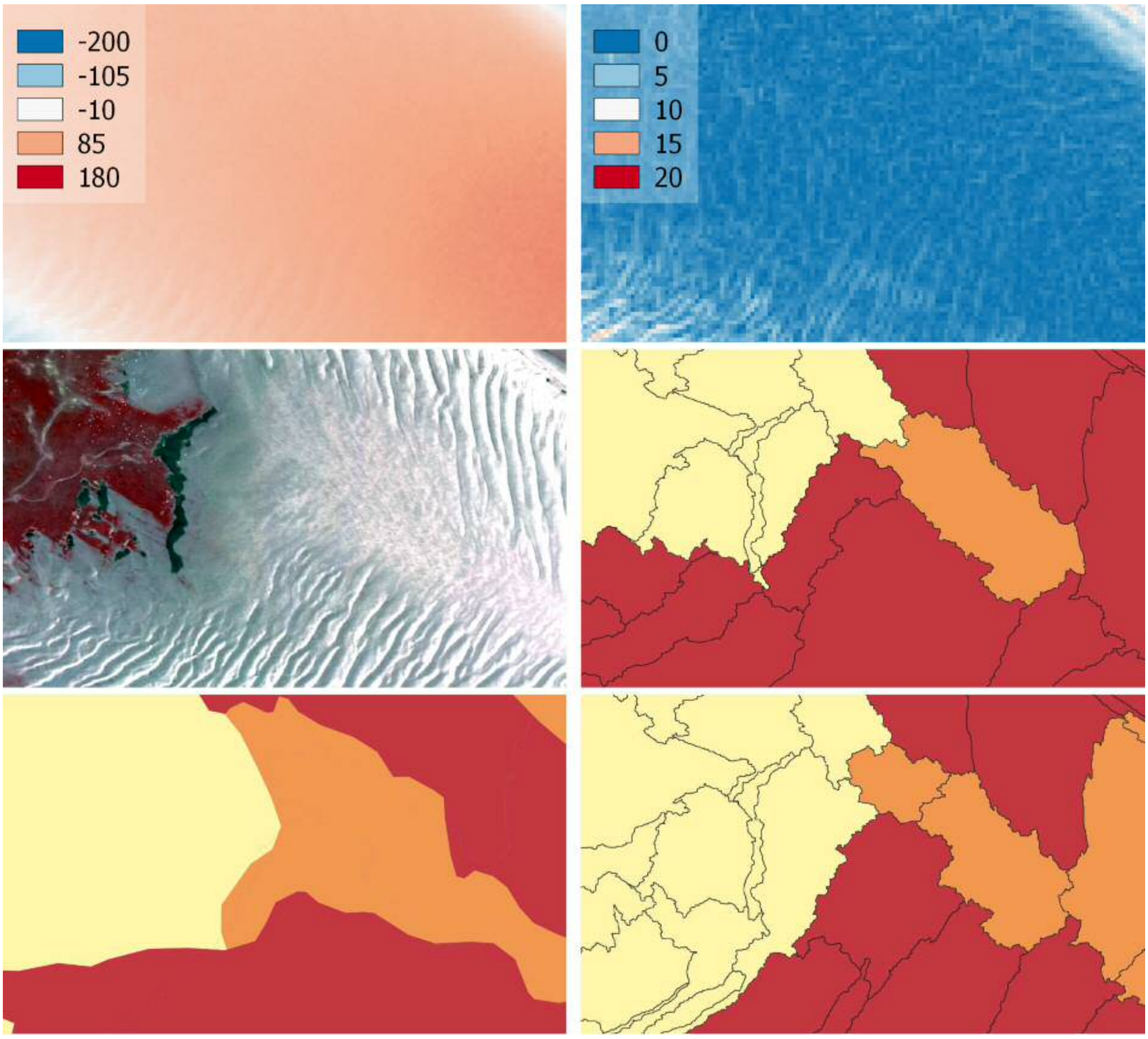

Figure 6. Classification of bare surface on the basis of bed elevation data (top left, in cm+NAP, 2 m horizontal resolution), bed slope (top right, in degrees), and aerial photograph (stretched image middle left). Width of the image is about 300 m. Classification by visual interpretation (bottom left), automated image segmentation alone (middle right) and by inclusion of bed slope and bed slope variation in the automated method (bottom right).