Geomorphological mapping of intertidal areas with Object Based Image Analysis

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Key words: OBIA, intertidal areas, geomorphological mapping, image recognition.

SUMMARY

Geomorphological maps are needed for the management of the intertidal areas in the main water systems in the Netherlands. Rijkswaterstaat, as manager of all the main water systems in the Netherlands, produces these maps on a regular basis only for the Western Scheldt and the Eastern Scheldt. The classic method used to produce these maps is based on manual mapping from false color aerial photographs. This method is labor-intensive and therefore expensive, which is the reason why they were never made for the much larger systems as the Wadden Sea and the Ems-Dollard.
Utrecht University developed an automated method which uses Object Based Image Analysis. The advantage of using objects instead of pixels is that beside the spectral properties texture and context can be used for the classification. (Douma et al., 2018). The classification is done in eCognition, using a ruleset where objects are stepwise assigned to classes. In total eight classes describing the geomorphology are recognized. The method is applicable on multiple water systems and on photographs of different years. As the method is sensitive to difference in quality and lightening conditions of the photographs, calibration on the main thresholds performed which are internally coupled with the rest of the ruleset.
The results are very good. The method is first developed on the Western Scheldt where the automated method agreed with the manual method for 73% (Douma et al. 2018). After some improvements it was tested on the Eastern Scheldt and the Wadden Sea. For the Eastern Scheldt the agreement with the manual method was 90%. For the Wadden Sea it was not possible to do a comparison with the manual method because the geomorphological maps where never made for these water systems. Here the results where validated by an expert of Rijkswaterstaat. This validation showed that 85% till 95% of the classification was correct (Douma et al., 2019a). The production time for a water system as the Western Scheldt is for the manual method roughly 400 hours and for the automated method 80 hours. This reduces the costs of geomorphological maps which makes it possible for Rijkswaterstaat to produce them for other large water systems, in particular the Wadden Sea and the Ems-Dollard.

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1. INTRODUCTION

Rijkswaterstaat is manager of all the main water systems in the Netherlands. This means they are responsible for protection against flooding, save and smooth traffic and water quality, which includes ecological quality. Ecological quality is important because of the European water framework directive and the fact that most of these water systems are designated as Natura 2000 areas which is the implementation of the European bird directive and the European habitat directive. To keep track of the water quality and the ecological quality of their water systems Rijkswaterstaat has an extensive monitoring program. Part of this monitoring program is the geomorphological mapping of the intertidal areas in the Western and Eastern Scheldt. The geomorphological maps are conducted from false-color aerial photographs which are manually interpreted and converted into geomorphological maps. This is a labor-intensive process and therefore rather expensive. This is the reason why these maps are only made for the smaller water systems Western and Eastern Scheldt and not for the much larger systems as the Wadden Sea and Ems-Dollard. Nevertheless, there is a need for this information for these large water systems. So, there was a need for an automated method to conduct these maps.
In 2015 Laura Coumou wrote her Bachelor thesis at Utrecht University on the geomorphological evolution of a tidal flat in the Wester Scheldt (Coumou 2015). She used Object Based Image Analysis (OBIA) to create geomorphological maps and compared these with the traditional made geomorphological maps. The results were very promising. In 2017 this method was for the first time tested on an entire water system for the Ems-Dollard as part of the Ems-Dollard 2050 research program (Douma et al., 2019b). The application in this area was somewhat problematic due to the poor availability and quality of the aerial photographs except the most recent. The result could also not thoroughly be tested because there were no traditionally made geomorphological maps of this area available. In 2018 Rijkswaterstaat asked Utrecht University to further develop this method and test it on the Western Scheldt. From this water system there is a large set of high-quality aerial photographs which are used to manually make geomorphological maps. The results led to a further fine-tuning of the method and a test on the Eastern Scheldt and application of the method to the Wadden Sea.

2. GEOMORPHOLOGICAL MAPS

Geomorphological maps of the intertidal area are giving an idea of the different morphological features and the circumstances in which they were formed. They give for example an insight in where there are places with high energetic circumstances and where there are places with low energetic circumstances which are suitable habitats for most macrozoobenthos species. With the classic method the maps are made from stereographic false-color aerial photographs and are manually divided into areas with the same geomorphological appearance. Then these areas are classified into the right geomorphological classes (figure 1). This process takes about 400 hours for a water system as the Western Scheldt.

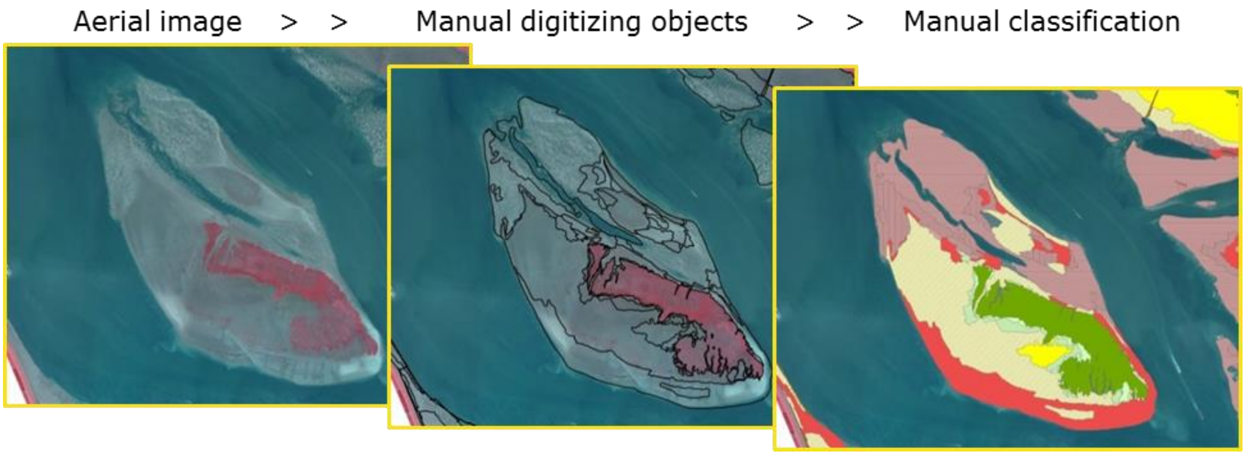

Figure 1: The manual process of making a geomorphological map

This manual process is rather subjective, especially when the maps are not every time made by the same person. The most important geomorphological classes that can be distinguished, with the classic method, are saltmarsh, pioneer saltmarsh, low energetic silty shoal, low energetic sandy shoal, high energetic flat shoal, mega ripples, anthropogenic hard substrate and natural hard substrate. Some examples are shown in figure 2.
There are several other classes and subclasses that are distinguished, with the classic method, but these are aggregated to the main classes for analysis and trend calculation. The production of several geomorphological maps from different years allows quantification of the development of these classes in time. See figure 3 for an example of the Western Scheldt.

Figure 2: Examples of different geomorphological classes

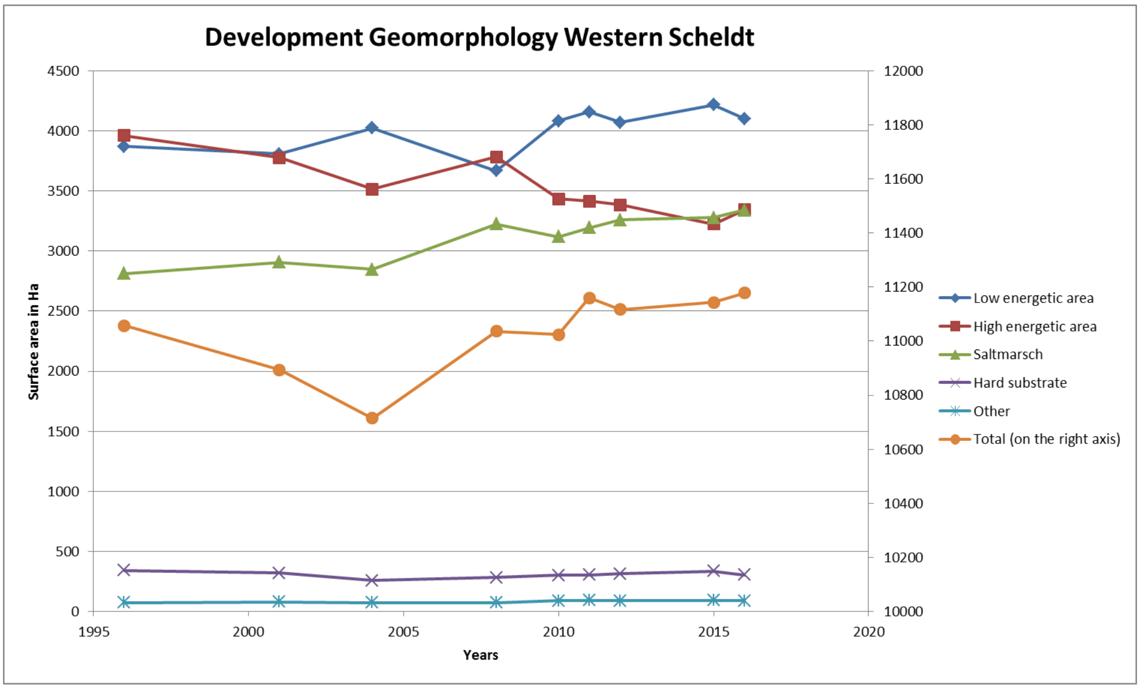

Figure 3: The development of the intertidal area of the Western Scheldt

This is valuable information for the management of the water system. However, this kind of information is only available for the Western Scheldt and the Eastern Scheldt and not for the large intertidal areas of the Wadden Sea and the Ems-Dollard.

3. OBJECT BASED IMAGE ANALYSIS

Utrecht University developed a semi-automatic classification method which uses Object Based Image Analysis (OBIA). This method uses objects instead of pixels. The objects are made of neighboring pixels which are spectrally comparable and therefor grouped into objects. The advantages of working with objects instead of pixels is that beside the spectral values texture and context can be used for the classification. OBIA is in some ways closer to human observation (Douma et al. 2018). Douma et al. developed a ruleset for the classification process in eCognition 9.2.1. The process is visualized in figure 4.

Figure 4: The automated process of making a geomorphological map

The spectral properties in aerial photographs depend on atmospheric conditions that differ in time and between systems. This means it is necessary to do some calibration if the ruleset is used on photos of another year or another water system. In the beginning of the process the ruleset looks to brightness and to the Normalized Difference Vegetation Index (NDVI). This is shown in figure 5. The first steps in classification are shown in this figure as vertical lines. To adjust for the conditions of the aerial photographs only the main thresholds, marked with an arrow in figure 5, are changed. The rest of the thresholds in the ruleset for classification is coupled (Douma et al. 2018).

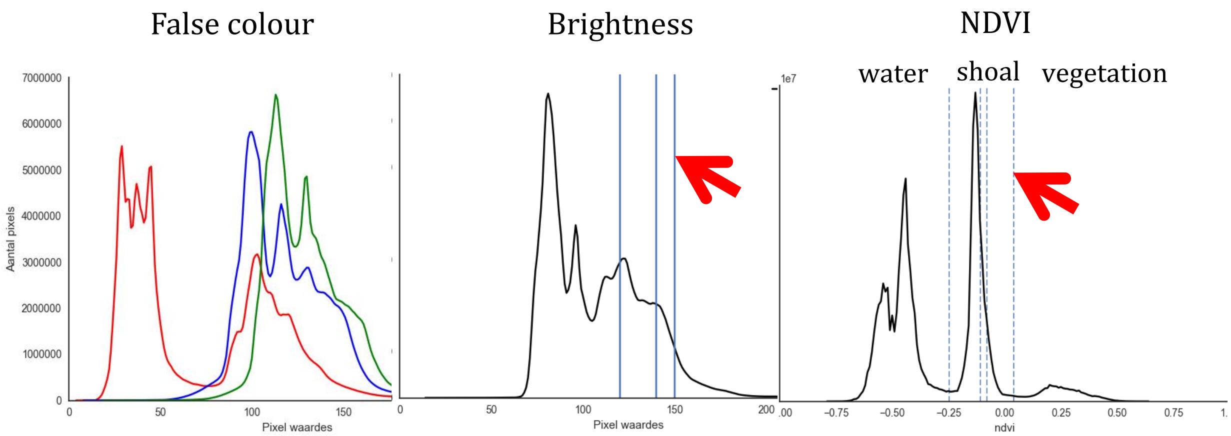

Figure 5: Main thresholds that can be changed to adjust for the conditions of the photo (Douma et al. 2018).

The computing time to classify the images into a geomorphological map is for the Western Scheldt 24 hours. However, the total time, including preparing the images and setting the main thresholds, on which the other thresholds depend, is 40 hours (Douma et al. 2018). The results need to be manually validated based upon expert judgement which takes about 40 hours as well. This brings the total time for the semi-automated method to 80 hours.

4. RESULTS

The ruleset was developed and tested on the aerial photographs of the Western Scheldt of 2016. The results were compared with the geomorphological map that was manually made with the same images. The two methods agreed without validation for 73%. After validation by a field expert the methods agreed for 86% (Douma et al. 2019a, Jentink 2019). The automated method can distinguish eight different geomorphological classes. This is less than the manual method but most of the main classes that are used for analysis and management purposes are present. The classes that can be distinguished are: saltmarsh, pioneer saltmarsh, open area within saltmarsh, saltmarsh creek, low energetic shoal, high energetic flat shoal, mega ripples and anthropogenic hard substrate. Saltmarsh is the geomorphological class that is recognized the best with an agreement of 95% The method shows more differences with pioneer saltmarsh, high energetic flat shoal and mega ripples (Douma et al., 2018), which is partly due to the problem of distinguishing the mega ripples from flat and undulating bed. The ruleset was also tested on images of 2010 with similar results although the overall agreement was with 67% a little bit lower. Still the overall results were pretty good. After some improvements in the ruleset it was tested on the Eastern Scheldt. The results were much better. For the Eastern Scheldt the agreement with the geomorphological map was 90% and after validation even 94%. The problem with the pioneer saltmarsh was solved but the high energetic flat shoal and the mega ripples were still the hardest classes to distinguish. The improved ruleset was also again applied on the Western Scheldt, but the results did not differ much with the previous run (Douma et al. 2019a) except for the pioneer saltmarsh. The ruleset was also applied on the Wadden Sea including the Ems-Dollard estuary. For these water systems there are no geomorphological maps available to verify the results. These results were therefore verified by an expert of Rijkswaterstaat, who did a 100% surface area check on the results. The Wadden Sea was divided into six different areas to avoid errors due to large differences in photo quality and atmospheric conditions. Nevertheless still some areas needed to be divided into several parts with different thresholds for brightness and NDVI in the ruleset. The results were very good with accuracy between 87 and 95% (Douma et al. 2019a)(figure 6). Appendix 1 shows an example where the classification worked very well. The borders of the objects are very neatly on the different morphological features and almost no correction in classification was necessary. Appendix 2 gives an example of an area where the classification went wrong. low energetic shoal with a lot of drainage gullies which were mistaken for mega ripples so the classification needed to be corrected.

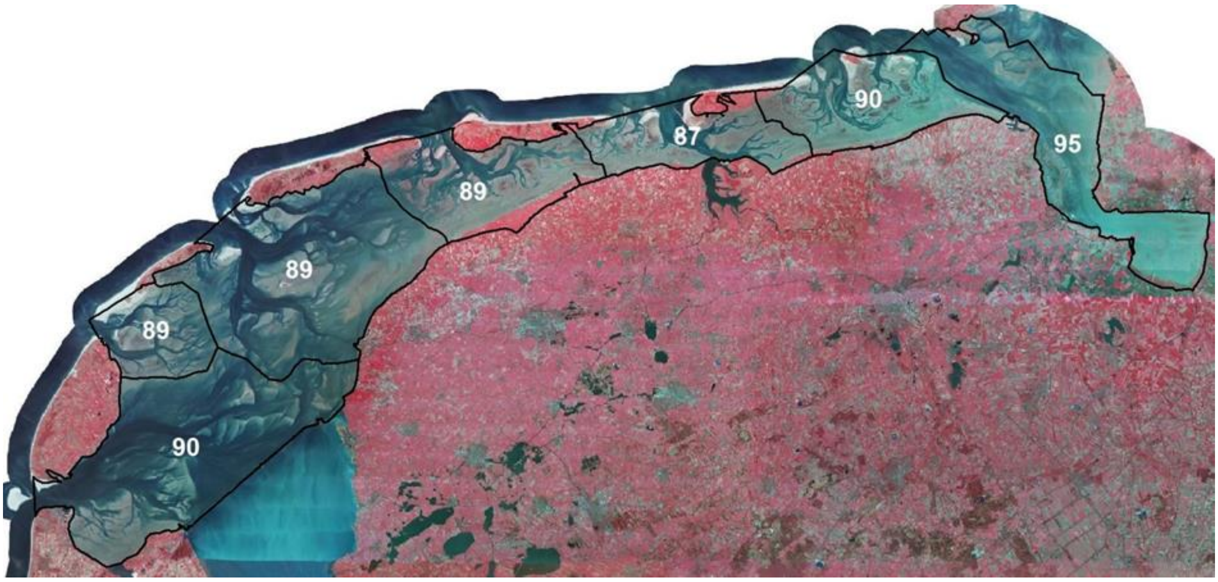

Figure 6: Accuracy (in %) of the tidal basins in the Wadden Sea

5. CONCLUSIONS

Object Based Image Analysis of aerial photographs of intertidal areas allows fast automated mapping of geomorphology. In most water systems the accuracy is between 85% and 95%. Only the Western Scheldt is performing less well with an accuracy of 73%. This could be caused by the fact that this system has the highest tidal amplitude and therefor a lot of different morphological features in close proximity of each other. Also, there is a lot of variability in the appearance of the different geomorphological classes. This makes it hard for the automated method to do a correct classification.
With the OBIA method it takes about 80 hours to make a geomorphological map of a water system like the Western Scheldt. This is five times faster than the manual method which takes about 400 hours. Therefore, it is now possible for Rijkswaterstaat to make these maps of the large intertidal areas of the Wadden Sea and Ems-Dollard.
The OBIA method distinguishes eight different geomorphological classes. This is less than the traditional method but most of those extra classes are never used and aggregated to a higher level when the maps are used. There are however three classes that do have added value that cannot be distinguished with the OBIA method. These are low energetic sandy shoal, low energetic silty shoal and natural hard substrate. The automatic method can also potentially be extended for more detailed vegetation mapping.
The OBIA method is a more objective method because it is not sensible for personal interpretation, to where to draw the line, from the person who is making the maps.
A uniform objective method for making geomorphological maps makes it possible to compare different water system with each other.
In 2020 a project will be started to further enhance the OBIA method. The goal will be to add the three missing geomorphological classes, to improve the results for the Western Scheldt and to improve the classification of mega ripples and high energetic flat shoal.

ACKNOWLEDGEMENTS

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BIOGRAPHICAL NOTES

Robert Jentink graduated in 2000 for the study Nature and Landscape Management at Larenstein university of applied science in Velp. He started working for Rijkswaterstaat as an ecological surveyor mainly in the intertidal areas of the Western and Eastern Scheldt. He conducted extensive fieldwork and obtained a lot of knowledge of ecological and morphological processes and the interaction in the intertidal environment. Nowadays he is working for Rijkswaterstaat as (senior) Advisor ecology and he is combining and analyzing ecological and morphological data to produce valuable information for the management of the water systems in the Southwestern Delta and the Wadden Sea area.

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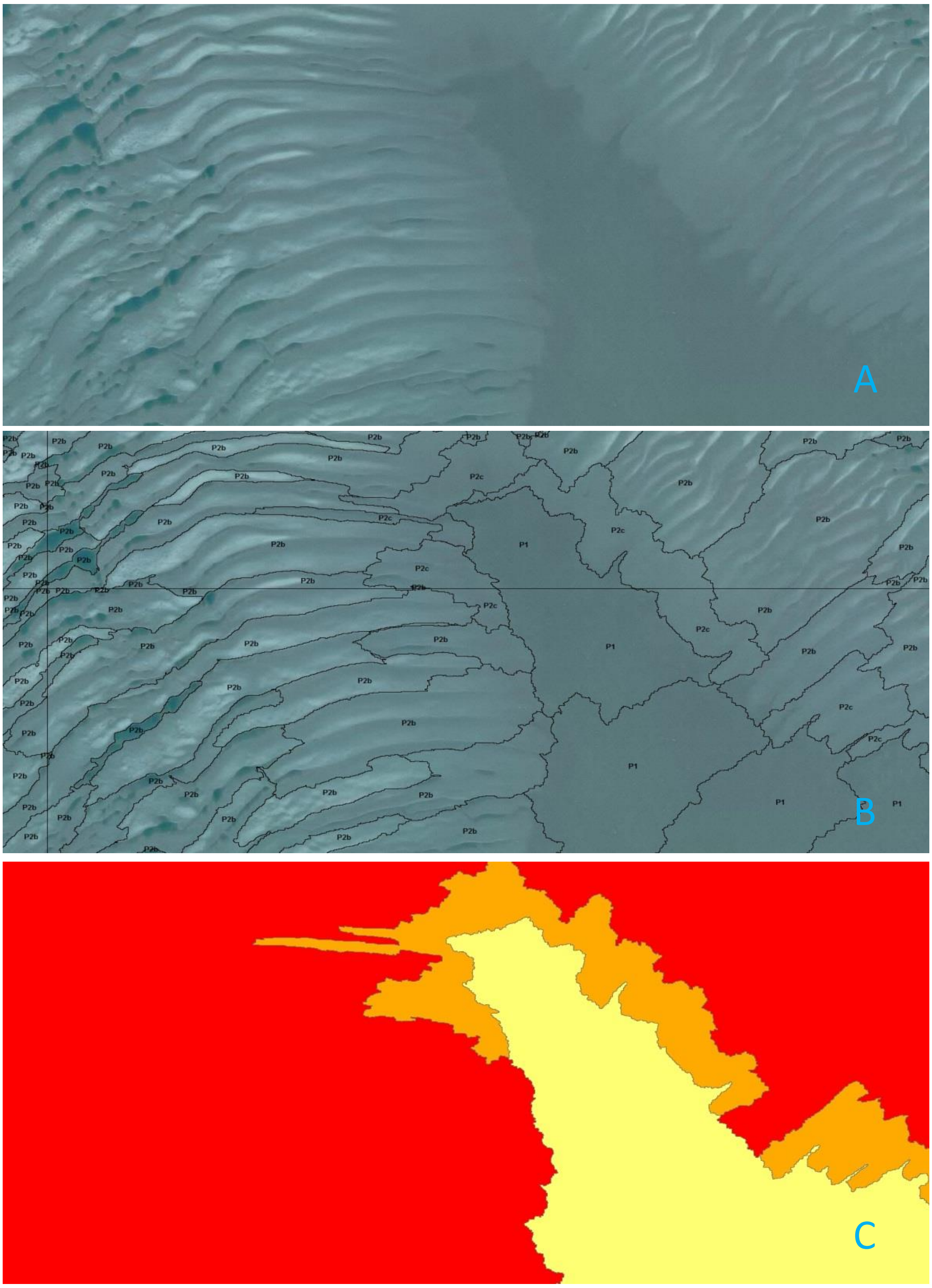
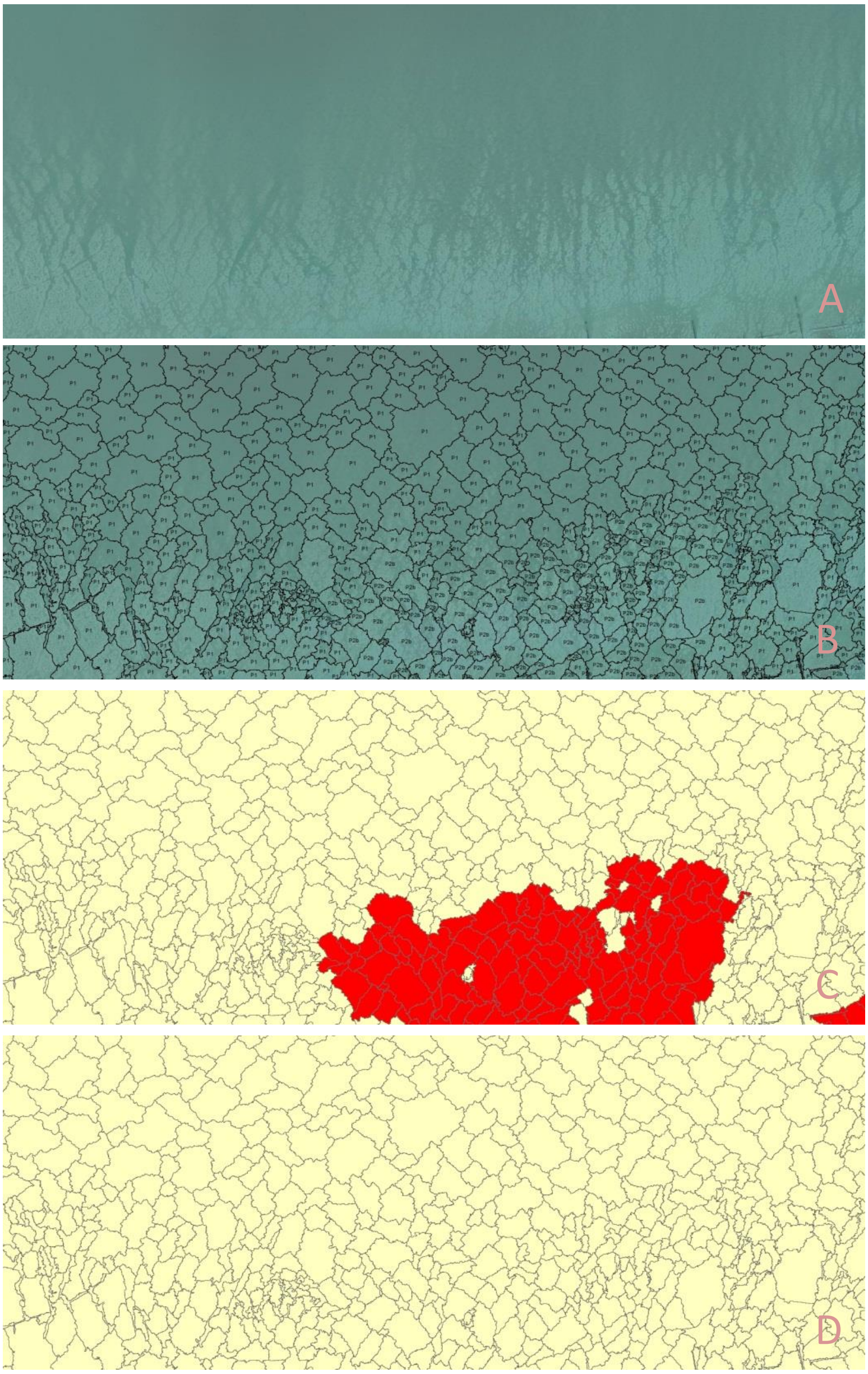
APPENDIX 1



A) Intertidal area with different morphological features B) Objects formed with ruleset and geomorphological classes are assigned C) Objects with the same class are dissolved into a map where yellow is low energetic shoal, orange is high energetic flat shoal and red is mega ripples

APPENDIX 2



A) Intertidal area with similar morphological features B) Objects formed with ruleset and geomorphological classes are assigned C) A part of the objects is classified as mega ripples (Red) D) After validation these objects are corrected to low energetic shoal (Yellow)