Supplementary Material to: Salt marsh and tidal flat area distributions along three estuaries

1 DESCRIPTION OF THE OBJECT-BASED CLASSIFICATION PROCEDURE

The aerial photographs were obtained under strict guidelines of low tidal water level range, lighting conditions, season, overlap, scale and resolution. The digital photographs made available to us were orthorectified and of uniform resolution for the four colors.

The method is designed such that it needs minimal calibration when applied to a new set of photos. Particularly illumination conditions differ between photo sets, which affects pixel values. Therefore, two thresholds need calibration when working with new photo sets: the brightness and the NDVI thresholds.

The method follows an object-based image analysis approach with a ruleset to distinguish the different classes. The classes are identified one by one (see Fig. S1), and for each class one or more new object sets are built from scratch, including all pixels that do not belong to a class yet. In each of the first five steps either a general class is identified or a general class is split into subclasses. All newly classified objects are then copied to the overall map, and the next step will be taken starting by segmenting the unclassified pixels into new objects. In the final step the remaining areas are assigned to a class based on the previously classified objects in their surroundings.

The classification is rule-based, which means that a unique combination of attributes can be used to distinguish each different class. In Fig. S1, the attribute categories used for each specific class are indicated in the upper right corner in the step where the class is mentioned the first time. The steps to classify objects are given on the following page, with step numbers corresponding to the columns in in Fig. S1.

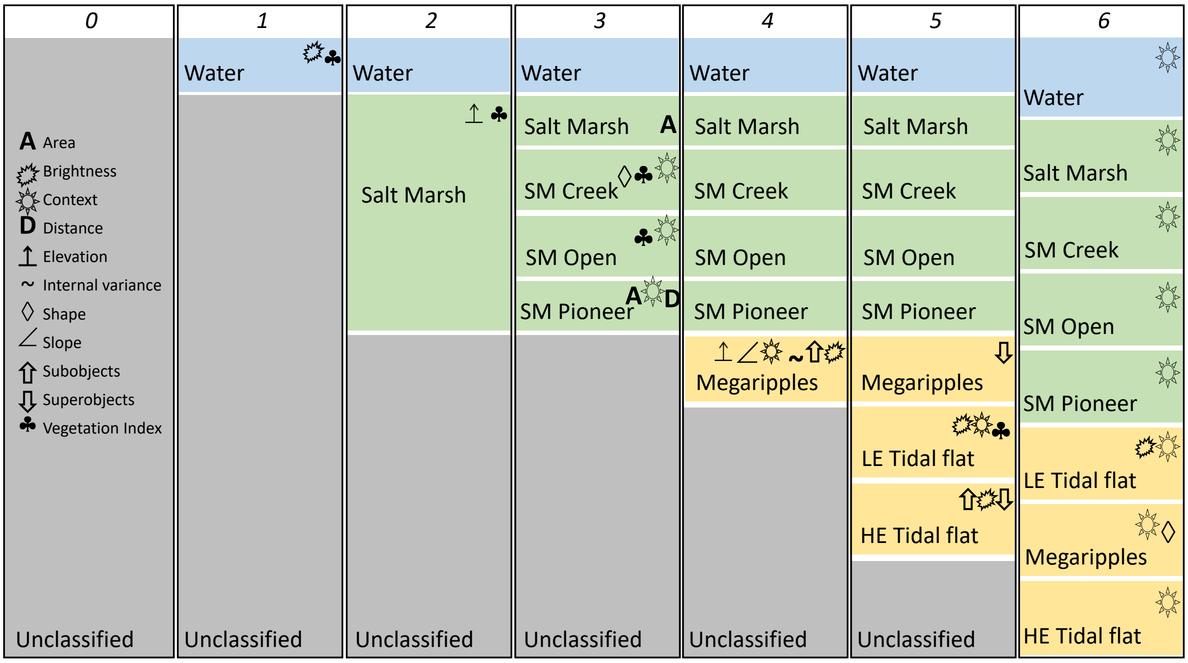

Figure S1. Schematic representation of the classification steps. Each column is one step and represents the full area with identified classes and unclassified area. The size of the class boxes does not represent the relative area of the classes. The legend for object attributes used in each class is given in the left column.

1.1 Step 1 Distinction of Water

1. Objects with a very low value for NDVI are labelled as Water.

2. Objects with a slightly higher NDVI combined with a very low brightness value are labelled as Water.

3. Objects with extremely high Brightness (caused by sun glint) are also labelled as Water.

1.2 Step 2 General distinction of Salt Marsh

4. All objects with a high NDVI value and a high elevation are identified as unspecified Salt Marsh. Step 3 Distinction of specific Salt Marsh classes

5. Unspecified Salt Marsh objects with an area exceeding the minimum mapping unit (400m2) are labelled as Salt Marsh.

6. Areas which include smaller Unspecified Salt Marsh objects that are closely together are labelled as Pioneer Vegetation. This step increases the total area of Salt Marsh as non-vegetated objects are part of this class.

7. Unclassified objects with a small width that are closer to Unspecified Salt Marsh than to other unclassified objects are identified as Creek candidate. When they are connected and their NDVI is sufficiently low, they are labelled as Creek.

8. Remaining Creek candidate objects surrounded by Salt Marsh are labelled Salt Marsh Open area.

1.3 Step 4 Megaripples

9. Objects with high Internal Variation of Brightness and low mean Brightness, which have a high number of subobjects of which a significant part is identified as Water on Shoal (very low NDVI) are labelled as Megaripples.

10. Objects with high Internal Variation of Brightness and high mean Brightness, and with a high number of subobjects which have a bimodal distribution in Brightness are labelled as Megaripples.

11. Remaining objects with high Internal Variation of Brightness and high mean Brightness that share at least 40% of their border with a Megaripple object are labelled as Megaripples as well.

1.4 Step 5 Low Energetic Tidal Flat (LEF) and High Energetic Tidal Flat (HEF)

These are the remaining two classes and they are addressed iteratively.

12. All objectives with high NDVI AND high Brightness values are labelled as LEF.

13. All objects with low Brightness values are labelled as LEF as well.

14. All objects where the subobjects are very elongated in shape are labelled LEF.

15. All objects with very high Brightness values are labelled as HEF.

16. Objects with high NDVI which share at least 50% of their border with LEF objects are labelled as LEF.

17. Objects earlier identified as HEF or Megaripples and objects with very high brightness and high Internal Variation of Brightness that have an elongated shape OR have a superobject labelled as pioneer SM or SM, OR border LEF objects are (re)labelled as LEF.

18. Objects earlier identified as LEF which share at least 50% of their border with Megaripples, AND do not share a border with Salt Marsh or Pioneer SM, are relabelled as Megaripples.

19. Objects earlier identified as LEF with a superobject labelled as unclassified, where at least one subobject has a strong elongated shape and which borders on a Megaripples object, are relabelled as Megaripples.

20. Objects with high Brightness values and with a superobject belonging to HEF or Megaripples are labelled as HEF.

1.5 Step 6 All classes

21. All unclassified objects are merged with one of their classified Megaripples, LEF or HEF neighbours if they are spectrally similar.

22. All objects smaller than the minimum mapping unit are merged into the spectrally most similar Megaripples, LEF or HEF object.

23. All Megaripples and HEF objects which are fully surrounded by LEF objects are merged into LEF objects.

2 COMPARISON TO THE ORIGINAL MANUAL METHOD

We compared the manually created maps with the automatically created maps (if available) by the ruleset. Independently of this comparison, an expert corrected the classes, but not the object boundaries, of the automatically created map and that corrected data was used in the analysis of the paper. The comparison in this supplement is done for the maps without expert intervention in order to assess the accuracy of the automated method. Moreover, the ruleset was optimized for the Western Scheldt, and here we show a test without modification of the ruleset for the Eastern Scheldt, for which manually created maps are also available. No manual maps were created for the Eems-Dollard system.

Here we show the results for the Eastern Scheldt (Oosterschelde in Dutch) in confusion matrices (Fig. S2). The overall agreement between the manual and automated method is about 90%. The locations of mismatching objects are indicated in Fig. S3. While this is quite good for an automated method, it is less clear to what degree the disagreement is due to errors in the automated method, and due to errors in the manual method. Two reasons for mismatch are obvious. First, most of the mismatch happens on the tidal flats, not only between the megaripples and flats but also between saltmarsh and flat due to presence of diatoms. Second, the automated method draws much more detailed boundaries than the manual method due to the resolution of the photographs.

3 SUPPLEMENTAL DATA

The online supplemental data contains high resolution maps and data of ecotope abundance along all three estuaries to facilitate plotting and comparison with other estuaries in the future. The high-resolution ecotope maps are provided for all three estuaries (while only the Eems-Dollard map is given in the paper in lower resolution) The open access data provided online (see data availability statement) allows for plotting and using the maps in GIS.

Three files are provided for the Eems-Dollard (ed.csv), Western Scheldt (ws.csv) and Eastern Scheldt (os.csv). The files have the following columns (within the box) as follows: The first column is the Data ID. The second column, ‘Location’, refers to the class Shore-connected or shoal. The third column, ‘Pol_number’, is the object number. The fourth column, ‘Geo_RJ’ lists the ecotope class. The fifth column, ‘Shape_Area’, gives the surface area (m2) of a 200 m long segment of the estuary. The sixth column, ‘Distance’, gives the distance (in km) of the segment along the estuary. By dividing the surface area by 200

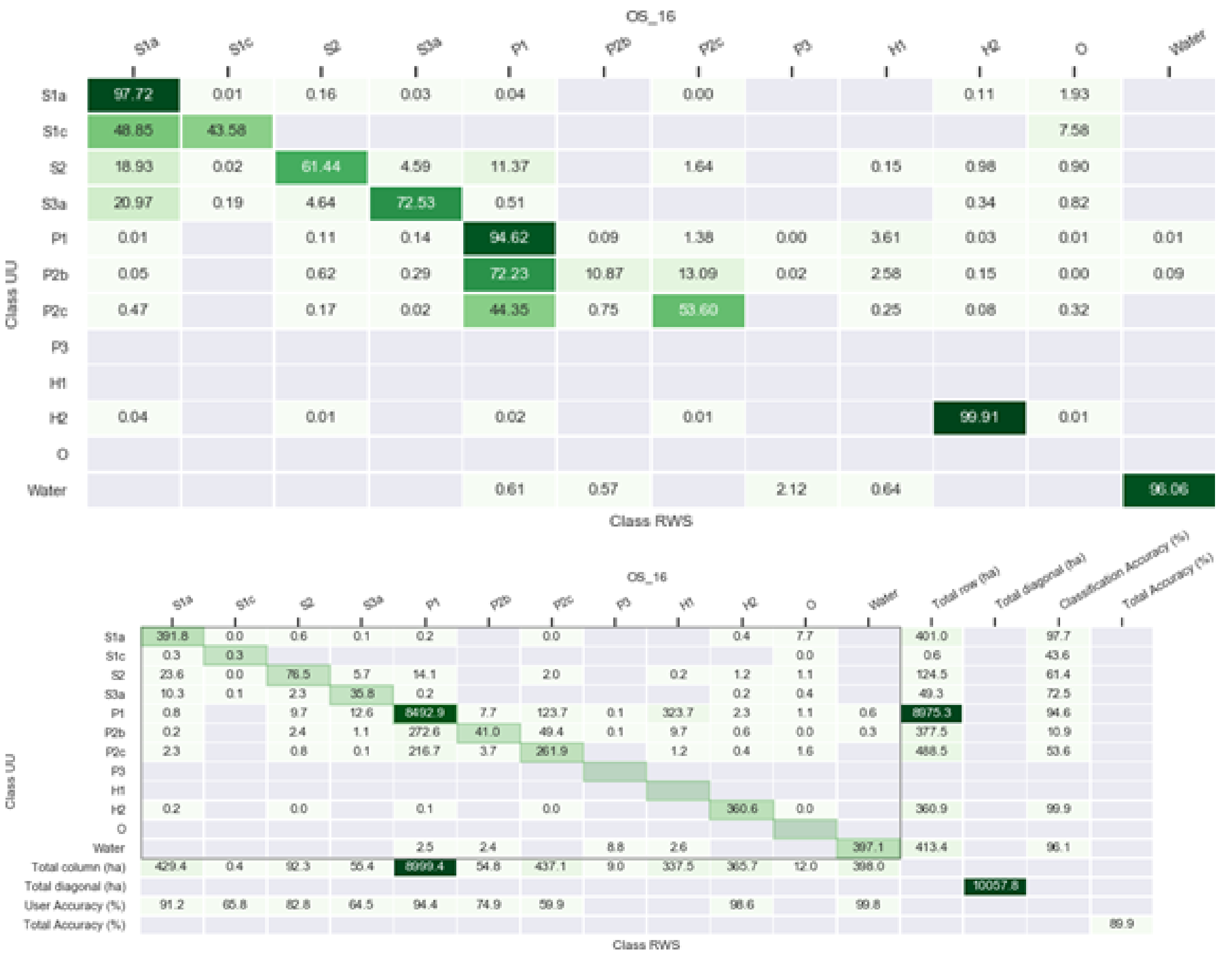

Figure S2. Confusion matrices for the Eastern Scheldt (Dutch: Oosterschelde, abbreviation OS) in 2016 for the automated method (UU) and the manual method (RWS). Top: in percentages, where the rows add up to 100%. Bottom: in hectares, with accuracy indicated in percentages. For abbreviations of class names, see Table 2 in the paper.

m, the width (in m) can be derived that this ecotope takes up for a certain distance (measured from river to coast with the highest distance at the mouth).

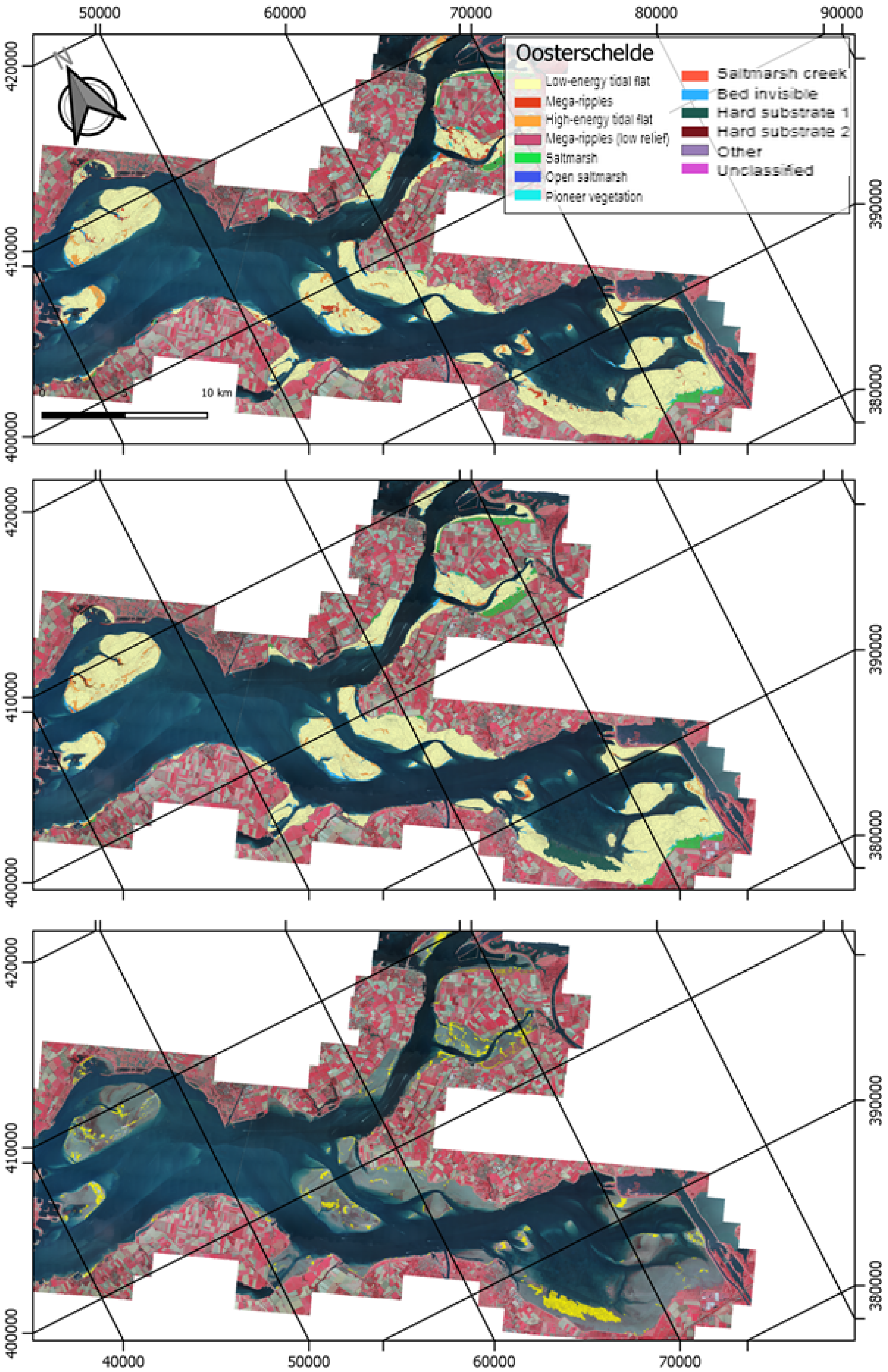

Figure S3. Top: manually created map for 2016. Middle: automated map before expert correction. Bottom: difference map in yellow, with exaggerated area due to plot line thickness.