TideSed: Time-dependent changes in the optical properties of sediments detected with remote sensing

KATHOLIEKE UNIVERSITEIT LEUVEN

UNIVERSITEIT GENT

Laboratory for Protistology and Aquatic Ecology

Marine Biology Section

Ilse Vitse, Stefanie Adam, Jaak Monbaliu

&

Tom Van Engeland, Koen Sabbe

&

Steven Degraer, Annelies De Backer, Magda Vinckx

&

Bart Deronde, Sindy Sterckx

&

Rodney Forster

Presented at the Airborne Imaging Spectroscopy Workshop, 7 October 2005, Bruges, Belgium

1. Study area

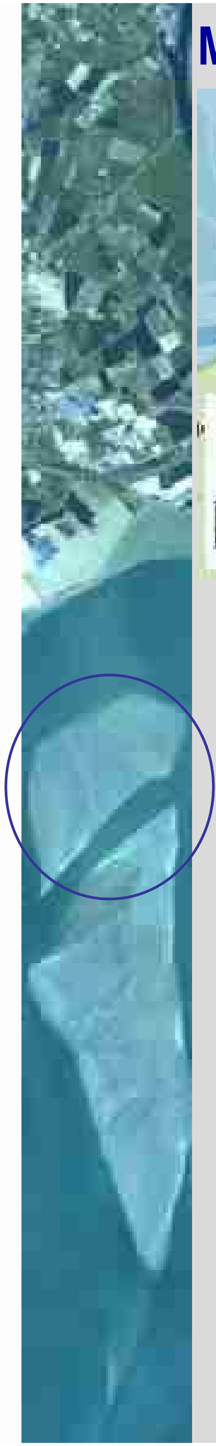
2. Objectives

3. Field Work

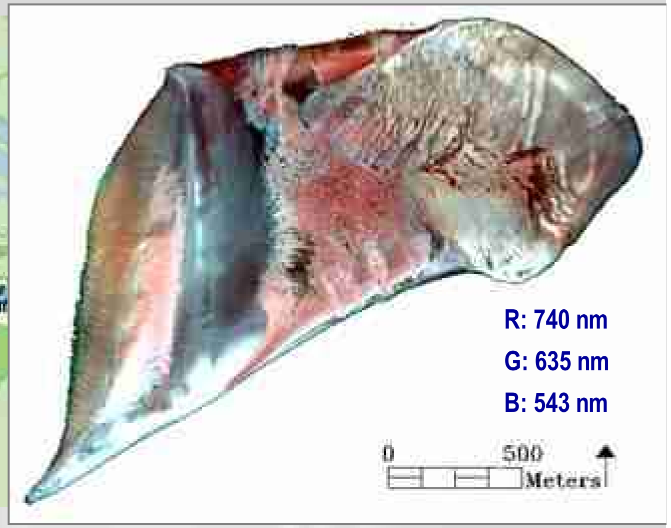
4. Methods

- Approach 1: Supervised classification
- Approach 2: Unsupervised classification
- End-user products
  - ecotope
  - chlorophyll a and primary productivity
  - erodibility

5. Conclusions



Molenplaat



HyMap sensor

- Geometrically, radiometrically and atmospherically corrected
- Characteristics

Date	06-08-2004
Moment of overflight	Between 11.40 and 12.00
Spatial resolution	4x4 m pixel size

Spectral Configuration of HyMap™			
Module	**Spectral range**	**Bandwidth across module**	**Average spectral sampling interval**
VIS	0.45 – 0.89 µm	15 – 16 nm	15 nm
NIR	0.89 – 1.35 µm	15 – 16 nm	15 nm
SWIR1	1.40 – 1.80 µm	15 – 16 nm	13 nm
SWIR2	1.95 – 2.48 µm	18 – 20 nm	17 nm

Molenplaat

- Intertidal mudflat in the Westerschelde estuary
- Located between ±1 meter relative to the mean tidal level. The mean tidal range is approximately 5 meters. The average period of emersion varies between 2 – 4 hours and 8 hours, for the highest location, per tidal cycle
- One of the largest wading bird populations in western Europe
- The estuary is a site of heavy industry, and is an important commercial shipping route

1. Study area

2. Objectives

3. Field Work

4. Methods

- Approach 1: Supervised classification
- Approach 2: Unsupervised classification
- End-user products
  - ecotope
  - chlorophyll a and primary productivity
  - erodibility

5. Conclusions

Objectives

- Investigation of the most important biological and physical parameters on the Molenplaat using HyMap imagery and field data
  - Pigment (chlorophyll a) content
  - Sediment grain size distribution
  - Water content
  - Organic matter content
- In addition, value-added products with relevance for coastal zone management will be produced
  - High-resolution map of primary production
  - Ecotope classification
  - Map of sediment stability
- Quantification of time-dependent changes during a tidal cycle in the reflectance of the sediment
- Consortium of five partners

KATHOLIEKE UNIVERSITEIT LEUVEN   NIOO   UNIVERSITEIT GENT   VITO

1. Study area

2. Objectives

3. Field Work

4. Methods

- Approach 1: Supervised classification
- Approach 2: Unsupervised classification
- End-user products
  - ecotope
  - chlorophyll a and primary productivity
  - erodibility

5. Conclusions

Field Work

1. Study area

2. Objectives

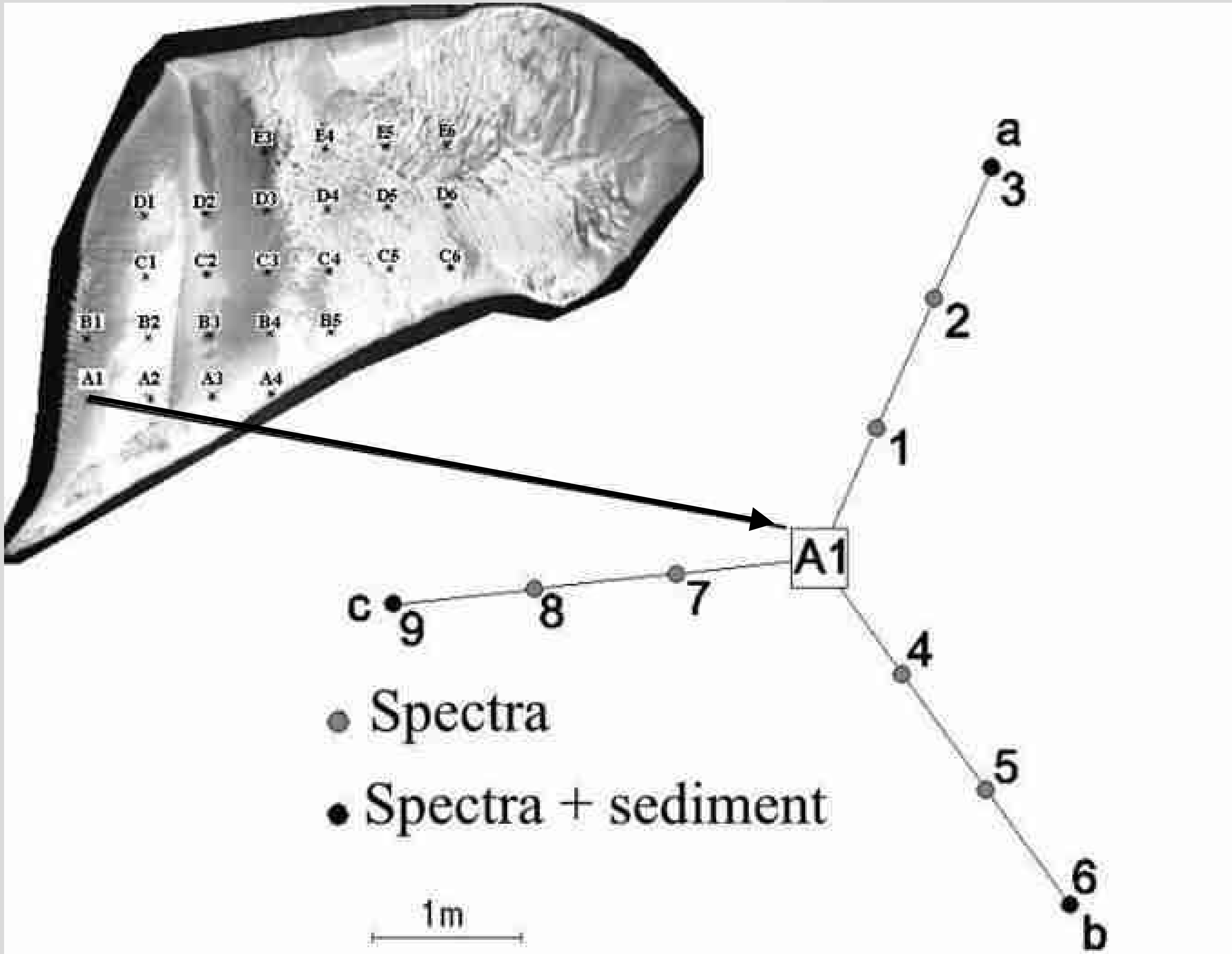
3. Field Work

4. Methods

- Approach 1: Supervised classification
- Approach 2: Unsupervised classification
- End-user products
  - ecotope
  - chlorophyll a and primary productivity
  - erodibility

5. Conclusions

Field Work



Methods

1. classification of ground truth

Grain size: mud (clay&silt>30%), muddy sand (clay&silt<30% and >15%), fine sand (clay&silt<15%)

Chlorophyll a: low (0-20mg/m^2), intermediate (20-40mg/m^2), high (>40mg/m^2)

Organic matter: low (0-2%), intermediate (2-4%), high (>4%)

Moisture content: dry (0-20%), semi-dry (20-30%), wet (30-40%), saturated (>40%)

2. supervised > VITO

Feature selection procedure

Multiple binary classification based on linear discriminant Analysis for each parameter

Integration of individual classifications into on ecotope map

3. unsupervised > KUL

Clustering of pixels using hierarchical PCT and two PC

Merging of classes based on separability measure

Labelling of classes using field data

Approach 1: Supervised classification

A. Feature selection procedure

- SFFS: sequential floating forward selection (Pudil, 1994)
- Principle: search for the best subset of features to obtain the highest classification acc's
  > Ideally: considering all possible combinations of features, but too labour intensive
  > hence, sub-optimal search algorithm: SFFS

First step: search for the one, best feature
Second step: add a second feature to obtain highest acc. with this subset
Third step: adding third feature but also removing least significant feature as long as cost function increases (= floating aspect)
X'th step: search stops if acc. decreases when adding new features

SFFS is run for each of the 4 parameters to be classified: median grain size, water content, chl a concentration, organic matter content

1. Study area

2. Objectives

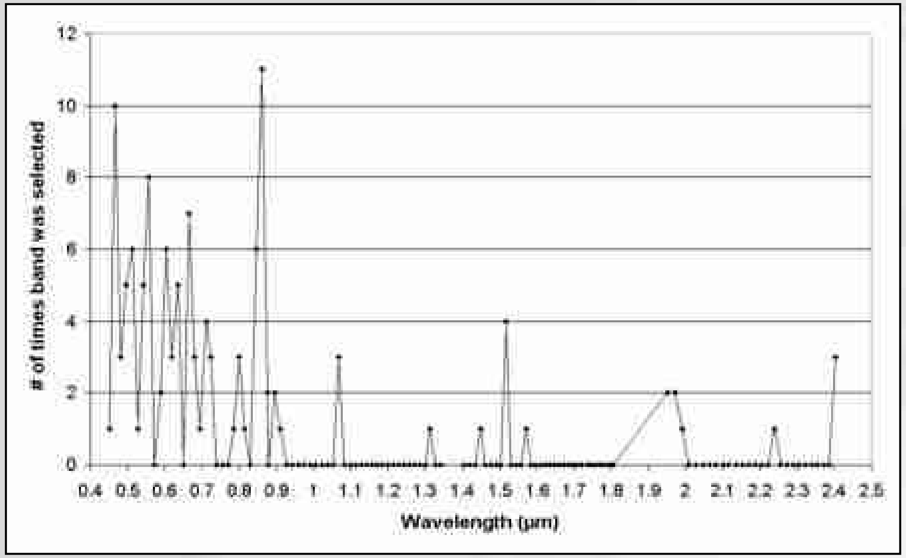
3. Field Work

4. Methods

- **Approach 1: Supervised classification**
- Approach 2: Unsupervised classification
- End-user products
  - ecotope
  - chlorophyll a and primary productivity
  - erodibility

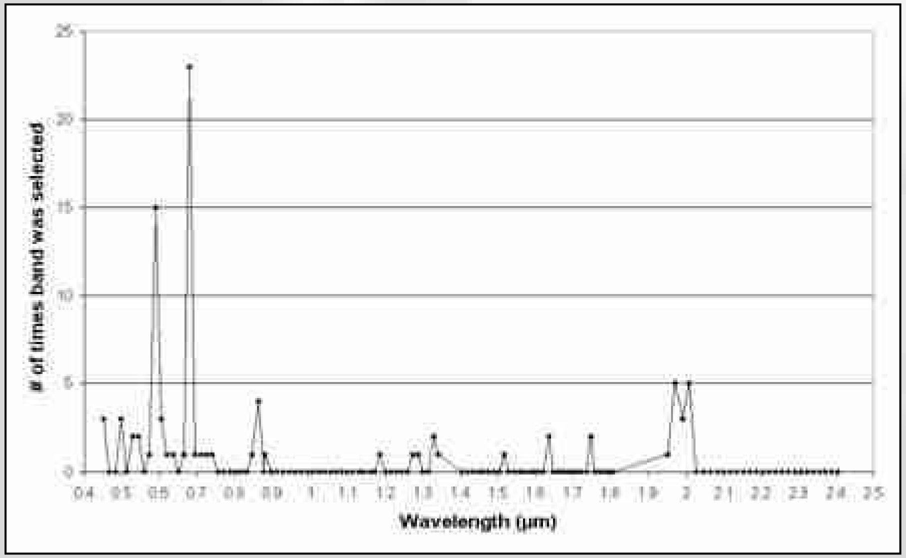
5. Conclusions

A. Feature selection procedure



Grain size

	Overall accuracy
1 band	63%
2 bands	79%
3 bands	84%
4 bands	**86%**
5 bands	86%
6 bands	86%



Chlorophyll a

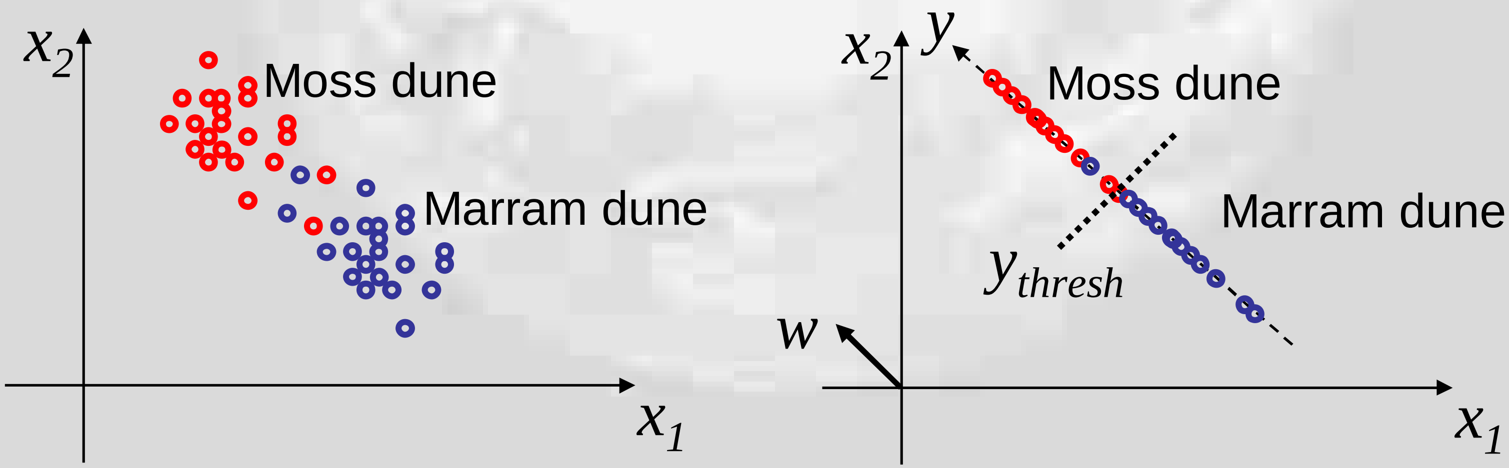
	Overall accuracy
1 band	51 %
2 bands	76 %
3 bands	**80 %**
4 bands	79 %
5 bands	81 %
6 bands	81 %
7 bands	81 %

B. Supervised classification

>> Fisher's Linear Discriminant analysis

Principle

- Make a new linear function $y=w^t x$ for which ratio "between class scatter" to "within class scatter" is maximized > max class separability!
- 2-class problem: projection to 1-dimension (*y*)
- 3-class problem: projection to 2-dimensions
  - Threshold y_{thresh} discriminates two classes



B. Supervised classification

>> Fisher's Linear Discriminant analysis

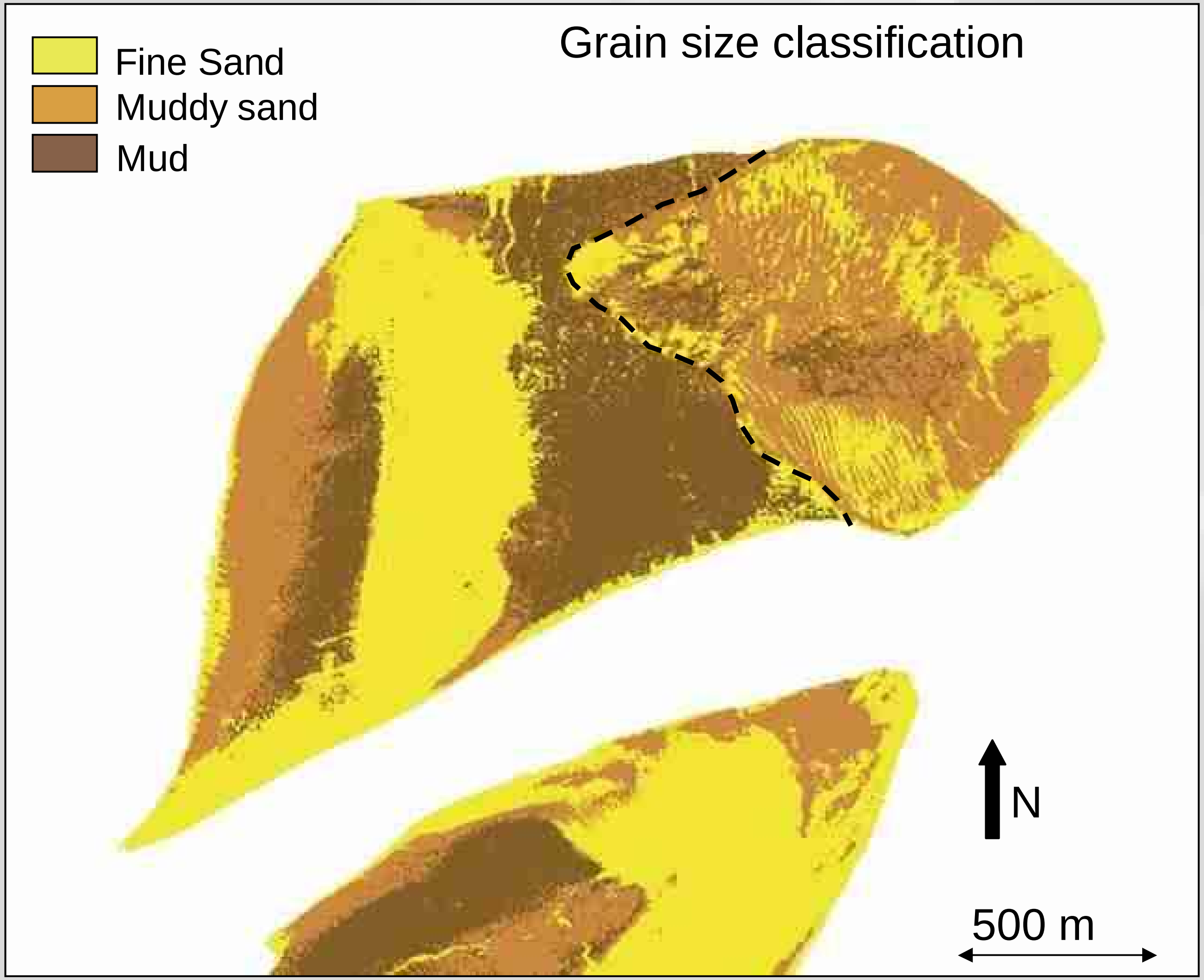
Maximum Voting: 4 class example

Bin Classifier	Result
1-2	2
1-3	3
1-4	4
2-3	2
2-4	4
3-4	4

Votes:

1 : 0
2 : 2
3 : 1
4 : 3 (Winner)

C. Results: individual classification



1. Study area

2. Objectives

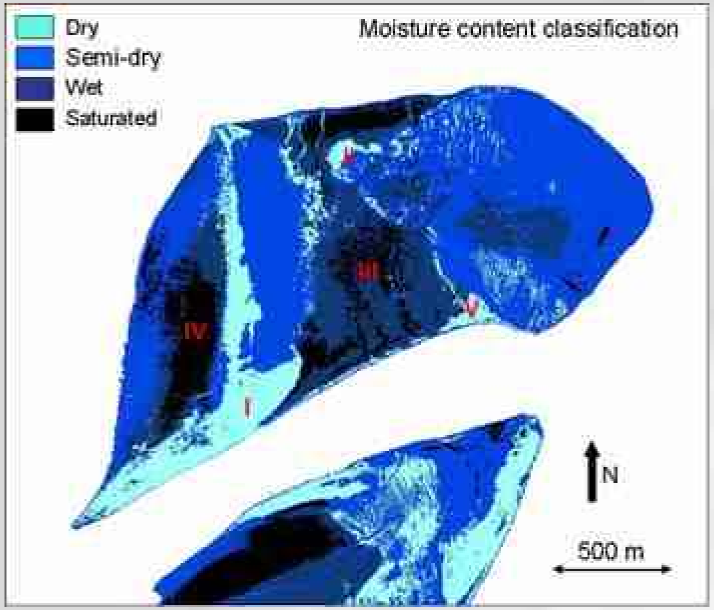
3. Field Work

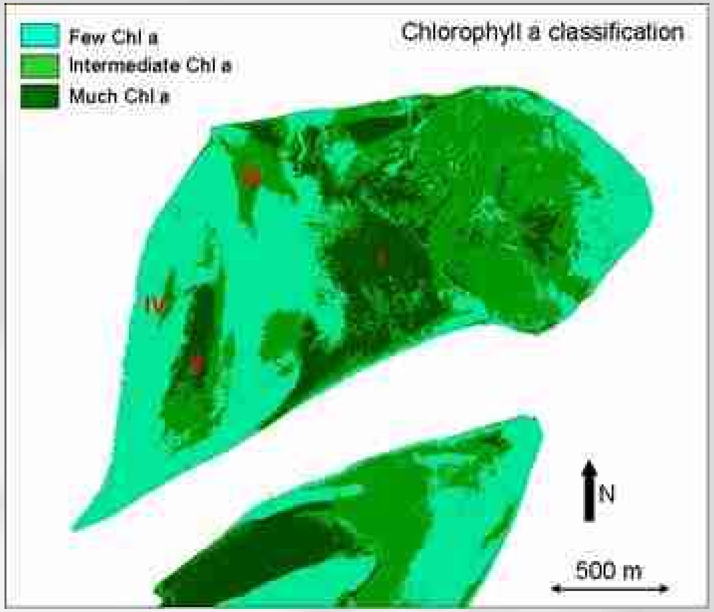
4. Methods

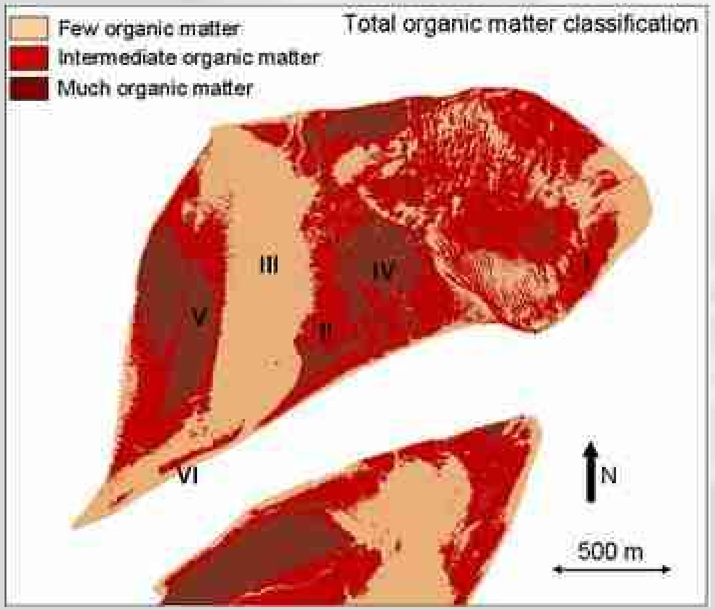
- Approach 1: Supervised classification
- Approach 2: Unsupervised classification
- End-user products
  - ecotope
  - chlorophyll a and primary productivity
  - erodibility

5. Conclusions

C. Results: individual classification







Parameters are highly correlated:

- Grain size ⟷ chl a
- Moisture content ⟷ chl a
- Organic matter ⟷ chl a

Clear distinction of two sand banks: Molenplaat and Brouwersplaat

1. Study area

2. Objectives

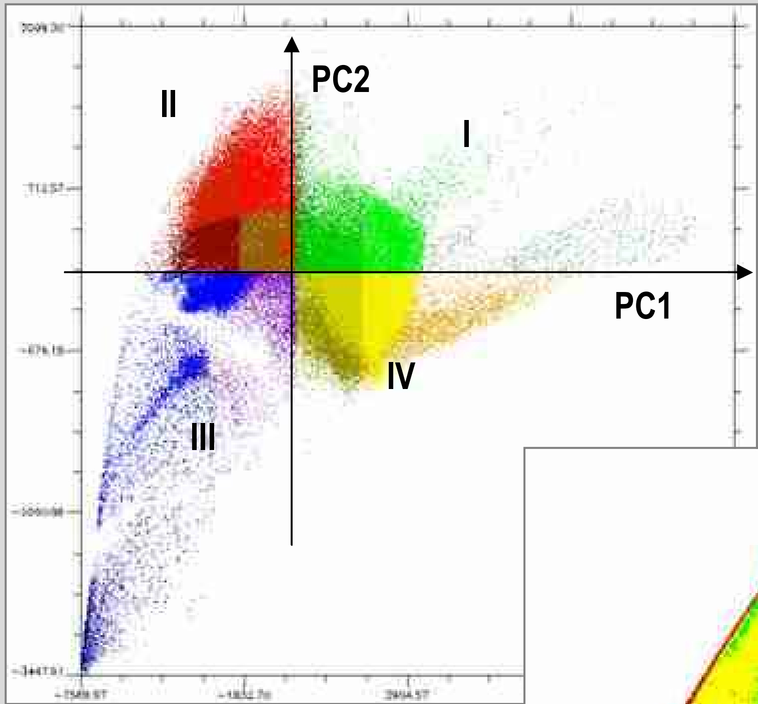
3. Field Work

4. Methods

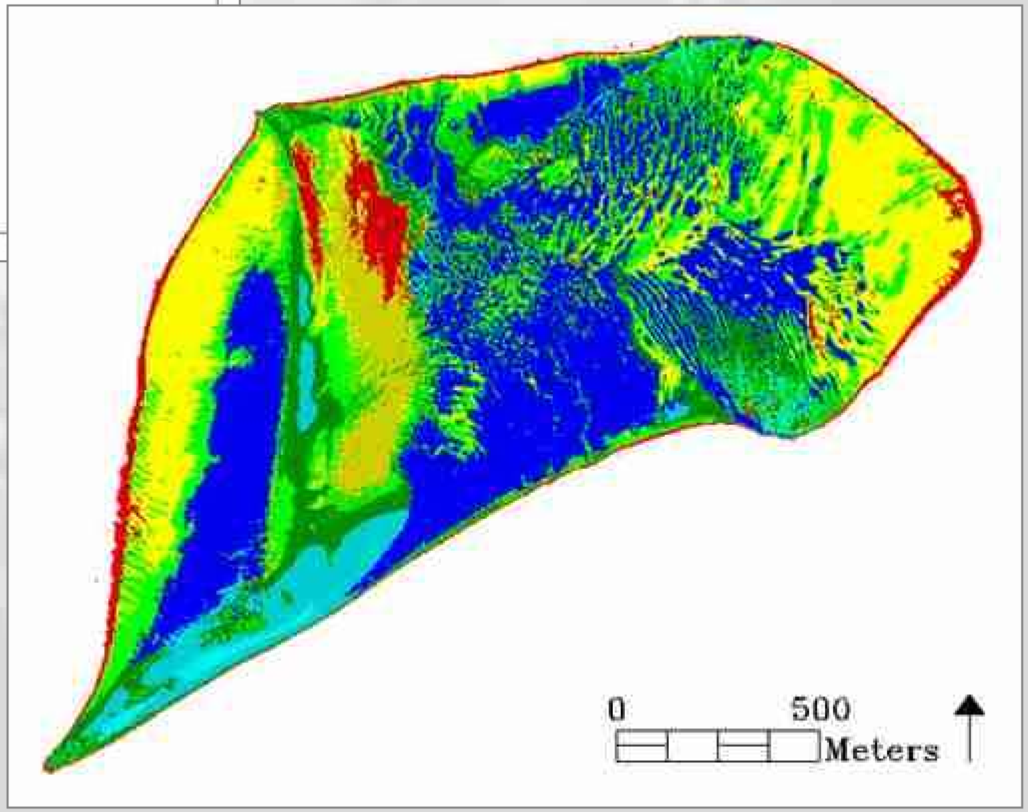
- Approach 1: Supervised classification
- Approach 2: Unsupervised classification
- End-user products
  - ecotope
  - chlorophyll a and primary productivity
  - erodibility

5. Conclusions

Approach 2: Unsupervised classification



PCT and using 2-dimensional space → 16 classes



Separability measure: JM distance

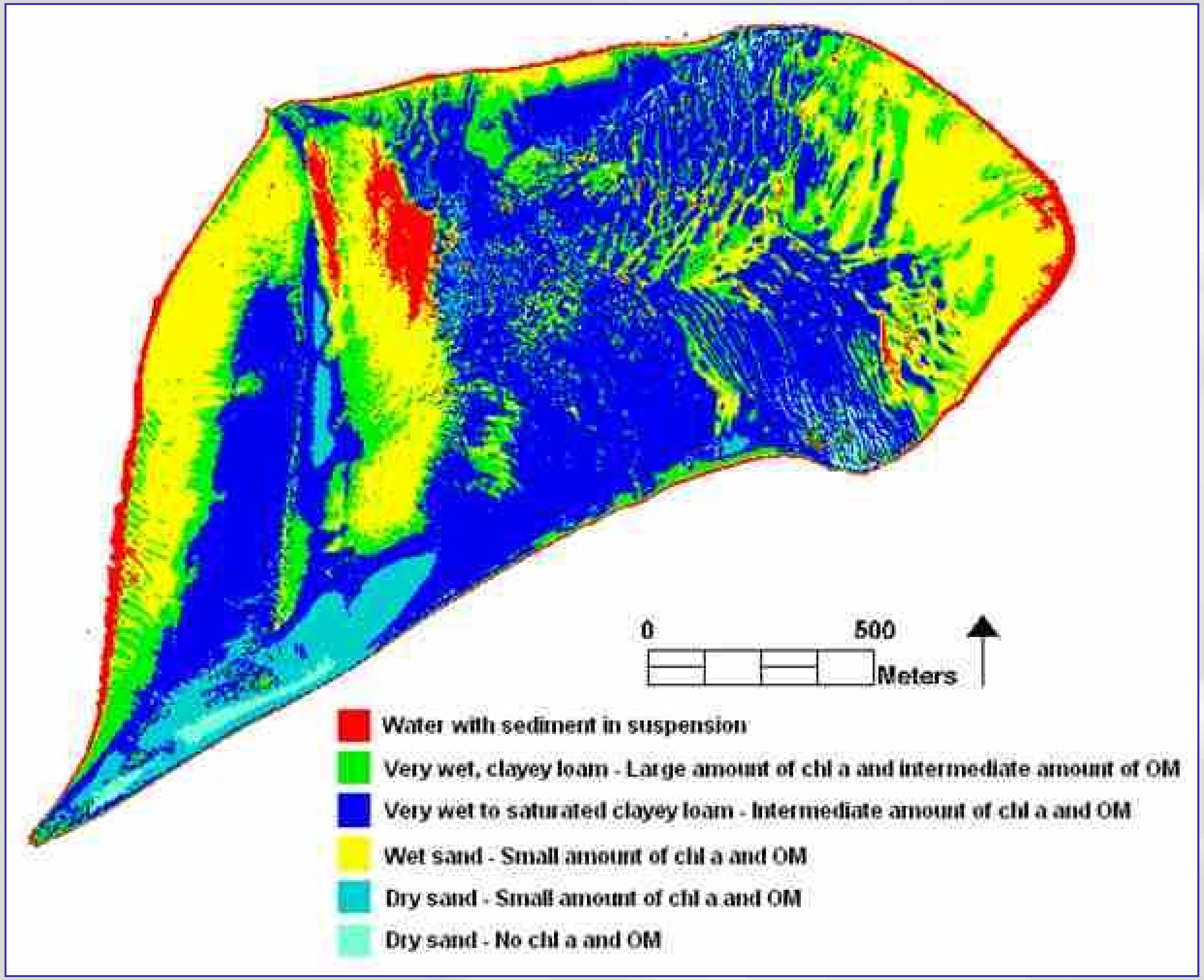
Value

➢1.9 → good separability

→ 11 classes

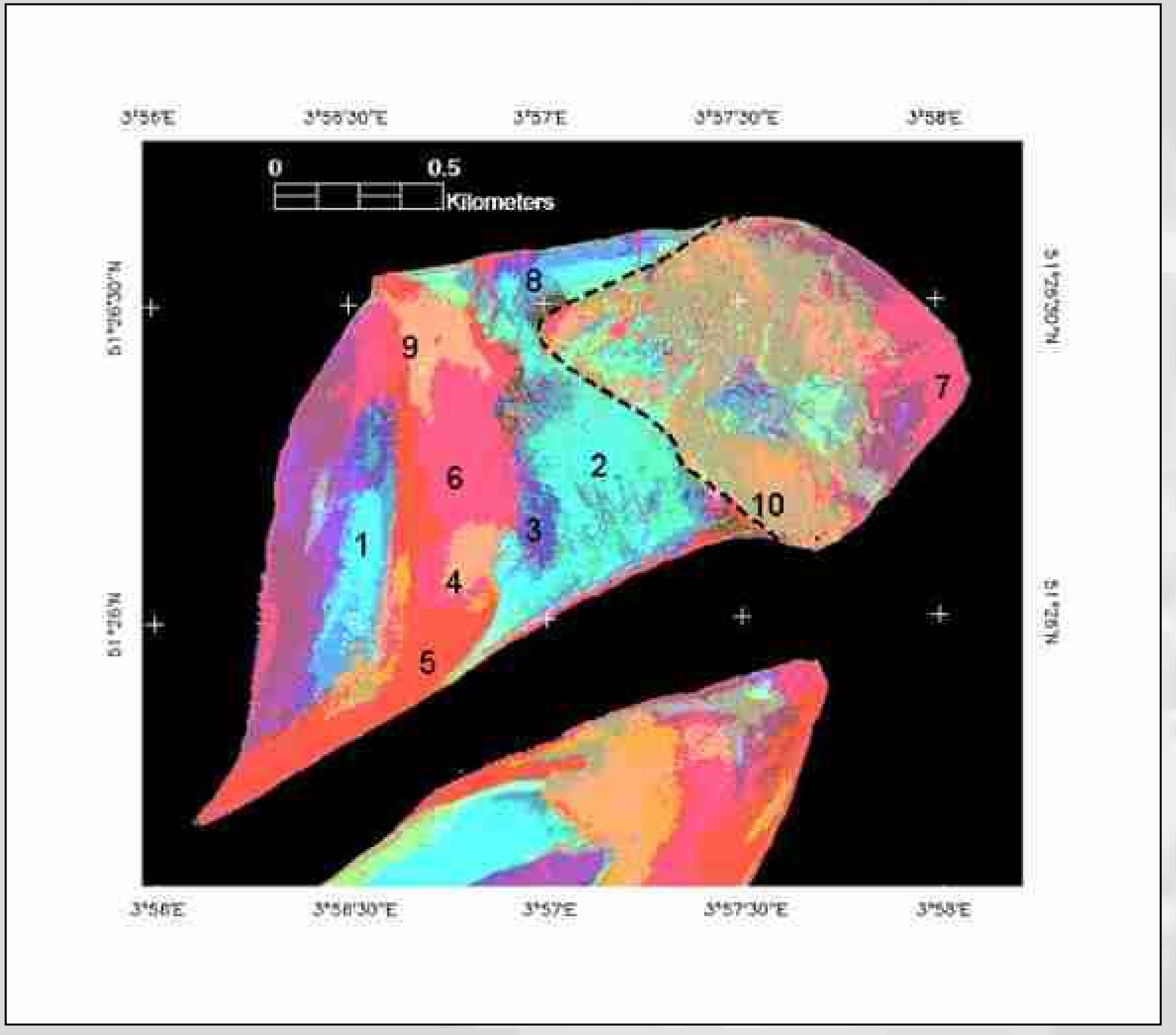
Problem: Not enough ground truth to label all the classes

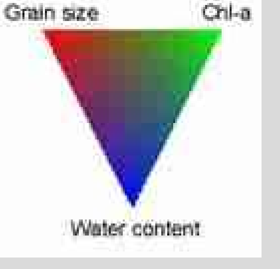
→ merging of classes



Results of unsupervised classification and comparison with supervised classification:
Vitse, I., Adam, S., Johannsen, C., Monbaliu, J., 2005. Sediment type Unsupervised Classification of the Molenplaat, Westerschelde estuary, The Netherlands. *EARSeL ePROceedings, submitted*

Ecotope map (ecotope = small, ecologically-distinct feature that supports similar populations of flora and fauna)





Results of supervised classification approach and ecotope map:
Deronde B., Kempeneers P., Forster R. and W. Debruyn, 2005, Imaging spectroscopy as a tool to study sediment characteristics on a tidal sand bank in the Westerschelde, <u>Estuarine Coastal and Shelf Science</u>, submitted.

1. Study area

2. Objectives

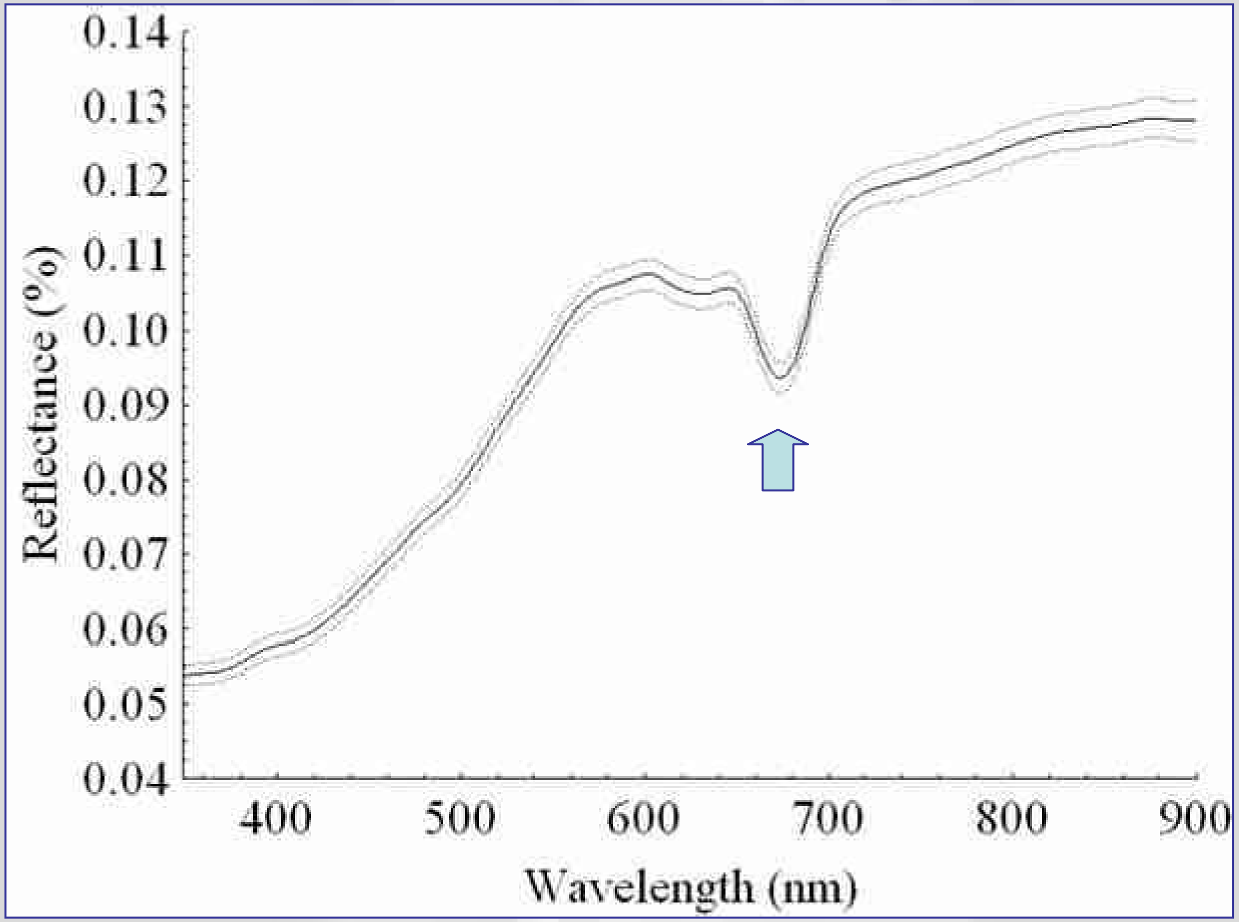
3. Field Work

4. Methods

- Approach 1: Supervised classification
- Approach 2: Unsupervised classification
- End-user products
  - ecotope
  - chlorophyll a and primary productivity
  - erodibility

5. Conclusions

Chlorophyll a and primary productivity map



1. Study area

2. Objectives

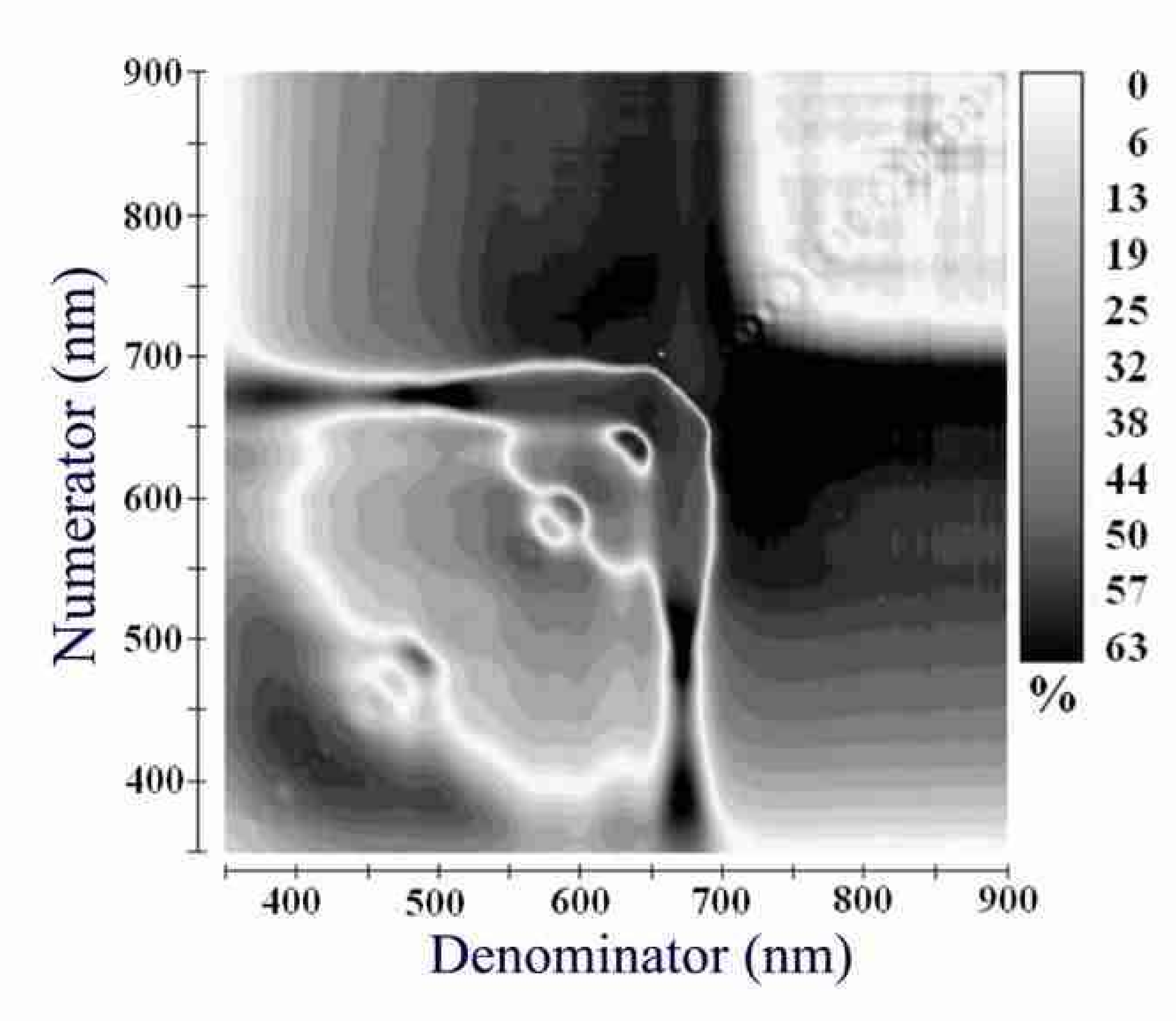
3. Field Work

4. Methods

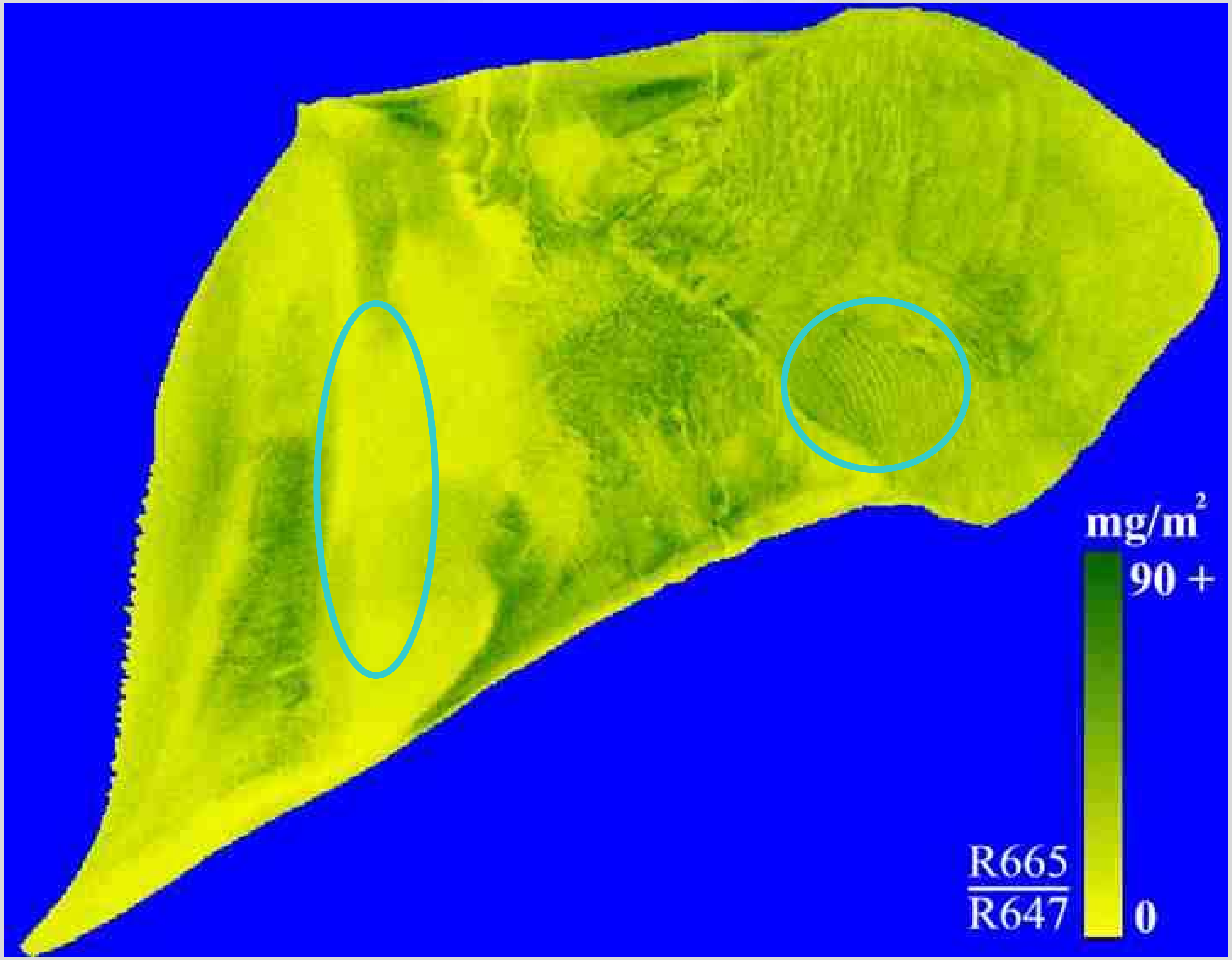
- Approach 1: Supervised classification
- Approach 2: Unsupervised classification
- **End-user products**
  - ecotope
  - **chlorophyll a and primary productivity**
  - erodibility

5. Conclusions

Ratio analysis: highest correlation with chl a concentration (field samples) for 665nm/647nm (field spectra)



Using R665/R647 for construction of chlorophyll a map



1. Study area

2. Objectives

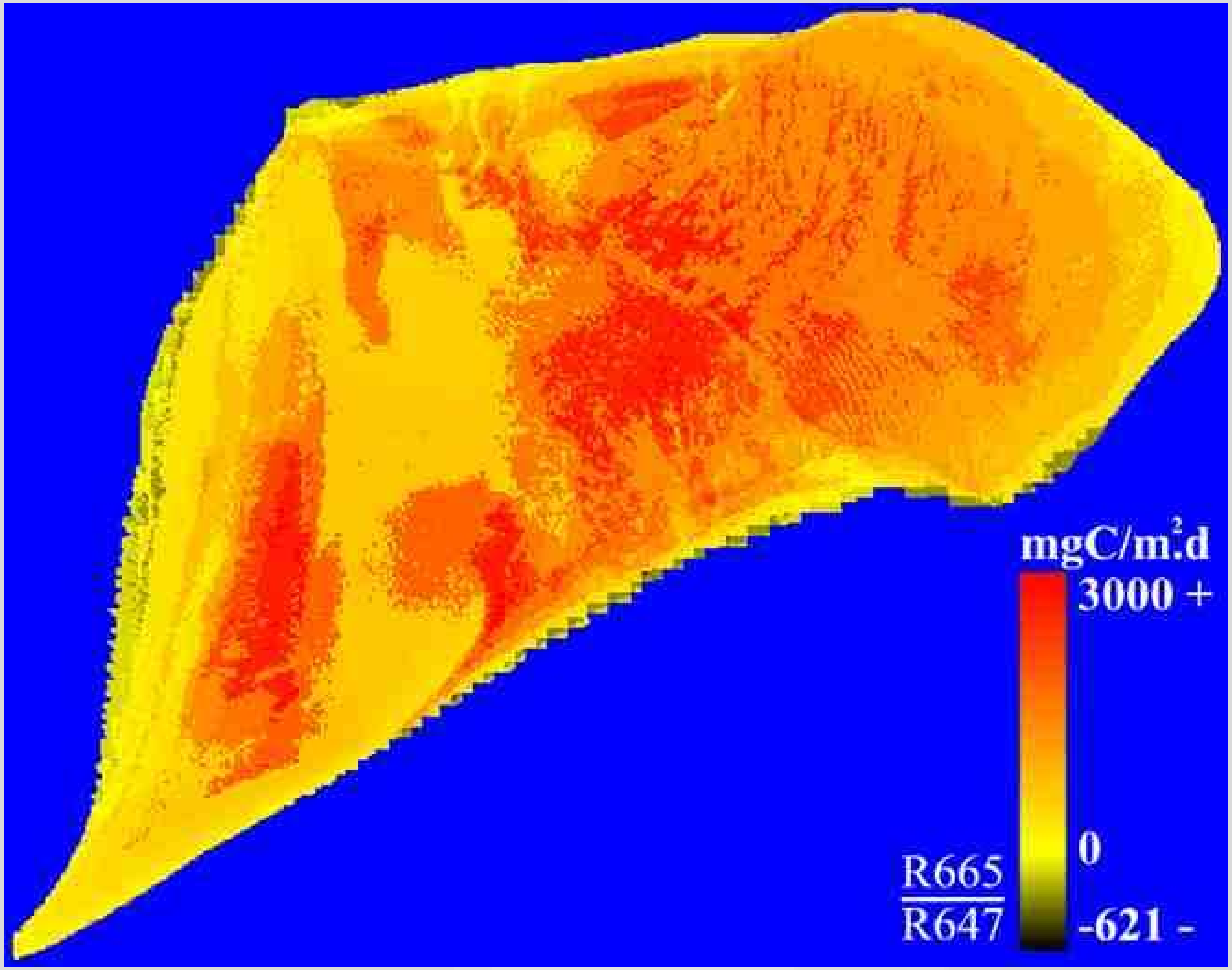
3. Field Work

4. Methods

- Approach 1: Supervised classification
- Approach 2: Unsupervised classification
- **End-user products**
  - ecotope
  - **chlorophyll a and primary productivity**
  - erodibility

5. Conclusions

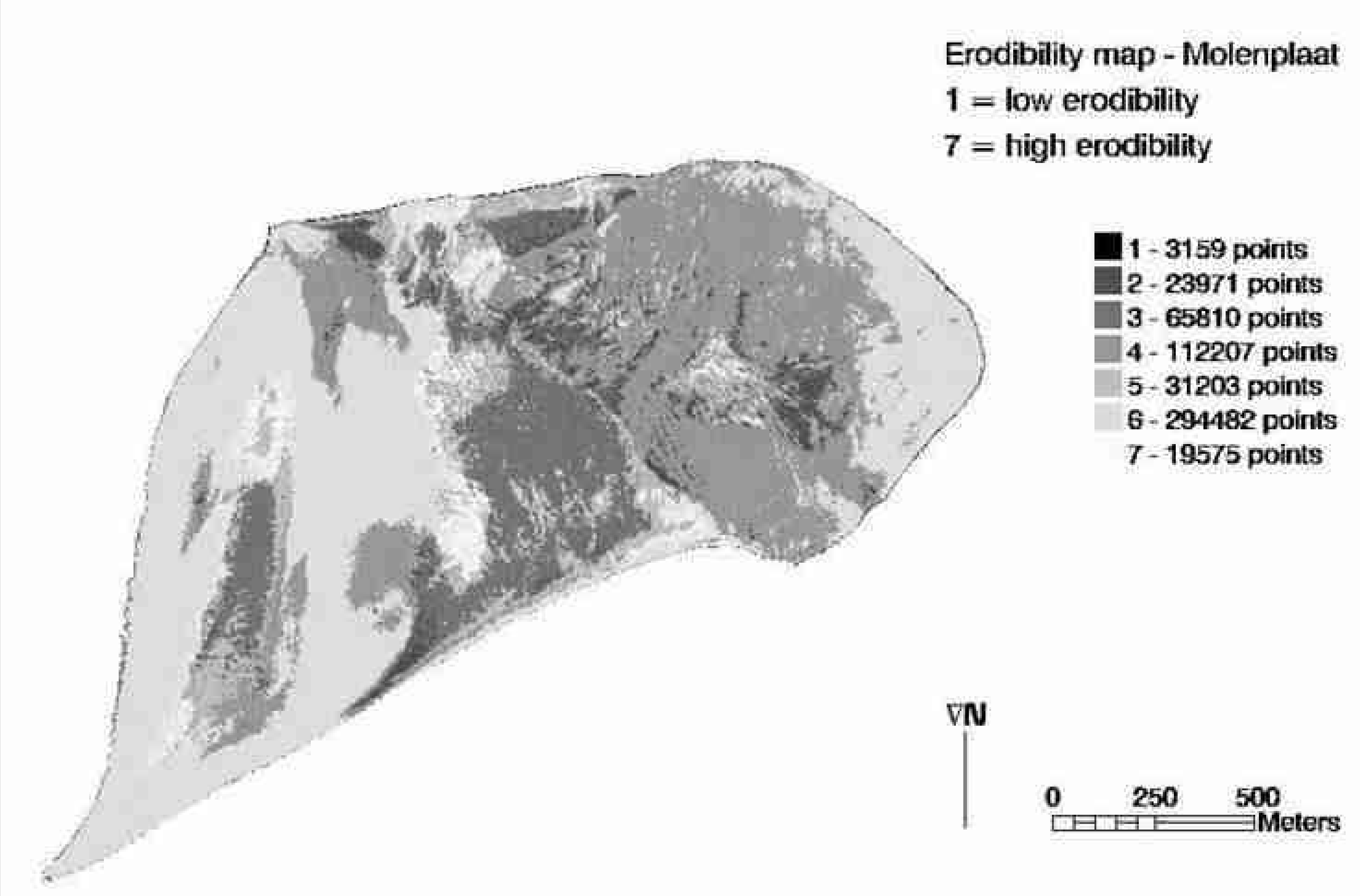
Primary productivity map using a model described in paper of R. Forster



Details in:

Van Engeland, T. 2005. Using field data and hyperspectral remote sensing to model microalgal distribution and primary production on an intertidal mudflat. Thesis for the Master of Sciences in Advanced Studies in Marine and Lacustrine sciences

Sediment stability map



Conclusions

The four parameters under investigation are highly correlated.

High accuracies were obtained in the supervised classifications of individual parameters (o.m.: 87%, grain size: 86%, chl a: 80%, water content: 81%).
In the feature selection procedure, bands in the VIS and NIR were chosen for each parameter, indicating that a common VNIR sensor is suitable for this application.

Unsupervised classification is useful in less accessible and remote intertidal areas.

Chlorophyll, primary production and sediment stability maps can be used for qualitative analysis.

Further work
- quantification of the influence of different environmental variables on a reflectance signal
- time-dependent changes of properties of intertidal mudflats during a tidal cycle
- comparison of supervised and unsupervised classification results

Acknowledgements

Belgian Science Policy Office

Maritime Access Division of the Ministry of the Flemish Community

Flanders Marine Institute – VLIZ

Poster presentations:

- VLIZ young scientists day, 25 February 2005, Brugge
- EARSeL 2nd Workshop Remote Sensing of the Coastal Zone, 9-11 June 2005, Porto
- International Conference on Dunes and Estuaries, 19-23 September 2005, Koksijde

Thesis:

- Using field data and hyperspectral remote sensing to model microalgal distribution and primary production on an intertidal mudflat - Tom Van Engeland
- Sediment type unsupervised classification of the Molenplaat, Westerschelde estuary, the Netherlands - Ilse Vitse

Papers (submitted):

- Deronde B., Kempeneers P., Forster R. and W. Debruyn, 2005, Imaging spectroscopy as a tool to study sediment characteristics on a tidal sand bank in the Westerschelde, Estuarine Coastal and Shelf Science
- Vitse, I., Adam, S., Johannsen, C., Monbaliu, J., 2005. Sediment type Unsupervised Classification of the Molenplaat, Westerschelde estuary, The Netherlands. EARSeL eProceedings,