Optilise kaugseire kasutamine merepõhja elupaikade kaardistamisel

Optical remote sensing for mapping seabed habitats

Kristjan Herkül, Mehis Rohtla, Roland Svirgsden, Jonne Kotta, Ele Vahtmäe, Tiit Kutser et al

TÜ Eesti Mereinstiuut

Uuringu tellis ja uuringut rahastab Eesti Teadusagentuur ERF-ist programmi RITA kaudu. Uuring valmib Keskkonnaministeeriumi eesmärkide elluviimiseks

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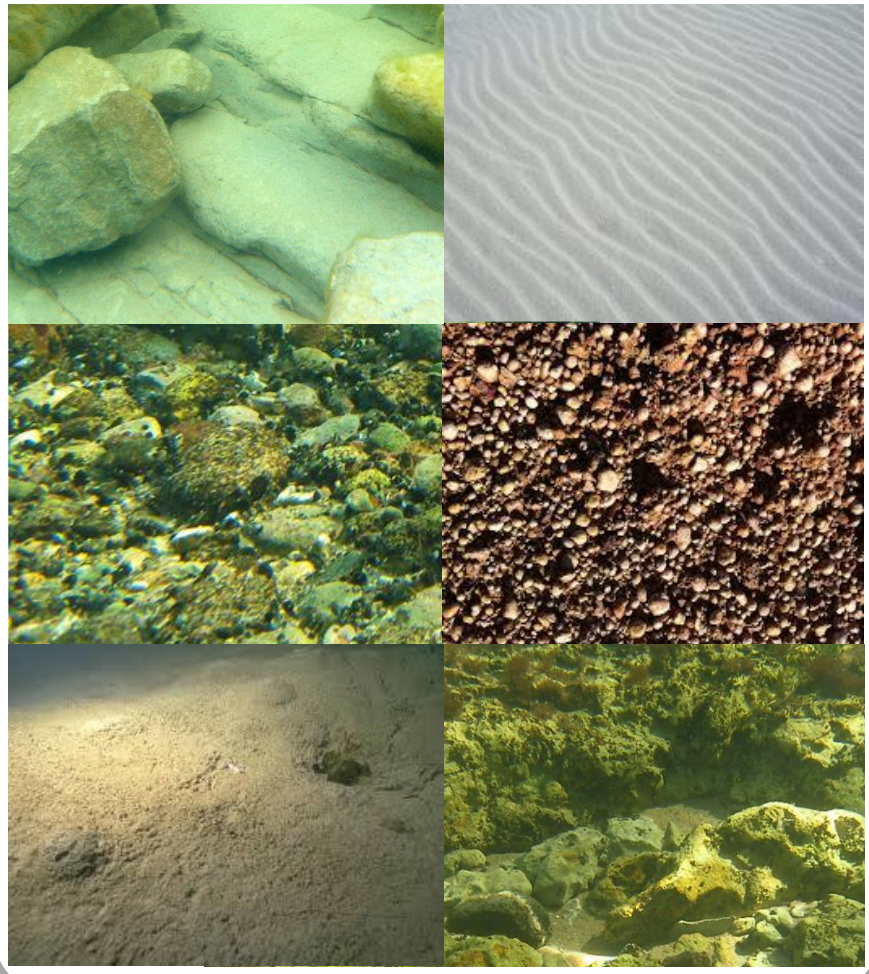
Introduction

- Project activities:
  - 2.3.1. Optical remote sensing for mapping seabed habitats
  - 2.6.1. Mapping different features of fish spawning sites with remote sensing
- General aim: development of methodology of mapping shallow water seabed habitats (incl. fish spawning and nursery areas) using different optical remote sensing imagery (airborne orthophoto mosaics, hyperspectral imagery, satellite imagery) together with *in situ* sampling and mathematical modeling.

Substrate

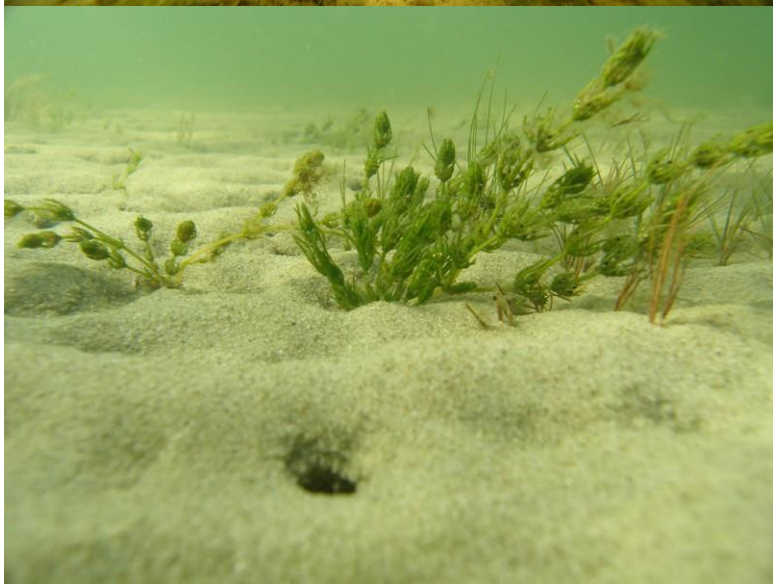


Phytobenthos

Zoobenthos

Reefs

Sandbanks



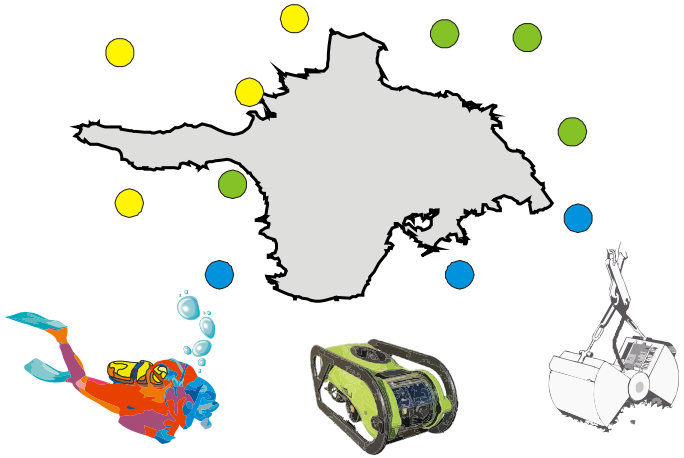
Why mapping of benthic habitats?

- Fundamental research
- Applied research
  - Environmental impact assessment
  - Environmental monitoring
  - Maritime spatial planning
  - Marine protected areas
  - Fish spawning and nursery areas
- EU obligations
  - Habitats directive (92/43/EEC)
  - Marine strategy framework directive (2008/56/EC)
  - Maritime spatial planning directive (2014/89/EU)

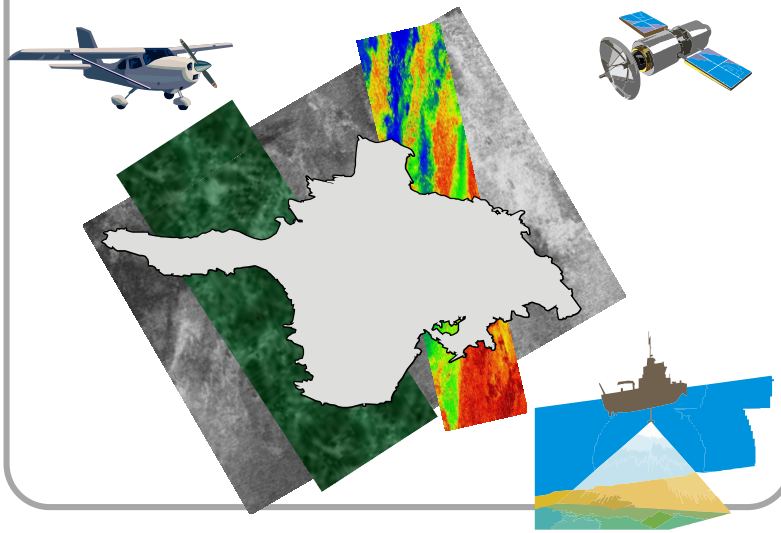
Fish spawning and nursery areas

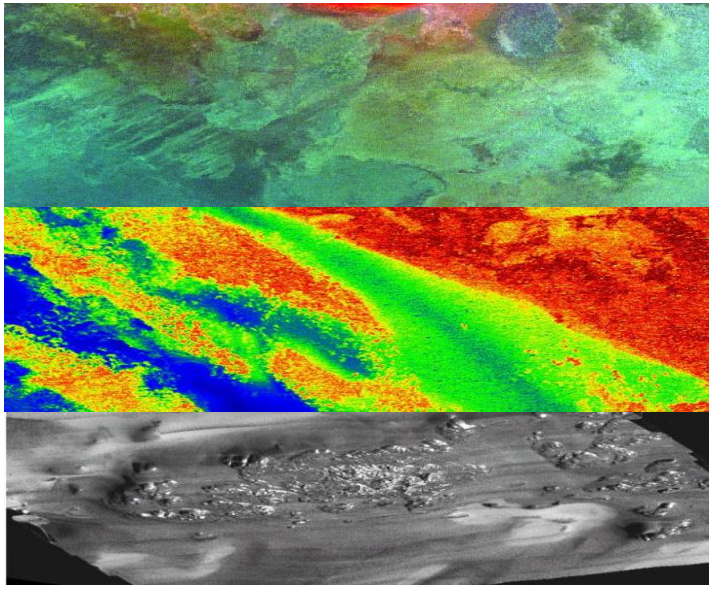
- Potential species: pike, roach, ide, burbot
- Focus species – pike
- General preferences
  - Mainly spawning in fresh water
  - Dense vegetation (cover > 50%): hatched larvae attach to vegetation, later hiding
  - Water depth 0.2-1 m
- Preferences in fresh water
  - Flooded meadows/wetlands
  - Sedges, grasses, aquatic mosses, watermilfoils, charophytes, reed
  - Water depth 0.2-0.5 m
- Preferences in coastal areas
  - Dense vegetation
  - Common reed, charophytes, aquatic mosses, bladder wrack?
  - Water depth 0.2-1 m, several meters in open water
  - Freshwater influence

In situ research: substrate, biota

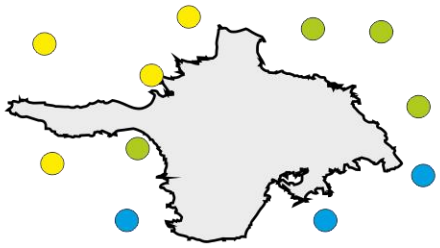


Remote sensing: optical, acoustic reflectance





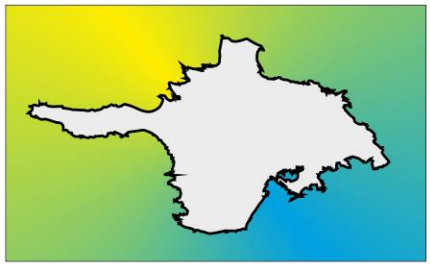
Response variable
point data of species



Predictor variables
GIS layers of environmental data

Model
GAM
BRT
RF

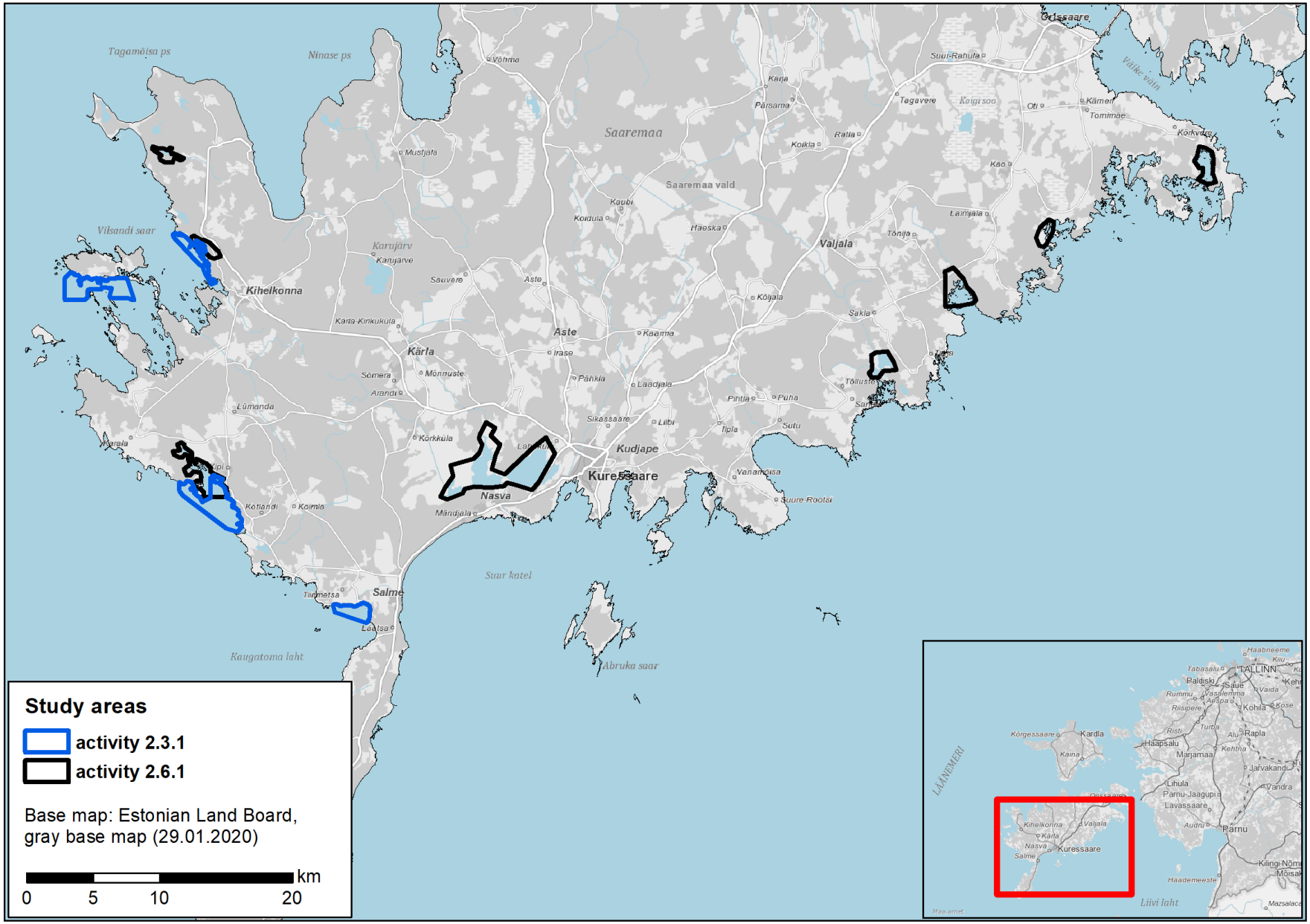
Prediction
occurrence of species



Model assessment

- validation (model accuracy)
- importance of predictiors
- shape of relationships

Material & methods



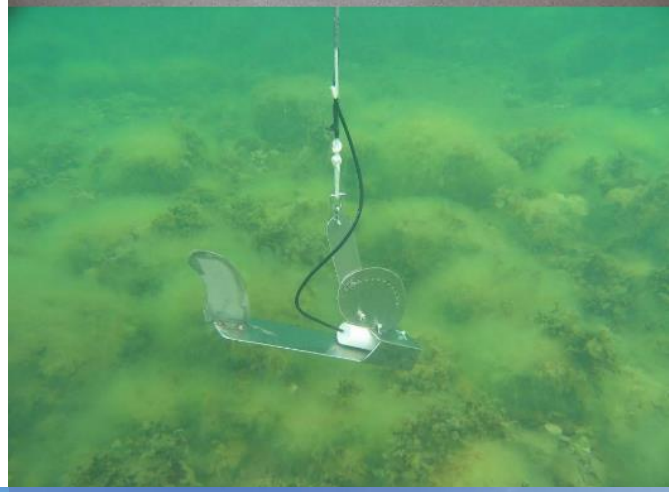
Remote sensing data

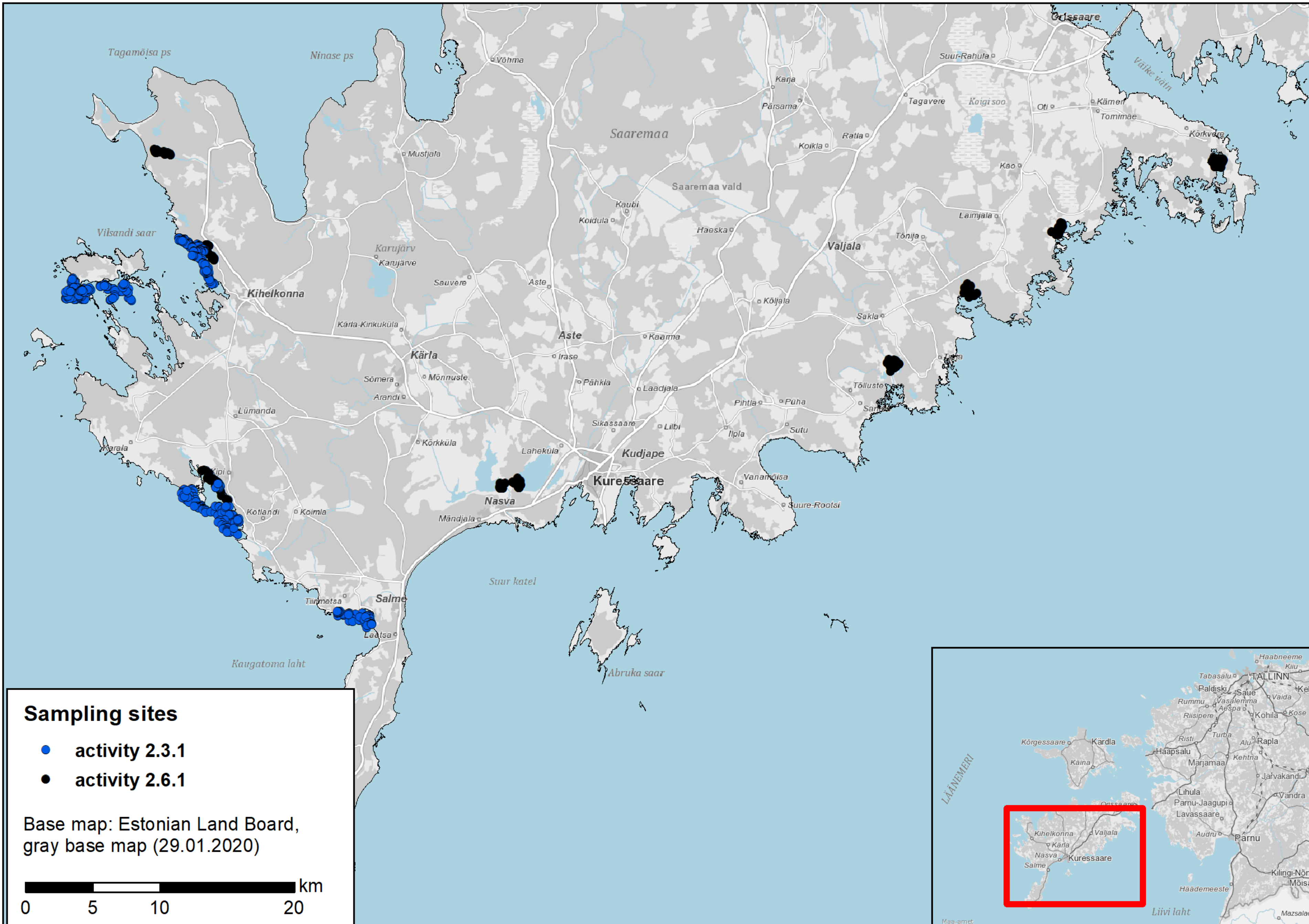
- Ortophotos of Estonian Land Board (LB)
  - RGB & NIR
  - 20 cm spatial resolution
  - 2017, 2019
  - Sun glint removal (Hedley et al 2005)
  - Model input: R, G, B, R/G, G/B, R/B
- Drone orthophotos
  - DJI Phantom 4 Pro V2.0
  - RGB
  - 3-6 cm spatial resolution
  - June, July 2019
  - Model input: R, G, B, R/G, G/B, R/B

- Hyperspectral imagery
  - Hyperspectral imager Hyspex (Norsk Elektro Optikk)
  - TU EMI's instrument on Land Board's airplane
  - 409-988 nm, 2.7 nm spectral resolution, 216 bands
  - 80 cm spatial resolution
  - July 2019
  - Model input:
    - Selected 12 bands
    - 12 first PCA components
- Sentinel-2 satellite imagery
  - 443-740 nm, 6 bands
  - 10-20 m spatial resolution
  - June, July 2019
  - Model input: 6 bands

In situ sampling

- 500 sites in 2.3.1
- 176 sites in 2.6.1
- Underwater video, handheld camera, direct observations
- Percentage cover of seabed substrate types, macrophytes, epibenthic bivalves, barnacles

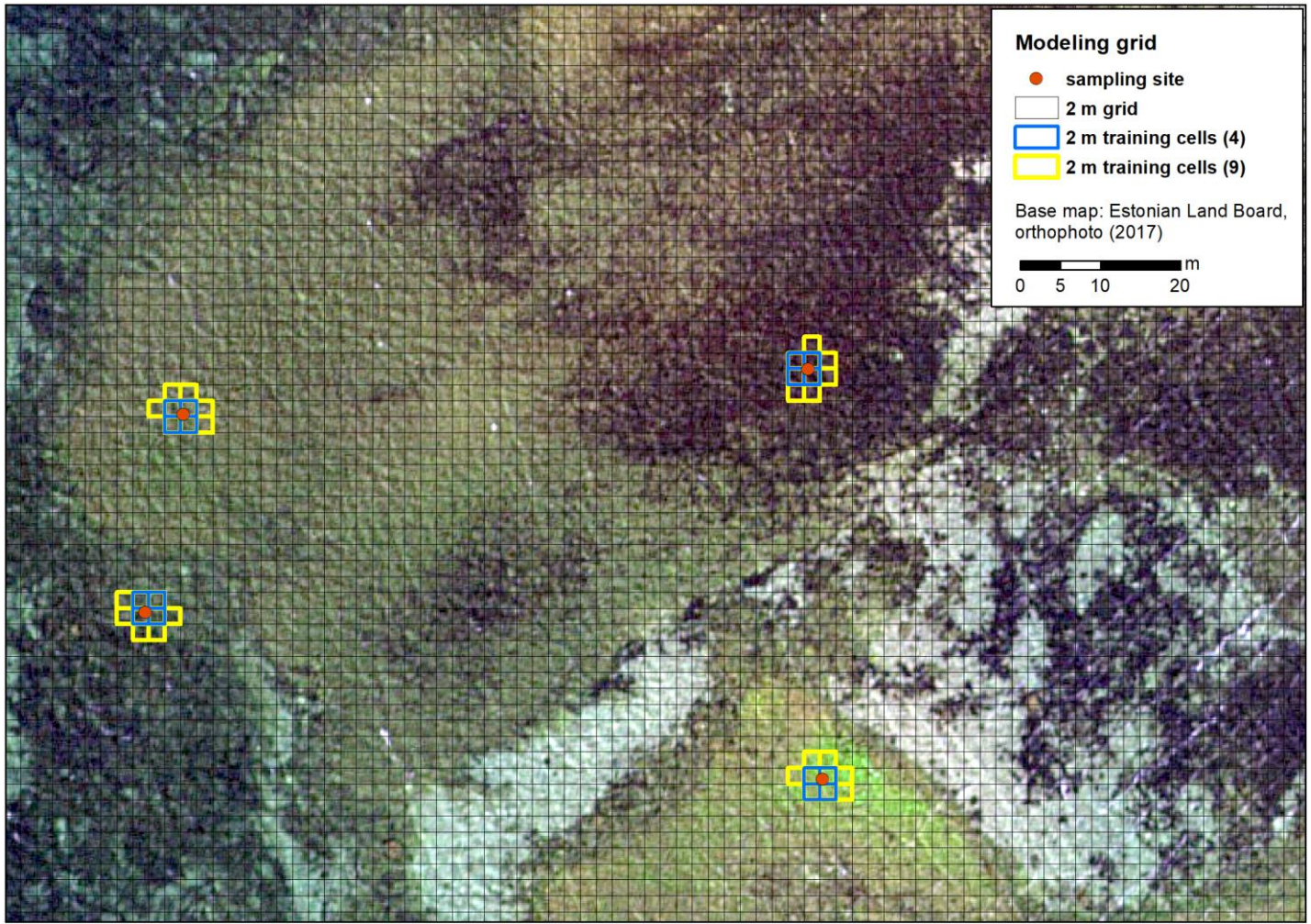




Sampling sites
activity 2.3.1
activity 2.6.1
Base map: Estonian Land Board,
gray base map (29.01.2020)
0
5
10
20
km
Saaremaa
Saaremaa vald
Kihelkonna
Kärla
Aste
Valjala
Kudjape
Kuressaare
Nasva
Salme
Vilsandi saar
Tagamõisa ps
Ninase ps
Suur katel
Abruka saar
Kaugatoma laht
Väike väin
LÄÄNEMERI
Liivi laht

Compilation of training and prediction data sets

- 2 m modeling grid, mean and st. dev. in each cell
- LB orthophoto and Hyspex: 4 and 9 nearest cells to sampling site



- Drone orthophoto: manual selection of grid cells
- Satellite: pixel value of sampling site

Modeling

- Algorithms
  - Random forest (RF)
  - Boosted regressioon trees (BRT)
  - Neural networks (NN)

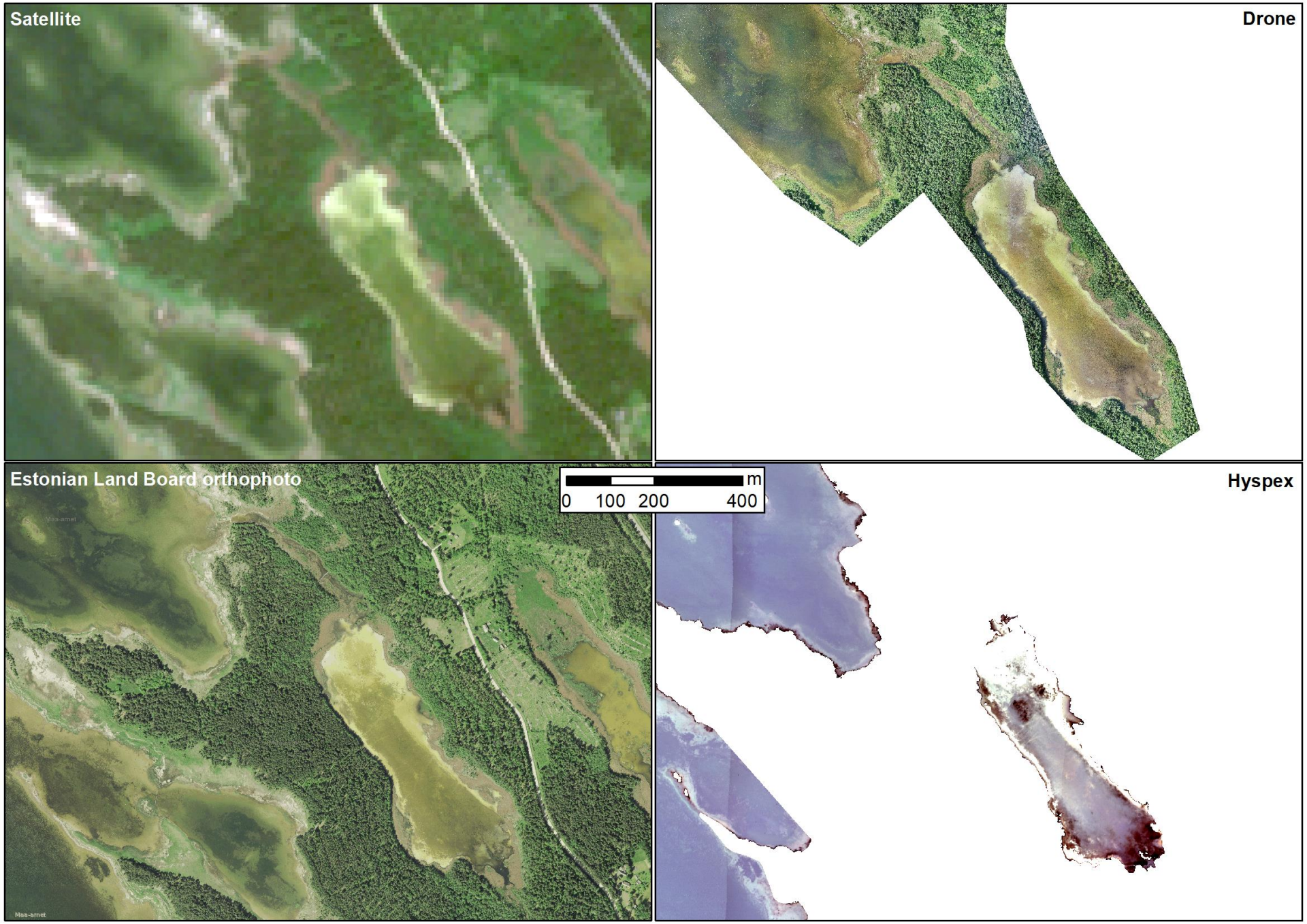
- Response variables
  - Seabed class (2.6.1)
  - Depth of water column (2.6.1)
  - Presence of reed belt (2.6.1)
  - Cover of hard substrate
  - Cover of sand
  - HELCOM HUB substrate type
  - Total cover of macrovegetation
  - Key species/groups: *Fucus*, *Zostera*, charophytes, filamentous algae, green algae, brown algae, red algae
- Additional predictor variables:
  - Depth
  - Wave exposure
  - Geographical coordinates

- Different sets of remote sensing predictors and additional predictors
- Area-based and pooled models
- R

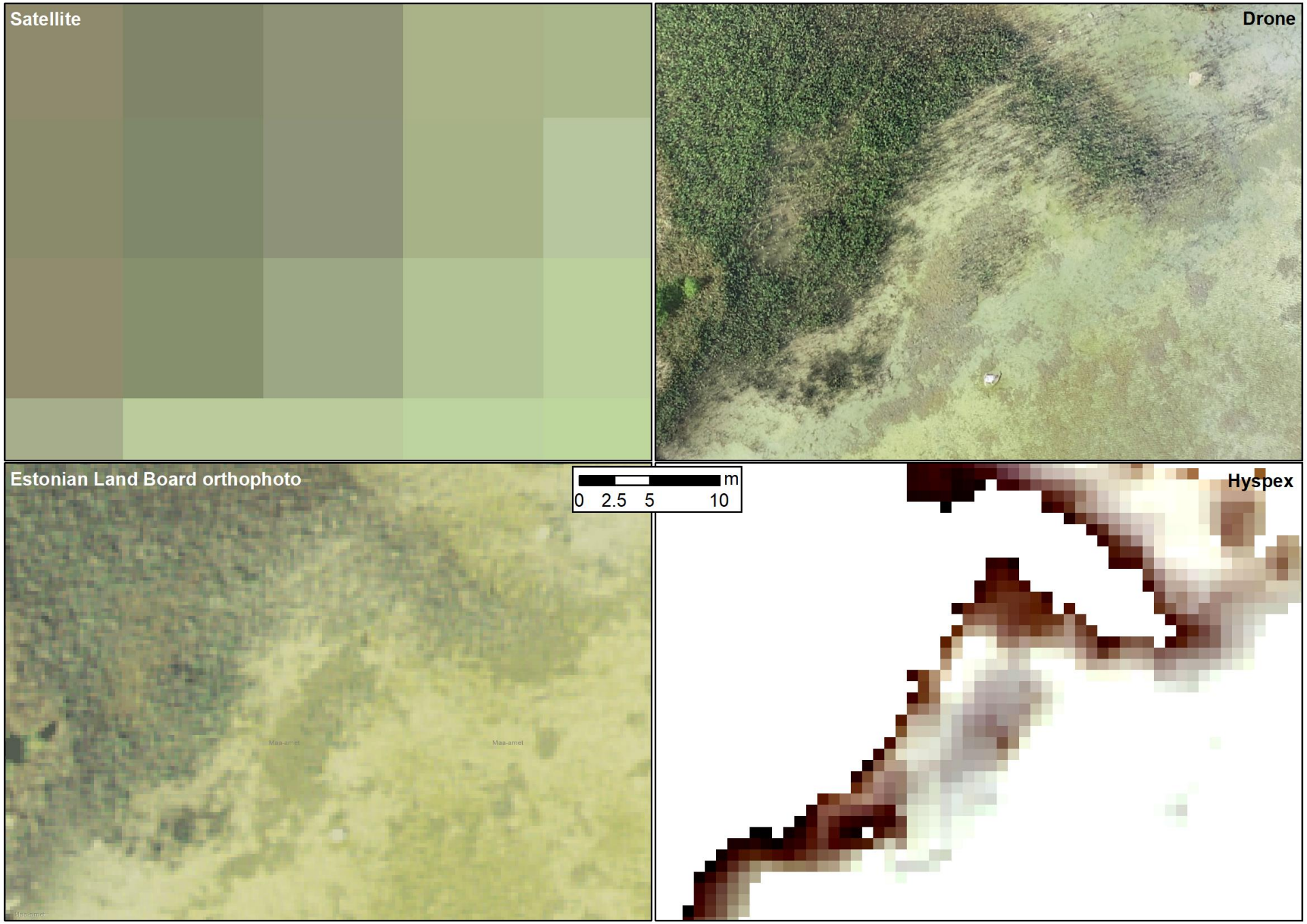
Model validation

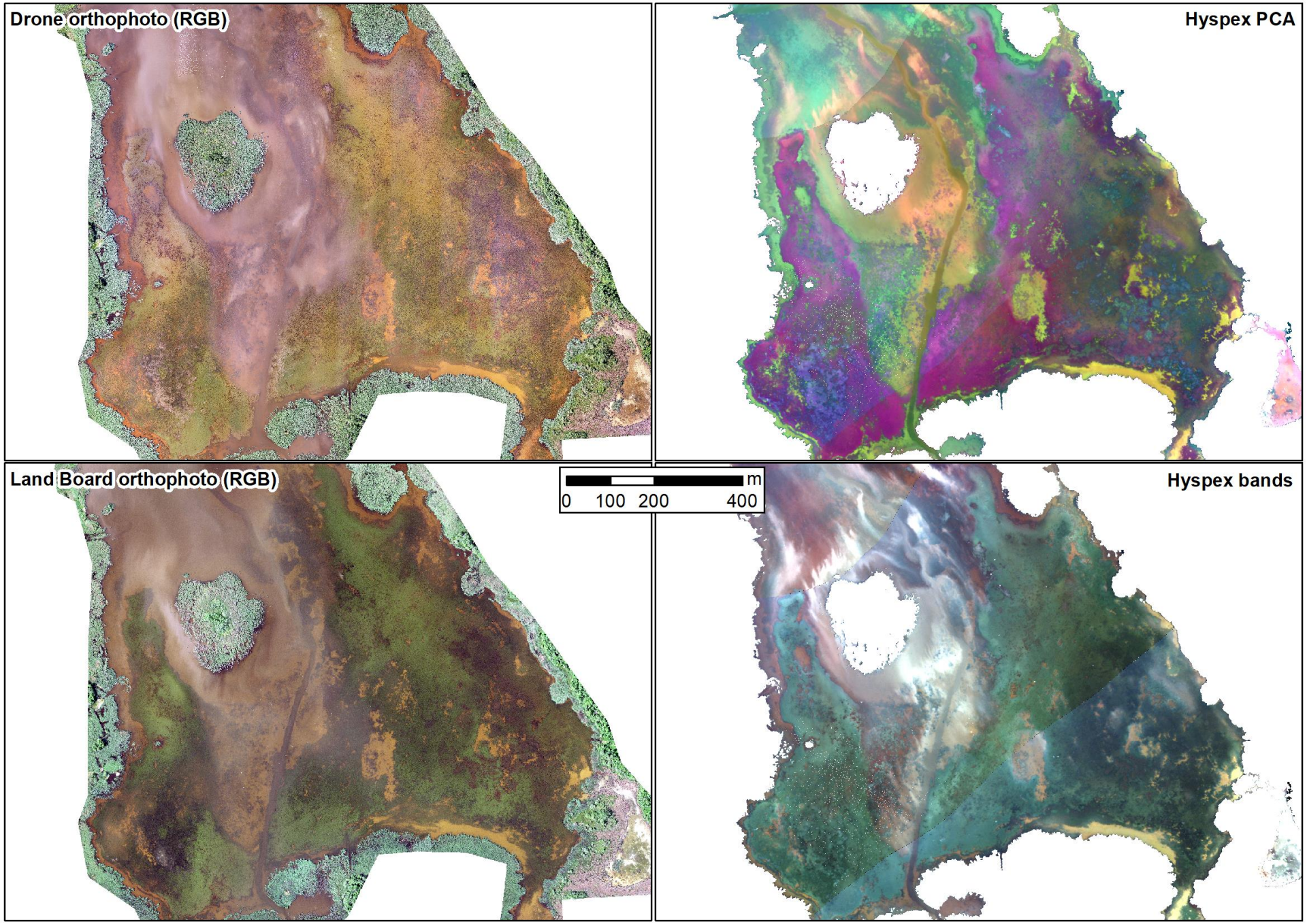
- Mathematical
  - 25% data reserved for external validation
  - 100% data for spatial predictions
  - Correlation coefficient, mean absolut error, classification accuracy, Kappa coefficient
- Visual expert assessment

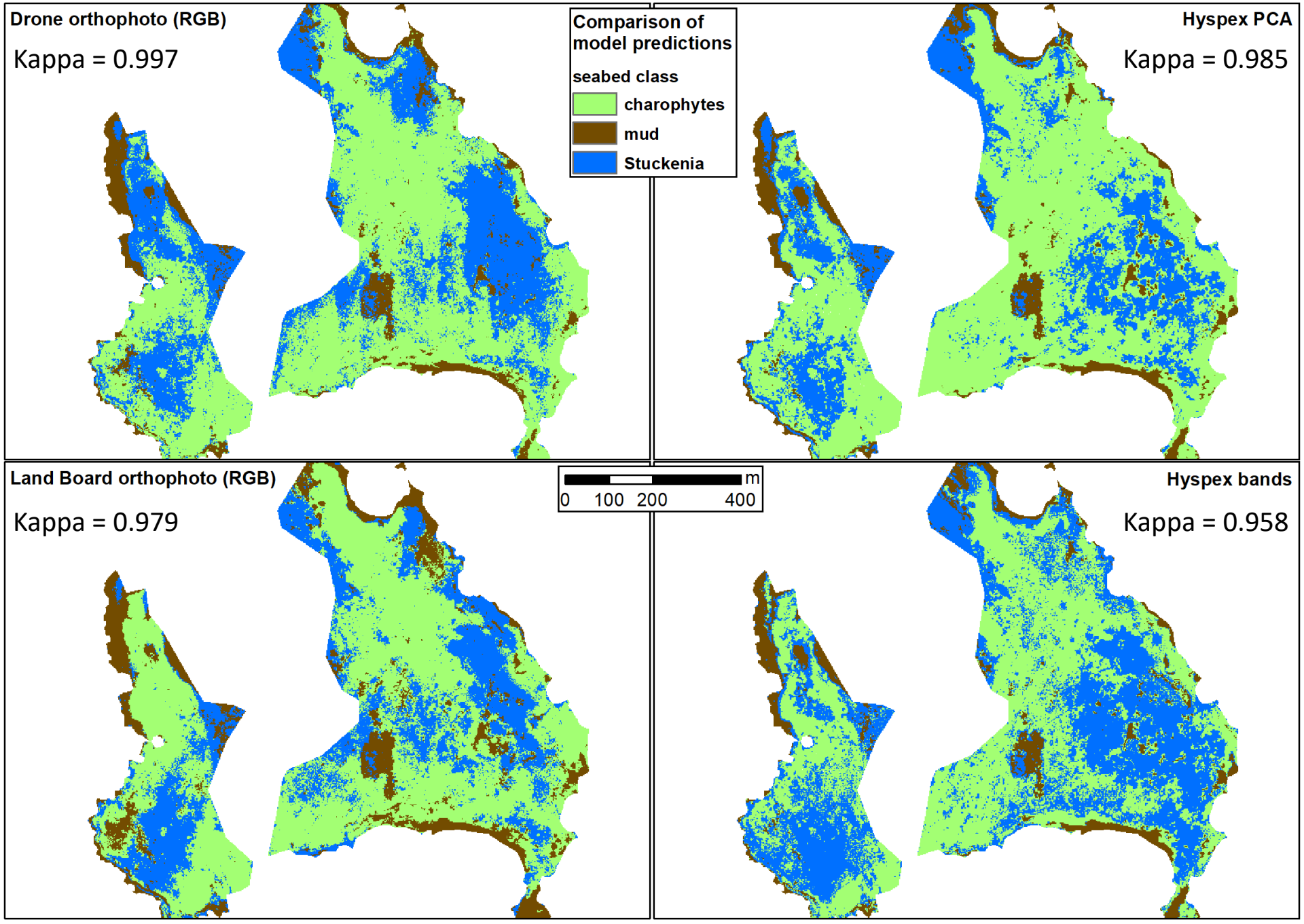
Results

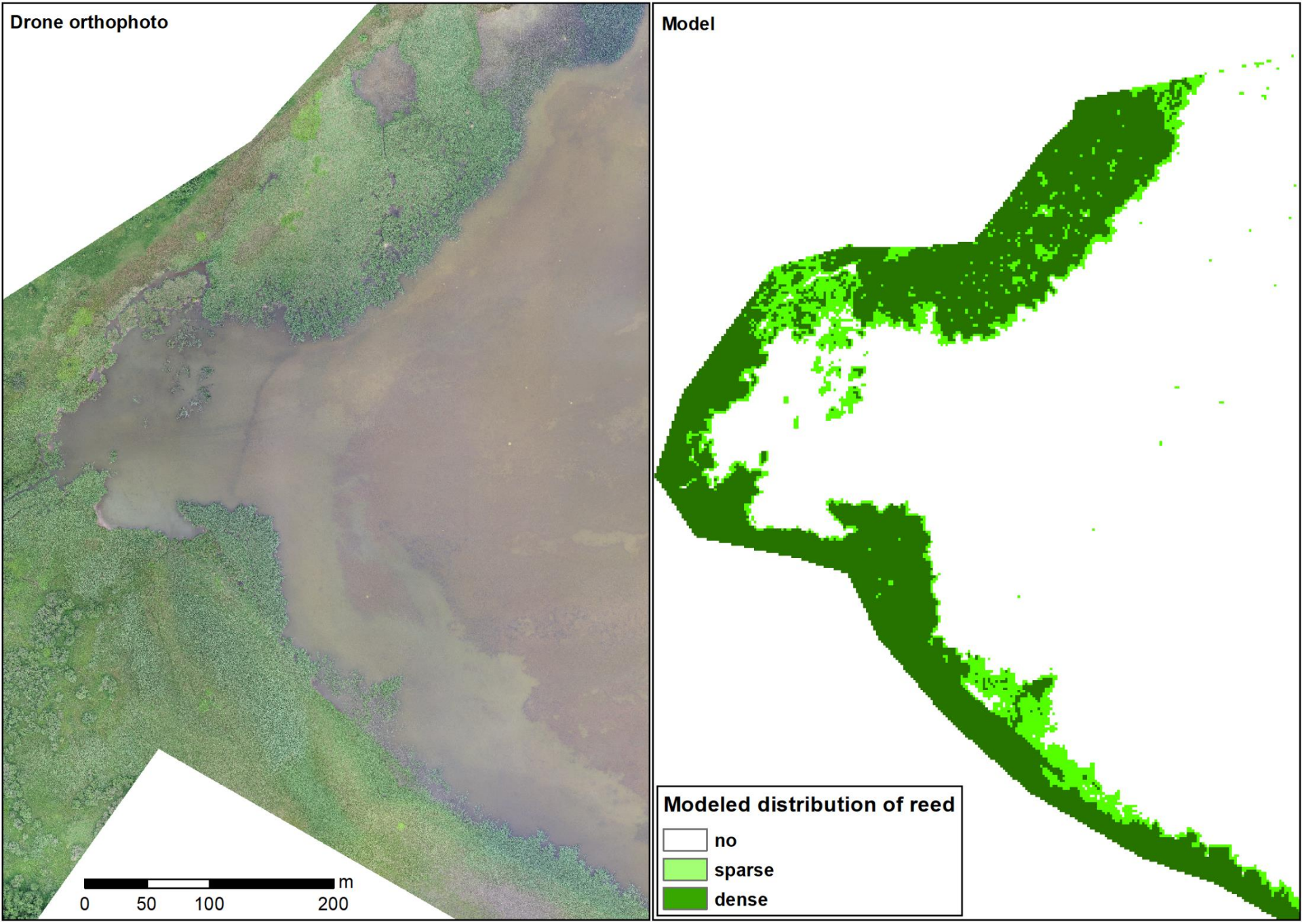

Satellite
Drone
Estonian Land Board orthophoto
m
0 100 200 400
Maa-amet
Hyspex

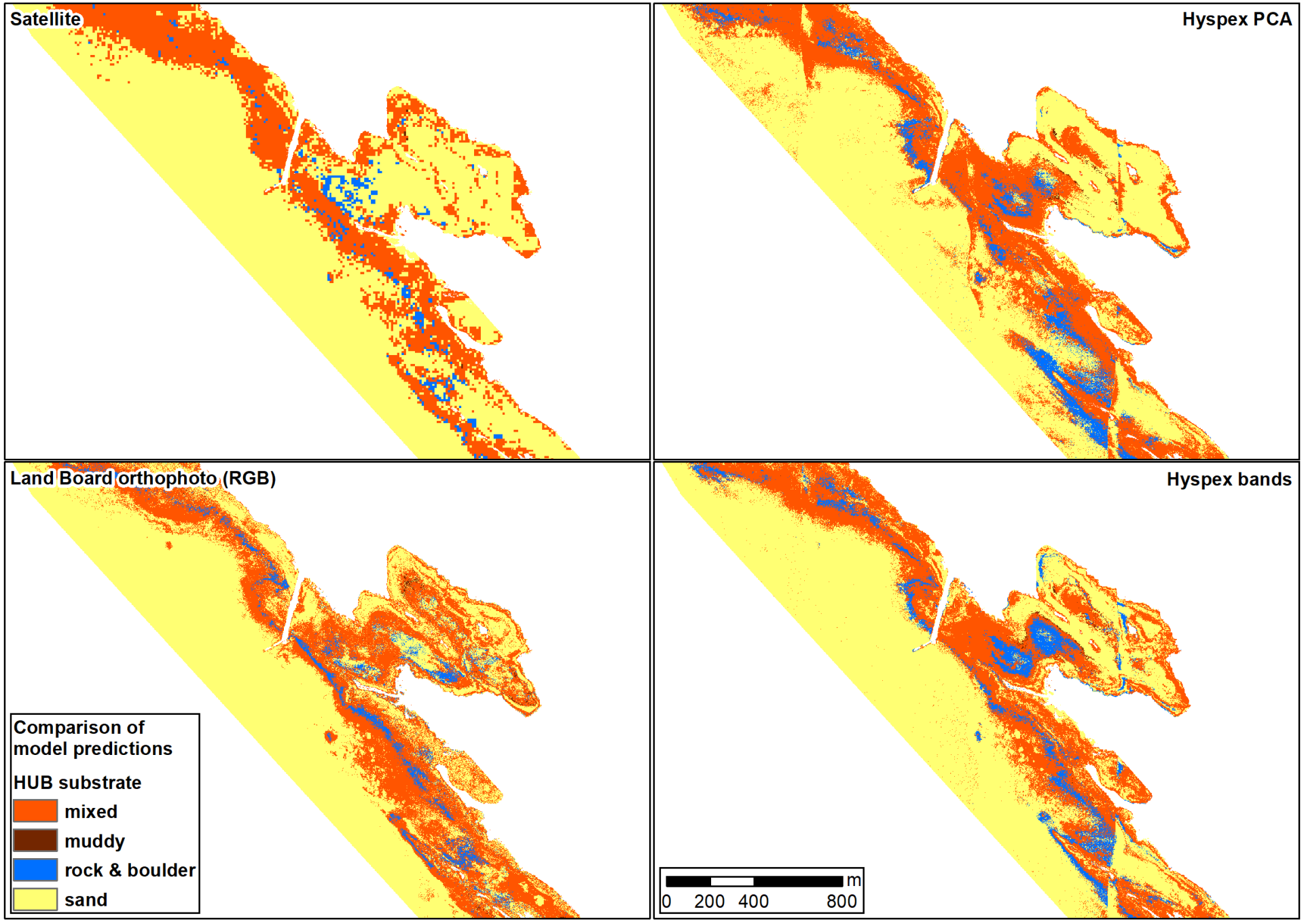
Hyspex

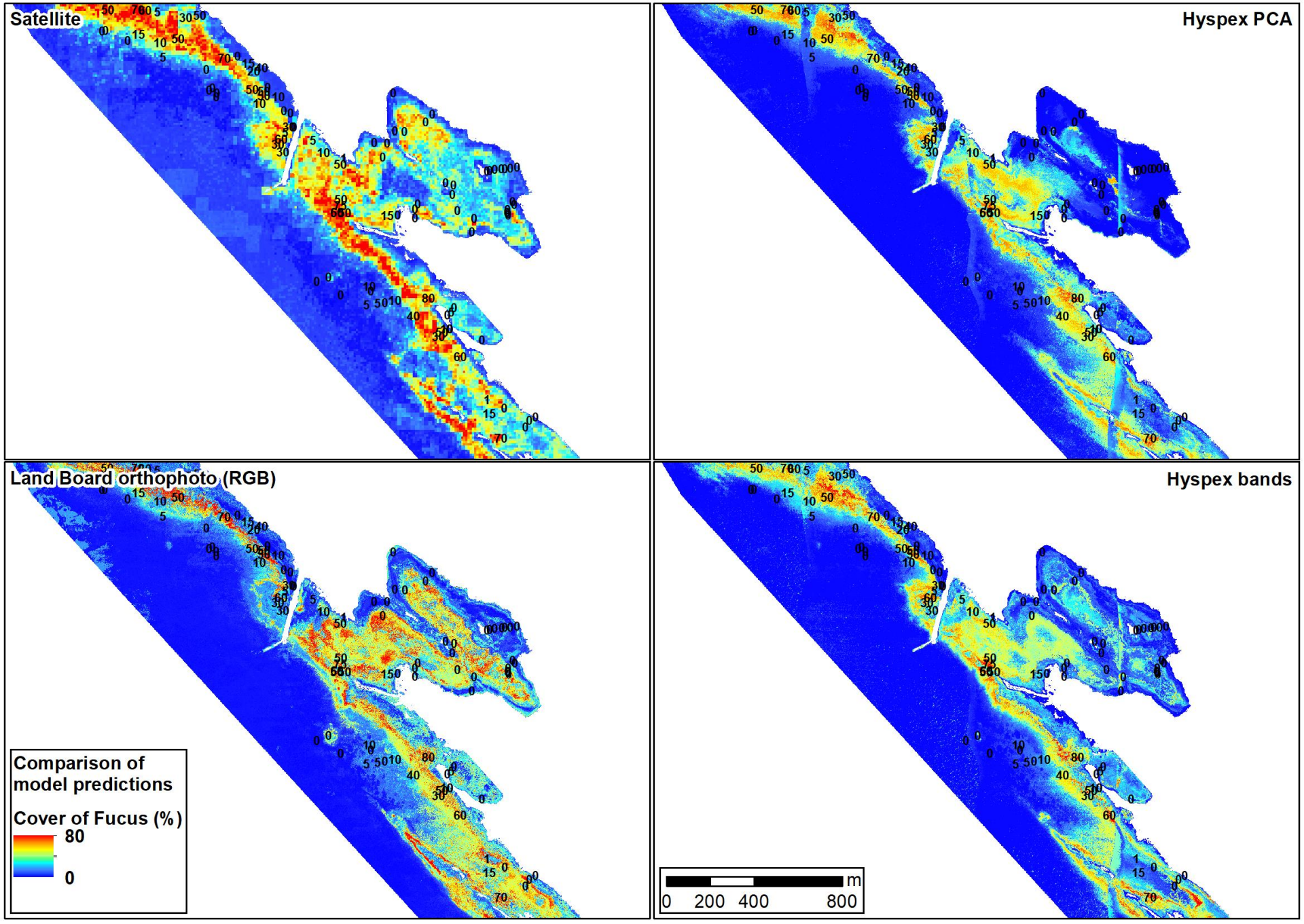

Satellite
Drone
Estonian Land Board orthophoto
m
0 2.5 5 10
Hyspex

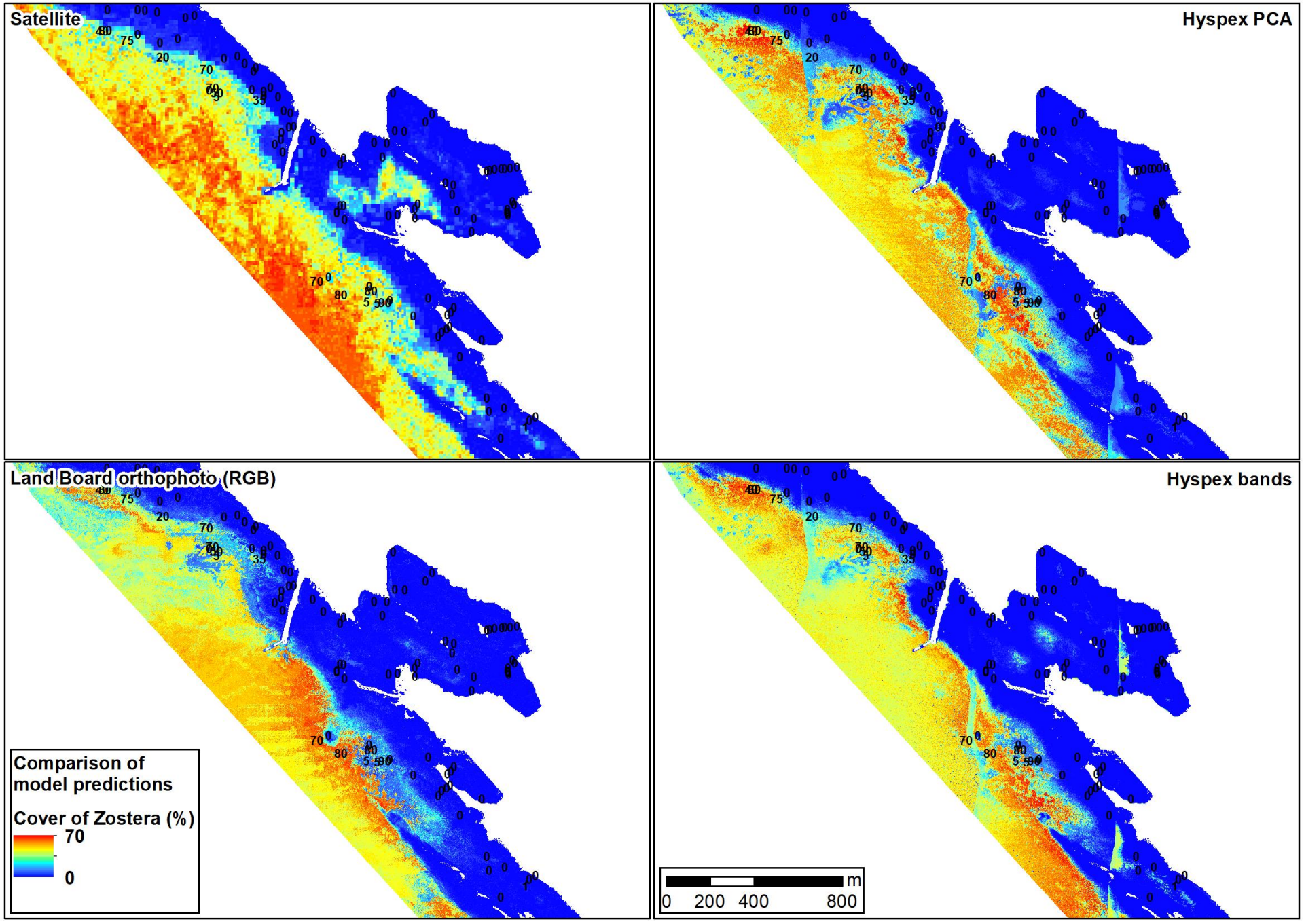

Drone orthophoto (RGB)
Hyspex PCA
Land Board orthophoto (RGB)
m
0 100 200 400
Hyspex bands

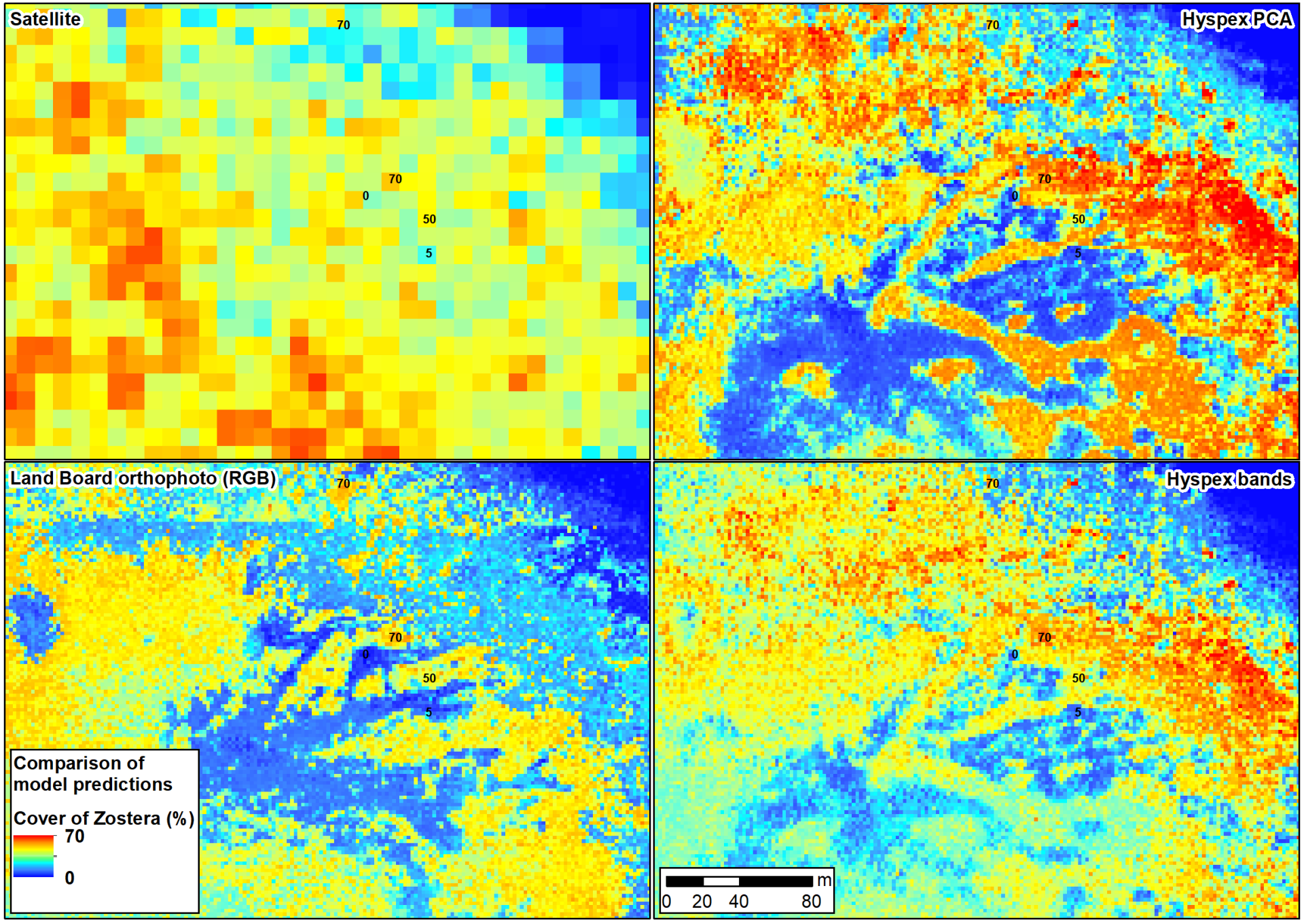

Drone orthophoto (RGB)
Kappa = 0.997
Comparison of model predictions
seabed class
charophytes
mud
Stuckenia
Hyspex PCA
Kappa = 0.985
Land Board orthophoto (RGB)
Kappa = 0.979
m
0 100 200 400
Hyspex bands
Kappa = 0.958

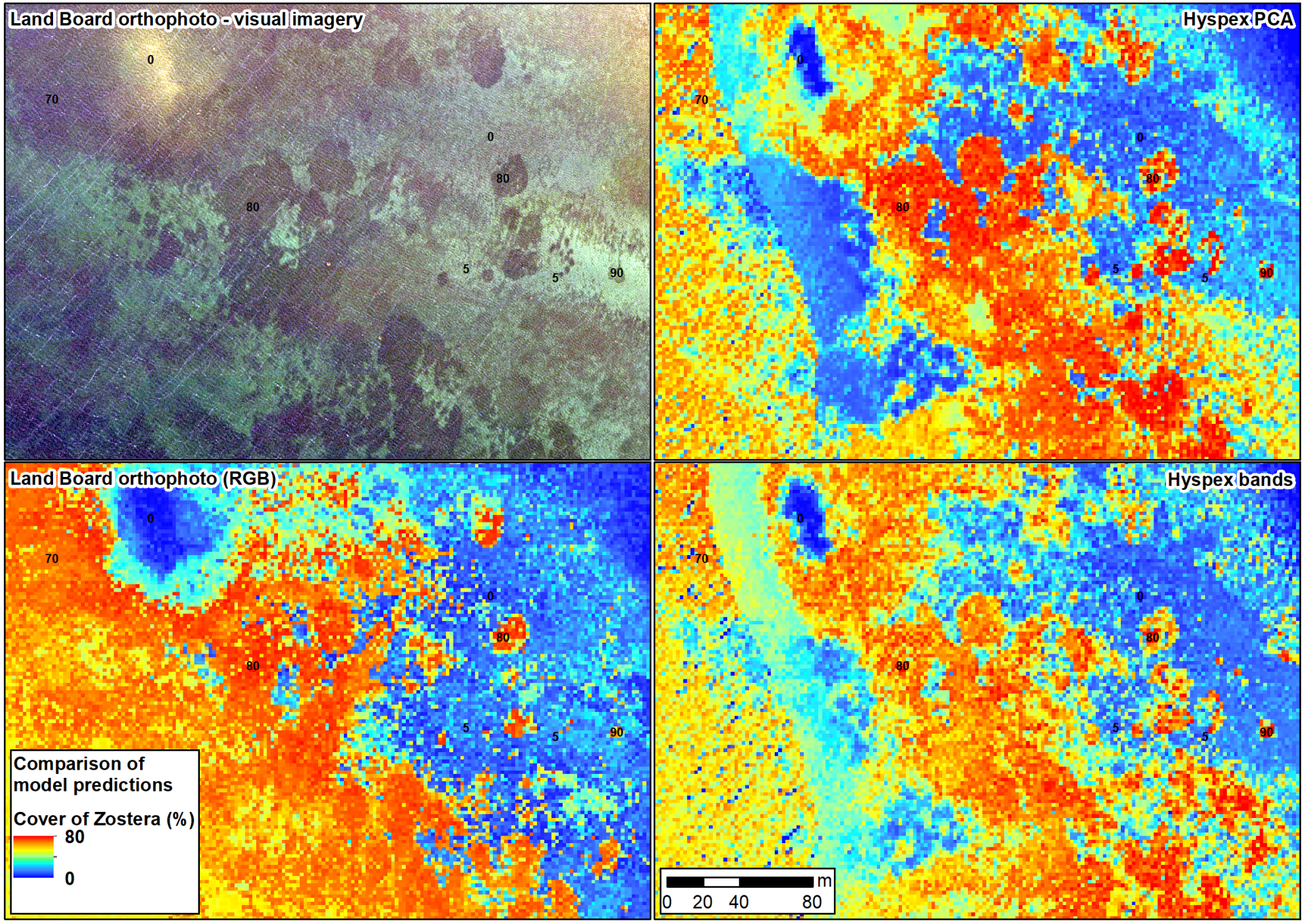

Drone orthophoto
Model
Modeled distribution of reed
no
sparse
dense
0
50
100
200
m


Satellite
Hyspex PCA
Land Board orthophoto (RGB)
Hyspex bands
Comparison of model predictions
HUB substrate
mixed
muddy
rock & boulder
sand
0 200 400 800
m


Satellite
Hyspex PCA
Land Board orthophoto (RGB)
Hyspex bands
Comparison of model predictions
Cover of Fucus (%)
80
0
0 200 400 800
m

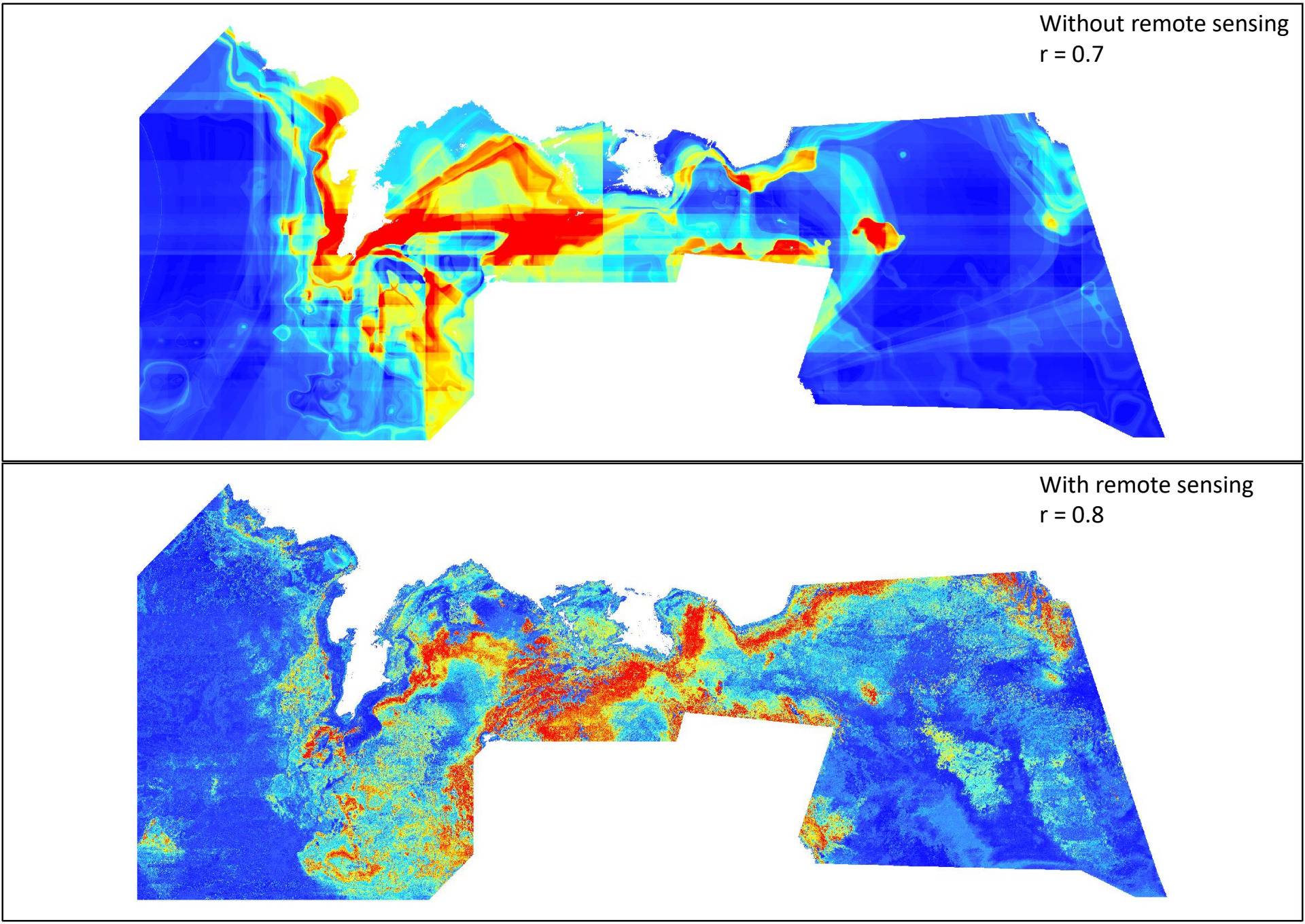

Satellite
Hyspex PCA
Land Board orthophoto (RGB)
Hyspex bands
Comparison of model predictions
Cover of Zostera (%)
70
0
0 200 400 800 m

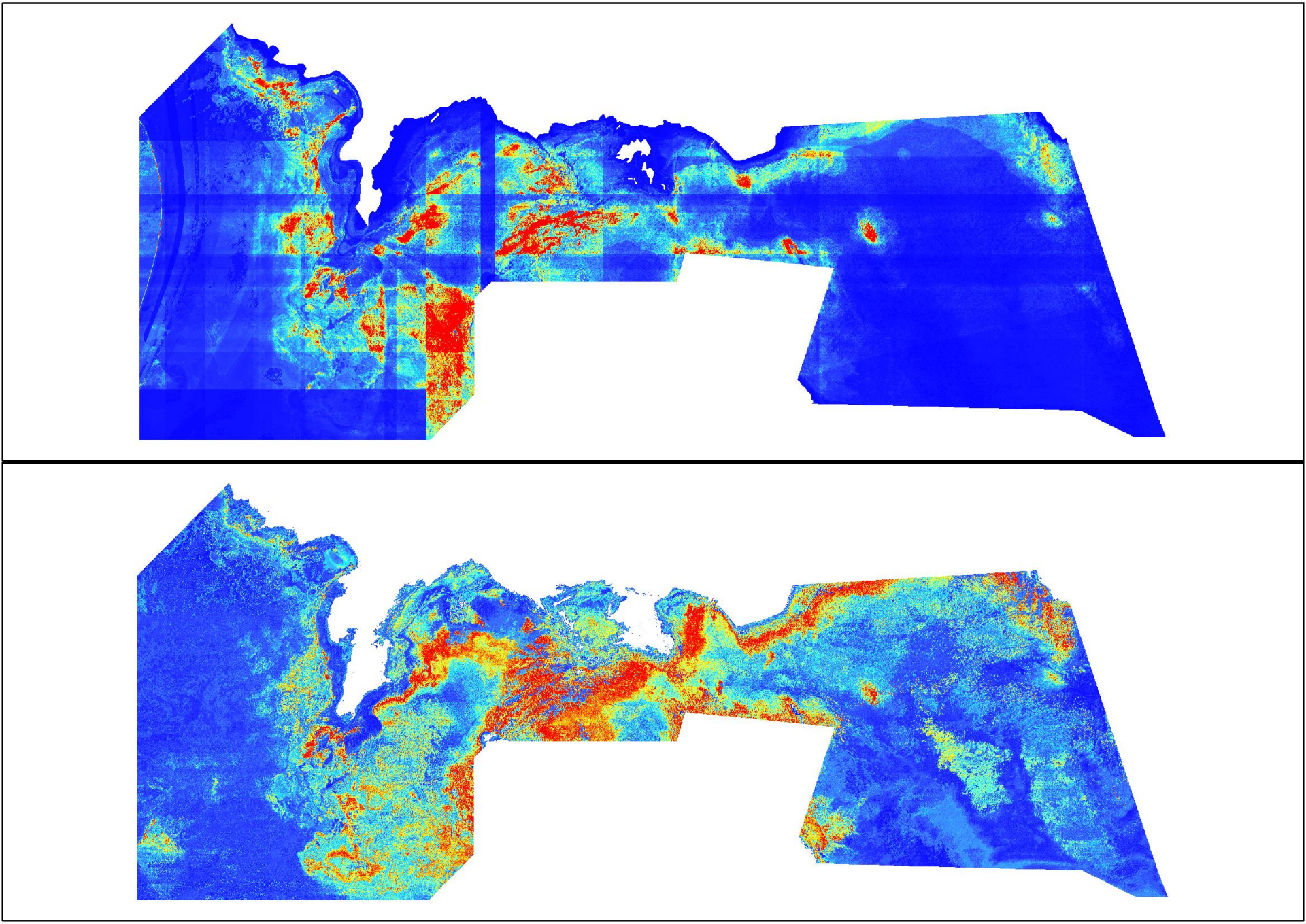

Satellite
70
70
0
50
5
Hyspex PCA
70
70
0
50
5
Land Board orthophoto (RGB)
70
70
0
50
5
Hyspex bands
70
70
0
50
5
Comparison of model predictions
Cover of Zostera (%)
70
0
m
0 20 40 80


Land Board orthophoto - visual imagery
Hyspex PCA
Land Board orthophoto (RGB)
Hyspex bands
Comparison of model predictions
Cover of Zostera (%)
80
0
m
0 20 40 80

Setting/model	👍	👎
Number of training cells per site	9	4
Area-based or pooled model	Area-based	Pooled model
Modeling algorithm	RF	BRT, NN
Orthophoto or Hyspex (2.3.1)	Hyspex	Orthophoto
Drone or Hyspex – visual features	Drone	Hyspex
Drone or Hyspex – modeling	?Hyspex?	?Drone?
Hyspex PCA12 or 12 bands	PCA12	12 bands

- Increase in prediction accuracy using remote sensing in 2.3.1
  - r: 0.7 → 0.8
  - MAE: 19 → 15
  - Class accuracy: 0.58 → 0.64
- Mathematical validation may fail to reveal overfitting artifacts and other un-natural patterns


Without remote sensing
r = 0.7
With remote sensing
r = 0.8



Conclusions

- Remote sensing (RS) increases the accuracy of benthic distribution maps
- RS is the only way to produce maps of very sparsely and spatially irregularly sampled shallow water bodies
- Different RS prducts are usable depending on
  - Spatial scale of a study area
  - Aim of the study
  - Sizes of features to be mapped
  - Availability and quality of RS data
  - Available resources (time, money)

Uuringu tellis ja uuringut rahastab Eesti Teadusagentuur Euroopa Regionaalarengu Fondist toetatava programmi „Valdkondliku teadus- ja arendustegevuse tugevdamine“ (RITA) tegevuse 1 „Strateegilise TA tegevuse toetamine“ kaudu. Uuring valmib Keskkonnaministeeriumi eesmärkide elluviimiseks.

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