Airborne hyperspectral remote sensing of the dynamic dunes along the Belgian coast

HYPERKART

Luc Bertels, Sam Provoost & Ann Willekens




Belgian Science Policy

AWZ
Administratie Waterwegen en Zeewezen

VITO Flemish Institute for Technological Research

Institute of Nature Conservation

GIS VLAANDEREN ONDERSTEUNEND CENTRUM

- Need for recent & accurate vegetation maps of the dunes :

  - Safety management; e.g. protection against storms and floods
  - Biodiversity studies & nature conservation
  - Management of public property

- New method should be :

  - Objective & fast
  - Cost efficient & highly automatic

  Aerial photography ⟶ Airborne Hyperspectral RS

- Users

  - LIN-AWZ-AWK
  - IN
  - Scientific community

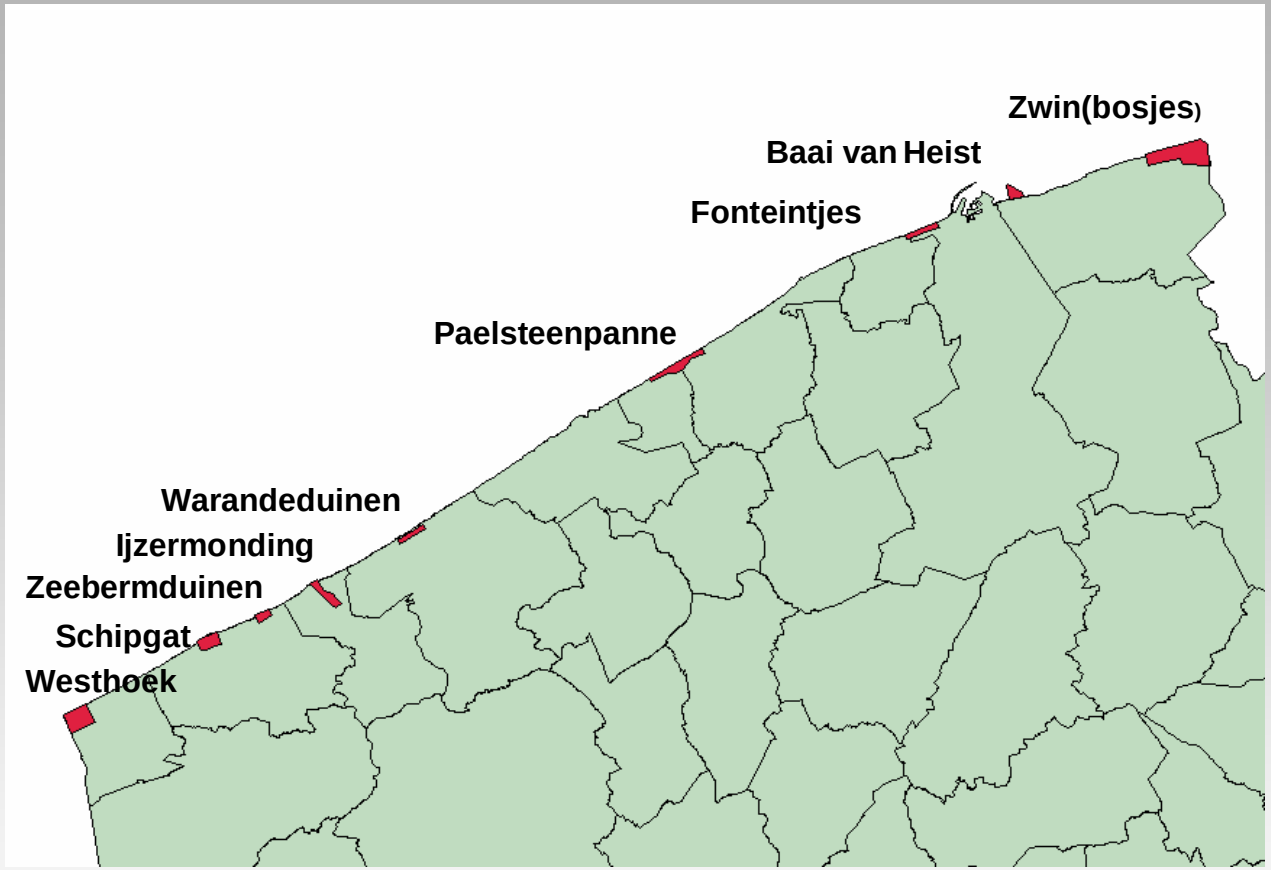
Introduction

Ecological background

Classification methods

Conclusions

Study area & available data



- Preliminary study using CASI-2 (October 2002) & ground truth data of 2003
- New flight campaign in May - June 2004

= optimal period for vegetation studies

Dune landscapes

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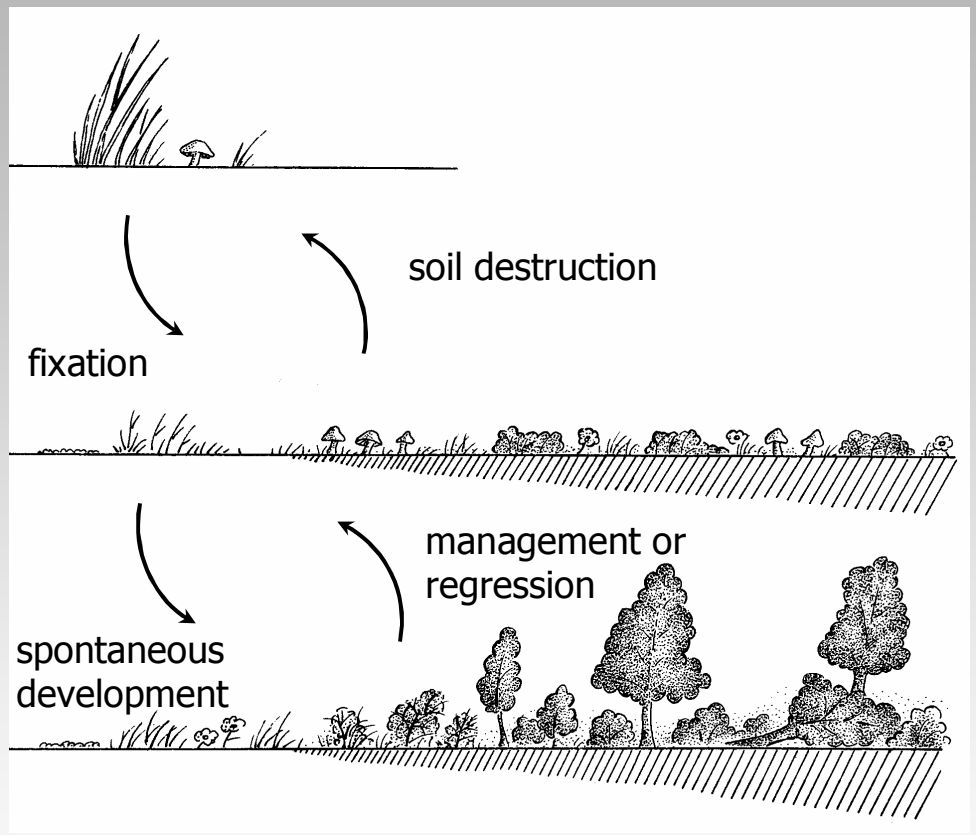

DYNAMISC LANDSCAPE

STRESSED LANDSCAPE

UNCONSTRAINED LANDSCAPE

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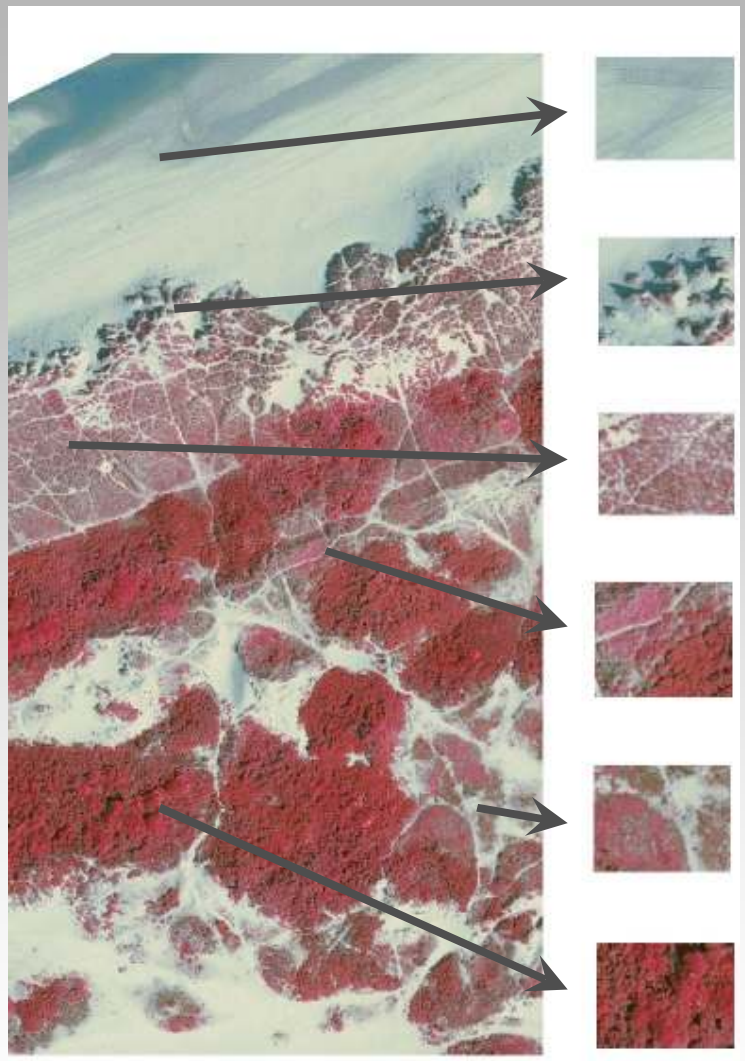
Vegetation types



Sand (with variation in moisture content)

Mobile dune with tussocks of *marram grass* *(Ammophila arenaria)*

Semi-fixed marram dune

Dewberry ***(Rubus caesius)*** **and scrub with sea*buckthorn*** ***(Hippophae rhamnoides)***

Moss dune ***(Tortula ruralis)*** **and dry dune grassland** ***(Carex arenaria, Festuca rubra, …)***

Scrub with sea*-buckthorn* ***(Hippophae rhamnoides)*** **and *elder*** ***(Sambucus nigra)***

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Sampling strategy

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Vegetation classification

Date: 05-08-2003	
RELEVEE Nr	21
Mean veg. hight	25
% sand	10
% moss	2
% herb/grass	75
% scrub	0
% litter	13
Achillea millefolium	p1
Ammophila arenaria	5
Ammophila arenaria (dead)	1
Arenaria serpyllifolia	p1
*Brachythecium albicans	m1
*Bryum capillare	p1
Carex arenaria	m4
Cerastium semidecandrum	p1
Festuca rubra	2
Rubus caesius	1-
Sedum acre	a2
Senecio jacobaea	p1
*Tortula ruralis ruraliformis	m1
Tragopogon dubius	r1

	embryonic dune			dynamic dune				*sea buckthorn* scrub				fixed maram dune						moss dune						dune grassland						tall grassland				
	613	607	218	108	511	510	220	76	88	236	79	97	230	232	576	579	264	266	190	648	519	531	694	7	8	4	12	14	18	13	626	548	562	565
ELYMUS FARCTUS	2	3	4	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AMMOPHILA ARENARIA	-	-	2	4	2	4	4	-	1	1	2	2	2	3	3	3	1	-	-	-	-	-	-	3	2	1	3	2	-	-	-	-	1	-
HIPPOPHAE RHAMNOIDES	-	-	-	-	-	-	-	5	4	5	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FESTUCA RUBRA	-	-	1	2	2	2	1	-	2	1	-	2	-	2	2	2	1	-	-	1	1	-	-	1	1	1	2	3	3	1	1	2	2	2
TORTULA RURALIS	-	-	-	-	-	-	-	-	-	1	-	1	3	2	2	2	1	4	5	3	4	4	4	-	-	-	-	-	-	-	-	-	-	-	-
CAREX ARENARIA	-	-	-	-	-	-	-	1	-	-	2	-	-	-	1	1	-	1	1	2	2	1	3	1	1	4	2	2	5	1	1	1	2	1
GALIUM VERUM	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	2	1	1	3	-	1	-	-	3	2
RUBUS CAESIUS	-	-	-	-	-	-	-	1	-	2	-	1	-	2	1	-	-	-	-	-	-	-	-	-	5	-	3	4	-	5	5	3	3	2
ARRHENATERUM ELATIUS	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	2	3	4
	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
								1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
								0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0

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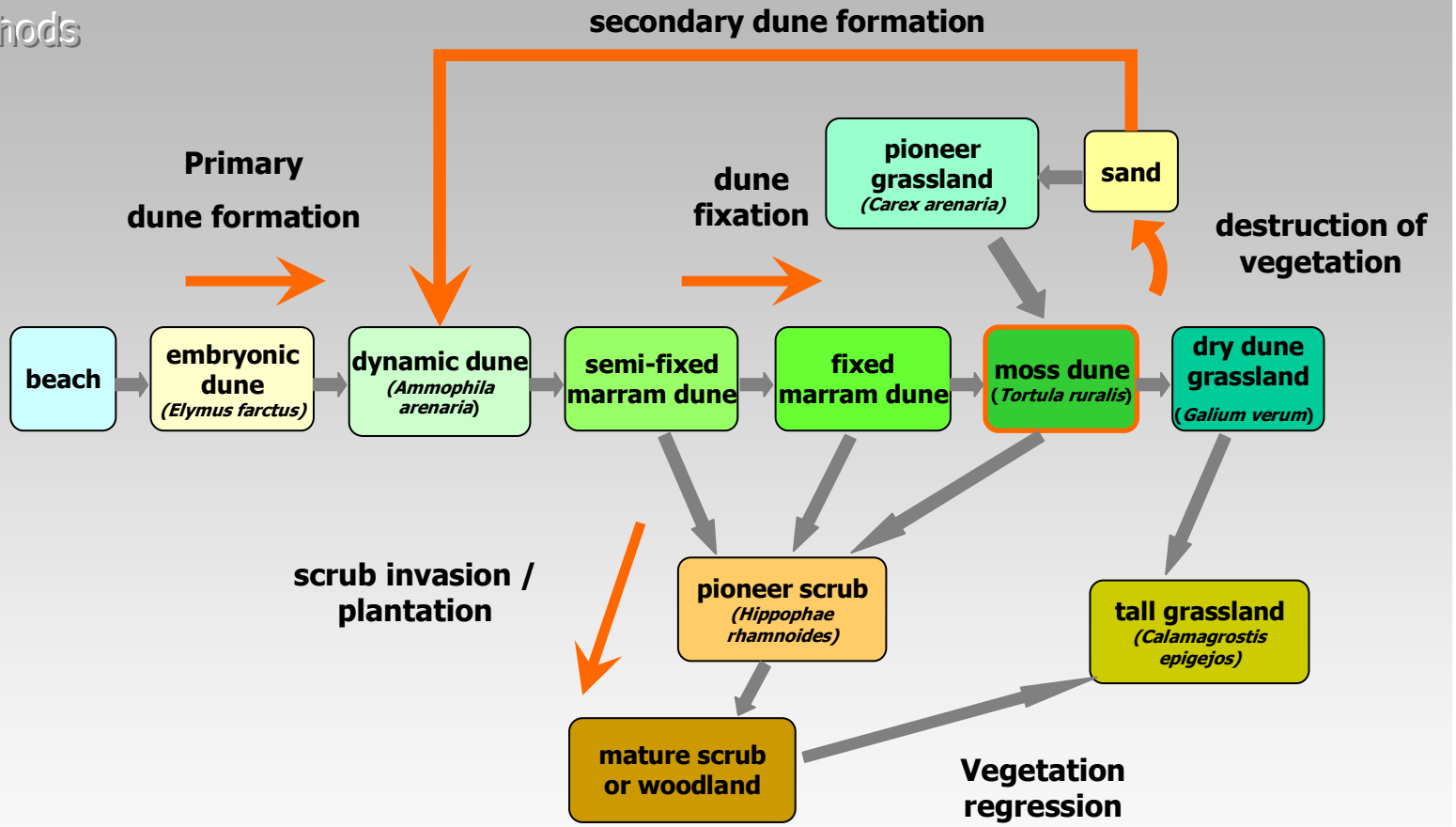
Dry dune vegetation development



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Preprocessing of the data

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- Pixel based
- Object-oriented

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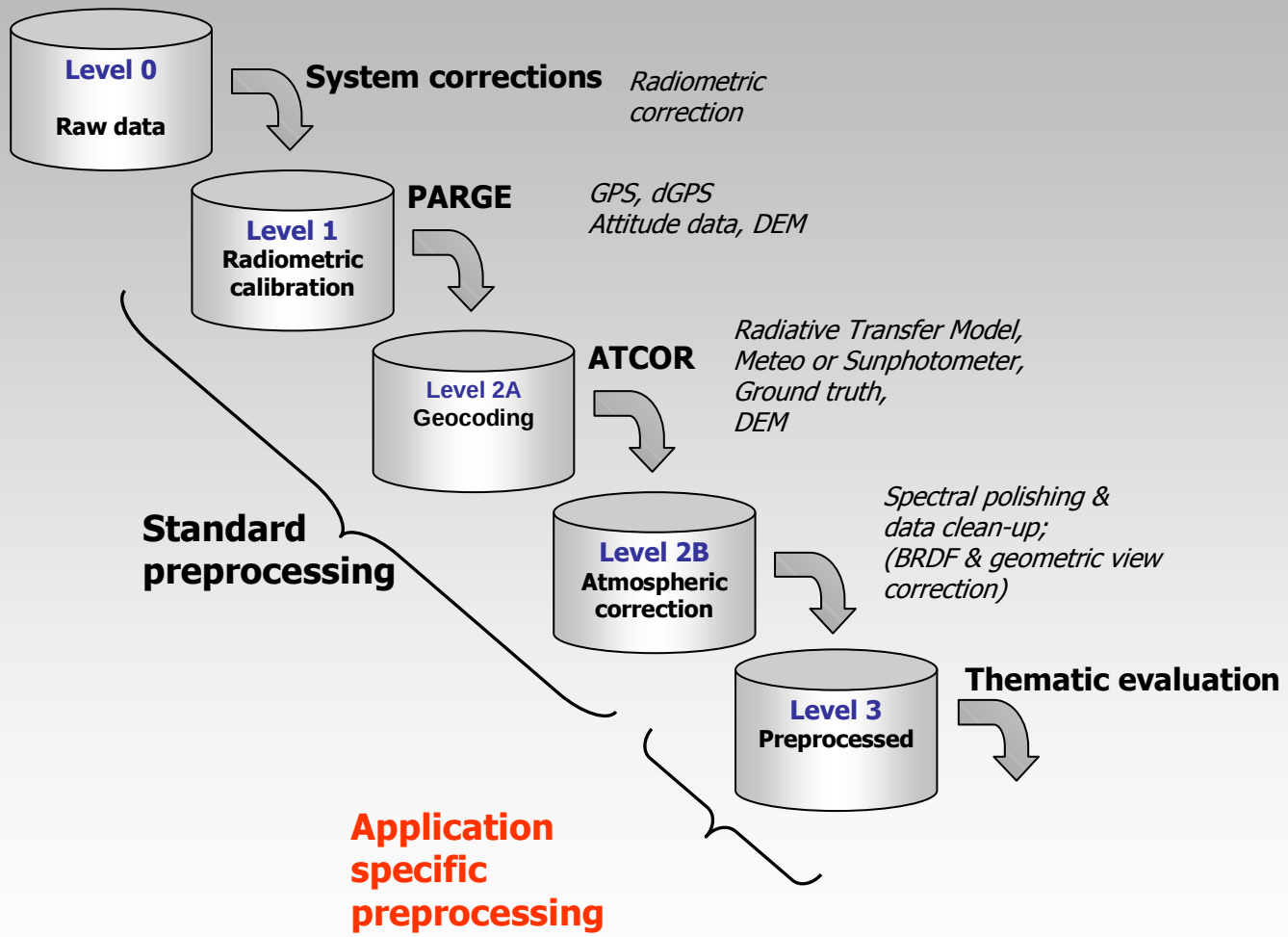


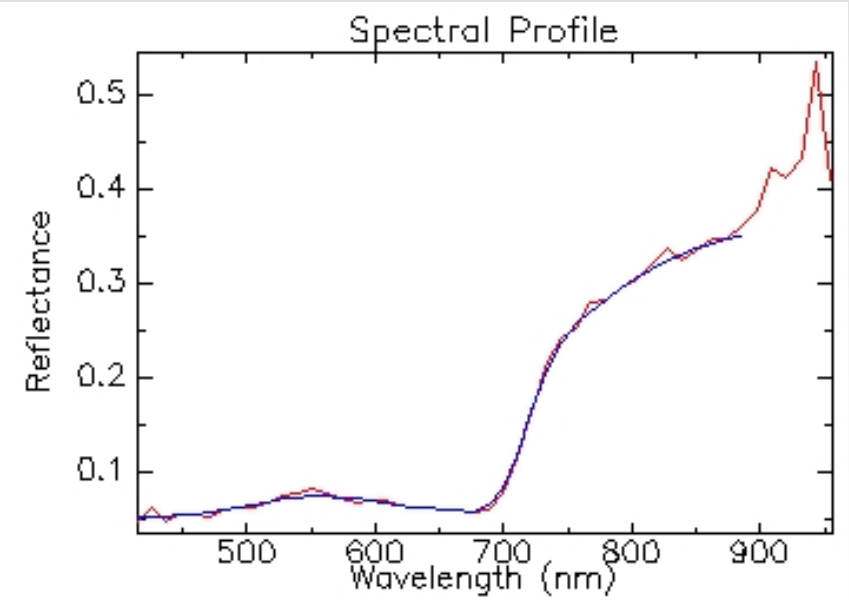
Spectral polishing

Noise inherent to the hyperspectral signal

➢ Using the innovative

Semi-Interactive Spectral Polishing Algorithm (SISPA)

Spectral group	Wavelength (nm)	Number bands	Polishing factors	Spectral feature
1	414 – 630	20	10	VIS
2	642 – 757	11	1	Red-edge
3	768 – 885	11	10	NIR
Removed	897 – 956	6	-	Water vapor

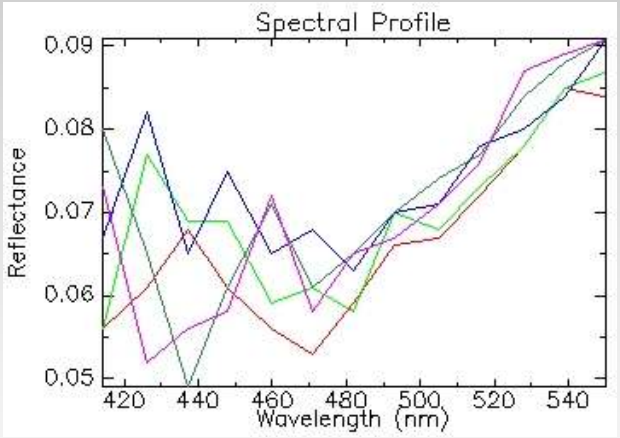


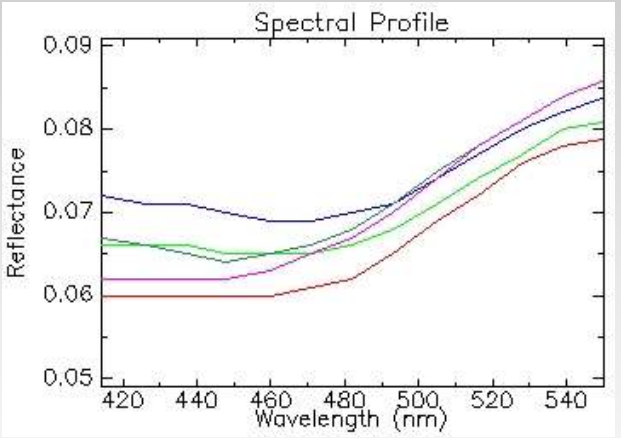
Bad Bands removal

Poor signal/noise ratio in the lower bands

➢ Low irradiance in the blue region of the spectrum

Removal of 7 bands (< 493 nm)





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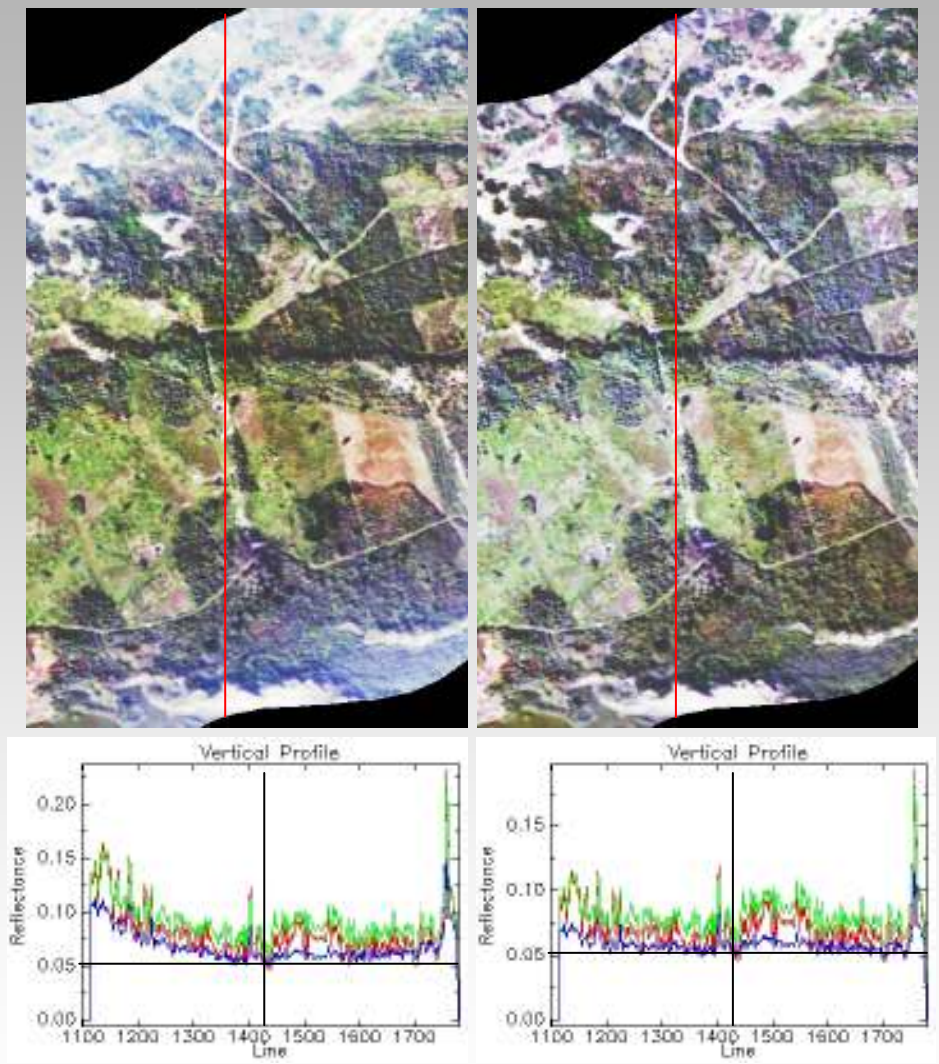
Correction of geometric look-effects



Correction of the across-track illumination differences

Introduction

Ecological background

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- Pixel based
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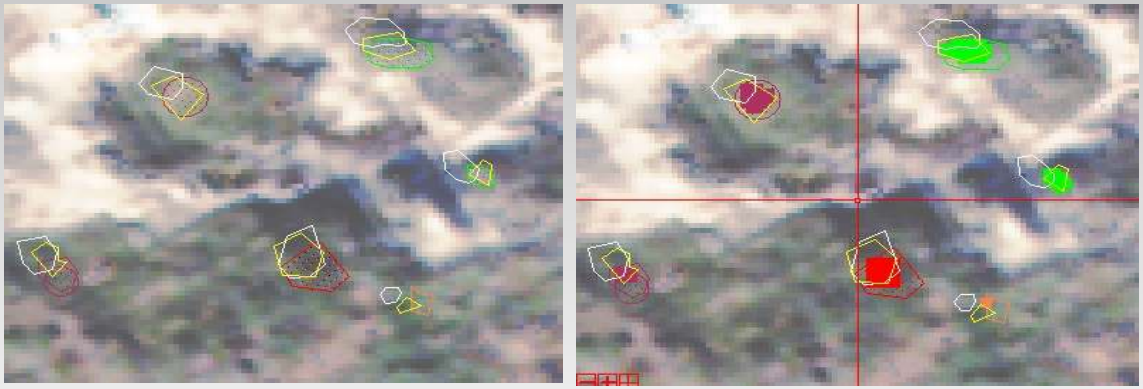
Conclusions

Selecting the reference spectra by means of ROI's

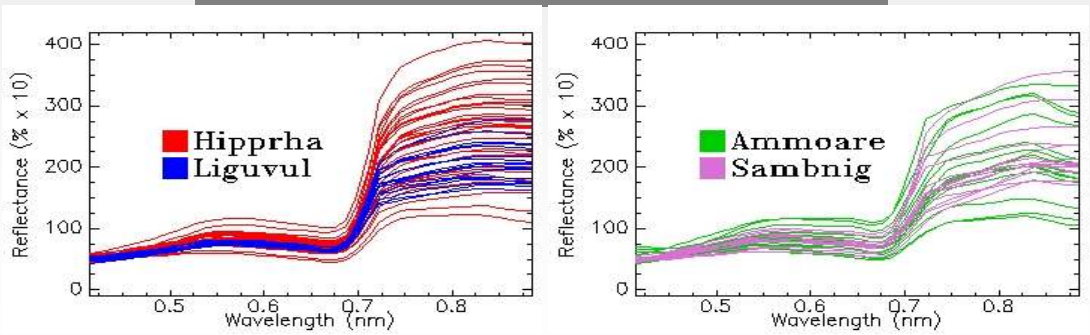
Limited geometric accuracy of the hyperspectral images

➢ Redefining initial ROI's (IN) by Vito and OC-Gis by means of visual inspection

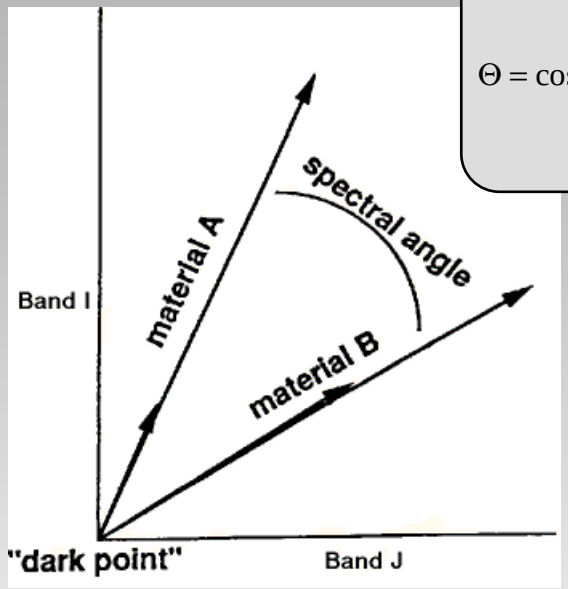
Common pixels were used as reference spectra



- IN - OCGis - - -Vito



The supervised Improved SAM classification (SISAM)



$$\Theta = \cos^{-1}\left(\frac{\sum_{i=1}^{n} t_i r_i}{\sqrt{\sum_{i=1}^{n} t_i^{\,2} \sum_{i=1}^{n} r_i^{\,2}}}\right)$$

Spectral Angle Mapper

- Determines similarity between two spectra by calculating spectral angle between both
- Compares image spectra to reference spectra of spectral libraries (lab, field, image)
- Two spectra are treated as vectors in N-d space (N = number of spectral bands)
- Method is insensitive to illumination differences

Improved :

- Reduction of the selected reference spectra
- Maximum & unique SAD for each reference spectrum
- ROI's are perfect classified

Classification result

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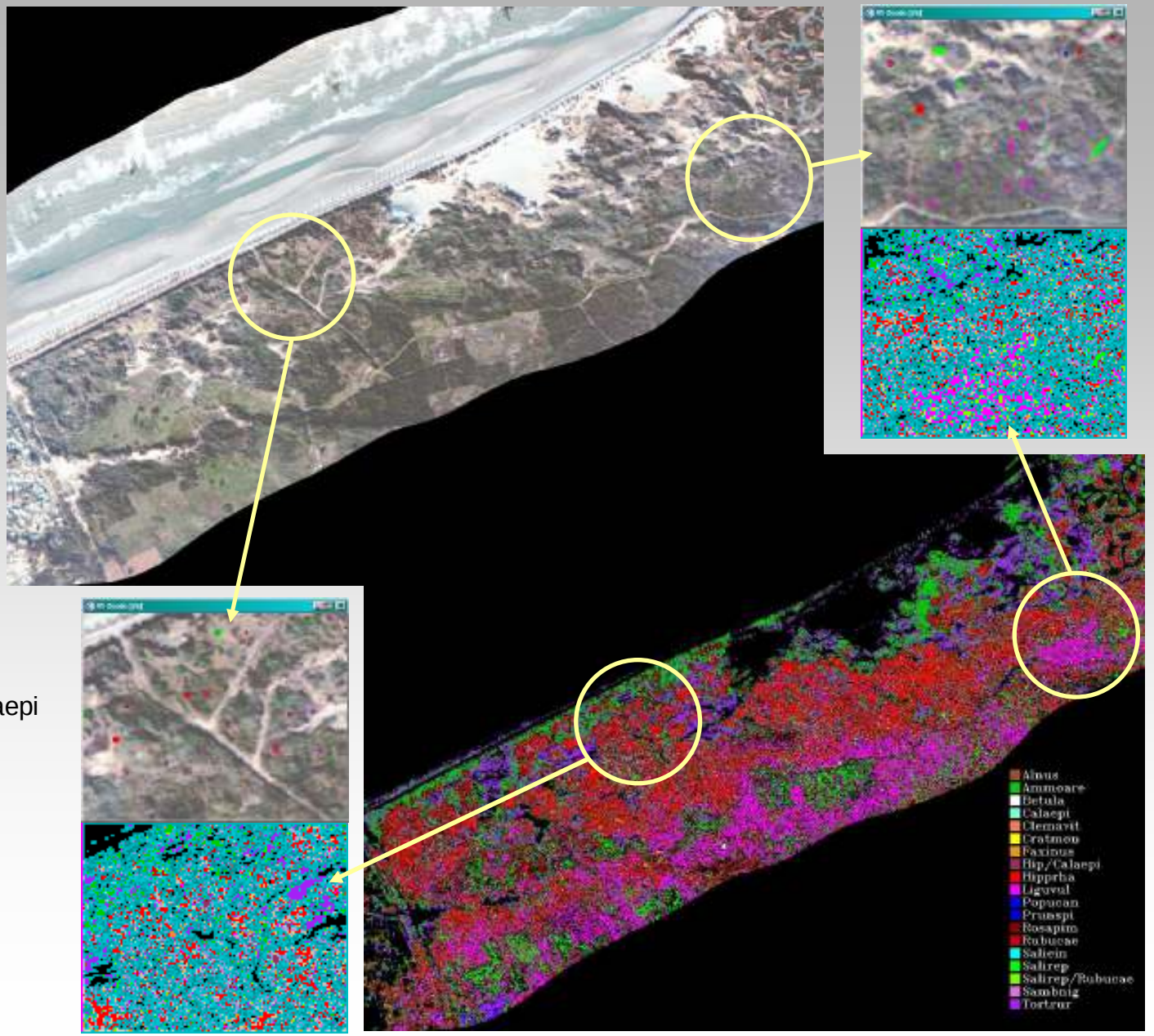
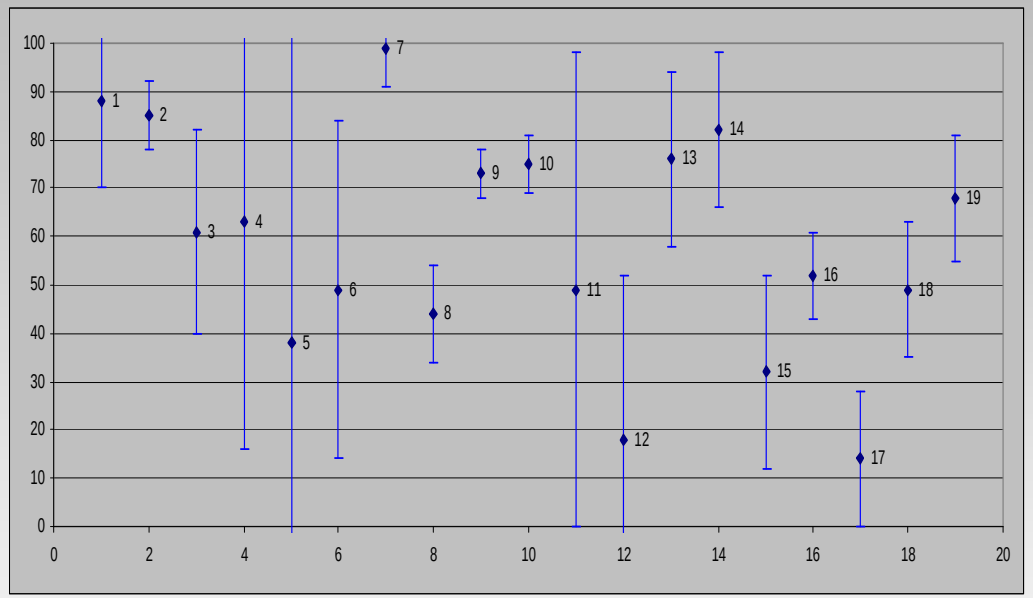


Classification accuracy and SEM

- Introduction
- Ecological background
- Classification methods
  - Pixel based
  - Object-oriented
- Conclusions



Overall accuracy: 66%

		# training pixels
1	Alnus	26
2	Ammoare	185
3	Betula	40
4	Calaepi	8
5	Clemavit	4
6	Cratmon	16
7	Faxinus	16
8	Hip/Calaepi	191
9	Hipprha	705
10	Liguvul	381
11	Popucan	8
12	Prunspi	9
13	Rosapim	44
14	Rubucae	43
15	Salicin	42
16	Salirep	219
17	Salirep/Rubucae	46
18	Sambnig	89
19	Tortrur	87

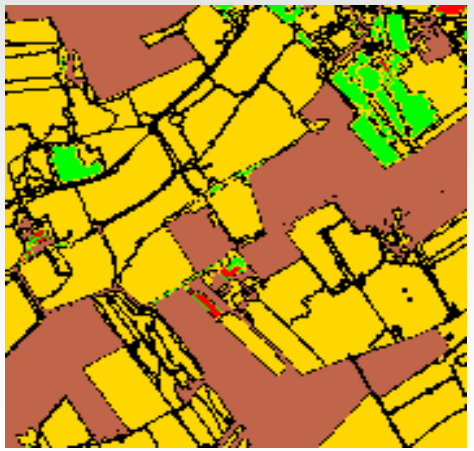
Object-oriented classification (eCognition)

Pixel-based classification

- Basic processing unit for classification = PIXEL
- Salt & pepper effects

Object-oriented classification

- Basic processing unit for classification = IMAGE OBJECT / SEGMENT
- No salt & pepper effects
- Geometric relationship between image objects



Object-oriented classification (eCognition)

1. Multiresolution segmentation
   Image -> image objects

Segmentation parameters

2. Classification of image objects or segments
   Image objects -> Class

Class description → Nearest neighbor
Membership function

Multiresolution segmentation

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- Spectral Angle
- Object-oriented

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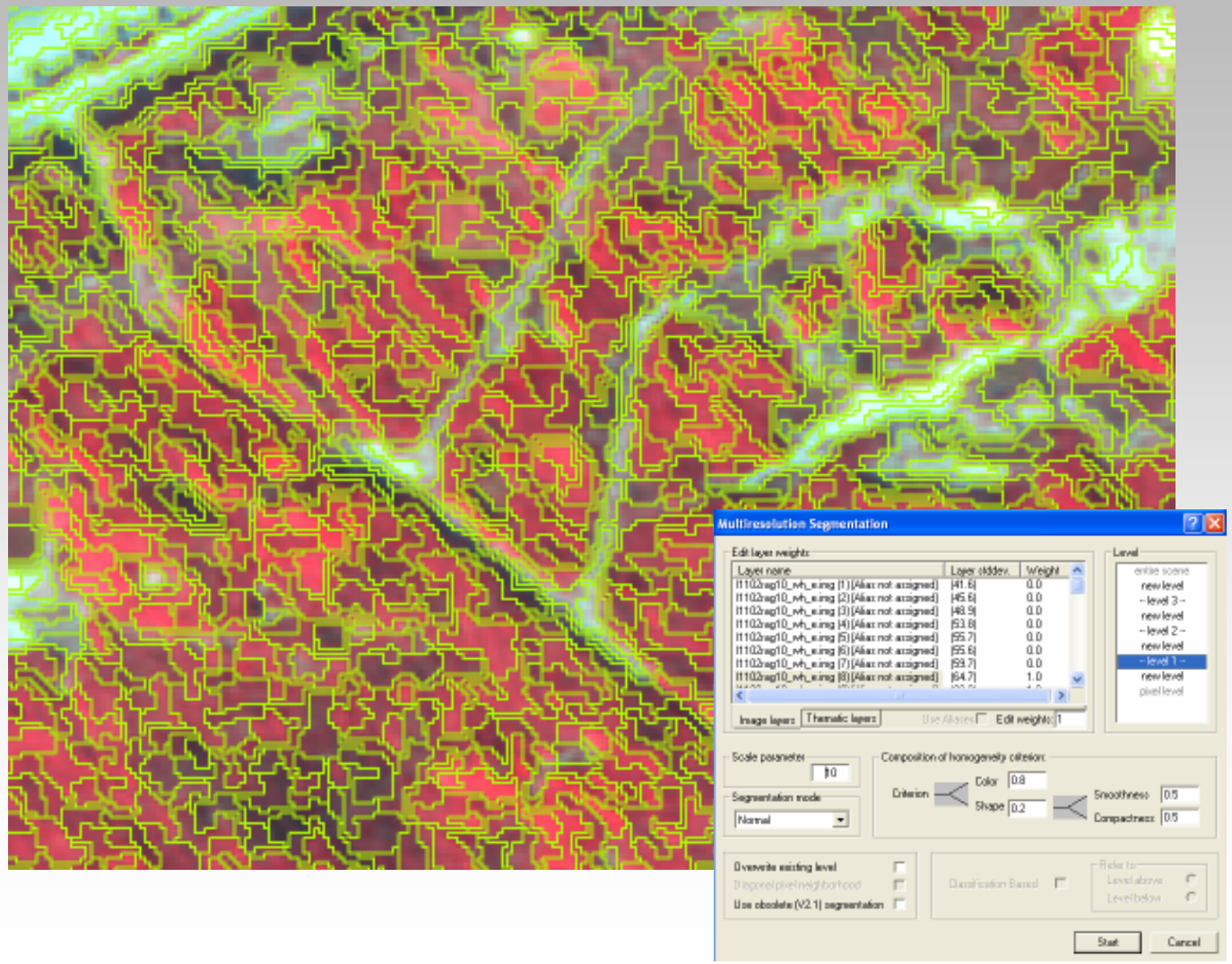
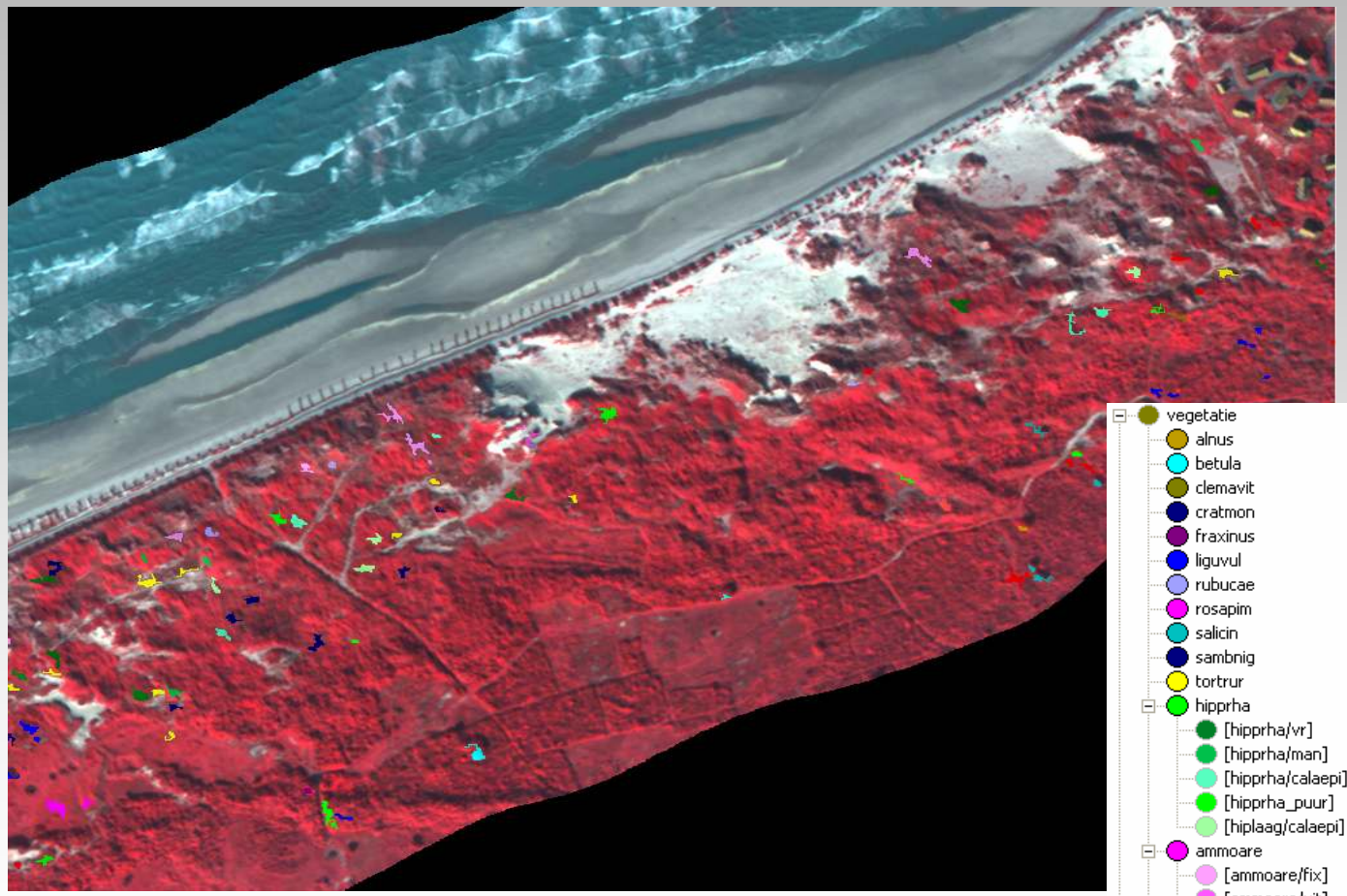


Classification – selection of 'sample objects'

- Introduction
- Ecological background
- Classification methods
  - Spectral Angle
  - Object-oriented
- Conclusions



Classification – Nearest Neighbor

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- Ecological background
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  - Spectral Angle
  - Object-oriented
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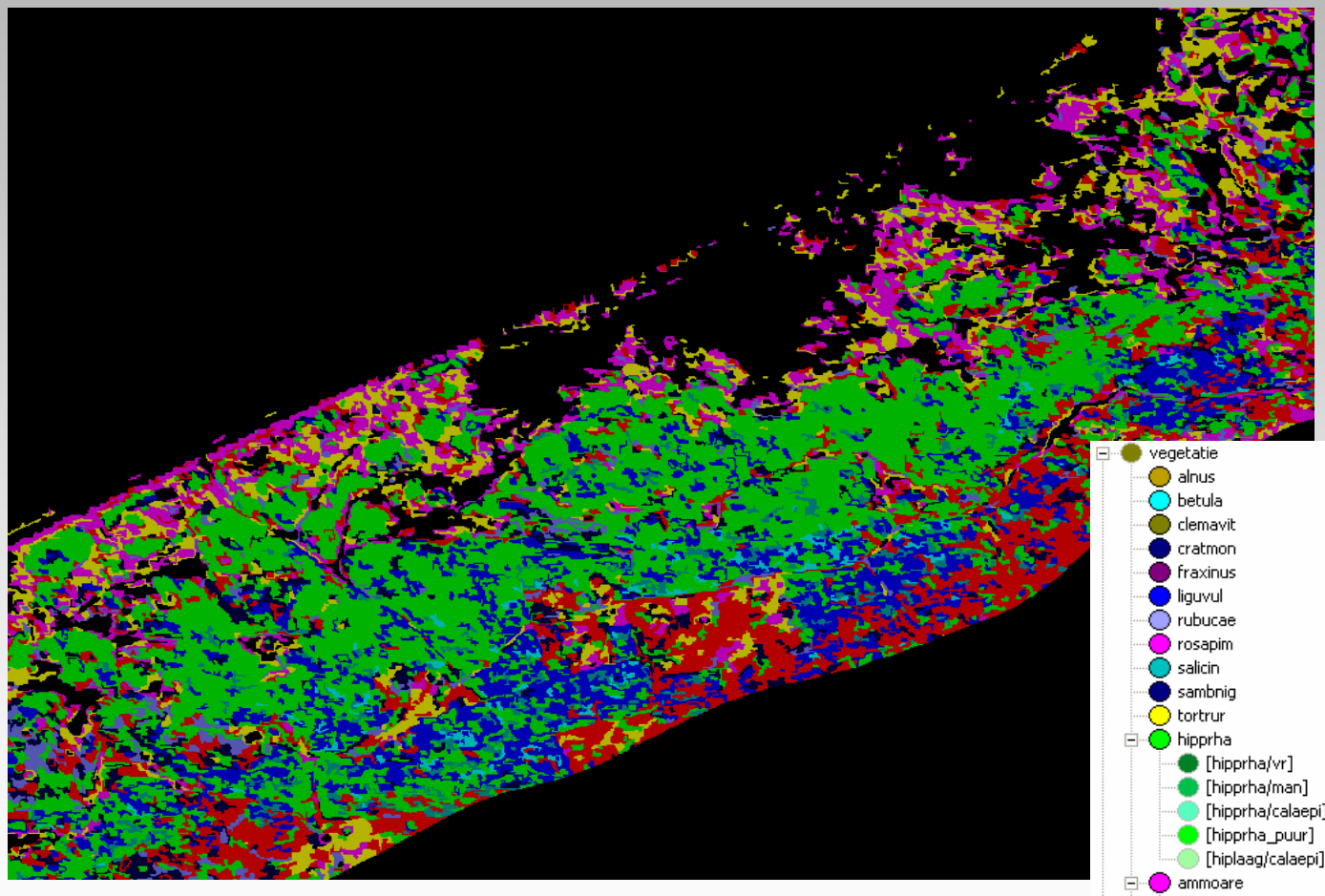

Totals	
Overall Accu...	0.535
KIA	0.406

- vegetatie
  - alnus
  - betula
  - clemavit
  - cratmon
  - fraxinus
  - liguvul
  - rubucae
  - rosapim
  - salicin
  - sambnig
  - tortrur
  - hipprha
    - [hipprha/vr]
    - [hipprha/man]
    - [hipprha/calaepi]
    - [hipprha_puur]
    - [hiplaag/calaepi]
  - ammoare
    - [ammoare/fix]
    - [ammoare/vit]
  - salirep
    - [salirep/rubucae]
    - [salirep_puur]
- not vegetatie

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To do …

Improve object-oriented classification method

- Search for optimal segmentation parameters
- Use well defined membership functions to describe the vegetation classes
- Include a priori expert knowledge into the classification process
  - Groundwater depth
  - DEM -> aspect / slope
  - …

Challenge

How to ‘merge’ the different classification methods ?
(SAM, Wavelet, eCognition)

– Supplement the pixel-based image analysis (SAM, Wavelet) of the hyperspectral images with an object-oriented post-classification by eCognition ???

General conclusions

- Selection of reference spectra (ROI's) is crucial for the obtained classification result.

  - Flight campaign at the right moment (May- June)
  - Accurate georeferencing of the images is necessary to avoid the need for visual inspection

- Obtained classification accuracy (eCognition: 54%, SISAM: 66%, Discriminant analysis: 80%) might be improved by merging the advantages of the different methods.

  - E.g. segmentation result by eCognition used in post classification clean-up

Future work

- Integration of the different methods
- New flight campaign, preprocessing of the data and applying the newly developed method
- Selection of ROI's which are representative for the entire coast
- Development of a profound field validation method
- Method automatisation