Applied vegetation monitoring with high resolution sensors

Annett Frick, Luftbild Umwelt Planung, Potsdam

Habistat Workshop 2010
13.10.2010
Biodiversity and remote sensing

High spatial resolution:
e.g. QuickBird 0.6 m

High spectral resolution:
e.g. HyMAP 125 bands (4 m)

High temporal resolution:
e.g. RapidEye monthly (6.5 m)

Habitat structure, composition

Habitat inventory (species; plant associations)

Habitat function; phenological trends

Mai
August
July
September
Outline

Applied Natura 2000 reporting:
  - Heathland monitoring

Applied ecosystem assessment:
  - Peatland monitoring
  - Habitat modelling for Aquatic Warbler (*Acrocephalus paludicola*)

Research & Development:
  - Vegetation monitoring with hyperspectral data
  - Vegetation monitoring with multitemporal/multisensoral data
Heathland Monitoring – Background

Objectives

- the federal state of Brandenburg has to report about more than 15,000 ha of heathland (due to military history), mostly contaminated with old ammunition
- joint R&I project (SARA'04) to develop methods to analyse very high resolution multispectral satellite data
- Natura 2000 – monitoring and evaluation of LRT 4030 and 2310 habitat types

Partners

- Luftbild Umwelt Planung GmbH, Technical University Berlin, Regional Environmental Agency Brandenburg

Project duration: 2003 – 2006

This project was funded by EFRE.
This project was funded by the Ministry of Economics Brandenburg.
Heathland Monitoring - Study areas in Brandenburg

- Marienfliess
- Wittstock
- Döberitzer Heide
- Potsdam
- Hackenheide
- Schorfheide
- Schwedt
- Jägersberg
- Lieberoser Endmoräne/Reicherskreuzer Heide
- Forst Zinna/Keilberg
- Heidehof/Golmberg
- Prösa

Additional areas in Thuringia (Green Belt), Schleswig-Holstein (Stör), Mecklenburg-Western Pomerania (Peene) and Poland (Warthe)
Heathland Monitoring – Data and Methods

Classification methods:

⇒ hierarchical approach (top down)

⇒ knowledge based iterative classification
  • A) **formalised experience** of aerial image interpreters
    ⇒ e.g.: trees have shadows
  
  • B) **spectral characteristics**, determined from a large set of test areas
    ⇒ e.g.: deep and clear water always has a NDVI < 0

• C) **a-priori knowledge** in form of geodata (e.g. CORINE)
  ⇒ e.g.: training areas for floating leaf vegetation should be searched only in zones where the landuse data record water or wetland vegetation

Data:

⇒ very high resolution satellite data (QuickBird)
⇒ old biotope type and landuse maps
**Heathland Monitoring – Results**

**Monitoring of European dry heath**  
(habitat types 4030 and 2310)

<table>
<thead>
<tr>
<th>Habitat-nr.:</th>
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</tr>
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<tbody>
<tr>
<td><strong>in % total area</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>wood</td>
<td>8%</td>
<td>60%</td>
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<tr>
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**impairments:**  
A C B

moss, open sand and grass can be covered by higher stands
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Moss, open sand and grass can be covered by higher stands
Heathland Monitoring – Results

Acc. Assessment with 1341 random points and through the mapping of transects (273 sites):

⇒ Acc. very high for wood and dry open classes like heath or dry grassland (> 90%) - very precise and sufficient for Natura 2000 reporting

⇒ Acc. high to moderate for wetland classes since spectral and textural differences are smaller (>70 - 85%)

⇒ Some agricultural classes are very difficult (intensive grassland / extensive grassland)

## Peatland Monitoring – Background

### Objectives

- The restoration of degraded and damaged ecosystems has become a major task throughout the world, especially peatland was subject to heavy degradation and thus is now in the focus of large scale restoration attempts.

- Monitoring of both vegetation development and balance of matter is crucial since an important objective of peatland rewetting is the restoration of their sink function.

- Western Pomerania initiated a “Peatland conservation programme” in 2000 – up to now, more than 10,000 hectares of fens have been rewetted.

- Our aim was to use remote sensing to: detect wetland vegetation classes very precisely as an input to biomass modeling and to assess the rewetting success in drained moorlands.

### Partners

- Luftbild Umwelt Planung GmbH, University of Greifswald (Institute of Botany and Landscape Ecology), Regional Environmental Agency Mecklenburg-Western Pomerania (Department of Nature Conservation)
Peatland Monitoring - Study areas in Western Pomerania

- Beestland (2008)
- Peene (2010)
- Ochsendamm (2008)
- Ziethen (2007)
- Grambow (2010)
- Rosin (2010)
- Landgraben (2010)

Areas used for algorithm development (5,000 ha)
Operational application (12,000 ha)
Peatland Monitoring – Data and Methods

Classification methods:

⇒ ensemble classification (Boosting and Bagging)
⇒ iterative approach (RandomForest, See5, AdaBoost and Maximum Likelihood)

Assessment methods:

⇒ Net aboveground biomass of *Phragmites australis*, *Typha latifolia*, *Glyceria maxima*, *Carex* spp. and *Phalaris arundinacea* was harvested from randomly chosen sites (0.25 m²) in mono-dominant stands
⇒ Carbon content of dry mass was measured with a CHN-Analyzer "Vario EL III".

Data:

⇒ very high resolution satellite data (QuickBird, GeoEye, WorldView I and II)
⇒ in situ collected training sites and plant samples for biomass and carbon content assessment
Vegetation classes:

- Open water
- Floating leaf vegetation
- Submersed plants (Ceratophyllum)
- Duckweed (Lemnaceae)
- Phragmites
- Typha
- Carex
- Phalaris
- Fallow grassland
- Juncus
- Glyceria
- Eleocharis
- Wood
- Other classes
- Clouds
Peatland Monitoring – Results

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Peatland Monitoring – Results

Acc. assessment by Random Sample Analysis (75% of the terrestrial data were for training 25% were hold away for acc. assessment)

Overall Kappa of 86.4%

Habitat modelling for Aquatic Warbler – Background

Objectives

⇒ The world population of *Acrocephalus paludicola* collapsed in the course of the 20th century due to wetland drainage and agricultural intensification

⇒ The species went extinct in France, Belgium, Italy, and the Netherlands; in NE Germany the population shrank to probably <1% of its former size

⇒ The federal state of Brandenburg initiated a Management Plan to restore habitats

⇒ Our aim was to use remote sensing to: detect potentially suitable areas for habitat restoration

Partners

⇒ Luftbild Umwelt Planung GmbH, Dr. Franziska Tanneberger, Dr. Jochen Bellebaum

⇒ support: Dr. Martin Flade, BirdLife International Aquatic Warbler Conservation Team, Dr. Torsten Langgemach, Head of Staatliche Vogelschutzwarte Brandenburg, Lars Lachmann, Manager EU-LIFE-Project “Conserving Acrocephalus paludicola in Germany and Poland”, Dr Janusz Kloskowski, Scientific Advisor EU-LIFE-Project “Conserving Acrocephalus paludicola in Germany and Poland” and Dr Jaroslaw Krogulec, Conservation Director Polish Society for the Protection of Birds
Habitat modelling for Aquatic Warbler – Data

Satellite data:

- mono-temporal IRS satellite data with high spatial resolution to describe vegetation structure:
  - IRS-P6 LISS III and LISS IV satellite images captured mainly in April or June 2005 (23.5 and 5.8 m)
- multi-temporal MODIS satellite data with medium spatial resolution to describe vegetation phenology:
  - Terra-MODIS 16-day NDVI composites (250 m) for March and June 2005

GIS data:

- biotope type map (1992/93) as geometric base for modeling
- soil map
- INVEKOS

Presence/Absence data:

- 17 presence sites (from Brandenburg and Poland)
- 86 potentially suitable habitats added as presence sites to the model
- 1338 absence sites
Habitat modelling for Aquatic Warbler – Methods

Multi model approach:

- Presence only (Maxent)
- Presence/Absence (Cubist)
- Combination of several models (no threshold approach but balance between false-positive and false-negative predictions)

Most important parameters (GIS, Satellite):

- Biotope type group, Soil type, Area size, Perimeter, Modis NDVI March (min), Ratio NIR/green (min), Modis NDVI March (mean), Variance green 7x7 (max), Variance red 3x3 (mean), Ratio green/blue (min), Variance pan 3x3 (mean), Variance blue 3x3 (mean), Variance green 7x7 (min), Modis NDVI July (mean), Variance green 3x3 (min), Modis NDVI July (max), Variance blue 3x3 (stdev)
Habitat modelling for Aquatic Warbler – Results

Acc. Assessment:

\[ 80/20 \ (AUC = 0.93) \]

\[ \text{in situ (overall acc. = 85\%)} \]
Habitat modelling for Aquatic Warbler – Results

Acc. Assessment:

- 80/20 (AUC = 0.93)
- in situ (overall acc. = 85 %)

potential areas for habitat restoration
unsuitable
Habitat modelling for Aquatic Warbler – Results

- Identification of suitable areas for habitat restoration
- Aquatic warbler is umbrella species for fen mires

Identification of areas for protection of wetlands and their biodiversity
Research & Development Projects

High spectral resolution:
HyMAP 125 bands (4 m)

High temporal resolution:
RapidEye monthly (6.5 m)

SARA–EnMAP (in co-operation with GFZ):
➔ HyMAP (2008)
➔ field spectroscopy (ASD)

CARE-X (in co-operation with TU Berlin):
➔ RapidEye (monthly)
➔ TerraSAR-X (quarterly)
➔ field spectroscopy (ASD)
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<tr>
<td>LUFTBILD UMWELT PLANUNG</td>
<td>Technical University Berlin</td>
</tr>
<tr>
<td>14469 Potsdam</td>
<td>Institute for Landscape Architecture and Environmental Planning</td>
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</table>

SARA–EnMAP and CARE–X Objectives

Research focus:

⇒ Development of methods for the classification of selected biotope types and plant associations

⇒ Collection of a large spectral library for selected plant species and associations

⇒ Integration of data mining methods and classic approaches

⇒ Examination of a multisensor and multitemporal analysis

⇒ Adjustment to phenological phases

⇒ Improvement of methods for Natura2000 habitat monitoring on local and regional scale
SARA–EnMAP and CARE–X - Study Area and Data

- Nature conservation areas Ferbitzer Bruch & Döberitzer Heide
- part of Natura2000 SCI and SPA
- former military training site
- habitat for many endangered species, especially in wetland and dry heathland habitats
SARA–EnMAP and CARE–X – Ground truth data collection

- 80 sample sites were marked with magnets and GPS
- Sample site size 2 x 2m
- Biotope types and plant species as well as their dominance were mapped
- ASD field-spectrometer measurements started in June 2007 and last until October 2011
- Mean of 25 measurements per plot, 1m above ground/vegetation
- Accuracy assessment with 246 transect points
SARA–EnMAP and CARE–X – Ground truth data collection

Assemblage of distinct classes (18 Biotope types, 20 plant associations > 32 classes):

<table>
<thead>
<tr>
<th></th>
<th>Code</th>
<th>Code (year)</th>
<th>Description</th>
<th>Biotope Type</th>
<th>Plant Association</th>
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<tbody>
<tr>
<td>2</td>
<td>MEPA_CAR_PHA</td>
<td>04514</td>
<td>reed canary grass in eutroph / polytroph fens and swamps</td>
<td>Caricion elatae W. Koch 1926</td>
<td>Phalaridetum arundinacea Lib. 1931</td>
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<tr>
<td>3</td>
<td>GFS_CAR_XAC</td>
<td>05101</td>
<td>grassland dominated by sedges</td>
<td>Caricion elatae W. Koch 1926</td>
<td>Caricetum acutiformis Eggler 1933</td>
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<td>4</td>
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<td>Aszod 1936</td>
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<td>GFP_MOL_MOL</td>
<td>05102 (6410)</td>
<td>nutrient-poor wet grassland</td>
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<td>Molinietum caeruleae W. Koch 1926</td>
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<td>7</td>
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<td>8</td>
<td>GAFP_PHR_PHR</td>
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<td>fallow grassland dominated by common reed</td>
<td>Phragmition australis (W. Koch 1926)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Schmale 1939</td>
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<td>GAFJ_ELE_ELE</td>
<td>051315</td>
<td>fallow grassland dominated by spike rush</td>
<td>Eleocharito-Sagittarion sagittifoliae Pass. 1964</td>
<td>Eleocharitetum uniglumis Almqu. 1929</td>
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thus concentration on indices and derivatives rather than original spectra

indices used e.g.:

- Cellulose absorption index
- Red edge NDVI
- Pigment specific simple ratio-chlorophyll-b and chlorophyll-a
- Ratio analysis of reflectance spectra-chlorophyll-b and chlorophyll-a
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SARA-EnMAP and CARE-X – Methods

- application of spectral library information only, no ground truth training vectors
- concentration on derivatives and indices instead of original spectra
- combination of traditional methods with CART classification (ensemble classification)
- Iterative classification (Pixel of agreement): where all classifiers in the first run indicate the same class a new training pixel is located
- Second and further classification runs are based on these image related training information
- application of posterior probabilities/contrast maps derived from the spectral library as weight for the final weighted majority vote
Classification with phenological-spectral libraries

Pixel will be allocated or not to the habitat

interpolated phenological optimal gradient with STDEV

field spectroscopy

Slide: Michael Förster, TU Berlin
CARE-X - Methods

**NDVI Rapideye**

- **Molinietum**
- **Phragmitetum**

**NDVI ASD**

- **Mai**
- **Juli**
- **August**
- **September**
## SARA-EnMAP and CARE-X - First Results

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<td>Caricetum appropinquatae (W. Koch 1926) Aszod 1936</td>
</tr>
<tr>
<td>GFP_MOL_MOL</td>
<td>05102</td>
<td>nutrient-poor wet grassland</td>
<td>Molinion caeruleae W. Koch 1926</td>
<td>Molinietum caeruleae W. Koch 1926</td>
</tr>
<tr>
<td>GFR_CAL</td>
<td>05103</td>
<td>nutrient-rich wet grassland</td>
<td>Calthion palustris Tx. 1937</td>
<td>-</td>
</tr>
<tr>
<td>GAFP_PHR_PHR</td>
<td>051311</td>
<td>fallow grassland dominated by common reed</td>
<td>Phragmition australis (W. Koch 1926)</td>
<td>Phragmitetum australis (Gams 1927) Schmale 1939</td>
</tr>
<tr>
<td>GAFJ_ELE_ELE</td>
<td>051315</td>
<td>fallow grassland dominated by spike rush</td>
<td>Eleocharito-Sagittarion sagittifoliae Pass. 1964</td>
<td>Eleocharitetum uniglumis Almqu. 1929</td>
</tr>
</tbody>
</table>
SARA–EnMAP and CARE–X– First Results

- accuracy assessment with 163 transect points

- accuracy ranges for both datasets (HyMAP and RapidEye) from 45 to 90 % for the single classes

- classes that have a strong phenological change throughout the year (e.g. due to mowing) can better be distinguished with multitemporal data (RapidEye)

- classes with small phenological changes and only subtle spectral differences (e.g. different sedge species) can better be distinguished with hyperspectral data (HyMap)
SARA-EnMAP and CARE-X - Difficulties and Limitations

⇒ to obtain good results a very comprehensive spectral library is necessary

⇒ all possible variations of a biotope type/ plant association have to be measured throughout the year

⇒ a good atmospheric and geometric correction of the imagery is crucial

⇒ a precise phenological correction is necessary
Remote sensing with either high spatial, high spectral or high temporal resolution can be a very important database for the monitoring of vegetation especially for:

- Natura 2000
- Biodiversity
- Invasive species
- Habitat modelling

Operational applications are already available

The standardised collection of spectral vegetation characteristics and the integration in a public database should be widely propagated

More model-based approaches should be tested for complex natural habitats (e.g. PROSPECT+SAIL)
Thank you very much!

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