Hyperspectral-based characterization of grassland for the control of agri-environmental measures

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Context

Grassland is an important component of the agricultural landscape.

Monitoring grassland at the regional level is closely linked to the knowledge of regional:

- **Inventory of forage production & quality**
- **Management practices**
- **Control of application of agri-environmental measures**

With the recently airborne imaging spectroscopy development, a new method for non-destructive grassland characterization can be explored

Presentation

- **Scientific objectives**
- Material
  - Study area
  - Field campaign (before flight)
  - Field campaign (during flight)
- Method
  - Spectral analysis at Pixel level (intra-parcel)
  - Spectral analysis at parcel level (inter-parcel)
- Results
- Conclusions

Scientific objectives

- **Agri-Environmental Measures (AEM):**
  - Now compulsory (CAP reform, WR regulations)
  - Temporal constraints (Specific cutting or grazing periods)
  - Opportunity of using airborne imaging spectroscopy to trace the recent history of grasslands in terms of managements

- **Working hypothesis: cutting or grazing actions**
  - Can be considered as major stresses, which have an impact on the spectral signatures of grass canopy.
  - Changes of spectral signature depend not only on the nature and the intensity of the action, but also on the time spent between the action and the remote sensing data acquisition.

Scientific objectives

CASI-ATM 2003 project :

- **A continuum and a possible validation of the first campaign**:
  - CASI-2 (VIS/NIR) and SASI (SWIR) sensor
  - August 2002
  - Lorraine test site
  - Biophysical (wet matter, biomass, grass height…)
  - Biochemical (protein, VEM, DVE…)

- **Tries to enlighten how imaging spectroscopy are capable to:**
  - Determine grassland management practices
  - Control of application of Agri-Environmental Measures

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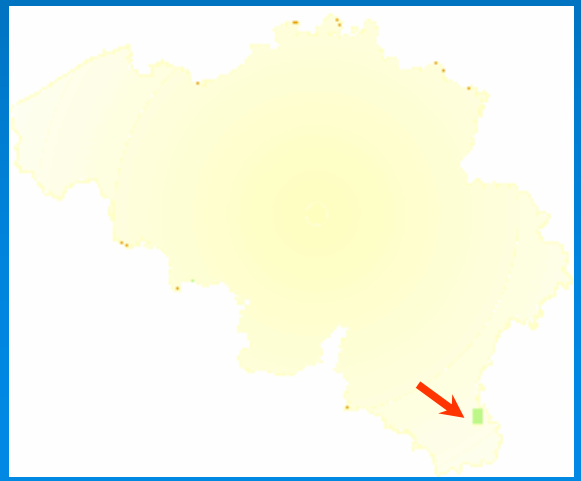
Study area = Attert

- South-east of Belgium.
  Luxembourg Province (near Arlon).
- Located in Natura 2000.
- Grassland > 75% of land-use
- Study area = ±35 Km²



- A subset of 33 parcels was followed:
  - Ground cover was scored visually from the middle of May to the airborne flight.
  - Biophysical parameters (GH, FMY, DMY…)
  - Field spectroradiometer (ASD)

Field campaign (before flight)

Table 1. Management practices observed on the 33 monitored parcels and their respective observed management class (MCo). (R = Restoration, F = Haying, P = grazing, NP NF = No Grazing and No Haying).

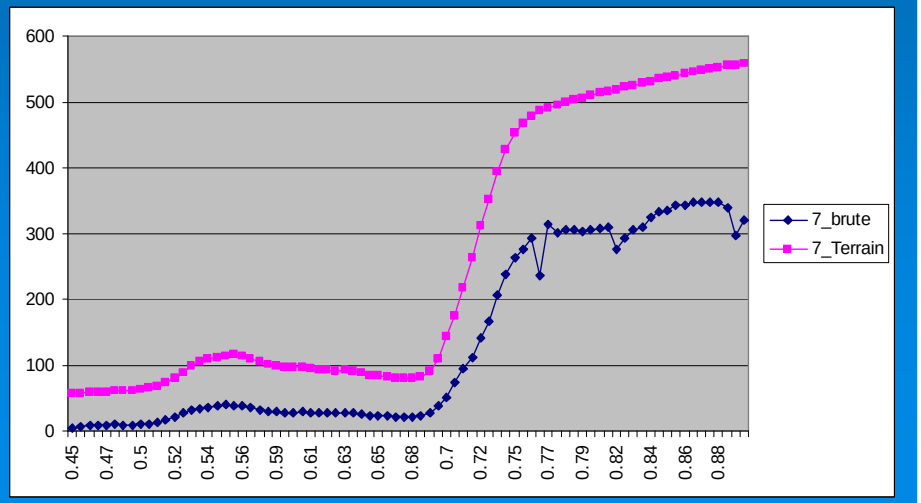
PARCEL	OBS1	OBS2	OBS3	OBS4	OBS5	OBS6	OBS7	OBS8	OBS9	OBS10	OBS11	MCo	LAST CUT
1	*	P	RP	P	P	P	RP	RP	P	RP	F	P	22/06/2004
2	P	P	P	P	P	P	P	P	P	P	F	P	22/06/2004
3	*	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	F	RF	F	18/06/2004
4	*	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	F	RF	RF	F	14/06/2004
5	*	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	F	RF	F	18/06/2004
6	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	F	RF	RF	F	15/06/2004
7	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	
8	*	P	P	P	P	P	P	P	P	P	P	P	
9	NP NF	NP NF	NP NF	F	RF	RF	RF	RF	RF	RF	RF	F	28/05/2004
10	P	P	R	R	R	P	P	P	P	P	RP	P	
11	RF	RF	RF	P	P	P	RP	P	P	P	P	P	
12	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	F	RF	RF	RF	RF	F	09/06/2004
13	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	F	F	22/06/2004
14	NP NF	NP NF	NP NF	F	RF	RF	RF	RF	RF	RF	RF	F	27/05/2004
15	NP NF	NP NF	NP NF	F	RF	RF	RF	RF	RF	P	RP	F	28/05/2004
16	*	P	P	P	P	P	P	P	P	P	P	PP	
17	*	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	F	RF	RF	F	14/06/2004
18	*	NP NF	NP NF	NP NF	NP NF	NP NF	F	RF	RF	RF	RF	F	07/06/2004
19	*	P	P	P	PR	P	P	RP	RP	RP	RP	PP	
20	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	
21	*	P	P	P	PR	P	P	P	P	P	RP	PP	
22	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	
23	P	P	RP	P	P	P	P	P	P	P	P	PP	
24	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	F	RF	RF	F	14/06/2004
25	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	F	RF	RF	RF	RF	F	07/06/2004
26	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	F	RF	RF	F	14/06/2004
27	*	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	F	RF	RF	F	14/06/2004
28	*	NP NF	P	P	P	P	P	P	P	P	P	P	
29	*	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	F	RF	RF	RF	F	10/06/2004
30	*	P	P	P	P	P	P	P	P	P	P	PP	
31	*	P	P	P	P	P	P	P	P	RP	RP	PP	
32	*	NP NF	NP NF	NP NF	NP NF	NP NF	F	RF	RF	RF	RF	F	09/06/2004
33	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	NP NF	F	RF	F	18/06/2004

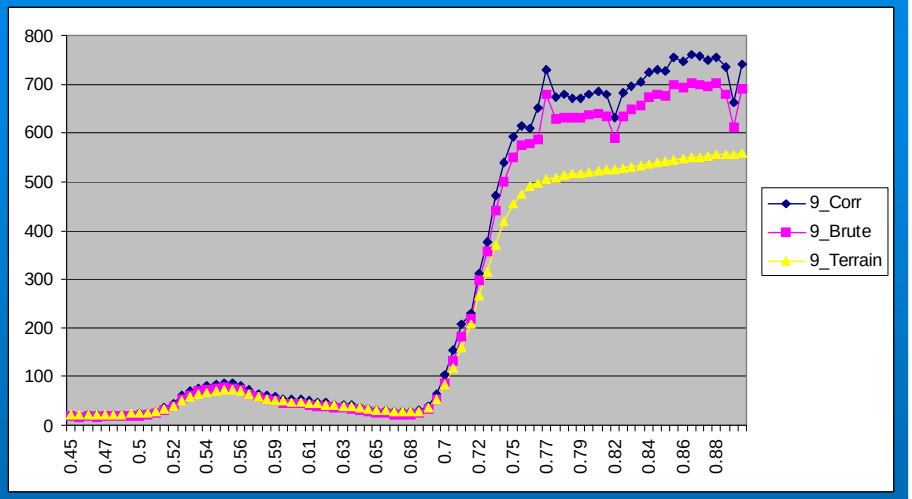
Hyperspectral data acquisition

- End of June
- CASI resolution:
  - 2.4 x 2.4 m
  - 96 spectral bands
- 10 transects by sensors
- Quality check (signal & geometric)

  Bad weather conditions
  - Signal problems
  - Image correction

  => 24 parcels were preserved





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Spectral analysis at Pixel level

- This spectral analysis at pixel level is used to investigate and validate CASI/SASI-2002 results, with regards to the characterisation of grass canopy with quantitative information regarding biophysical parameters (FMY, DMY, GH).

- CASI-ATM pixel responses were average within 3x3 pixel subset centered around the sampling unit.

- In addition to the standard channels a number of channel ratios and normalized channel difference indices were developed.

  - Photochemical Reflectance Index (**PRI**).
  - Red-edge slope (**RESL**), Red-edge step (**REST**) and Red-edge maximum slope wavelength (**REMS**).
  - Water Band Index (**WBI**)
  - Normalized Difference Vegetation Index (**NDVI**).
  - …

Spectral analysis at Pixel level

Table 2. Observed correlation coefficients between the different indices and grassland characteristics .

	Leaf water content	FMY	DMY	Grass Height	Biomass
λRESL	0.297	0.078	0.023	0.19	0.087
NDVI	**0.814**	**0.753**	**0.303**	**0.417**	**0.585**
PRI	0.716	0.567	-0.016	0.243	0.029
RESL	0.579	**0.637**	0.215	0.149	0.172
REST	0.55	**0.595**	0.195	0.127	0.152
WBI1	**-0.688**	**-0.587**	-0.163	**-0.641**	**-0.335**
WBI2	**-0.722**	-0.504	-0.074	**-0.534**	-0.123

- **Leaf water content is more highly correlated with spectral reflectance than either total wet biomass or total dry biomass.**

Results show that ground truth data collection or canopy sampling for remote sensing studies of grass canopies should measure the total wet biomass and the total dry biomass. This will allow for the calculation of the leaf water (also Compton conclusions).

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- **Red-Edge indicators (Slope, Step, REMS) have bad correlation coefficients compared to 2002 campaign. REST had 0.63 for GH and 0.68 for Biomass.**

This difference is probably the consequence of the poor images quality resulting of bad meteorological conditions during the flight.

Spectral analysis at Pixel level

- Red-edge indicators seems to be too sensible to the meteorological conditions and can not be considered for an operational system.

- **Inspection of the regression results obtained in the 2002 and 2003 campaigns indicates that NDVI, WBI1 and PRI are the best indicators to estimate biophysics characteristics**.

Confirm CASI-SASI 2002 results on biophysical parameters (FMY, DMY, GH) directly linked to the age and the management practices supported by grasslands.

Spectral analysis at Parcel level

- In a second step, the project has analysed the possibility to classify grassland in 3 management classes:
  - Haying grasslands (P)
  - Grazing grasslands (F)
  - Neither haying nor grazing grasslands (NP NF)

- The grassland classification is based on the hypothesis that management practices can be identified by the combination of

  - Textural indices (**qualitative parameters**) with
  - Vegetation indices (**quantitative parameters**) selected at the pixel level

- Different textural indices were calculated:

  - Global approach (global variance)
  - Local approach (moving windows of 3x3 pixels)

Spectral analysis at Parcel level

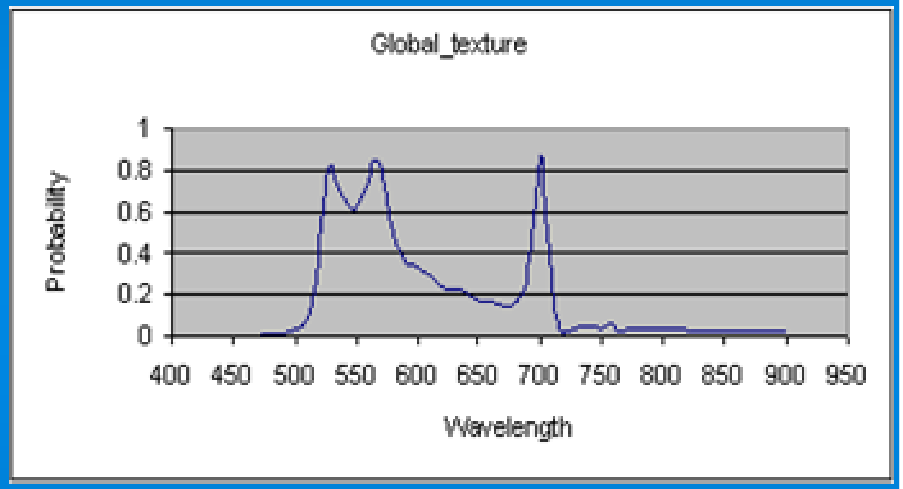
- **Step 1:** Discriminant analysis to identify regions of interest in the reflectance spectra and to choose the relevant textural indices

Probability level of the differences between grassland classes

Global texture parameter

=> 2 regions of interest

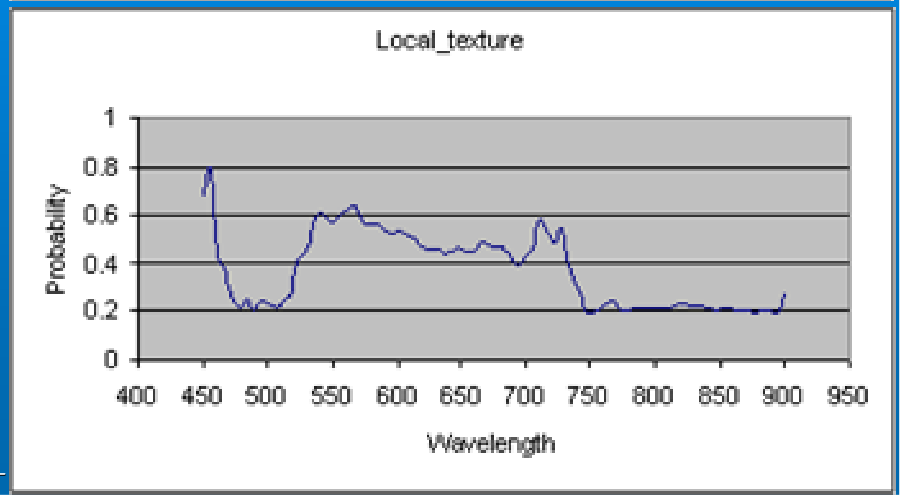
- Below 500 nm
- Above 725 nm.



Local texture

=> Quite different

- Around 500 nm
- Above 750 nm
- BUT observed level are not significant (P<0.05).



Spectral analysis at Parcel level

- **Step 1:** Based on these results, 2 wave bands from the global texture analysis have been selected (450 nm and 725 nm) together with previously defined vegetation indices.

- **Step 2:** Discriminant analysis with all the selected dependent variables (vegetation indicators & textural indicator)

  - The stepwise discriminant analysis identified 3 vegetation indices, (**PRI, NDVI and WBI1**) and one textural **global index (450nm)** as significant.

  - Cross validation procedure show that about **83% of correct classifications** may be obtained.

Results: Cross classification

Classification results	Observed management classes		
	F	NP NF	P
F	13	0	1
NP NF	2	3	1
P	0	0	4
N total	15	**3**	6
N correct	**13**	**3**	**4**
Proportion	86,70%	**100%**	66,70%

- **All the parcels with AEM are well identified MCo = MCi = NP NF**
- **Only 4 parcels have been classified in a bad management class (MCo ≠ MCi).**

Results: Cross classification

- **Only 4 parcels have been classified in a bad management class**

2 parcel with **MCo = F**	classified in	**MCi = NP NF**
1 parcel with **MCo = P**	classified in	**MCi = NP NF**
1 parcel with **MCo = P**	with	**MCi = F**

These misclassifications can easily be explained by a regrowth of grass after a long period without pasture or after haying.

- **These results also show that if the 24 parcels had been declared in AEM, and 18 parcels of them would be irregular (MCo ≠ NP NF), only 3 parcels would not have been identified as irregular by remote sensing (MCi = NP NF).**

Conclusions

- These study assess the ability of Imaging Spectroscopy to be reliable method for estimating grassland management practices and to control if AEM are correctly applied.
- 3 vegetation indices (PRI, NDVI and WBI1) are confirmed as good quantitative parameters
- Textural indices (qualitative parameters) and vegetation indices (quantitative parameters) are linked to the age and the management practices supported by grasslands
- Changes of spectral signature depend not only on the nature and the intensity of the action, but also on the time spent between the action and the remote sensing data acquisition.
- Classification results are promising and must be validated with better images quality due to the bad meteorological conditions.