User-driven requirements of the European Hyperspectral Remote Sensing Community

Jens Nieke, the HYRESSA Team,
and 150 European anonymous HSI researchers

HYRESSA Workshop, Davos, Switzerland, 14-15 Mar 2007
HYRESSA - HYperspectral REmote Sensing in Europe specific Support Actions

Background

What is HYRESSA?

EC project HYRESSA (FP6-2004-Infrastructures-6-SSA, Contract Number 026194); 10 partners, 9 nations:

Vito: Flemish institute for technological research, Mol, Belgium (coordination)
DLR: German Aerospace Centre, Wessling, Germany
RSL: University of Zurich, Remote Sensing Laboratories, Zurich, Switzerland
GFZ: GeoForschungsZentrum, Potsdam, Germany
WUR: Wageningen University, Centre for Geo-Information, Wageningen, The Netherlands
INTA: Instituto Nacional de Técnica Aeroespacial, Torrejon de Ardoz-Madrid, Spain
ILE ASCR: Academy of Sciences, Institute of Landscape Ecology, Czech Republic
TO: Tartu Observatoorium, Toravere, Tartumaa, Estonia
U-Helsinki: University of Helsinki, GeoInformatics Research Group (GIRG), Helsinki, Finland

Background

EC-INFRASTR-6: Accompanying Measures for promoting a more coordinated approach to research infrastructures in Europe

HYRESSA Goals:

- To improve the coordination of flight campaigns and to increase the use of hyperspectral images in Europe,
- To investigate the needs of the EU hyperspectral research community,
- To evaluate needed accuracy, quality and conformity of hyperspectral images,
- To refine protocols related to calibration, acquisition, processing and in-situ measurements in compliance with standards.

Background

Task	Duration	Who	month from project start	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
AM1 Management of HYRESSA		**Vito**																									
Management of HYRESSA	24m																										
AM2 Coordination		**Vito**		M					M																		
Coordination	24m																										
Kick off meeting	2d			★																							
Final report	1m																										
AM3 Dissemination		**Vito**				D1					M										M						M/D9
Website development	2m																										
Website maintenance	21m																										
Presentations, publications	12m																										
AM4 Contact database		**GFZ**				M	M/D2																				
Unification of contact database	2m																										
Literature study	1m																										
Internet study	1m																										
AM5 SWOT and User Needs workshop		**DLR**							M	D3																	
Preparation of workshop	3m																										
User need workshop	3d								★																		
Workshop report	1m																										
AM6 Questionnaire on User Needs (QUN)		**RSL**										D4					D5										
Preparation of questionnaire	2m																										
Evaluation of questionnaire	2m																										
Evaluation report	1m																										
AM7 Exploratory workshop		**WUR**																	M	D6							
Preparation of workshop	3m																										
Exploratory workshop	3d																		★								
Workshop report	1m																										
AM8 Review and refinement protocols		**INTA**																				M		D7			
Review and refinement protocols	3m																										
Protocol meeting	2d																					★					
Protocol report	1m																										
AM9 Future collaboration plan		**UEDIN**																							M	D8	
Future collaboration plan	2m																										
Future collaboration meeting	2d																								★		

HYRESSA Project

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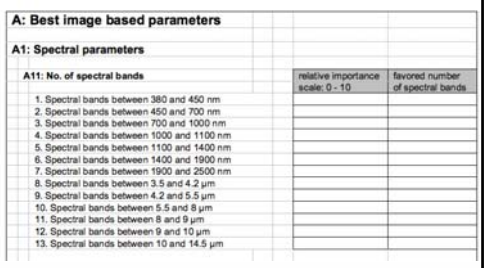
Metho

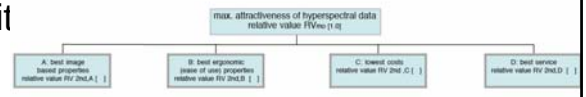
QUN: Questionnaire o

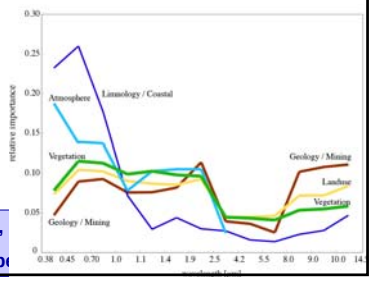
VBA: Value Benefit

Evaluation of Results

Presentation/Dissemination







Value Benefit Analysis

Goals of a Value Benefit Analysis*:

(method commonly applied in operations research and politics)

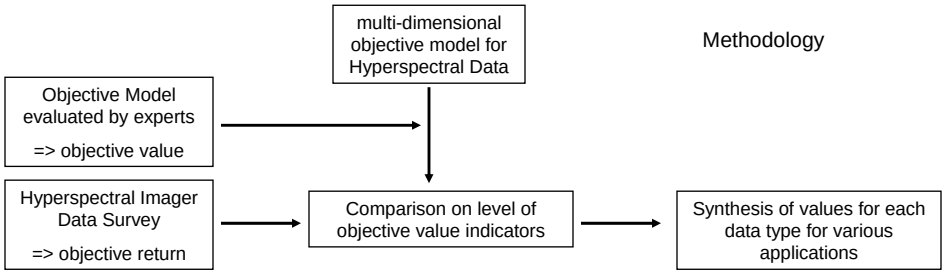
- analysis of user needs
- compare alternatives
- prepare decision-making
- unveil the decision process

* Christof Zangemeister: Nutzwertanalyse in der Systemtechnik - Eine Methodik zur multidimensionalen Bewertung und Auswahl von Projektalternativen, 1974 (ISBN 3-923-26400-3)

VBA

Procedure:

- Compilation of a multi-dimensional objective system
- Evaluation of objective system by experts / users
  => objective value (of users)
- Description of the related alternatives using the objective system
  => objective return (of sensor data)
- Value synthesis of users values and sensor data return



Objective Model for Hyperspectral Data

1. Definition of the Main Objective:
   "Max. attractiveness of hyperspectral data"
2. Definition of properties of hyperspectral data
3. Development of a hierarchical structure in form of a tree diagram with main objective (top) and subordinated objectives (low):
   - A: Best image based properties
     - A1: Best spectral parameters
     - A2: Best spatial parameters
     - A3:…
   - B: Best ergonomic properties
   - C: Low costs
   - D: Best service
3. Lowest level of an objective model are the objective indicators

* in function of user interest, applications etc.

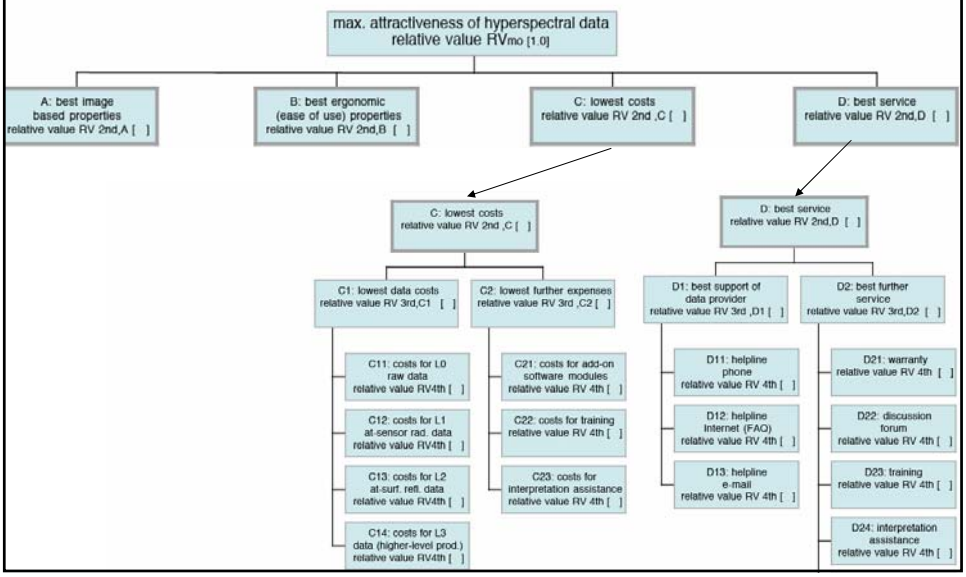
Mathematical Model

1. Law of Comparative Judgement $0 \leq w_{mn} \leq 10$
2. Weights of all objective on one level = 1 $\sum_{m=1}^{K} g_m = 1$
3. Each alternative in evaluated using a target value $W_n = \sum_{m=1}^{K} g_m \cdot w_{mn}$
4. Completeness of the preference order

TIFF (Uncompressed) decompressor are needed to see this picture.

Literature:
Torgerson; Therory of methods and scaling; Wiley & Sons (1954)
Keeney & Raiffa; Decisions with Multiple Objectives; Preferences and Value Tradeoffs; Wiley & Sons (1976)

Objective Model



Objective Value

Who was asked?

47 % University, 38 % Research Institute, 15 % Government

Out of the 150 “only” 74 researchers filled out the QUN completely:

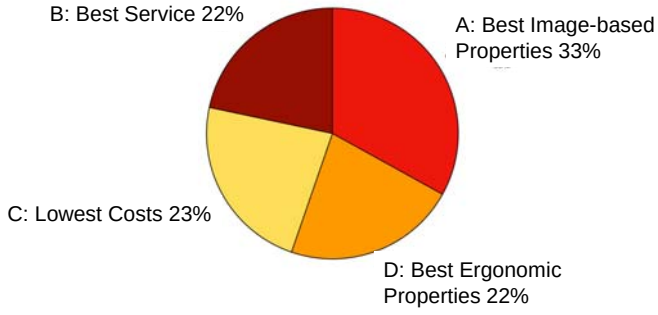
Application area	Number of Replies
Atmosphere	3
Limnology /Coastal Waters	10
Geology and Landuse	19
Vegetation (incl. Agriculture and Forestry)	42

Country of Origin	Number of Replie
Belgium	14
Czech Republic	2
Estonia	1
Finland	2
France	4
Germany	13
Great Britain	5
Italy	2
Netherlands	9
Norway	3
Poland	4
Slovakia	1
Spain	5
Switzerland	9

Objective Value

What makes HSI data attractive?

For the average user



Relative values for the all application areas and all users for 1st objective level!

Objective Value

What makes HSI data attractive?

Objective (2nd level)	Vegetation	Land	Water	Atmosphere
A - Best Image based Properties	0.35	0.35	0.28	0.30
B - Best Ergonomic Properties	0.21	0.23	0.24	0.21
C - Lowest Costs	0.23	0.23	0.23	0.24
D - Best Service	0.21	0.19	0.25	0.25

Relative values for the main application areas vegetation, land, water, and atmosphere for 1st objective level!

Objective Value

What makes the best HSI *image*?

Objective	Vegetation	Atmosphere	Land	Water
A1 – Spectral Parameters	0.29	0.28	0.29	0.29
A2 – Geometric Parameters	0.25	0.22	0.25	0.23
A3 – Radiometric Parameters	0.27	0.24	0.28	0.27
A4 – Temporal Parameters	0.19	0.26	0.18	0.21

Relative values for the main application areas vegetation, land, water, and atmosphere for 2nd objective level: image-based properties

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Objective Value

What makes the *best spectral parameters* of a HSI image?

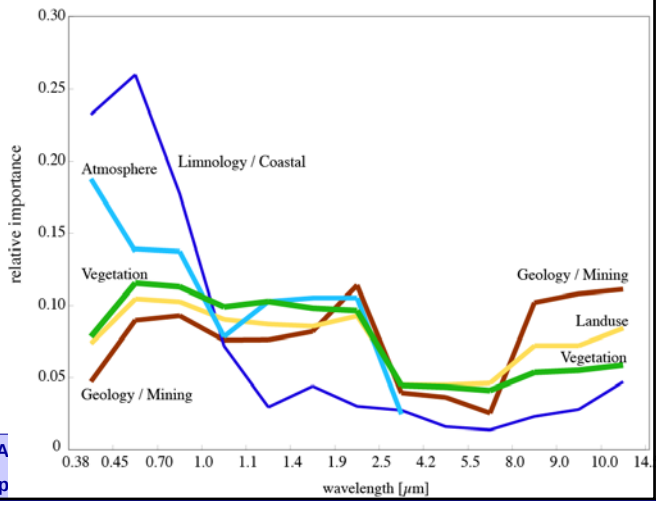
Objective	Vegetation	Atmosphere	Land	Water
A11 – No. Of Spectral Bands	0.31	0.35	0.30	0.33
A12 – Spectral Resolution	0.32	0.35	0.32	0.33
A13 – Spec. Calibration Quality	0.37	0.30	0.38	0.33

Relative values for the main application areas vegetation, land, water, and atmosphere for 3rd objective level: spectral parameters

Objective Value

Which spectral range has the highest importance for each application?

Objective Indicators for the main application areas vegetation, land, water, and atmosphere : *Relative Importance of Spectral Range (A11)*

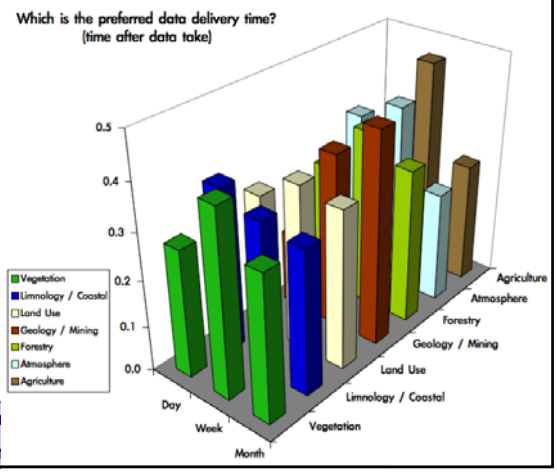


Objective Value

Q: Which is the preferred data delivery time?

A: One week is the optimal time of delivery (0.3-0.5), days and months are less important, except for Geologists.

Objective Indicators for the main application areas vegetation, land, water, and atmosphere : *Relative Importance of Spectral Range (B15)*

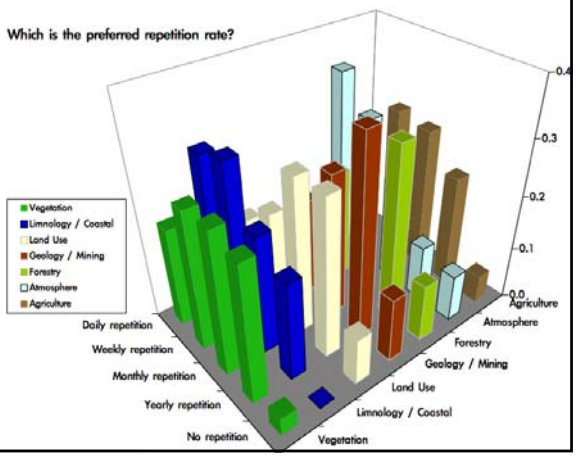


Objective Value

Q: Which is the preferred repetition time?

A: for Atmosphere, Limnology: daily - weekly repetition
Geology, Forest: towards yearly repetition
Vegetation, Agriculture: weekly - monthly

Objective Indicators for the main application areas vegetation, land, water, and atmosphere : *Preferred Repetition Time (A42)*

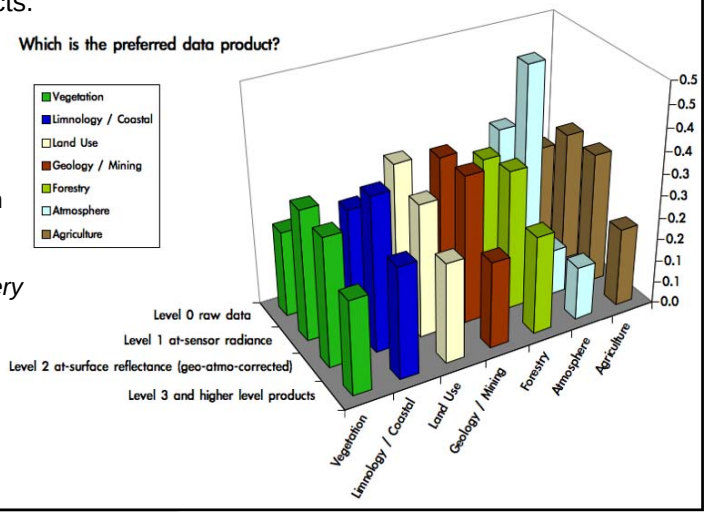


Objective Value

Q: Which is the preferred data product?

A: L1 (at-sensor radiance) - L2 (geo- and atmo-corrected) data are the most important products.

Objective Indicators for the main application areas vegetation, land, water, and atmosphere : *Delivery of image data (B13)*

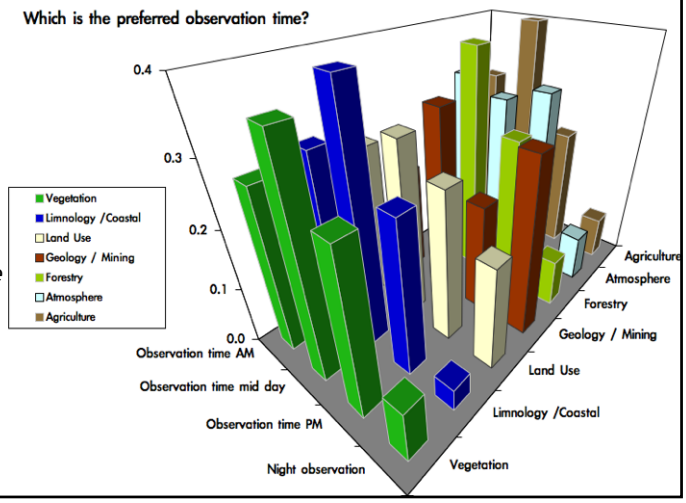


Objective Value

Q: Which is the preferred observation time?

A: very important between AM and PM with peak at noon, night time for geology.

Objective Indicators for the main application areas vegetation, land, water, and atmosphere : *Daytime of observation (A41)*



Objective Value

Q: How important is add-on software?

A: Very important to all users and all applications

Objective Indicators for the main application areas vegetation, land, water, and atmosphere : *Add-on SW modules (D25)*

Objective Value

What are the absolute requirements of the user community?

Problem for the estimation of the absolute values:

The Agriculture-Forestry-Vegetation Group was re-distributed (after re-assessment by experts) in

Group 1) the "*bio-chemical*" group, with a main interest in high spectral and spatial resolution,

Group 2) the "*classification*" oriented vegetation group, interested in a relatively broad spectral (< 30 nm) and lower spatial (10-30 m) resolution.

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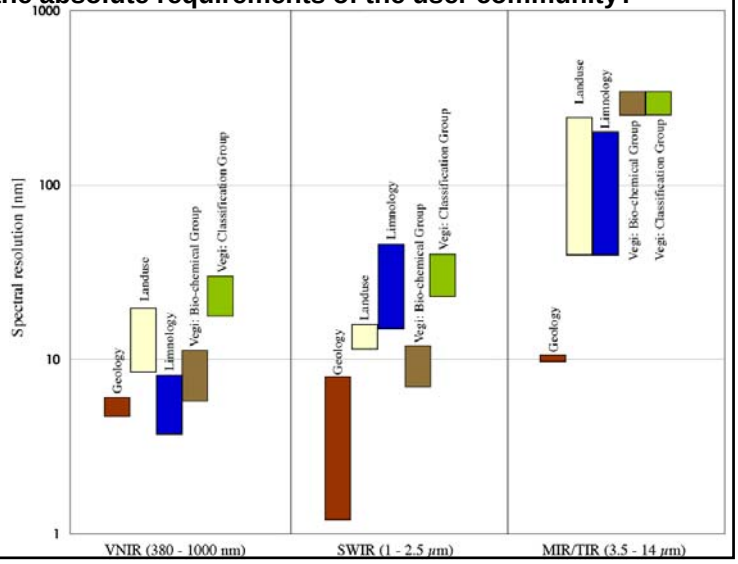
Objective Value

What are the absolute requirements of the user community?

Spectral requirements:



HYRESSA

	Atmos-phere[14]	Geology	Land-use	Limnology	Vegetation[15] Group-1 Group-2
No. of bands in total (VNIR-TIR)	3000	300	200	200	200 100
Spectral resolution VNIR [nm]	0.05 - 0.5	6-10	8 - 15	4 - 8	6 - 12 15 - 30
Spectral resolution SWIR [nm]	0.2 - 0.5	2 - 8	10 - 12	10 - 40	8 – 12 25 - 40
Spectral resolution MIR/TIR [nm]	NA	10	40 - 220	40 - 200	300
Spatial resolution VNIR/SWIR [m]	2500	5	4	5 - 20	4 - 5 10 - 30
Spatial resolution MIR/TIR [m]	NA	20 - 30	15	10 - 15	15 30
Swath width VNIR/SWIR [km]	1200	15 - 30	15	25 - 30	20 70
Swath width MIR/TIR [km]	0	15	15 - 20	30 - 40	20 200
SNR VNIR	1500	400	400	700	450
Preferred observation repetition rate	daily-weekly	yearly	monthly-yearly	daily-weekly	weekly-yearly
Preferred data product?	Level 1	Level 1-2	Level 1-2	Level 2	Level 1-2
Preferred observation time?	mid day	mid day or night	daytime	mid day	mid day
What implies an improved service?	add-on SW	add-on SW	add-on SW	add-on SW	add-on SW
Preferred data delivery time?	day-week	month	week	day-week	week

Objective Return

What is the performance of the HSI data provided?

Spaceborne:

	HYPERION	CHRIS
No. of bands in total	240	18-62
Spectral resolution VNIR [nm]	10	6-33
Spectral resolution SWIR [nm]	10	NA
Spectral resolution MIR/TIR [nm]	NA	NA
Spatial resolution VNIR/SWIR [m]	30	17-33
Spatial resolution MIR/TIR [m]	NA	NA
Swath width VNIR/SWIR [km]	7.5	14
Swath width MIR/TIR [km]	NA	NA
SNR VNIR	200	200
Data Provider	USGS	ESA

Airborne:

AHS-160, AISA Dual, APEX, ARES, AVIRIS, CASI-3, HYSPEX

Synthesis

What is the best data for all applications?

	Atmosphere[12]	Geology	Landuse	Limnology	Vegetation	Mean
AHS	0.62	0.68	0.66	0.66	0.70	0.66
AISA (DUAL)	0.56	0.55	0.54	0.55	0.56	0.55
APEX	0.70	0.74	0.72	0.78	0.76	0.74
ARES	0.67	0.75	0.72	0.74	0.75	0.73
AVIRIS	0.57	0.62	0.59	0.61	0.62	0.60
CASI	0.58	0.60	0.57	0.59	0.60	0.59
CHRIS	0.70	0.71	0.72	0.74	0.72	0.72
HYPERION	**0.75**	**0.77**	**0.78**	**0.78**	**0.78**	**0.77**
HYSPEX	0.69	0.72	0.68	0.72	0.72	0.71

Synthesis

What is the best data for vegetation research?

	A	B	C	D	Total
AHS	0.23	0.19	0.15	0.13	0.70
AISA - DUAL	0.19	0.10	0.15	0.13	0.56
APEX	0.22	0.21	0.15	0.18	0.76
ARES	0.23	0.20	0.15	0.17	0.75
AVIRIS	0.22	0.17	0.15	0.09	0.62
CASI	0.17	0.16	0.15	0.13	0.60
CHRIS	0.17	0.16	0.23	0.16	0.72
HYPERION	0.20	0.19	0.23	0.16	0.78
HYSPEX	0.22	0.21	0.15	0.15	0.72

Image-based Properties (A), Best ergonomic Properties (B), Lowest Costs (C) and Best Service (D)

Main Conclusion

- Reduce costs for HSI end-users!
- Better service (helplines, workshops, courses etc.) is recommended.
- Reasonable pricing policies of HSI data must be elaborated within a future European HSI infrastructure, e.g., trans-national group-shoots,
- Standardized and coordinated action to provide the requested HSI data with good service at reasonable price,
- HSI users have very individual preferences, leading to
  - very specific sensors requirements for a specific application group (e.g., atmospheric research), or
  - Super-sensors, which are accounting for all application groups equally.

Next Steps

- Results are currently discussed within the HYRESSA Team,
- QUN and VBA shall be further evaluated at RSL to squeeze out the utmost,
- Peer-review paper on VBA results is in preparation.

Conclusion on Methodology

The study showed, that a VBA is a very good method

- to analyse needs of hyperspectral data
- to support sensor/data specification-building process

Advantage:

- Easy and clear handling
- Comprehensive evaluation

Disadvantage:

- Efforts

USER NEEDS OF THE EUROPEAN HYPERSPECTRAL REMOTE SENSING COMMUNITY

Jens Nieke[1] and Klaus I. Itten [1]

Ils Reusen[2] and Stefan Adriaensen[2]

and the HYRESSA team: www.hyressa.net

1) University of Zürich, Department of Geography, RSL, Zurich, Switzerland; nieke@geo.unizh.ch
2) VITO – TAP, Boeretang 200, B-2400 Mol, Belgium

ABSTRACT

While there is a strong need for hyperspectral imagery, the user-driven requirements are not well defined in view of protocols for calibration, acquisition, processing and in-situ measurements in compliance with existing standards. Therefore an analysis was performed in the frame of the EC project HYRESSA, regarding the question “What are the individual user requirements on hyperspectral imagery and the related data products?”. For this analysis a questionnaire and a subsequent benefit-value analysis helped to retrieve users needs and evaluate open items accordingly.

The EC funded HYRESSA project /1/ aims at investigating the user needs of the European hyperspectral research community with respect to access to and accuracy, quality and conformity of hyperspectral images - especially with the advent of next-generation European hyperspectral sensors - in order to refine protocols related to calibration, acquisition, processing and in-situ measurements in compliance with standards. This knowledge was gathered through a SWOT and User Needs workshop (at DLR in July 2006) and an on-line questionnaire (released in Nov. 2006).

The purpose of the paper is to answer the question “What makes hyperspectral data attractive?”. Following the methodology of the benefit-value analysis (BVA) /2/, the answer can be described in hierarchical ordered multidimensional objective model.

The BVA serves as well-known tool for systematic problem solving process as a possibility of comparing projects or solutions. It enables the evaluation on the basis of a multidimensional objective model and can be extended by expert’s preferences. Therefore the scaling method (Law of Comparative Judgment) was applied for receiving the desired ranking judgments. The result, which is the relative value of projects concerning a well-defined main objective can now be produced analytically.

Accordingly, BVA is utilized for the determination of the rank of existing or planned hyperspectral data products and is subdivided in 6 main tasks: (1) Defining an Objective Model for hyperspectral data, (2) Objective model weighting procedure of experts, (3) Compilation of an Earth observation hyperspectral data survey, (4) Comparison on the level of the objective value indicators, (5) Synthesis of values for each sensor data and (6) Evaluation of the results.

The investigation showed, that a BVA is a suitable method to analyse needs of hyperspectral data and to support sensor/data specification-building process. The BVA has the advantage, to be easy and clear to handle, resulting in a comprehensive evaluation. The disadvantage are the necessary efforts and the partly non-availability of all sensor data parameters. The paper summarizes all results of the analysis and gives insight to BVA methodology, statistics and others more.

Keywords: HYRESSA, Benefit-Value-Analysis, data products, quality assessment, User Needs in Europe

References:

1/ FP6-2004-Infrastructures-6, Contract Number 026194; URL: www.hyressa.net

2/ Zangemeister, C. (1970): Nutzwertanalyse in der Systemtechnik. Eine Methodik zur multidimensionalen Bewertung und Auswahl von Projektalternativen. München, 370 S.