



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

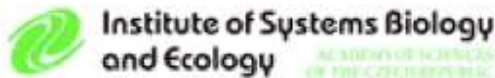
WUR: Wageningen University, Centre for Geo-Information, Wageningen, The Netherlands

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



WAGENINGEN UNIVERSITY
WAGENINGEN UR



UNIVERSITY OF HELSINKI



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.

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Background



			month from project start																							
Task	Duration	Who	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

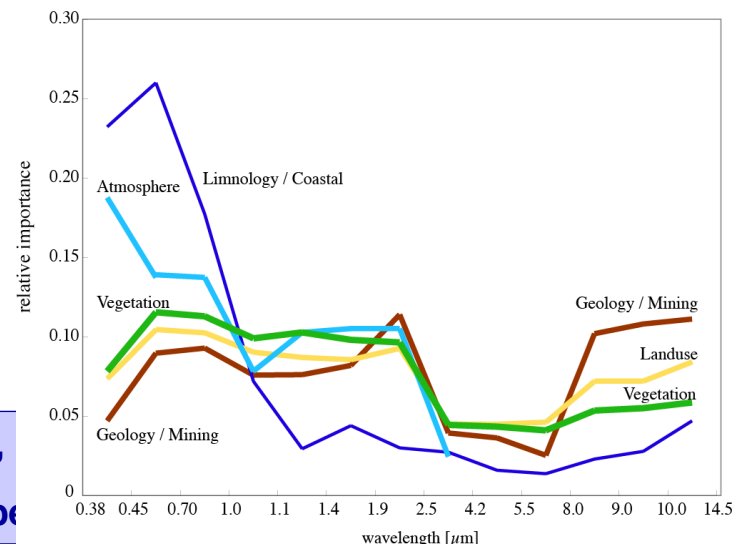
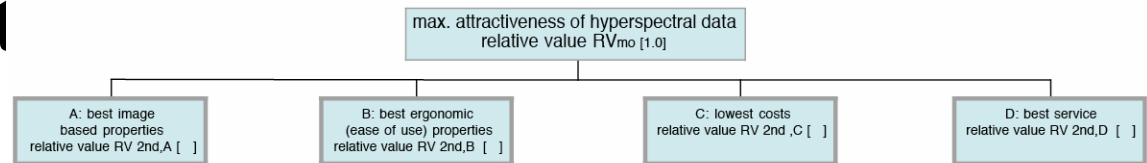
QUN: Questionnaire c

VBA: Value Benefit

Evaluation of Results

Presentation/Dissemination

A: Best image based parameters			
A1: Spectral parameters			
A11: No. of spectral bands		relative importance scale: 0 - 10	favored number of spectral bands
1. Spectral bands between 380 and 450 nm			
2. Spectral bands between 450 and 700 nm			
3. Spectral bands between 700 and 1000 nm			
4. Spectral bands between 1000 and 1100 nm			
5. Spectral bands between 1100 and 1400 nm			
6. Spectral bands between 1400 and 1900 nm			
7. Spectral bands between 1900 and 2500 nm			
8. Spectral bands between 3.5 and 4.2 μm			
9. Spectral bands between 4.2 and 5.5 μm			
10. Spectral bands between 5.5 and 8 μm			
11. Spectral bands between 8 and 9 μm			
12. Spectral bands between 9 and 10 μm			
13. Spectral bands between 10 and 14.5 μm			





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

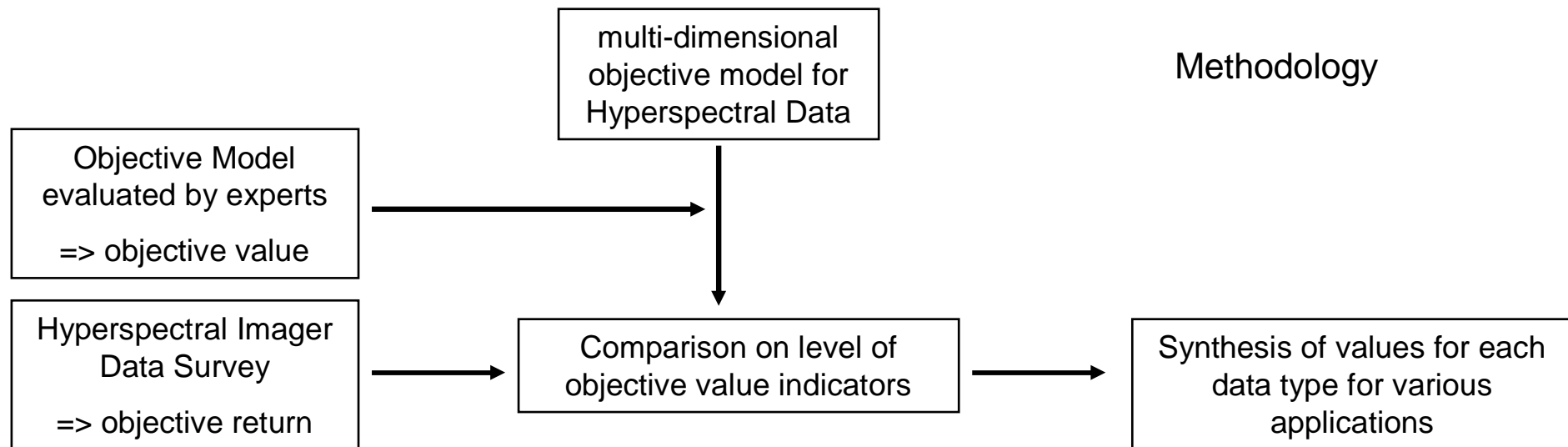
* Christof Zangemeister: Nutzwertanalyse in der Systemtechnik - Eine Methodik zur multidimensionalen Bewertung und Auswahl von Projektalternativen, 1974 (ISBN 3-923-26400-3)

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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.

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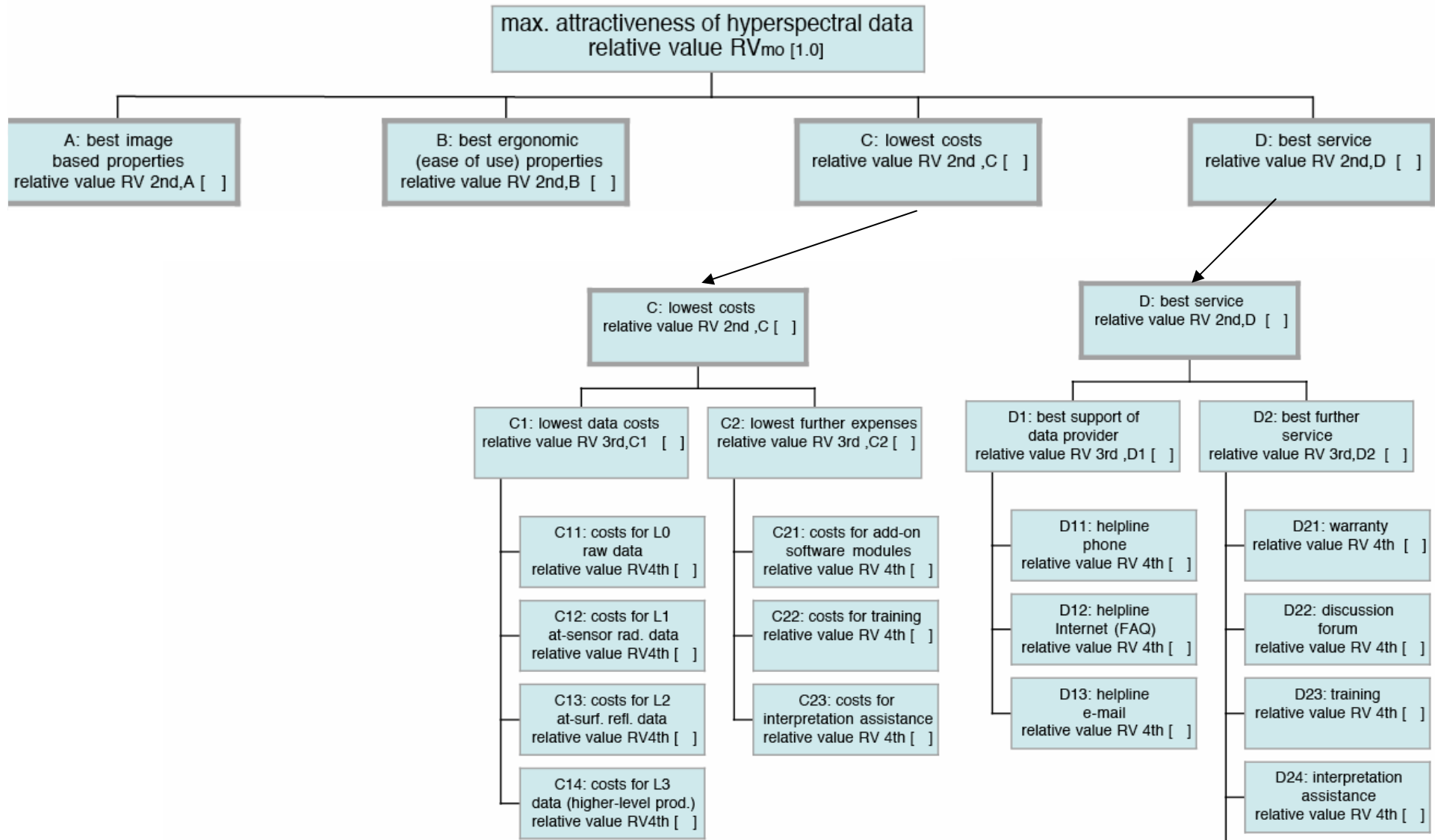


1. Law of Comparative Judgement $0 \leq w_{mn} \leq 10$
2. Weights of all objective on one level = 1 $\sum_{m=1}^K g_m = 1$
3. Each alternative is evaluated using a target value $W_n = \sum_{m=1}^K g_m \cdot w_{mn}$
4. Completeness of the preference order TIFF (Uncompressed) decompressor are needed to see this picture.

Literature:

Torgerson; Theory of methods and scaling; Wiley & Sons (1954)

Keeney & Raiffa; Decisions with Multiple Objectives; Preferences and Value Tradeoffs; Wiley & Sons (1976)





Who was asked?

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

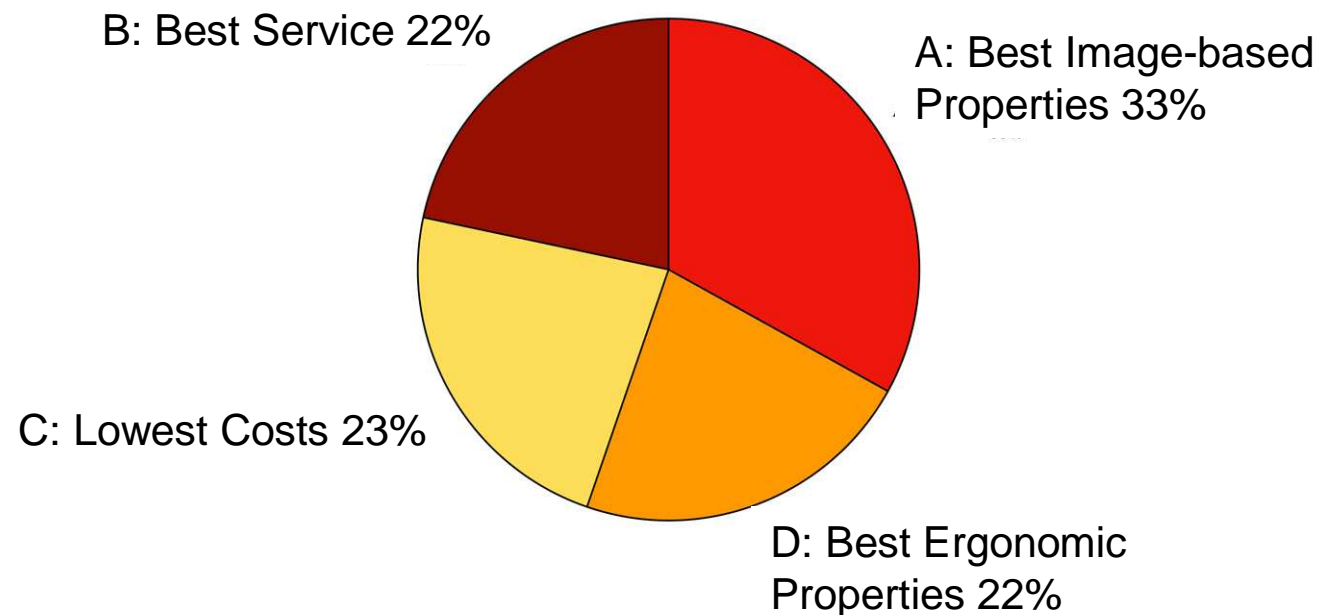
Out of the 150 “only” 74 researchers filled out the QUN completely:

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 Replies
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

What makes HSI data attractive?

For the average user



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



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!



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



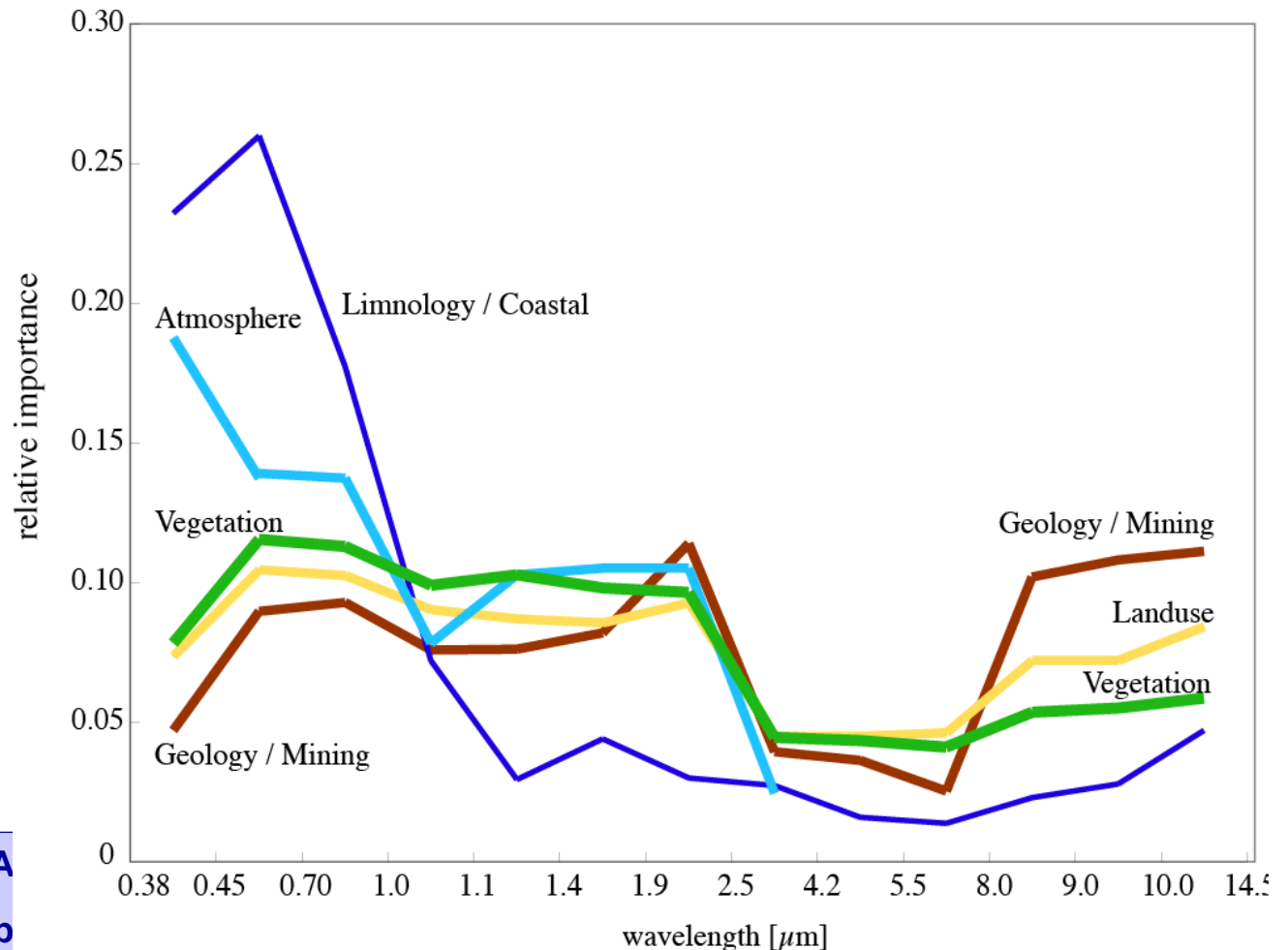
What makes the *best spectral parameters* of a HSI image?

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

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)*

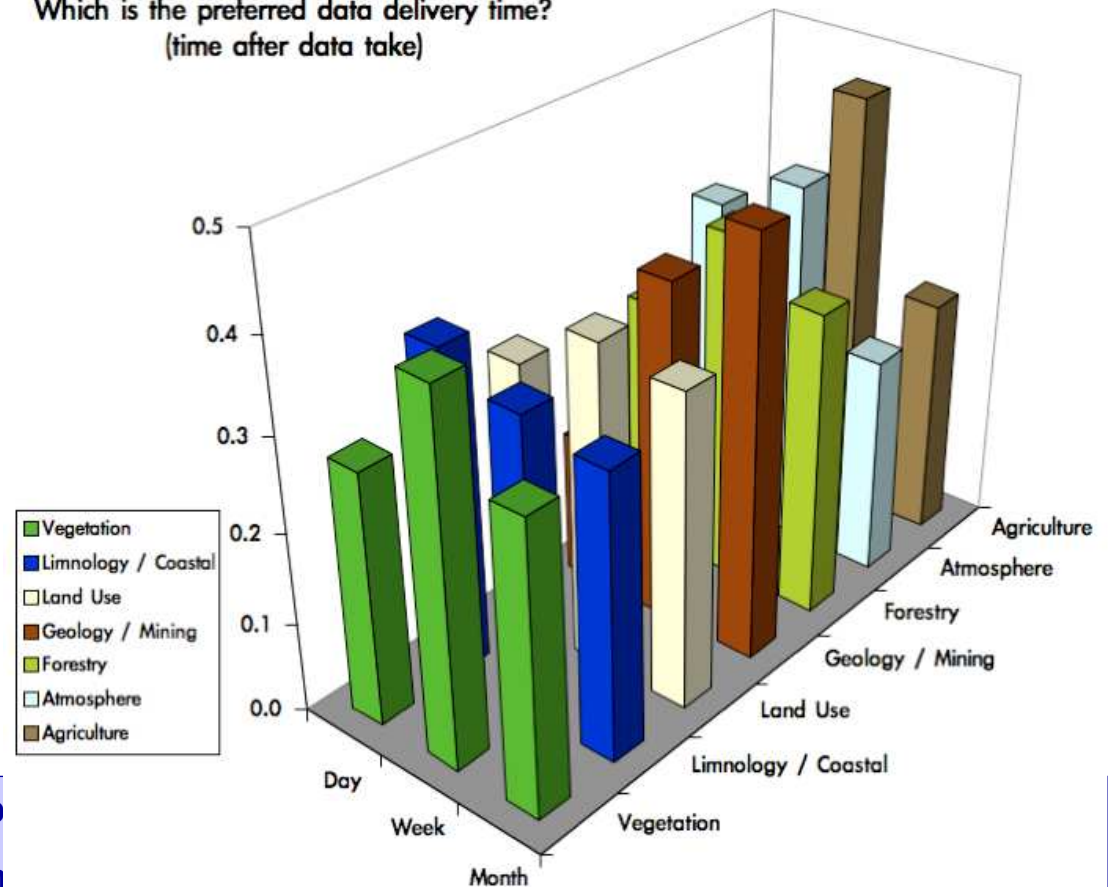


Q: Which is the preferred data delivery time?

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)*

Which is the preferred data delivery time?
(time after data take)

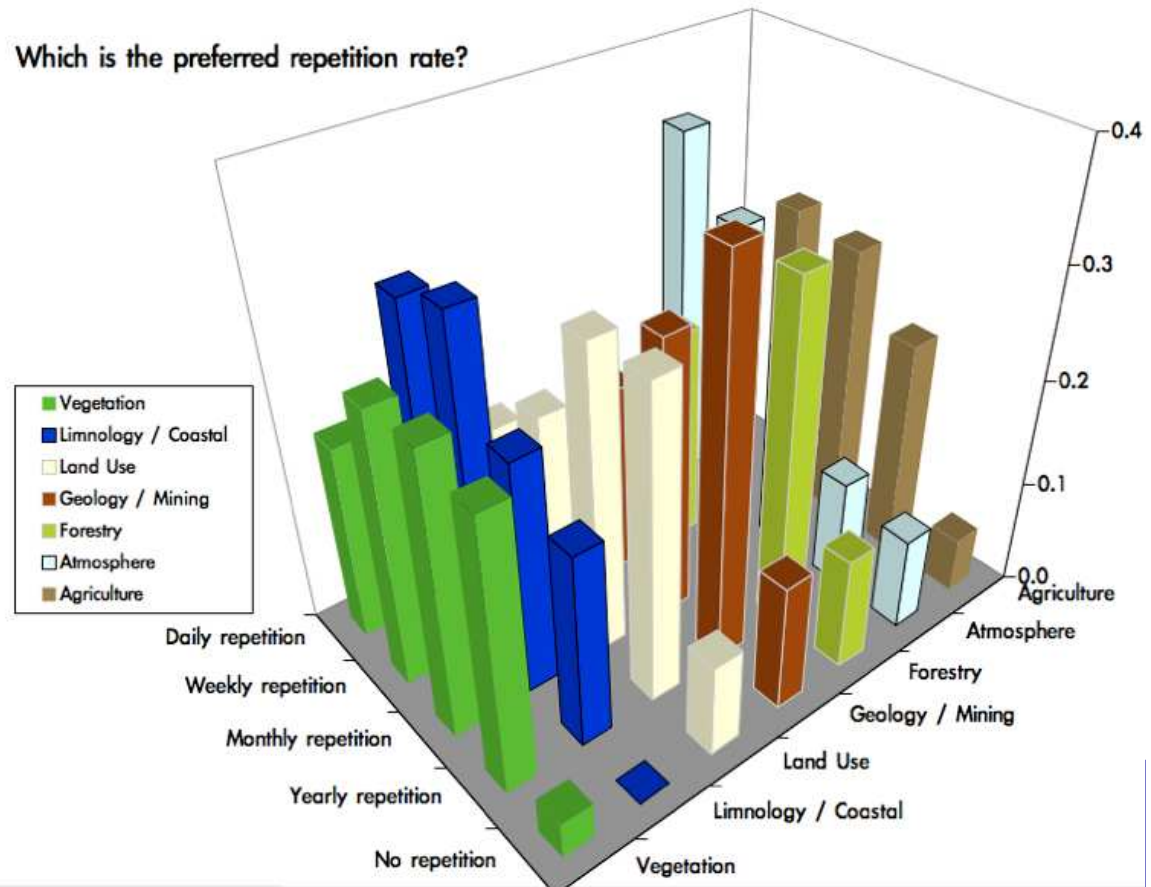


Q: Which is the preferred repetition time?

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)

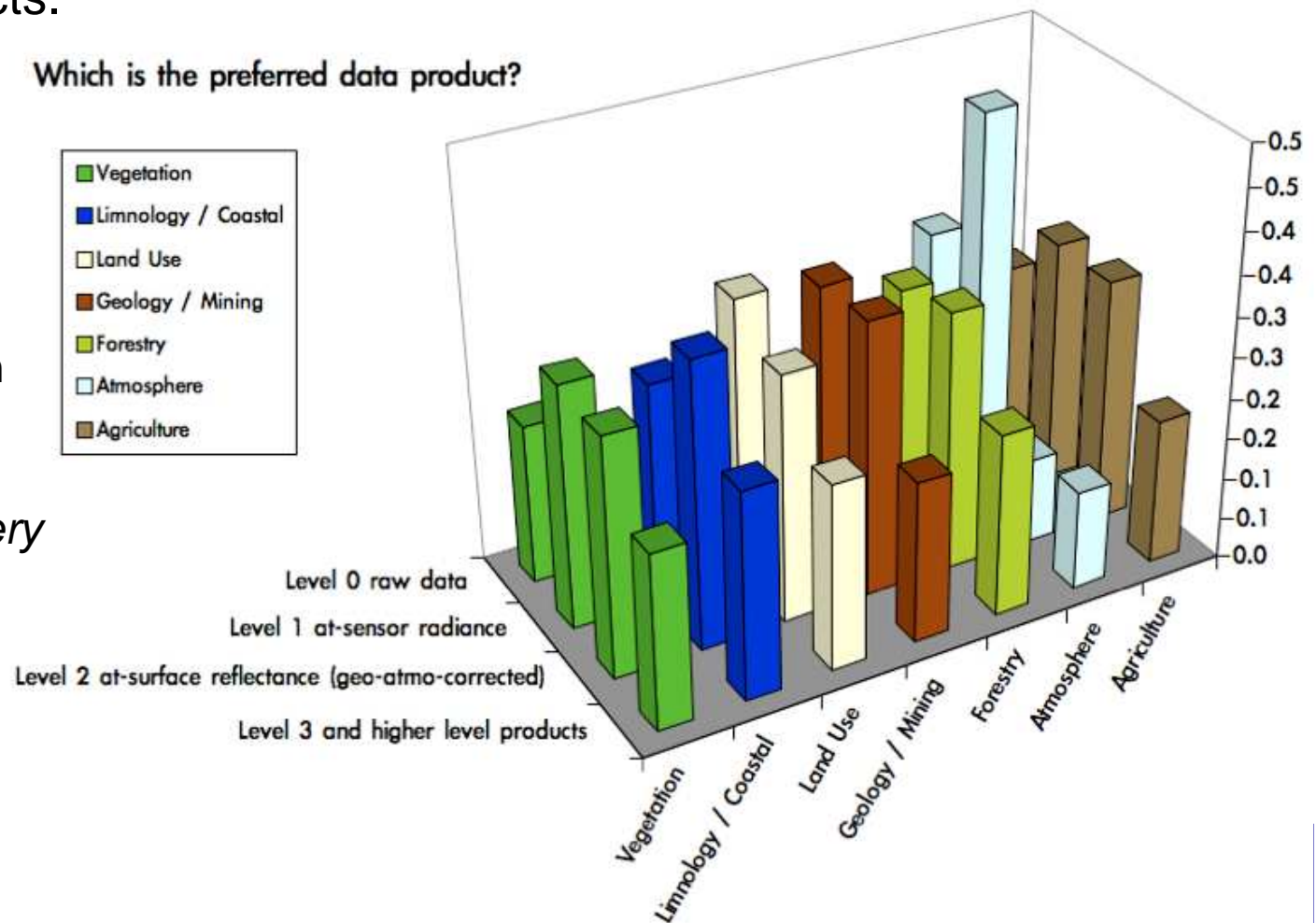
Which is the preferred repetition rate?



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)*

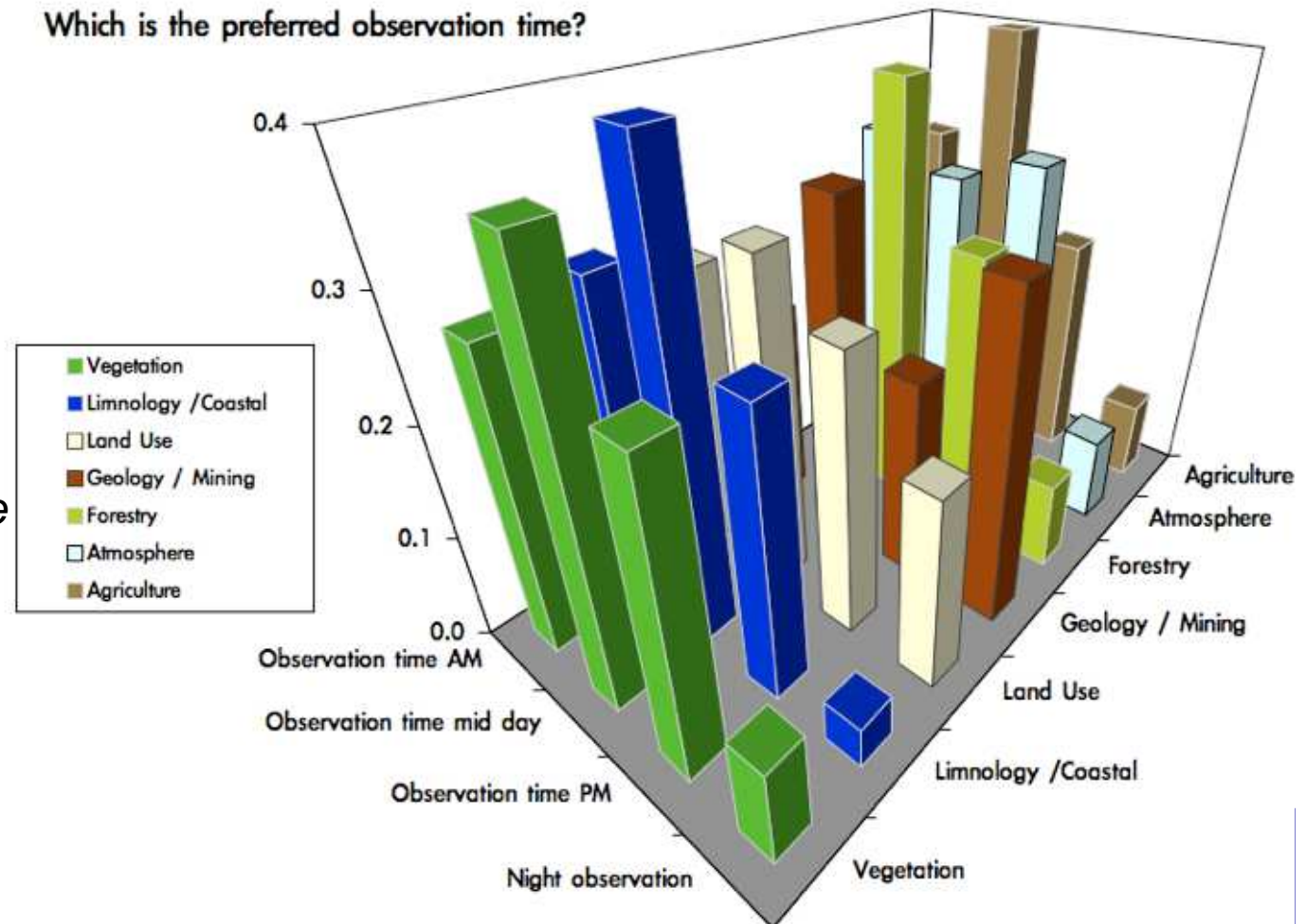


Q: Which is the preferred observation time?

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)*

Which is the preferred observation time?





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)*

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What are the absolute requirements of the user community?

Problem for the estimation of the absolute values:

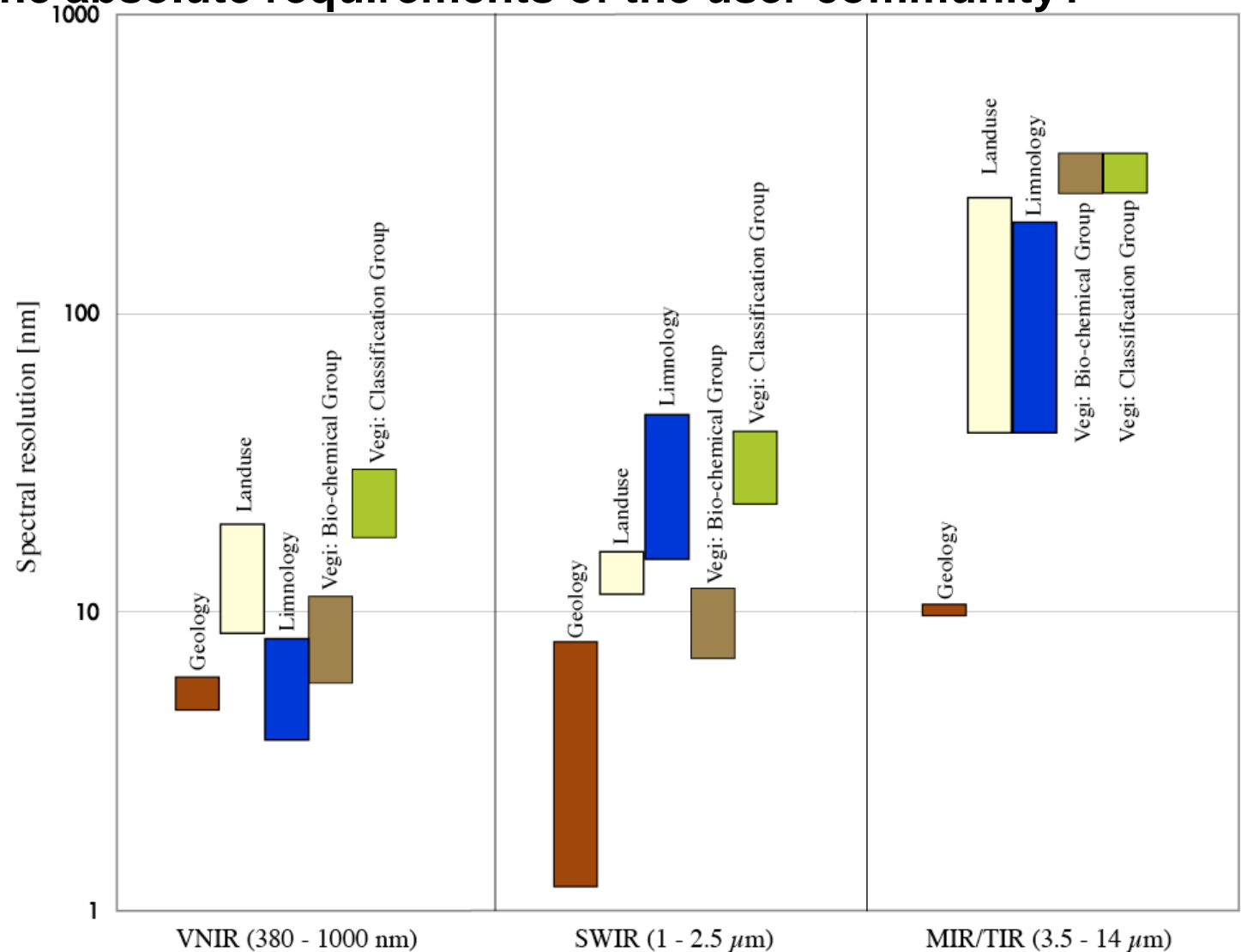
The Agriculture-Forestry-Vegetation Group was re-distributed (after re-assessment by experts) in

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.

What are the absolute requirements of the user community?

Spectral requirements:



	Atmos- phere¹⁴	Geology	Land-use	Limnology	Vegetation¹⁵ 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

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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

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.

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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.



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