Apport de l’Imagerie Hyperspectrale pour l’étude de l’écosysteme urbain…

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ANR HYEP **Hyperspectral imagerY for Environmental urban Planning**

LIVE,,
ESPACE
GEODE
ONERA
IGN
IRAP OMP
GIPSA

- The objectives of this project are
  - 1) to develop methods and tools adapted to hyperspectral data and promote a French hyperspectral sensor in the whole of the existing and future airborne and spaceborne sensors,
  - 2) to supply image-processing tools to derive useful information about urban organization from these images and,
  - 3) to constitute a morpho-spectral database compatible to these future space missions.

Urban complexity

- To cope with these goals : (1) which type of information can be delivered by these different sensors. Indeed, the bulk of sensor data available need to be carefully scoped in order to provide the best combination of sensor data for the defined objectives. The proposed project is based on several main work-packages in order:
- to describe urban features and associated indicators able to illustrate urban diversity and produce a dedicated **morpho-spectral database (MDB);**
- to select **methods and tools** to extract urban features adapted to define objectives;
- to specify the **choices** made according to image selections;

UMBRA ONERA-IGN campaign (October, 2012)

Caractéristiques	Hyspex VNIR	Hyspex SWIR	CamV2	Système IGN
Type d'acquisition	Push-broom	Push-broom	Snapshot	Snapshot
Nombre de pixels	1600	320	7256*5462	7256*5462 (*8)
Intervalle spectral	0,4-1 µm	1-2,5 µm	0,4-0,8 µm	0,4-0,8 µm
Nombre de bandes spectrales	160	256	panchro	4 (multi) et 4 (panchro)
Résolution spatiale à 2160m d'altitude	0,80m	1,6m	0,14m	0,24m et 0,12m
Fauchée à 2160m d'altitude	645m	520m	1033m	1775m

Principal characteristics of sensors implied in the UMBRA mission

New acquisition expected in June 2014 (ONERA campaign) and September 2014 (IGN-ONERA campaign). The first experiment will imply the ONERA Hyspex hyperspectral camera and a Pan sensor. The second one will use the same facilities completed by the IGN airborne topographic lidar, providing 3D point clouds

Themis Visions System VNIR 400T Kaunas(Lithuania) summer mission 2014

Performance

Spectral Range (Continuous Coverage)	400-1000nm
# Spectral Channels/bands	Up to 1000
# Spatial Pixels	1600
Field of view	30 degrees
F/#	F/2
Spectral Width Sampling/Row	~.6 nm centered
Spectral Resolution (FWHM)	2.8nm
Pixel Size	7.4µm x 7.4µm
Dynamic Range	14 bit
Frame Rate	40Mhz
Smile/keystone Distortion	< 5µm/.5nm
Noise Level	12 e-rms@10MHZ
Camera Type	CCD/KAI-2001
Lens mount standard (other & custom mounts per request)	c-mount
Cooling	2 Stage Peltier

Dimensions, Weight, and Power

Item	Dimensions (In/cm)	Weight (lb/Kg)
Sensor Footprint	L(10") x W(4") x H(5")	
	L(25.4cm) x W(10.16cm) x H(12.7cm)	
Sensor Weight		7lbs/3.18kgs

Motor Control

Motor Type	Servo Thread Driven
Control	Computer Controlled
Power Supply	24 Volt / Switchable Power

Portability

Mounting	2 (1/4 - 20) mounting Holes
Upright Microscopes	YES
Tripods	YES
Copy stands	YES
Aircraft Mounts	YES

Software and Data Processing

Function	Software
Acquisition	ETCorp's HyperVisual
Pre-processing	ETCorp's HyperVisual
Operating System	Microsoft XP
Analysis	ENVI

On-site Setup and Training

upon request: ask for quote for these services.
for ENVI training please contact
ITT systems - ENVI developers and Specialists.

- **WP1** is dedicated to data acquisition (ground data) and morpho-spectral database definition and creation.

- **WP2** concentrates on the development of the pre and processing tools taking into account the selected morpho-spectral data defined in WP1.

- **WP3** takes in charge the sensor capacities assessment towards urban applications, according to following topics: impervious soils, urban vegetation, roof and infrastructure material and urban wetland. This assessment exercise is planned in comparison with other hyperspectral sensors already planned (EnMap, Shalom or PRISMA) and actual multispectral sensors like Pleiades or future one like Sentinel-2.

- **WP4** deals with the integration of the previous results with two purposes:
  - HYPXIM mission to provide inputs for mission technical specifications
  - End user or local authorities' expectations: to provide some insight for planning purposes as (Trame verte, Plan Climat Energie Territoire, Schémas Régionaux de Cohérence Ecologique (SRCE) etc.).

WP1.1: Pre-processing

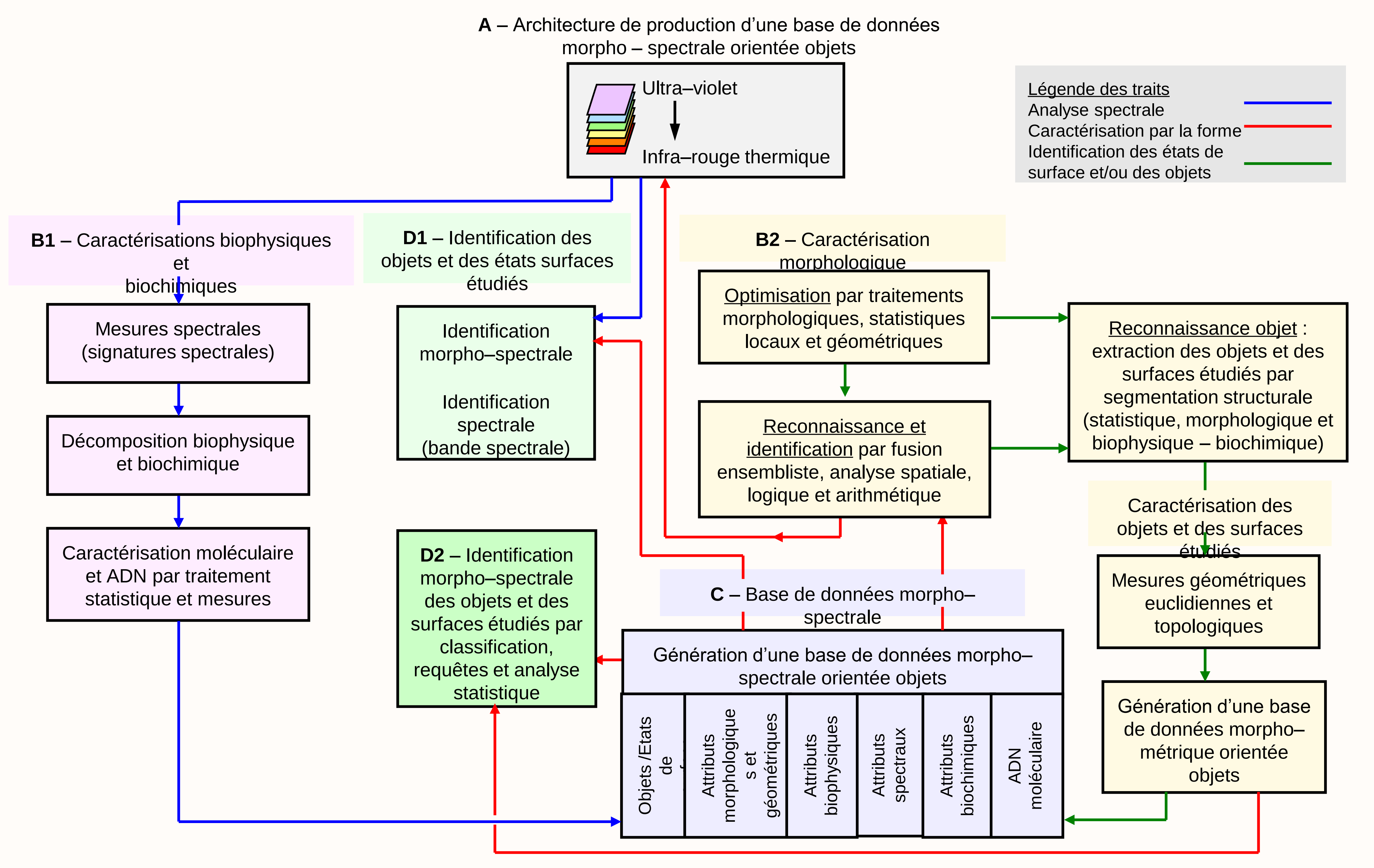
Adaptation of the existing end to end simulator to the different spectral and spatial characteristics of each sensor (EnMap, PRISMA, Shalom, HYPXIM, Pleiades multispectral and Sentinel 2). From an airborne acquisition, the corresponding top of atmosphere image will be simulated, then the spatial and spectral aggregations will be achieved to simulate a given space sensor and followed by an atmosphere compensation to retrieve the surface reflectance.

WP1.2: Measurements design

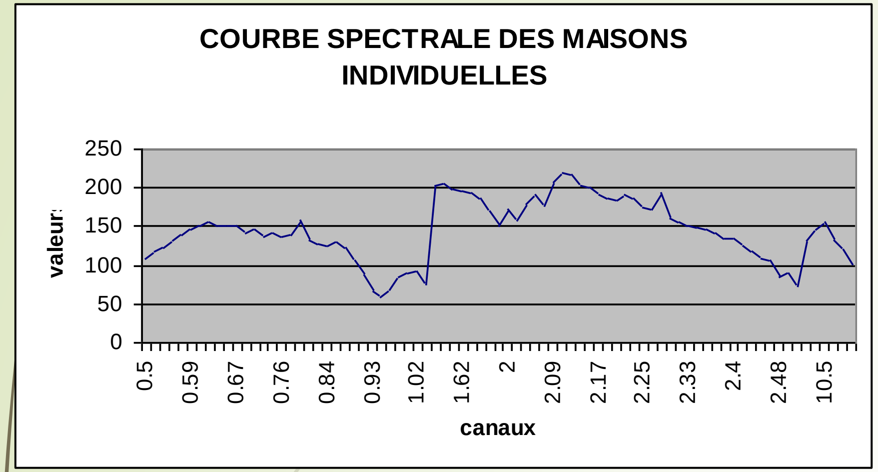
The measurements will be applied on a set of images (Toulouse and Kauna), corrected and provided by ONERA and UMR ESPACE, as a simulation test base with several images performed at various spatial resolution (actual and planned spectral and hyperspectral sensors) in order to extract spatial, spectral, geometric information.

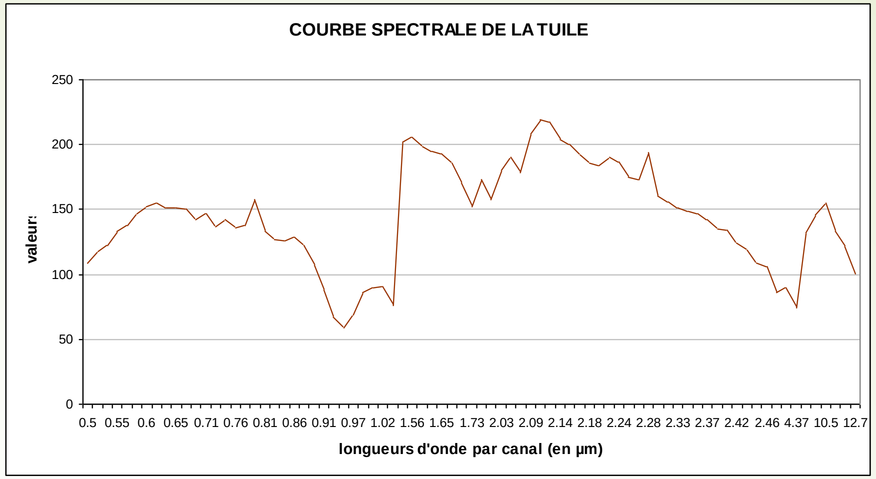
WP1.3: Constitution of standardized database

Information and morpho-physical knowledge will be designed from spectral, hyperspectral data extracted from remote sensing data simulation at various resolutions. These resolutions will be chosen to cope with existing or planned sensors, spectral and hyperspectral. The database will gather attributes and ontological characteristics (geometric, biophysical and categories of urban objects.

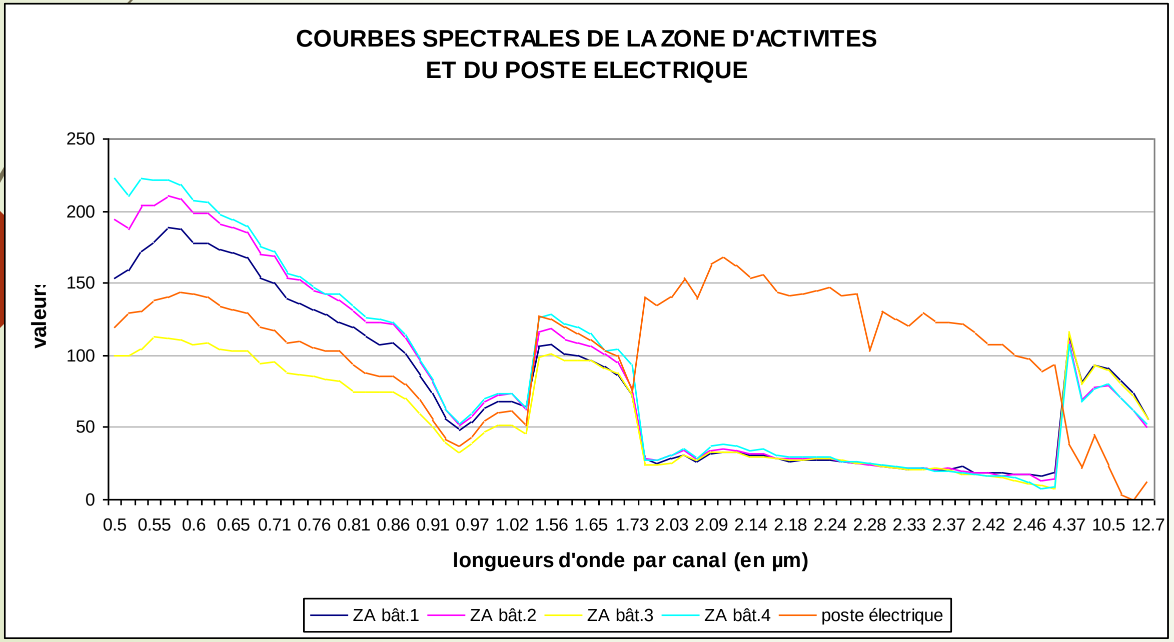


Source: INPI, Gadal, 2014

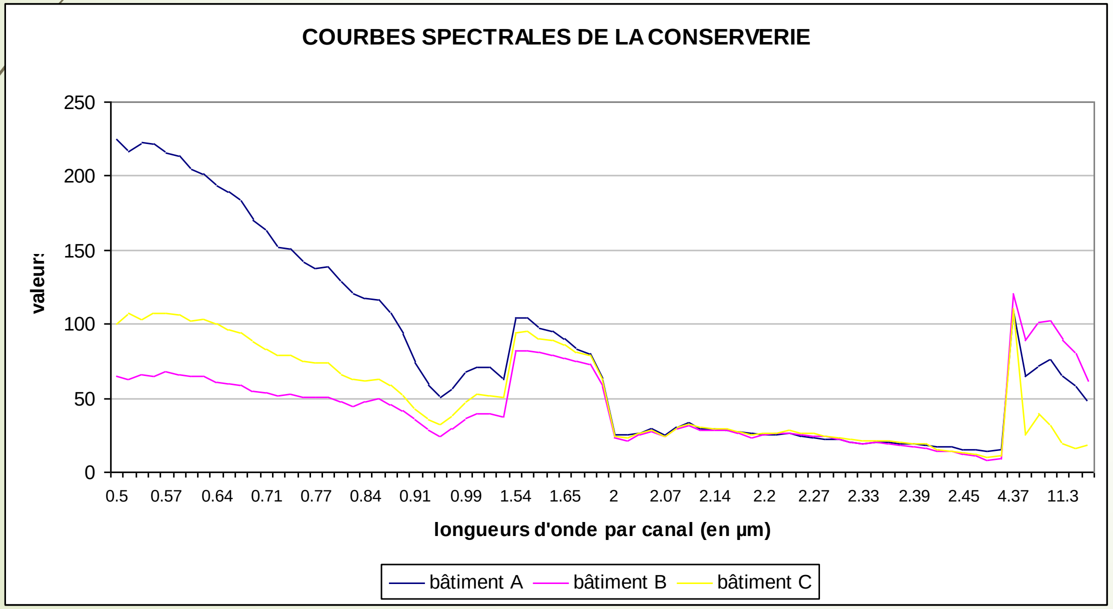




Tuile :	de 0.5 à 0.62 µm
	de 1.53 à 12.66 µm



Source, ASU, Lithuania, Gadal, Mogeris, Maisitis, 2012-2013


COURBES SPECTRALES DE LA CONSERVERIE
valeur
250
200
150
100
50
0
0.5 0.57 0.64 0.71 0.77 0.84 0.91 0.99 1.54 1.65 2 2.07 2.14 2.2 2.27 2.33 2.39 2.45 4.37 11.3
longueurs d'onde par canal (en µm)
bâtiment A
bâtiment B
bâtiment C

Urban trees

- **Spectral measurements**
- The hyperspectral scanning process was conducted using a new generation Themis Vision Systems LLC hyperspectral camera VNIR-400T(Bay St. Louis, MO, USA), covering the spectral range of 400–1000 nm with a sampling interval of 0.6 nm, producing 955 spectral bands

Table1. Methods of spectra data analysis used in our research

Analysis	Objective of the study				
	Spectral reflectance properties of common Lithuanian tree species and to determine the influencing factors	Determination ability of Scots Pine crown defoliation	Determination of concentration of some chemical constituents in the needles	Scots Pine provenance determination abilities	Spectral libraries of common Lithuanian tree species foliar reflectance
Checking the normality of samples spectral reflectance data distribution and homogeneity of variance in each spectral band	**Shapiro-Wilk test, Levene test**	**Shapiro-Wilk test, Levene test**	**Shapiro-Wilk test, Levene test**	**Shapiro-Wilk test, Levene test**	
Investigating the impact of the of samples acquisition to their spectral properties	**ANOVA, t-test**				
Determining the most informative spectral bands	**Principal component analysis (PCA)**	**PCA, t-test**		**PCA**	
Modeling/classifying various tree properties according to their foliage spectral reflectance data. Building spectral libraries	**Linear Discriminant analysis**	**Linear Discriminant analysis**	**Partial least squares regression (PLSR)**	**Linear Discriminant analysis**	**Construction of generalized spectral curves and 1-st derivative spectral curves**
Evaluating the accuracy of classification, PLSR models and spectral libraries	**Calculation of overall classification accuracy and kappa statistic**	**Calculation of overall classification accuracy, kappa and Z statistics**	**Calculation of R, R^2, RMSEP, MAPE**	**Calculation of overall classification accuracy, kappa and Z statistics**	**Spectral angle mapper (SAM) classification, calculation of overall classification accuracy**
Determining the optimal season enabling the best spectral separability of tree species under investigation	**Calculation of Jeffries-Matusita distance**			**Calculation of overall classification accuracy, kappa and Z statistics**	

Source, ASU, Lithuania, Maisitis, 2013

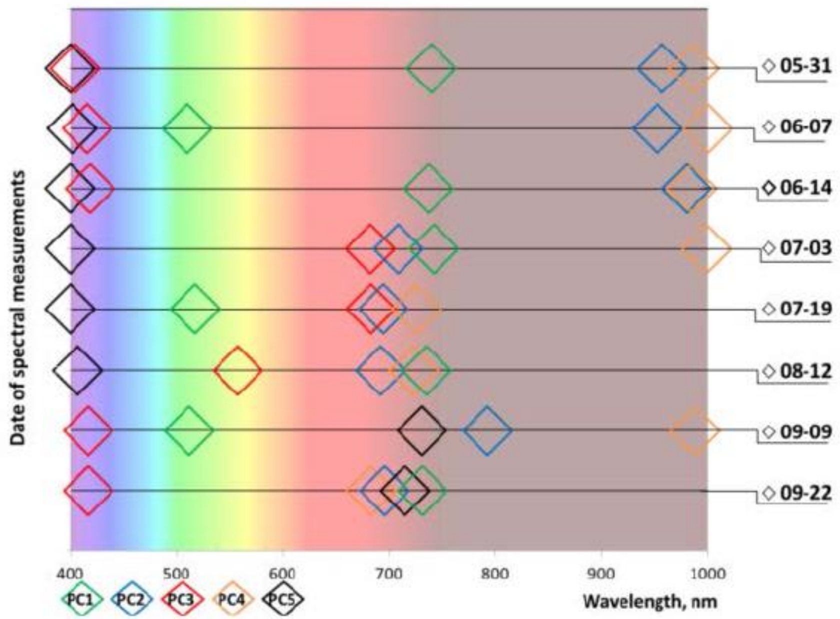


Figure 3. The optimal wavelengths for tree species spectral separation during the growing season

Table 3. Separability of healthy and heavily stressed coniferous trees needles (Student's t-test, $\alpha = 0.05$).

Tree species	Number of spectrally different ($p<0.05$) spectral bands (out of total 955)	Most informative spectral range for tree stress identification	Most informative wavelength for tree stress identification (the least p value)
Norway spruce	884	709.9–715.7 nm	713.1 nm
Scots pine	767	708.6–714.4 nm	711.2 nm
Siberian pine	698	862.3–868.1 nm	864.2 nm

Source, ASU, Lithuania, Maisitis, 2013

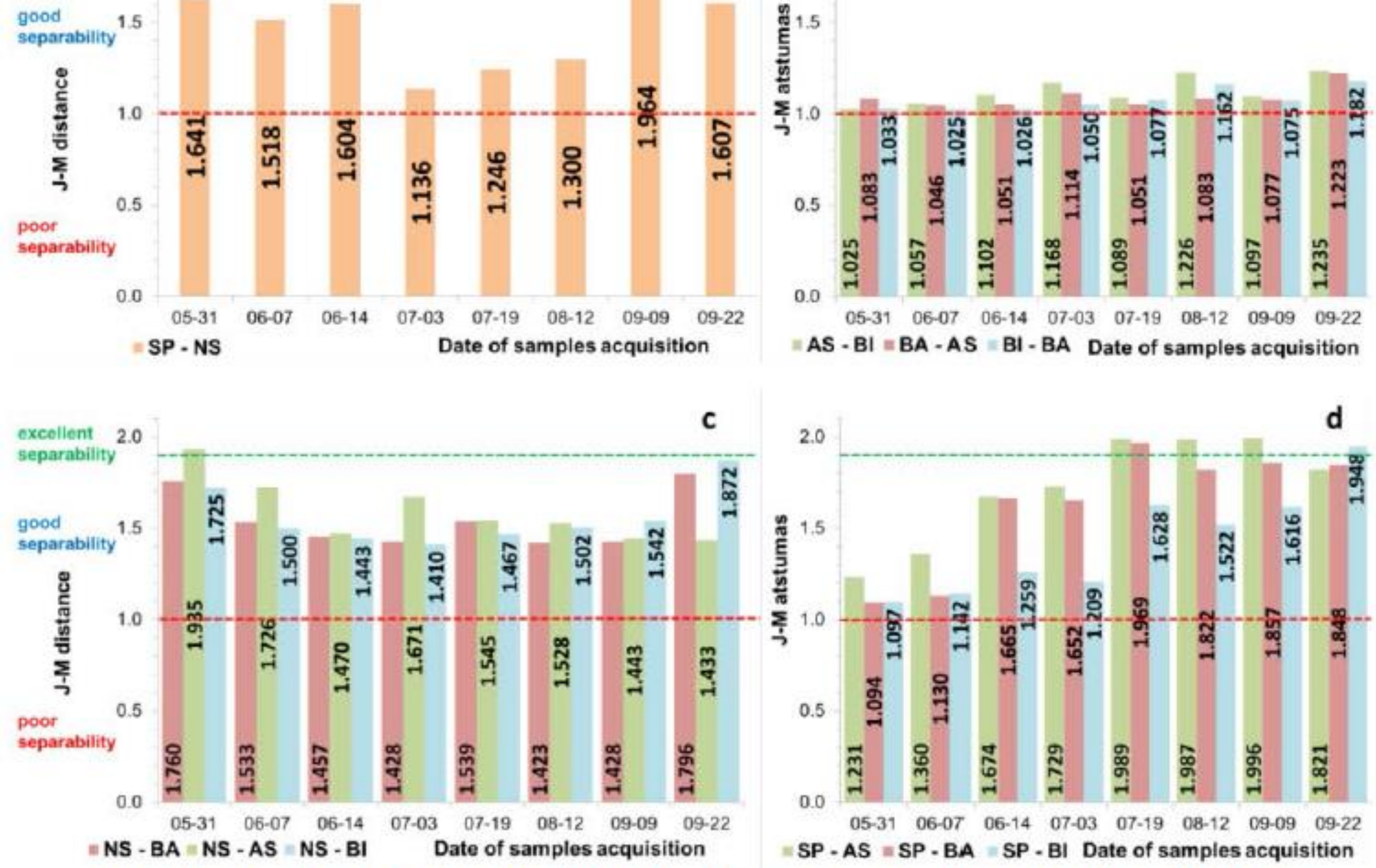


Figure 4. The Jeffries-Matusita distances between Scots Pine and Norway Spruce (a), between deciduous (b), between Norway Spruce and deciduous (c), and between Scots Pine and deciduous (d)

Source, ASU, Lithuania, Maisitis, 2013

Source, ASU, Lithuania, Maisitis, 2013

Table 11. The accuracy of PLSR models to predict the content of chemical constituents in needles (numerator refers to the current year, denominator refers to the previous year needles)

Model characteristic \ Element	Boron	Calcium	Copper	Iron	Potassium	Magnesium	Manganese	Nitrogen	Phosphorus	Zinc
R	0.33 / 0.60	0.56 / 0.35	0.20 / 0.04	0.26 / 0.21	0.40 / 0.33	0.20 / 0.10	0.49 / 0.31	0.61 / 0.46	0.57 / 0.49	0.57 / 0.13
R^2	0.11 / 0.36	0.31 / 0.12	0.04 / 0.00	0.07 / 0.04	0.16 / 0.11	0.04 / 0.01	0.24 / 0.10	0.37 / 0.21	0.32 / 0.24	0.33 / 0.02
RMSEP	3.36 / 2.85	0.03 / 0.07	1.08 / 0.66	20.19 / 14.03	0.05 / 0.05	0.01 / 0.02	91.90 / 245.30	0.08 / 0.09	0.02 / 0.01	6.66 / 11.19
MAPE	18.1 / 17.8	12.3 / 14.6	19.7 / 16.6	27.0 / 16.1	9.6 / 10.6	9.9 / 18.2	14.2 / 22.3	6.1 / 5.8	10.9 / 6.3	16.2 / 20.5

- Merci .....