Biodiversity Multi-Source Monitoring System: From Space To Species (BIO_SOS)

On behalf of BIO_SOS consortium
Palma Blonda, Coordinator
CNR-ISSIA, Bari-Italy

BIO_SOS

Objective

The development of a pre-operational multi-modular system suitable for multi-annual monitoring of NATURA 2000 sites and surrounds based on EO data

FP7-SPACE, 3rd call. GA 263435
1/12/2010 - 1/12/2013

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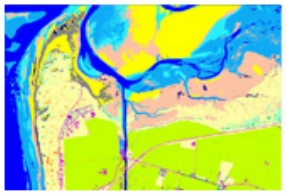
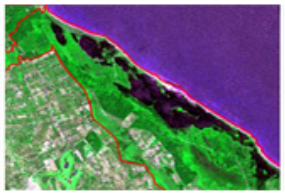
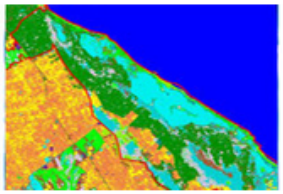
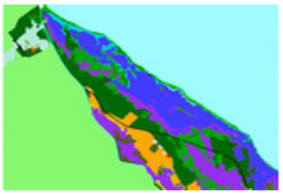
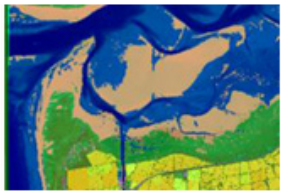
BIO_SOS

BIODIVERSITY MULTI-SOURCE MONITORING SYSTEM
FORM SPACE TO SPECIES

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News & events

18-19 November, Final BIO_SOS meeting in Brussels.

Relevant Results

BIO_SOS intranet access

BIO_SOS ftp site

BIO_SOS Final Policy Brief

BIO_SOS

FP7-SPACE-2010.1 G.A. 263435

Dec.2010 - Dec.2013

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The main objective of **BIO_SOS** is the development of a knowledge-based pre-operational ecological modelling system suitable for effective and timely multi-annual monitoring of NATURA 2000 sites and their surrounding areas particularly exposed to different and combined type of pressures.

Study areas located in three Mediterranean and two Western Europe Countries have been considered. To

COOPERATION

Remote sensing for habitat monitoring

- *Multi-temporal:* monthly (HR), on demand (VHR), daily through constellations for monitoring:
  - Plant phenology
  - Ecological processes' evolution
  - Changes in LCLU and habitats from archive EO time series
- *Multi-scale: spatial resolution* ranging from coarse to HR (3m – 30m) and VHR (<3m).
- *Multi or hyperspectral optical sensors*
- ***LIDAR*** *data can provide plant height measurements beside accurate DEM*
- *SAR* sensors can provide complementary information in Band P, C, X (BIOMASS, COSMO SkyMed, ERS 1/2,- ENVISAT) and are weather independent (North European sites !)

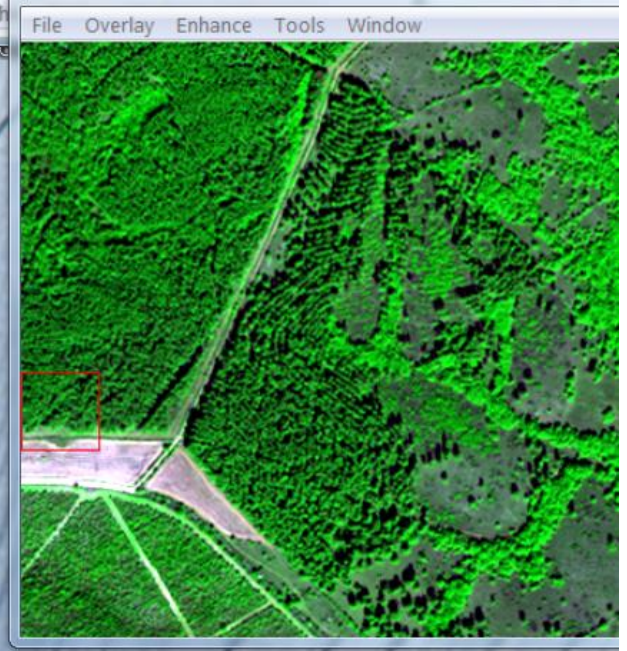
WorldView2

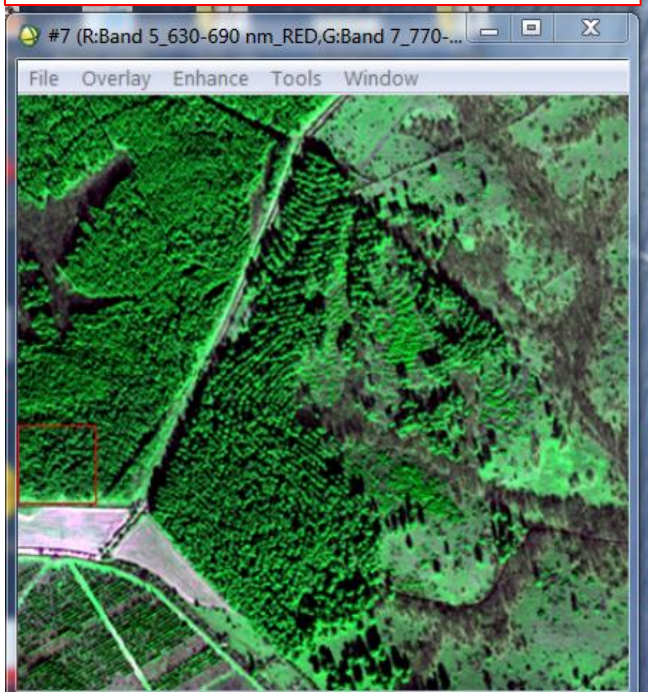
RBG:5,7,2

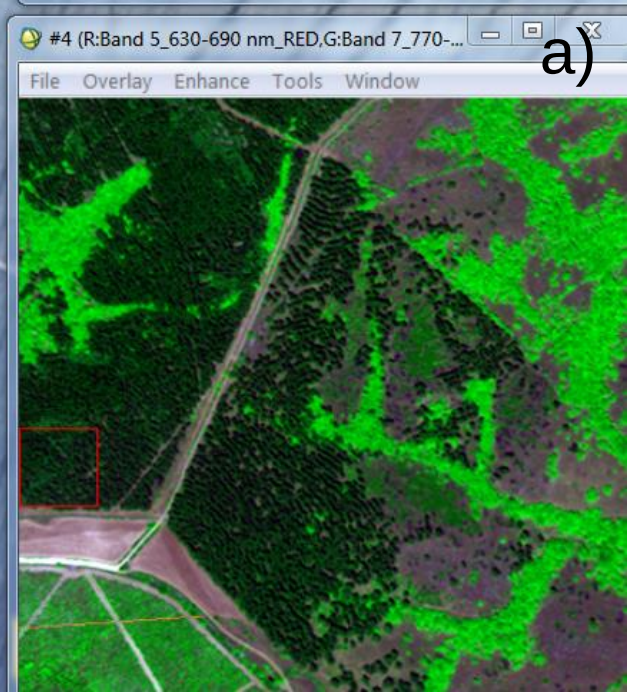
a)October 2011
b)January 2012
c)July 2012

Natura 2000,
IT9120007
Murgia Alta site (IT):

Coniferous, broadleaved deciduous and evergreen in different seasons







a)

b)

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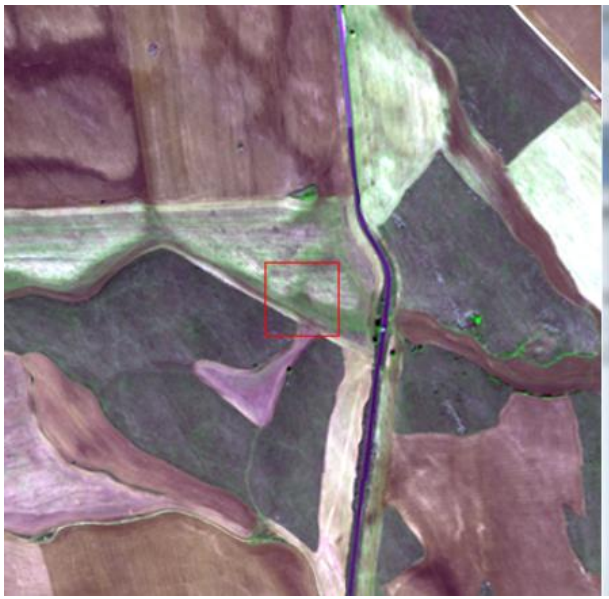

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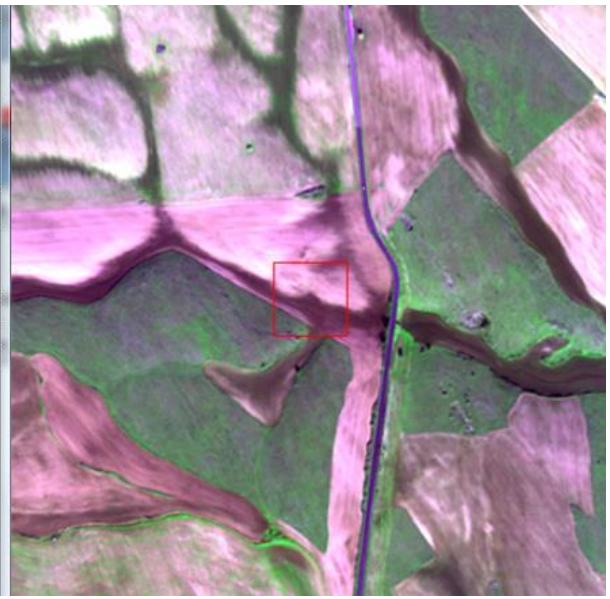

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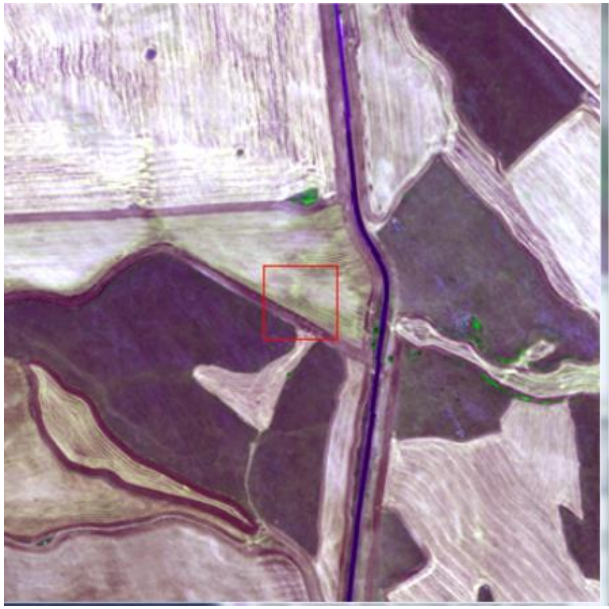

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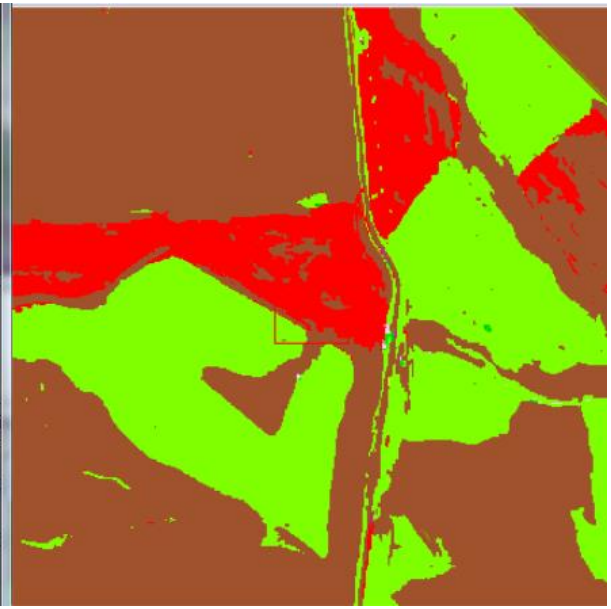

d)

Natura 2000, IT9120007

Murgia Alta site (IT):

fragmented
natural grassland area

WorldView2 ,

RBG:572

a) October 2011
b) January 2012
c) July 2012
d) Classified image in FAO-LCCS taxonomy

- natural grasslands (A12/A2.A6E6)
- cultivated herbaceous graminoids (A11/A3.A4)
- cultivated herbaceous annual mixed (A11/A3)

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Issues for habitat monitoring from space

- Selection of a taxonomy for LCLU and habitat classes
  - **LCLU:** *CORINE, **FAO-LCCS**, IGBP, etc.*
  - **Habitats**: *Eunis, CORINE Biotope, **GHC,** Annex I.*

- How to train an automatic classification system for LCLU and habitats mapping: data driven or ***knowledge-driven?***
  Pixel based or **object based?**

- Habitats diversity is considered as proxy of biodiversity:

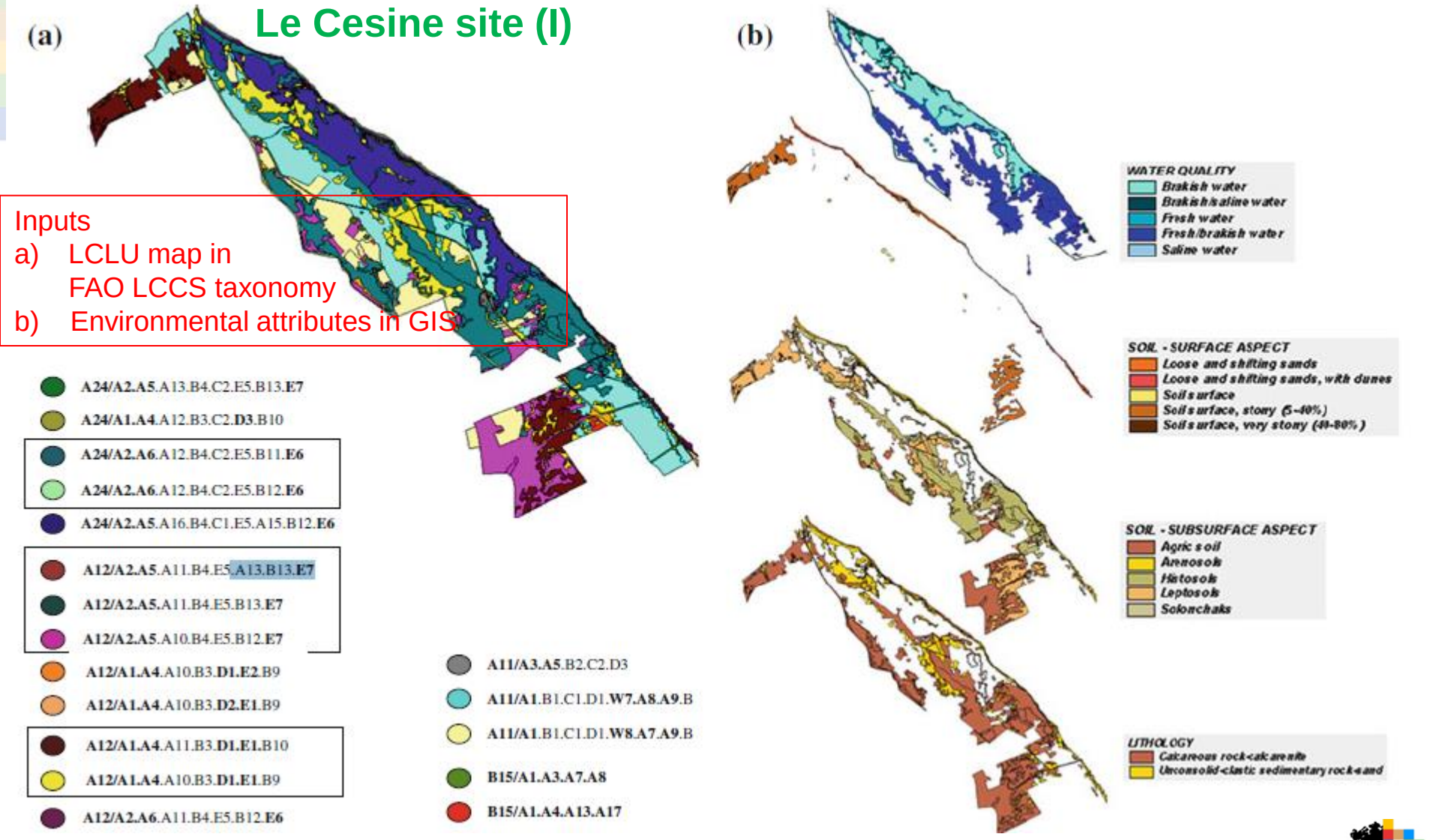
  - How to translate LCLU to Habitats?
    Ecological modeling at habitat level

  - How to define the *habitat conservation status?*
    Ecological modeling at landscape level

LCLU to habitat map translation

(Tomaselli et. al., 2013)

Le Cesine site (I)



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BIO_SOS

BIO_SOS working objectives

- The development of pre-operational automatic HR and mainly **VHR** EO data processing and understanding techniques for:
  - ✓ LCLU and LCLU change maps production as an improvement of GMES/Copernicus core services.

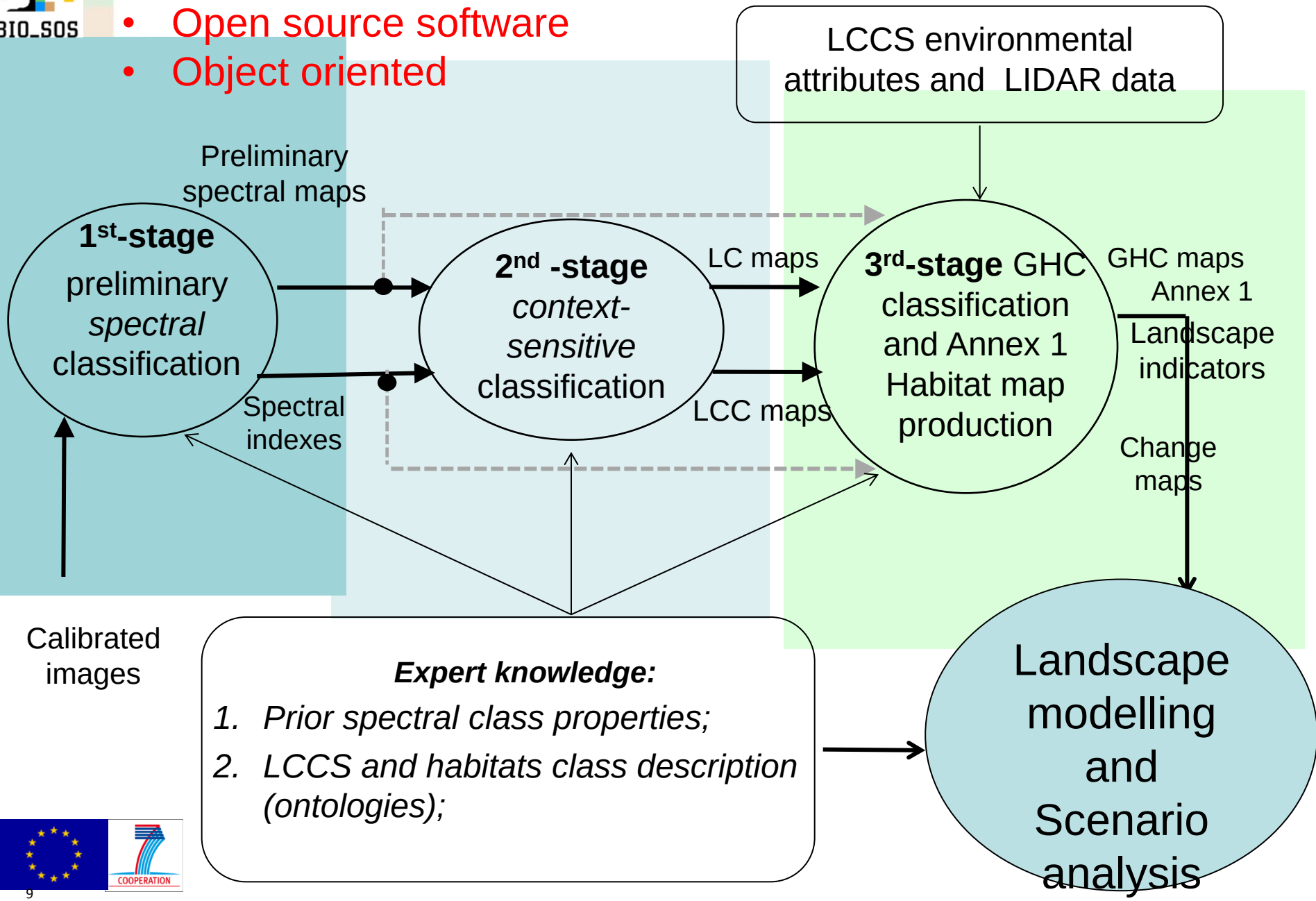
- The development of an ***ecological modelling framework*** at *both habitat and landscape level* to combine EO and *in-situ* data for:
  - ✓ Habitat and Habitat change mapping (GHC and Annex I)
  - ✓ Biodiversity indicator extraction (e.g. fragmentation).
  - ✓ Scenario analysis

  as an extension of GMES/Copernicous downstream–services

- Generalization of the techniques to non-european sites: Brazil and India study areas

EODHaM pre-operational system

- Open source software
- Object oriented



Service Portfolio for Murgia Alta (IT3)

Site / Serv.	IT3 Murgia Alta	Coverage	Temp. res.	Spatial coverage	Sensor 2m. Res.	Input for	Format Geotiff
S4	***NDVI/*** ***GI/*** ***WBI*** ***PSRI*** ***REP***	2009-2010; 2011-2012	Yearly, per each month considered	Local	QB or WV2 WV2 WV2	Landscape Modelling	
S5	**Texture** from green band		Yearly, Pre-Post Peak images	Local	QB or WV2	Landscape modelling	
S1_1	**Permanent natural grasslands** A12/A2.A6.E6		Yearly,	Local	QB and WV2	Landscape Modelling	Binary
S1_2	**Broadleaved deciduous A12/A3.D1.E2**		Yearly,	Local	QB and WV2	Landscape modelling	Binary
S1_3	**Broadleaved evergreen** A12/A3.D1.E1		Yearly,	Local	QB and WV2	Landscape Modelling	Binary
S1_5	**Extraction sites** B15/A2.A6		Yearly,	Local	QB and WV2	Landscape modelling	Binary

WP6
Task_6.2

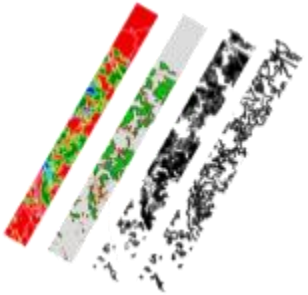
UNIVERSITÀ DEGLI STUDI DI BARI ALDO MORO

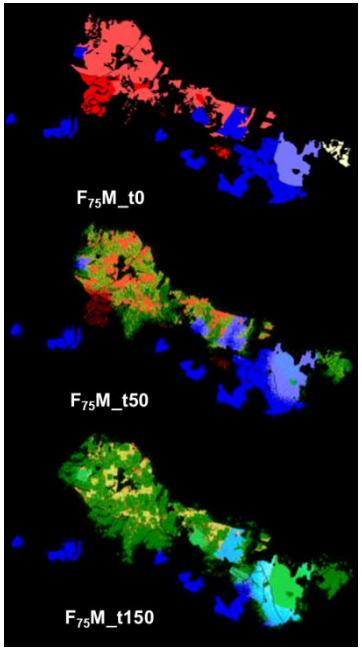
P8 UNIBA

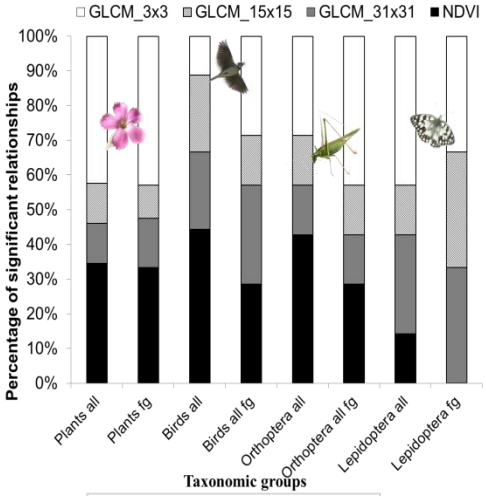
Contributions
P1 CNR_ISSIA
P10 UNIMIB

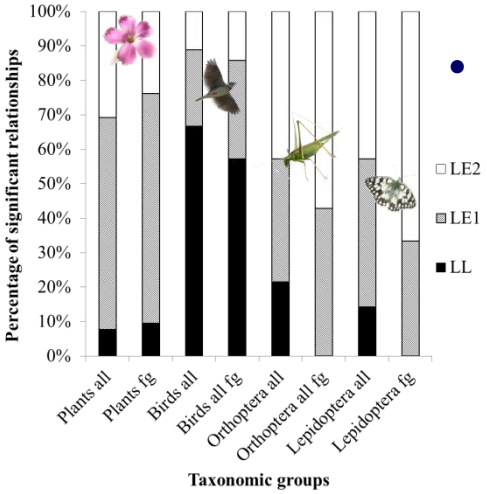
Clearly significant results for the whole period

- Developed and successfully tested a framework for identification of site and scale specific indicators of habitat fragmentation from LCCS maps, to quantify historical habitat fragmentation trends and for scenario analysis of future management and climate impacts.

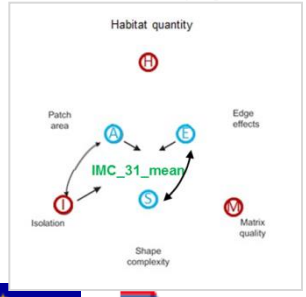




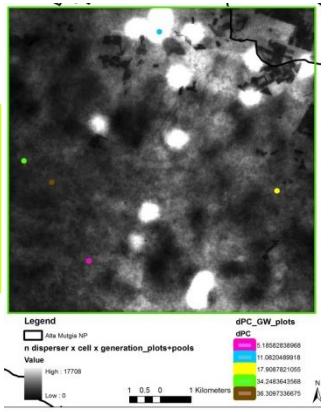




- Demonstrated the usefulness of VHR EO data as proxies for indicators of species functional groups and explored their inferential potential towards landscape and habitat structural characteristics, as required for monitoring.



- Explored a framework for landscape functional connectivity modeling using Environmental Niche Models (building on work from task 6.4) and based on both Graph Theory and existing field data for a species of conservation concern.



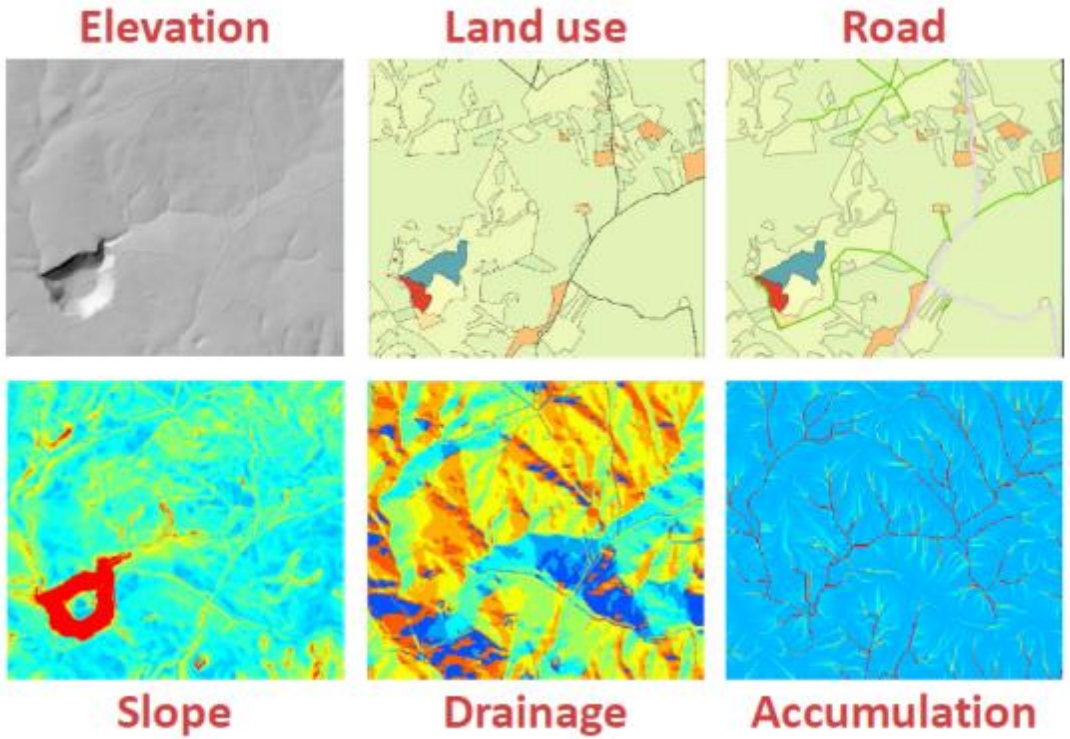
COOPERATION

WP6
Task_6.3

P1 CNR_IRPI

Contributions
P1 CNR_IAC
P1 CNR_ISSIA
P5 ATREE

Effect of roads on flow accumulation path



LANDPLANER model: To analyze quantitatively the connectivity of a landscape in terms of water runoff, water infiltration and erosion, two tools were developed: r.sim.road and LANDPLANER.
The tools allow to evaluate runoff and erosion triggering condition for different scenarios.

WP6

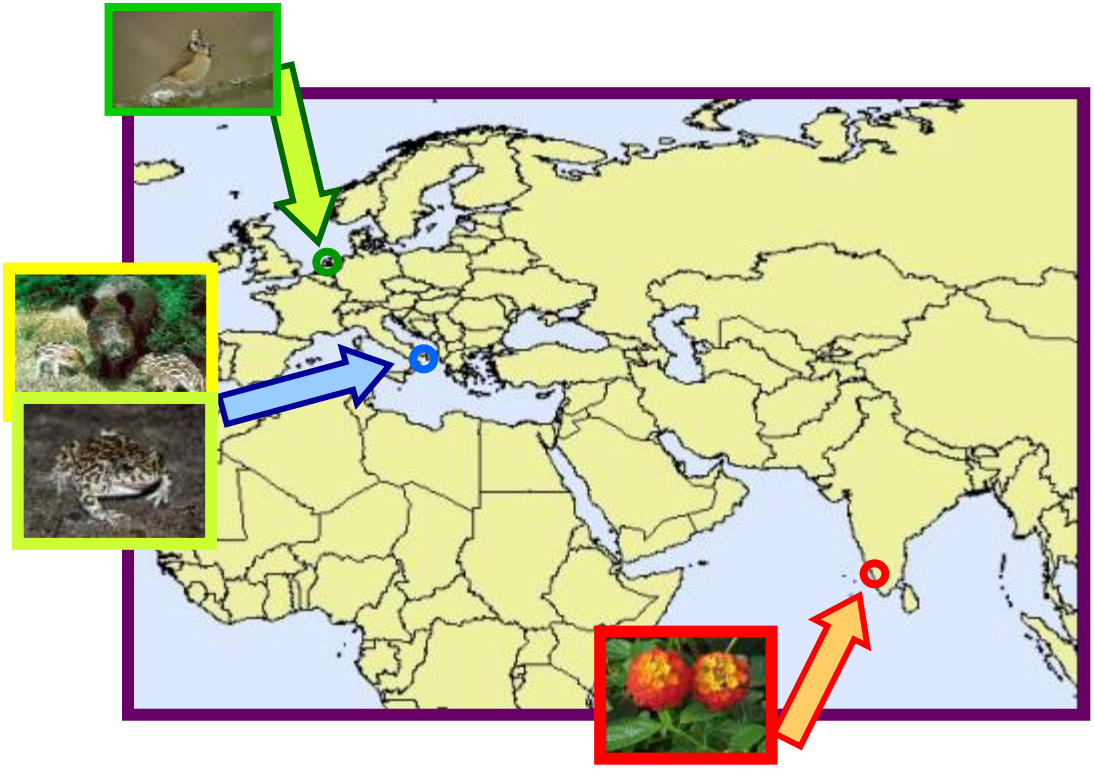
Task_6.4

P10 UNIMIB

Contributions
P1 CNR_IBBR
P1 CNR_ISSIA
P4 ALTERRA
P5 ATREE
P8 UNIBA

Clearly significant results for the whole period

Demonstrated the importance of Ecological Niche Models for linking habitat maps derived from EO data with field data on species distributions with case studies in Italy, the Netherlands and India.



Metapopulation dynamics for predator-prey population living in fragmented habitat

Fasma Diele,
Carmela Marangi,
Stefania Ragni
IAC-CNR

Taxonomies

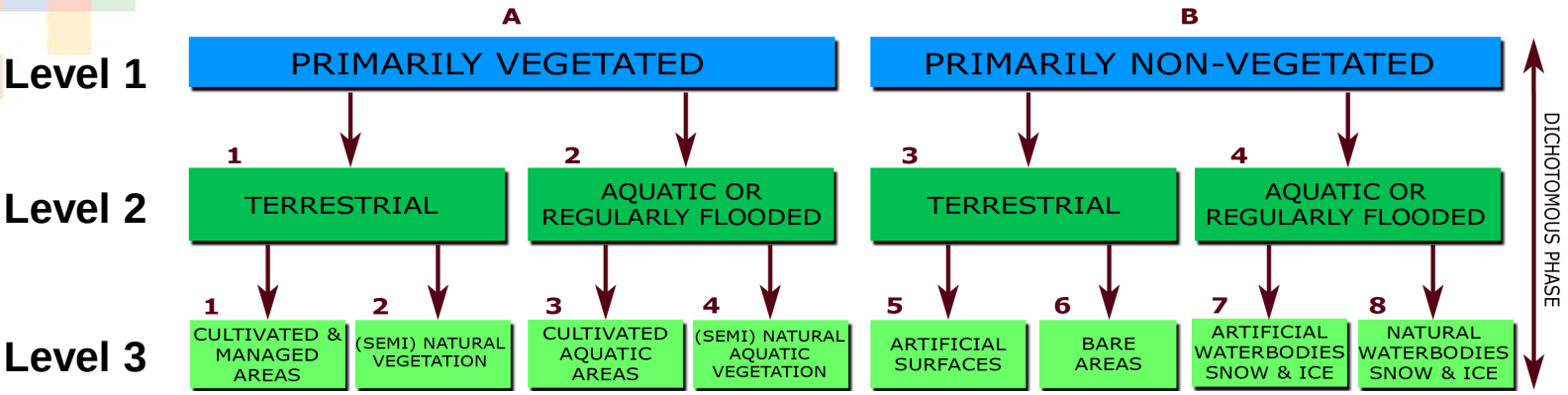
Taxonomies for LCLU and habitats classes

- *Land Cover/Use (LCLU):* FAO-LCCS
  - It provides a framework able to describe better than CORINE natural snd semi-natural habitats (Tomaselli et. al., 2013)
  - It provides a framework, based on environmental attributes, to integrate LCLU with in-situ data and translate LCLU to habitats
  - It can describe *within* class changes (e.g. in density)

- *Habitat classes*: General Habitat Category (GHC); Bunce 2008):
  - It is based on **plant life forms** with an emphasis on landscape-scale data collection **appropriate for biodiversity monitoring from Space**
  - **GHCs are linked to *Annex I* through a rule based system** useful to guide observers into an appropriate in-field class identification
  - **CHC system promotes consistent habitats identification between EU Countries and harmonize habitats taxonomies outside Europe.**

1) FAO_LCCS: Dichotomous phase

A dichotomous key is used to define eight major LC types



A primarily vegetated

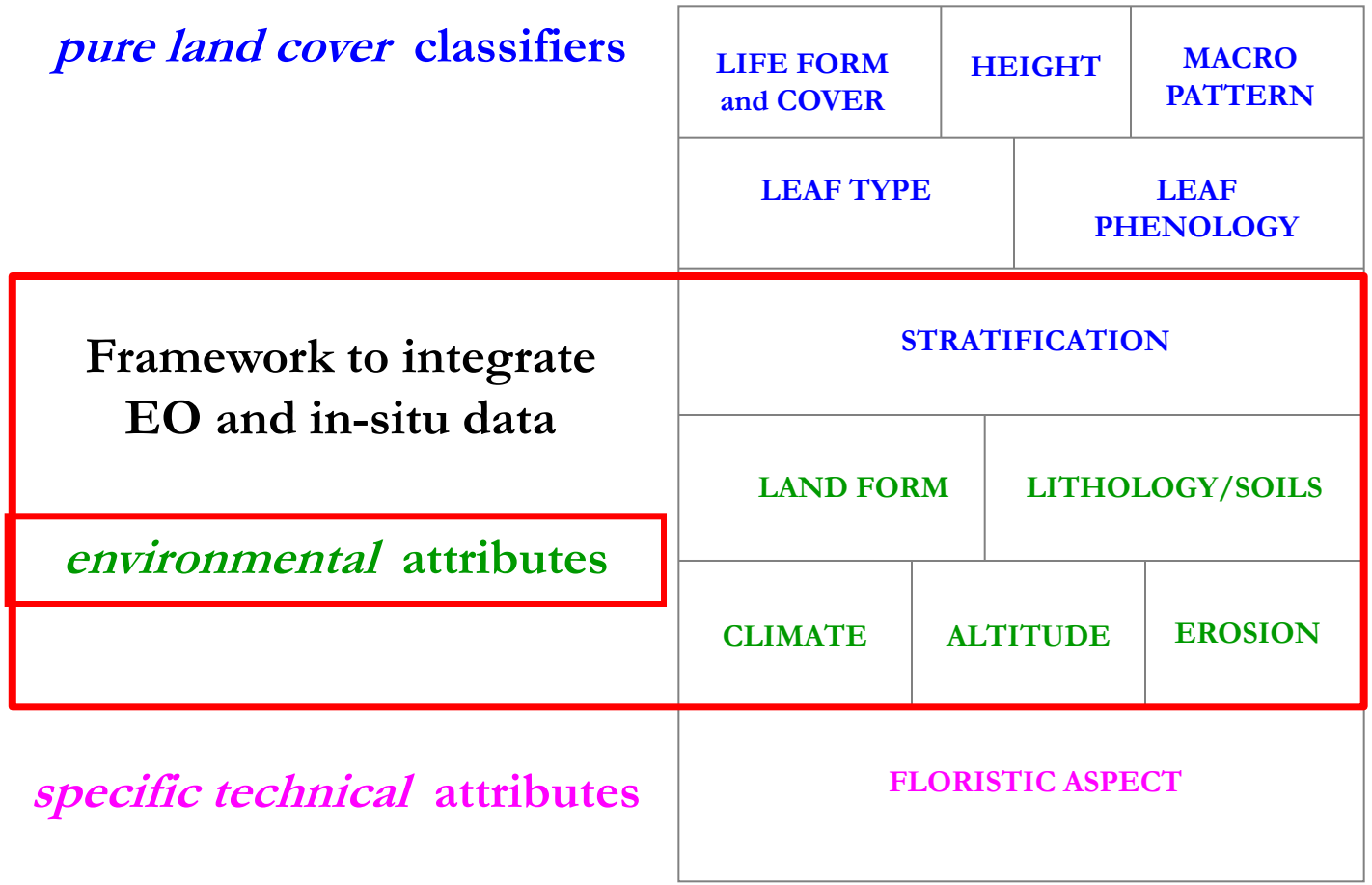
A11 cultivated and managed terrestrial areas **A12** natural and semi-natural terrestrial vegetation	terrestrial
A23 cultivated aquatic or regularly flooded areas **A24** natural and semi-natural aquatic or regularly flooded vegetation	aquatic

B primarily non vegetated

B15 artificial surfaces and associated areas **B16** bare areas	terrestrial
B27 artificial waterbodies, snow and ice **B28** natural water bodies, snow and ice	aquatic

2) FAO_LCCS: Modular-Hierarchical phase

For any major LC category, a set of diagnostic criteria, based on vegetation structure and physiognomy is applied



i.e., set of classifiers for the major land cover type A12 (natural and semi-natural terrestrial vegetation)

CLC3

4.2.1 - Salt marshes

Annex I 1410

Annex I 7210

Annex I 1420

A24

A1.A4.A12.B3.C2.D3./B10

A24

A2.A6.A12.B4.C2.E5/B11.E6

Perennial closed tall grasslands on temporarily flooded land

ANNEX I	Lithology-Parent material	Soil - suburface aspect	Water quality	Floristic attribute
1410	Unconsolid- Clastic sedimentary rock - Sand	Solonchaks	Brakish/Saline water	Juncus spp.; Carex spp
7210	Calcareous rock - Calcarenite	Histosols	Fresh/Brakish water	Cladium mariscus

Automatic classification learning scheme: data driven or knowledge driven?

Knowledge driven (deductive learning)

- Image preliminary spectral segmentation (spectral knowledge);
- Describing LCLU and habitat classes:
  - phenology to select EO images
  - and spatial relations (if any);
- Translating LCLU into habitats (integration with in-situ data)

- Ontologies and semantic networks for knowledge elicitation

The methodology can be applied to any scale and image

Temporal information (phenology)

LCLU and Habitat classes: phenology

LCCS	HABITAT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGO	SEP	OCT	NOV	DEC
A11/A3.A4.D3	1020												
B15/A1.A4.A13.A16	1050												
B28/A1.D2	1130												
A24/A2.A5.E5	1150												
A12/A2.A5.E5	1210												
A24/A2.A5.E7	1310												
A24/A2.A6.E5	1410												
A24/A1.A4.D3	1420												
A12/A2.A6.E6	2110												
A24/A2.A5.E5	3280												
A12/A1.A4.D1.E1	5330												
A12/ A1.A4.D1.E2.F1	5340 (F6.2)												
A12/A1.A4.C1	5420												
A12/A2.A6.C2.E5	6420												
A24/A2.A6.C3	72 A0 (A2.53)												
A12/A1.A3.D1.E1.F1	92 A0												
A12/A1.A4.B3	92D0												
A12/A1.A3.D1.E2.F1	9350												

	Dense vegetation and/or peak of biomass
	Sparse (younger) vegetation or minor green biomass
	Minor biomass with with withered/dry plants (or part of plants)
	Bare soils (or water in A24) with remnants of withered/dry plants

Ekvoles Kalama site (GR2120001), Greece

COOPERATION

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LCLU and Habitat classes: water coverage

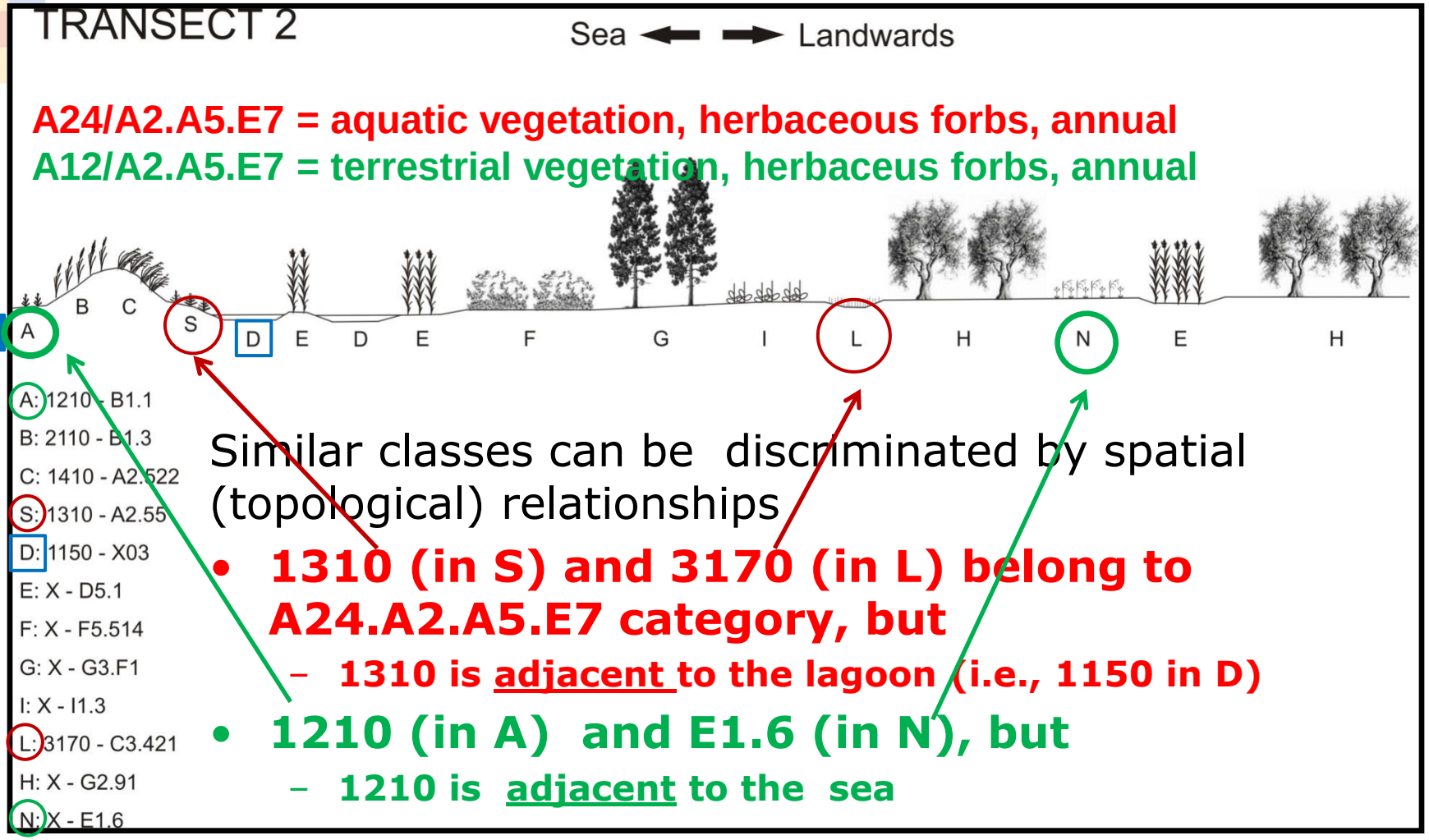
LCCS	HABITAT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGO	SEP	OCT	NOV	DEC
A11/A3.A4.D3	1020												
B15/A1.A4.A13.A16	1050												
B28/A1.D2	1130												
A24/A2.A5.E5	1150												
A12/A2.A5.E5	1210												
A24/A2.A5.E7	1310												
A24/A2.A6.E5	1410												
A24/A1.A4.D3	1420												
A12/A2.A6.E6	2110												
A24/A2.A5.E5	3280												
A12/A1.A4.D1.E1	5330												
A12/ A1.A4.D1.E2.F1	5340 (F6.2)												
A12/A1.A4.C1	5420												
A12/A2.A6.C2.E5	6420												
A24/A2.A6.C3	72 A0 (A2.53)												
A12/A1.A3.D1.E1.F1	92 A0												
A12/A1.A4.B3	92D0												
A12/A1.A3.D1.E2.F1	9350												

	Water
	Wet or waterlogged soil
	Dry (at the surface) soil

Ekvoles Kalama site, Greece

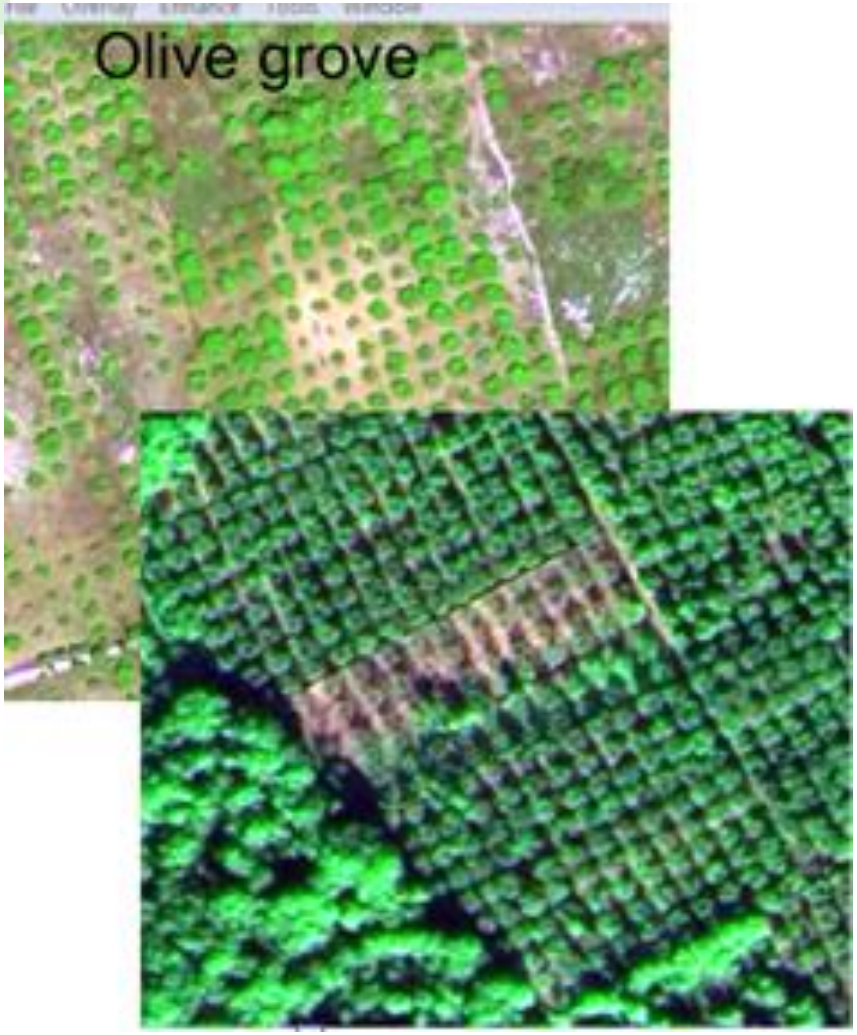
Spatial topological relations

Figure 3.3: Detail of the transect 2

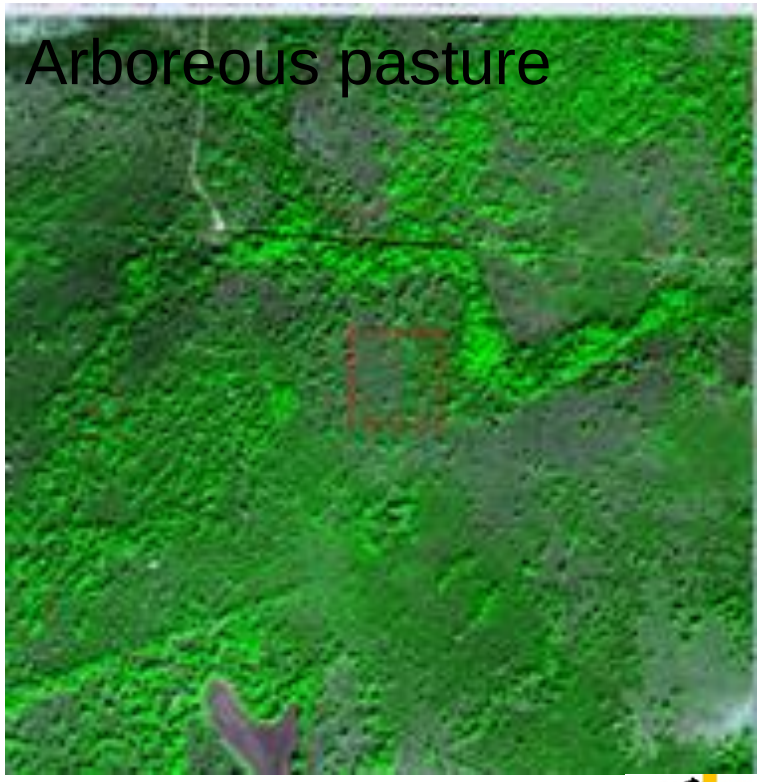


Core: olive trees
Context: soil and grassland

Class description is *scale dependent*



Core: deciduous trees
Context: soil and grassland



Ecological modeling:

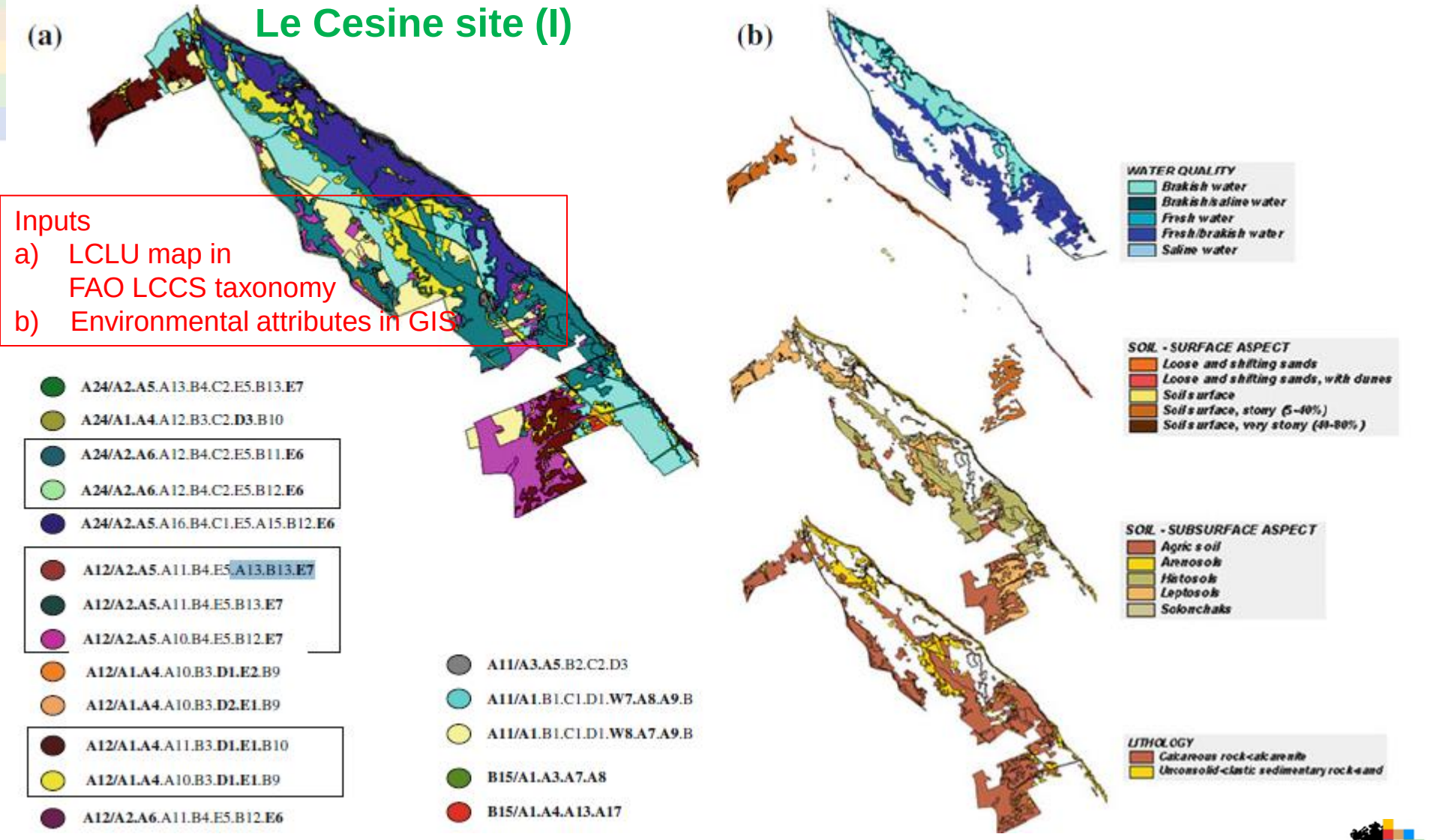
- at habitat level for integrating EO products with environmental in-situ data (if available)
- at landscape level for indicators extraction

EODHaM
3rd stage

LCLU to habitat map translation

(Tomaselli et. al., 2013)

Le Cesine site (I)



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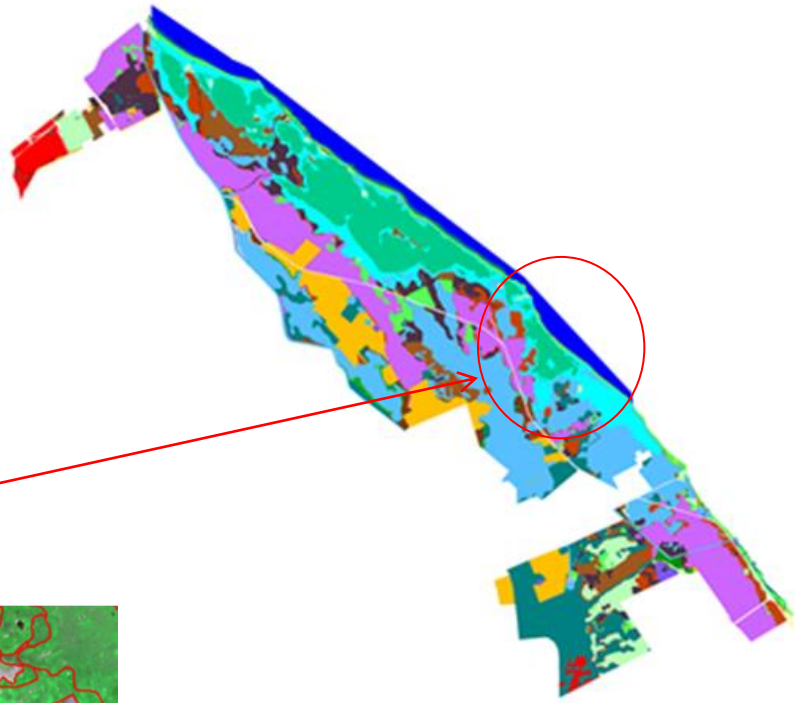
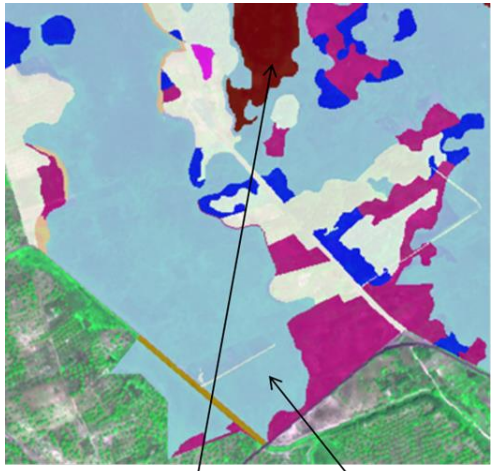
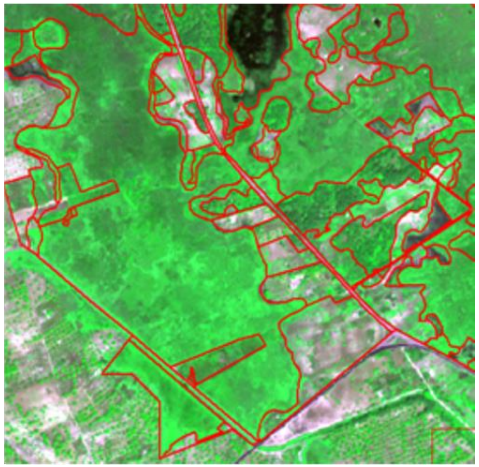
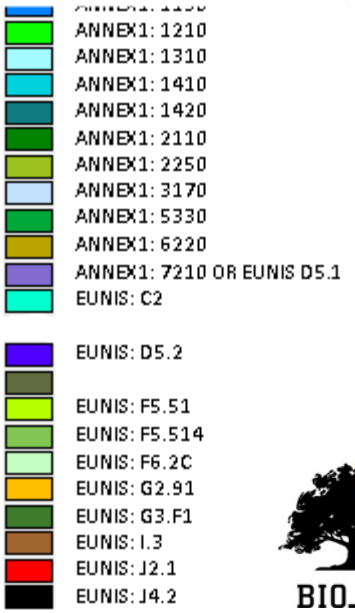
Habitat map: Annex I taxonomy, Le Cesine site (IT)



Close-up



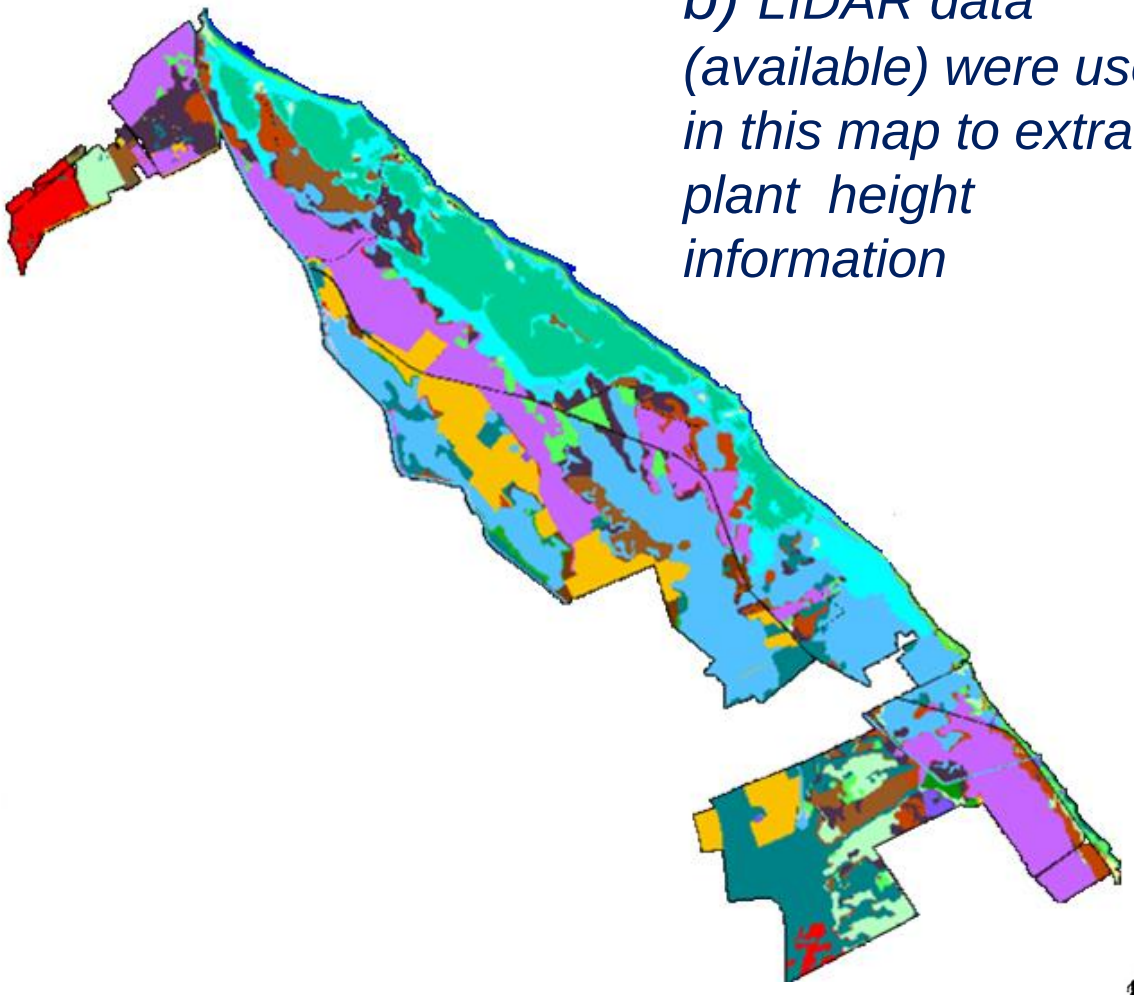




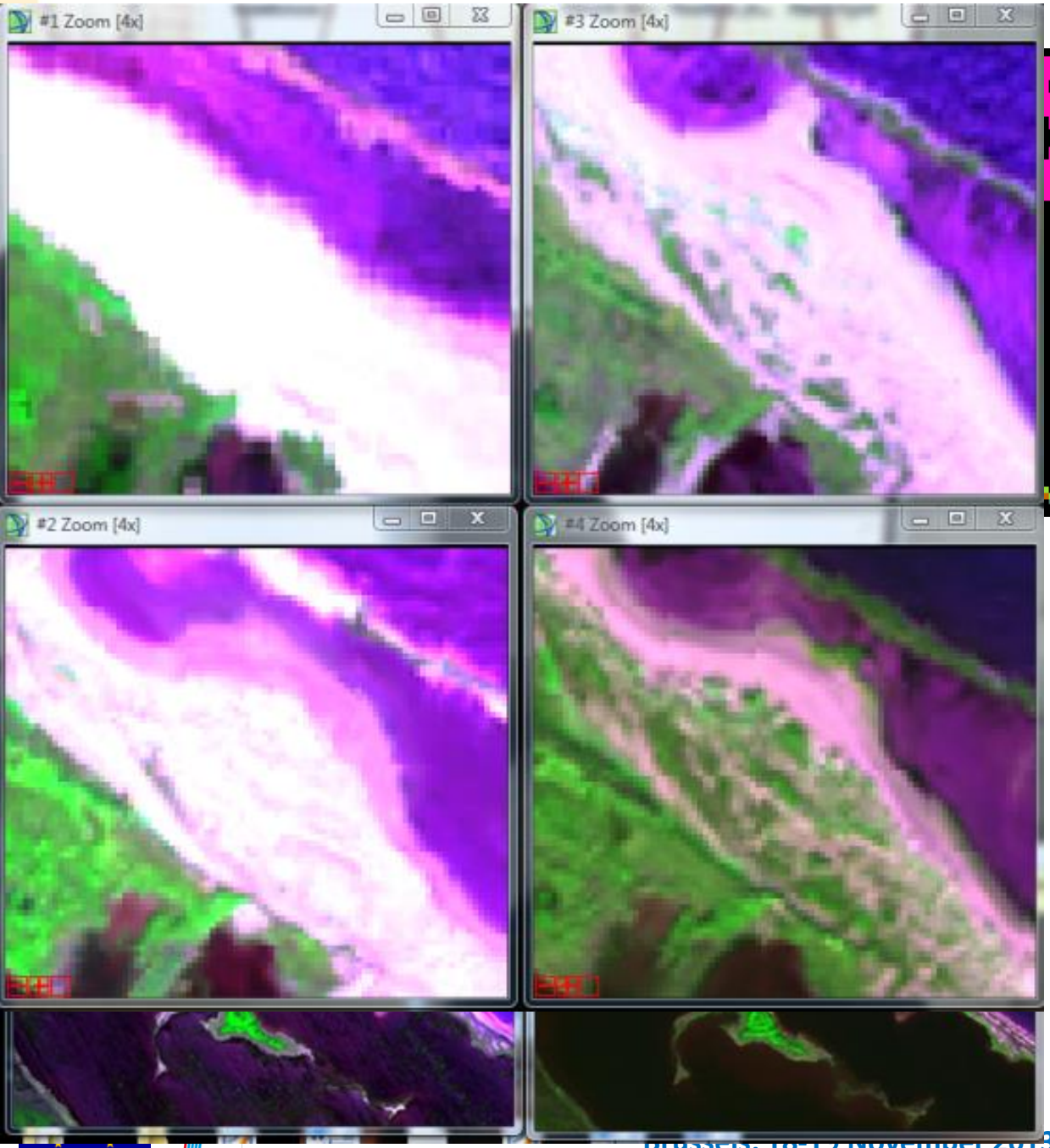
BIO_SOS

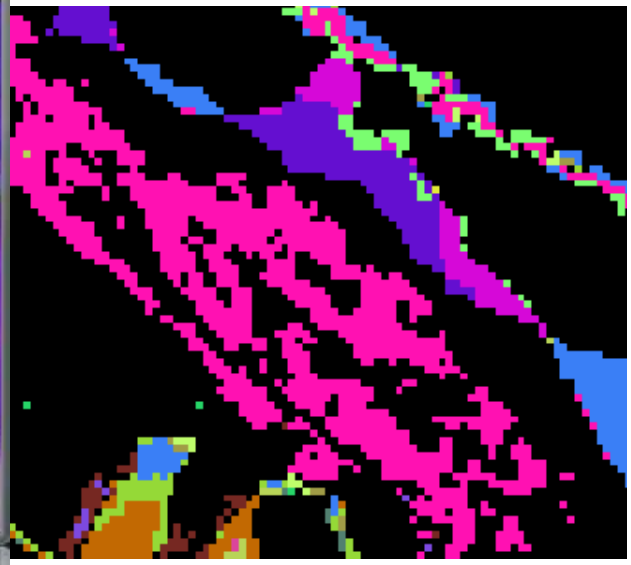
Habitat map: GHC taxonomy, Le Cesine site (IT)

Label	Look-up
CUL(WOC)	
CUL(CRO)	
HER(CHE)	
HER(EHY)	
HER(HEL)	
HER(SHY)	
HER(LHE)_OR_HER(HCH)_OR_HER(GEO)	
HER(THE)_OR_HER(GEO)	
SPV(SEA)	
SPV(AQU)	
URB(NON)	
URB(TRE)	
URB(GRA)	
URB(ART/ROA)	
URB(VEG)	
TRS(DCH)	
TRS(DCH/DEC)	
TRS(DCH/EVR)	
TRS(DCH/EVR/CON)	
TRS(SCH/DEC)	
TRS(SCH/EVR)	
TRS(SCH/EVR/CON)	
TRS(SCH/NLE)	
TRS(SCH/SUM)	
TRS(LPH/DEC)	
TRS(LPH/EVR)	
TRS(LPH/EVR/CON)	
TRS(MPH/DEC)	
TRS(MPH/EVR)	
TRS(MPH/EVR/CON)	
TRS(MPH/NLE)	
TRS(TPH/DEC)	
TRS(TPH/EVR)	
TRS(TPH/EVR/CON)	
TRS(FPH/EVR/CON)	
NON CLASS	



b) LIDAR data (available) were used in this map to extract plant height information





B15→A12

B28→B16

B15→B28

1. PEAK image 2009
2. POST image 2010

3. PEAK image 2012
4. POST image 2012

Study sites

BIO_SOS code	Natura 2000 code		Natura 2000 name
	SCIs /SACs	SPA	
IT1	IT9110008	IT9110039	Valloni e steppe pedegarganiche
IT2	IT9110005	IT9110038	Zone umide della Capitanata-Paludi presso il Golfo di Manfredonia
IT3	IT9120007	IT9120007	Murgia Alta
IT4	IT9150032	IT9150014	Le Cesine
GR1	GR2120001	GR2120005	Ekvoles Kalama
GR2	GR2120002	GR2120006	Elos Kalodiki
GR3	GR2120004		Stena Kalama
NL	NL9801023	NL3009017	Veluwe. Dutch case study concentrates on part N2K, namely Ginkelse and Ederheide, a heathland area and Weekeromse Zand an inland sand dune area
PT1	PTCON0021	PTZPE0037	Rios Sabor e Maçãs
PT2	PTCON0001	PTZPE0002	Peneda-Gerês
UK1	UK0014791		Cors Fochno
UK2	UK0014790		Cors Caron

- Additional areas are being considered in Brazil and India

Images Dataset: IT3_Murgia Alta site

Peak of Biomass
(April-May)
PoB

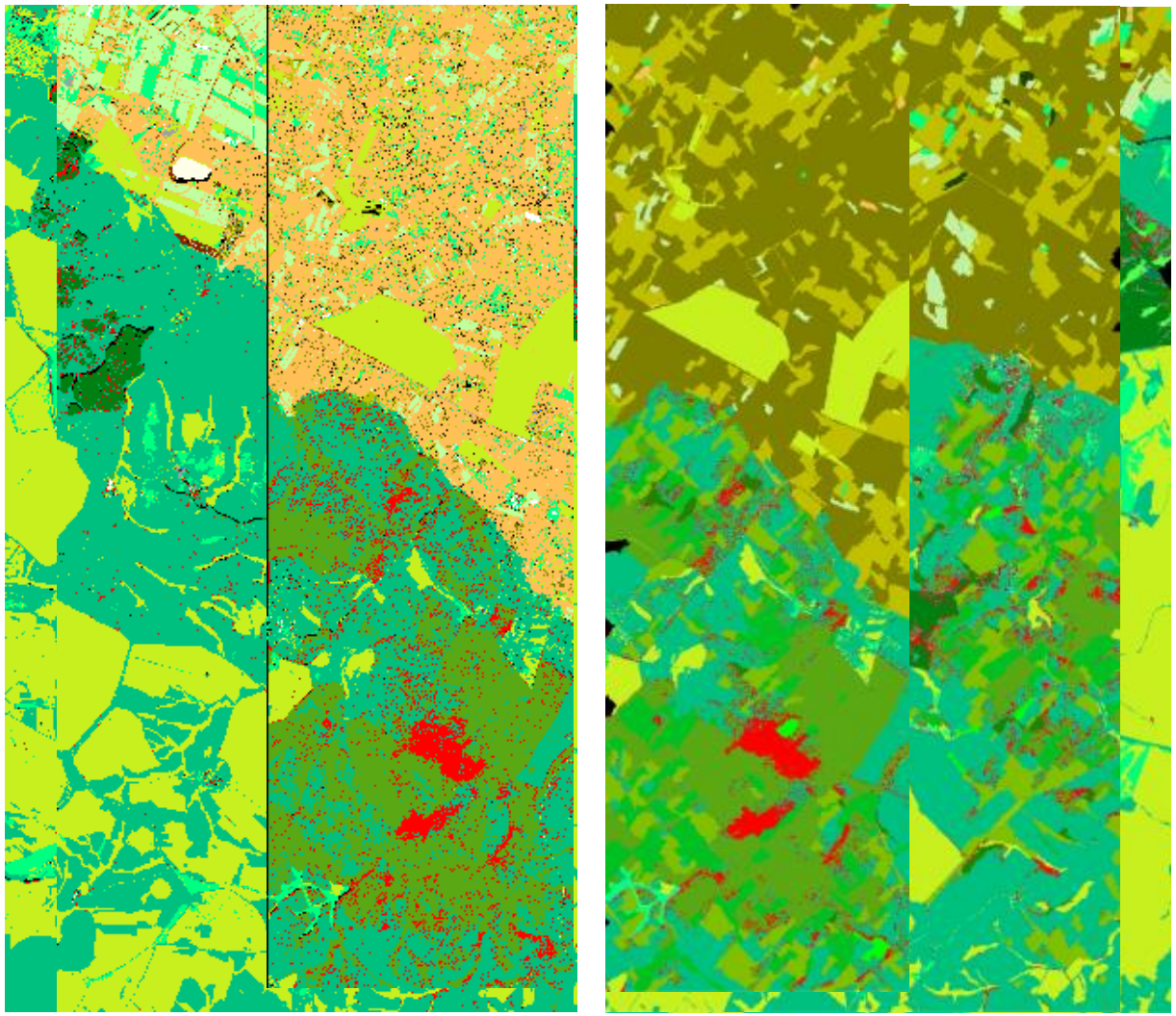
Post peak
(October)
PostPoB

Pre Peak
(January)
PrePoB

Dry Season
(July)
DS

Small Objects (SO) vs Large Objects (LO)

SO LO



A12/A2.A6
A12/A1.D1.E1
A12/A1.D1.E2
A12/A1.D2.E1
A11/A3.A4
A11/A3
A11/(A1orA2).A7.A9
A11/(A1orA2).A7.A10
A11/A2.A7.A10
A11/(A1orA2) cont.
B28 or B27
B15
B16
B15/A2.A6
SHADOW

A11/A3
A11/A3.A4
A12/A2.A6
A12/A1.D1.E1
A12/A1.D1.E2
A12/A1.D2.E1
A11/(A1orA2) cont.
B15
B15/A2.A6
B16
SHADOW
A11/(A1orA2).A7.A9
A11/(A1orA2).A7.A10
A11/A3 or A11/A2.A7.A10
B28 or B27
A11/A2.A7.A10
A12/A2.A6 + A12/A1.D1.E2
A12/A2.A6 + A12/A1.D1.E1
A12/A2.A6 + A12/A1.D2.E1
A12/A1.D1.E1 + A12/A2.A6
A12/A1.D1.E2 + A12/A2.A6
A12/A1.D2.E1 + A12/A2.A6

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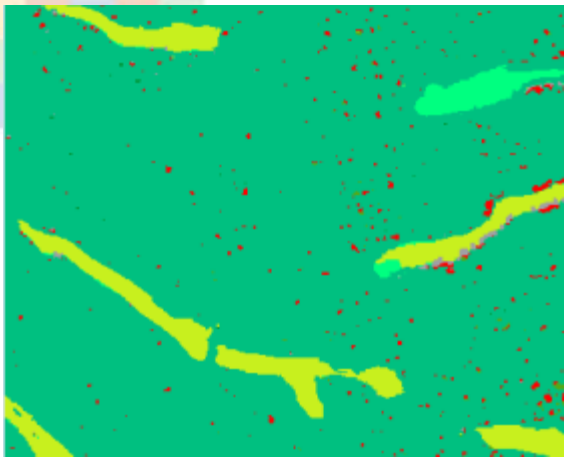
Examples

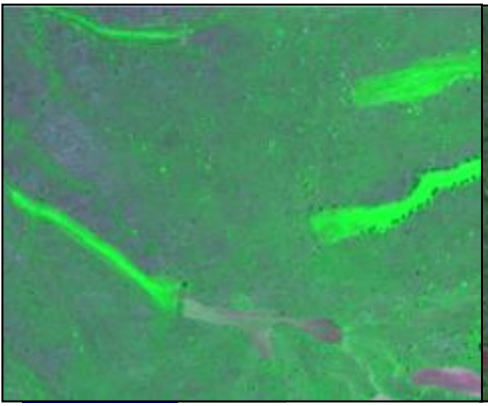
SO



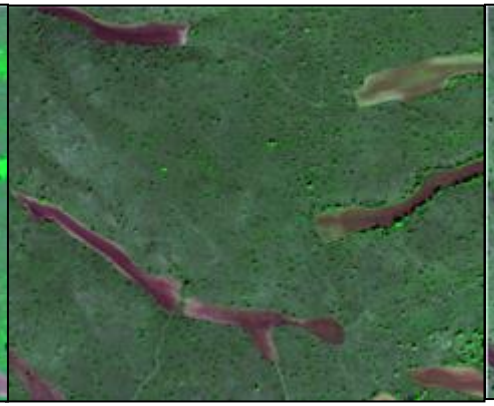
- A11/A3
- A11/A3.A4
- A12/A2.A6
- A12/A1.D1.E1
- A12/A1.D1.E2
- A12/A1.D2.E1
- A11/(A1orA2) cont.
- B15
- B15/A2.A6
- B16
- SHADOW
- A11/(A1orA2).A7.A9
- A11/(A1orA2).A7.A10
- A11/A3 or A11/A2.A7.A10
- B28 or B27
- A11/A2.A7.A10

LO

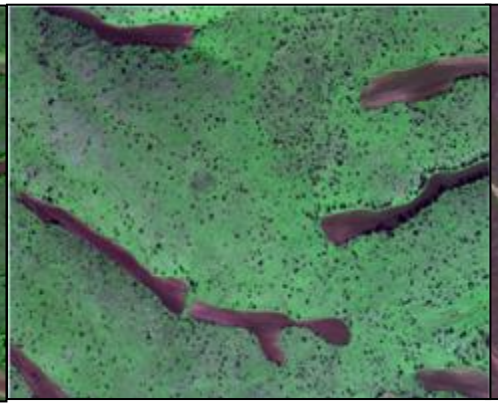
- A11/A3
- A11/A3.A4
- A12/A2.A6
- A12/A1.D1.E1
- A12/A1.D1.E2
- A12/A1.D2.E1
- A11/(A1orA2) cont.
- B15
- B15/A2.A6
- B16
- SHADOW
- A11/(A1orA2).A7.A9
- A11/(A1orA2).A7.A10
- A11/A3 or A11/A2.A7.A10
- B28 or B27
- A11/A2.A7.A10
- A12/A2.A6 + A12/A1.D1.E2
- A12/A2.A6 + A12/A1.D1.E1
- A12/A2.A6 + A12/A1.D2.E1
- A12/A1.D1.E1 + A12/A2.A6
- A12/A1.D1.E2 + A12/A2.A6
- A12/A1.D2.E1 + A12/A2.A6



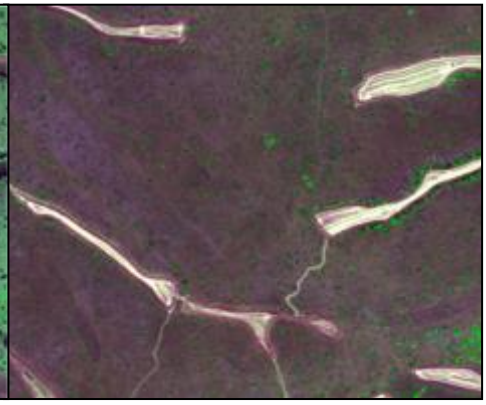
PoB



PostPoB



PrePoB

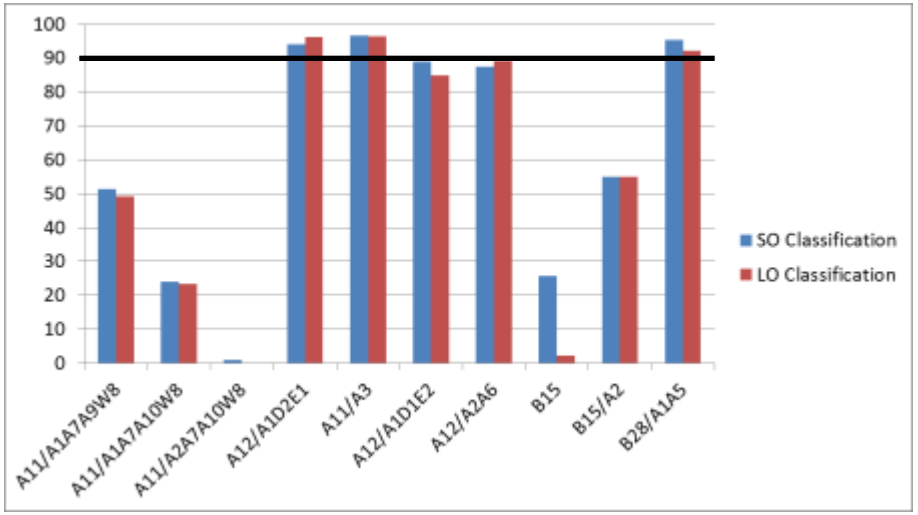


DS

Validation

LCCS MAP	OA%	error%
SO classification	84.0%	0.07%
LO classification	84.4%	0.08%
SO classification (with OTB cultivated_trees strata, no DTM)	78.5%	0.11%
LO classification (with OTB cultivated_trees strata, no DTM)	77.6%	0.13%

GROUND TRUTH CLASSES
A11/A1A7A9W8
A11/A1A7A10W8
A11/A2A7A10W8
A12/A1A3D2E1
A11/A3
A12/A1A3D1E2
A12/A1D1E1
A12/A2A6
B15
B15/A2
B28/A1A5



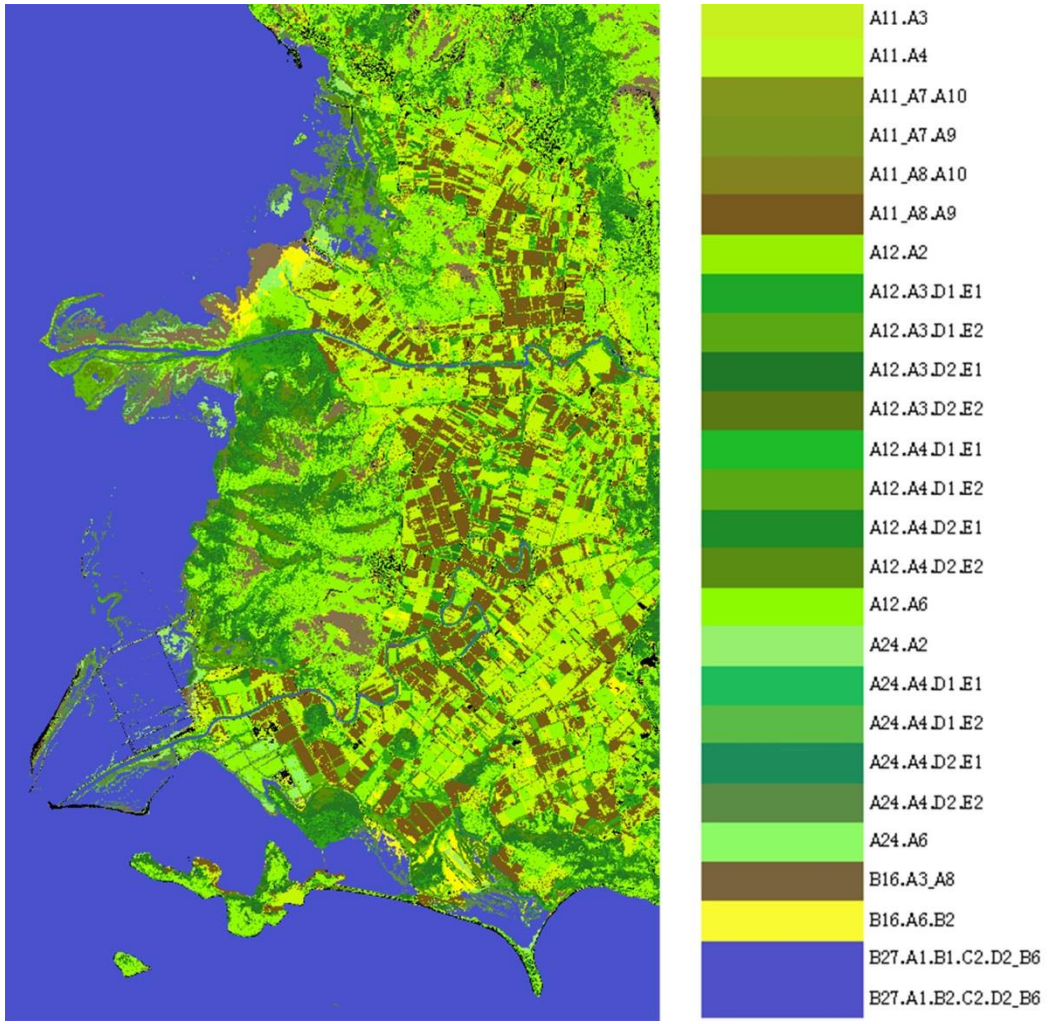
Recommendations for biodiversity monitoring (EO)

- Regular acquisition of **VHR** EO data (pre-flush, peak-flush, post-flush) on Natura 2000 sites as hotspots of biodiversity to detect changes (archive data!!!)
  - Clouded areas: SAR-optical and Sentinel data
  - Accurate pre-processing including atmospheric corrections is required
- LIDAR or stereo optical acquisitions for vegetation height measurement (CHM) and DTM.

Recommendations for biodiversity monitoring

- To link the ***spatial and in-situ*** components based on modelling expertise for LCLU to Habitats conversion.
- To produce validated LCLU maps in FAO-LCCS taxonomy or at least ground reference data in FAO-LCCS (not only in CORINE)
- To train terrain managers more in the use and interpretation of EO derived products.

Study site in Greece: LCLU map



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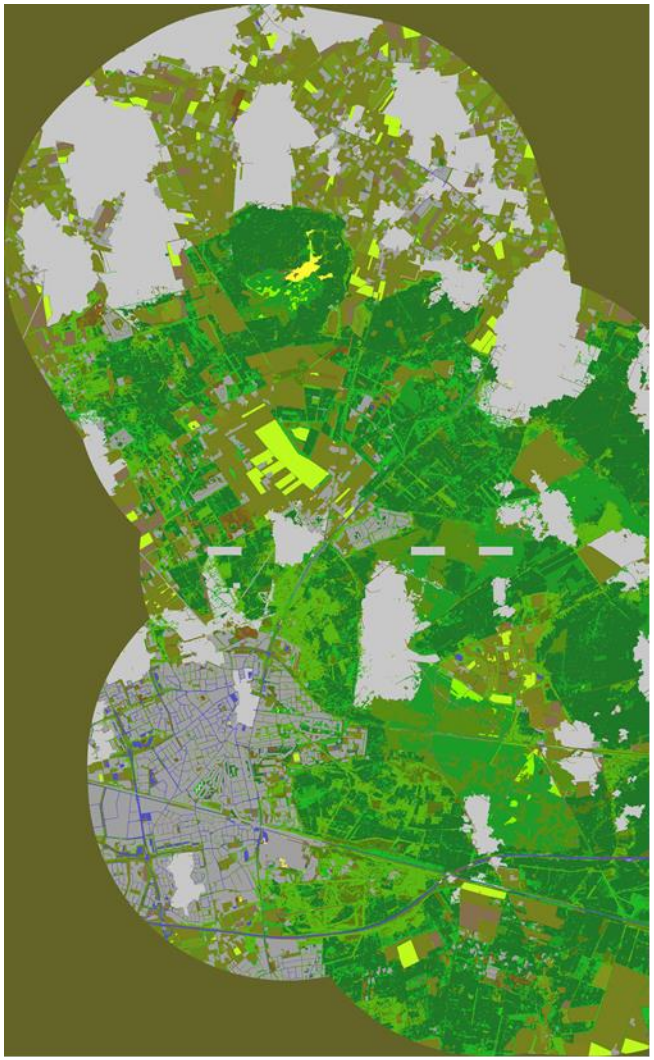
Veluwe, The Netherlands: LCLU map



B16.A3.A8
B27.A1
A12.A3.D2.E2
A12.A4.D1.E2
Clouds
A12.A3.D1.E1
A12.A4.D2.E2
A12.A3.D1.E2
A12.A3.D2.E1
A12.A1.D2.E2
A12.A4.D2.E1
A12.A4.D1.E1
A11.A1.A7.A9
A11.A2.A7.A9
A12.A4
A11.A1.A8.A9
B16.A6
A12.A6
B27
B15.A2
A11.A1.A7.A10
A11.A2.A7.A10
A11.A2.A8.A10
A11.A2.A8.A9
A11.A2
A11.A1.A8.A10
A11.A4
B15.A1
A12.A1.D2.E1
A11.A8.A10
A11.A3
A11.A8.A9

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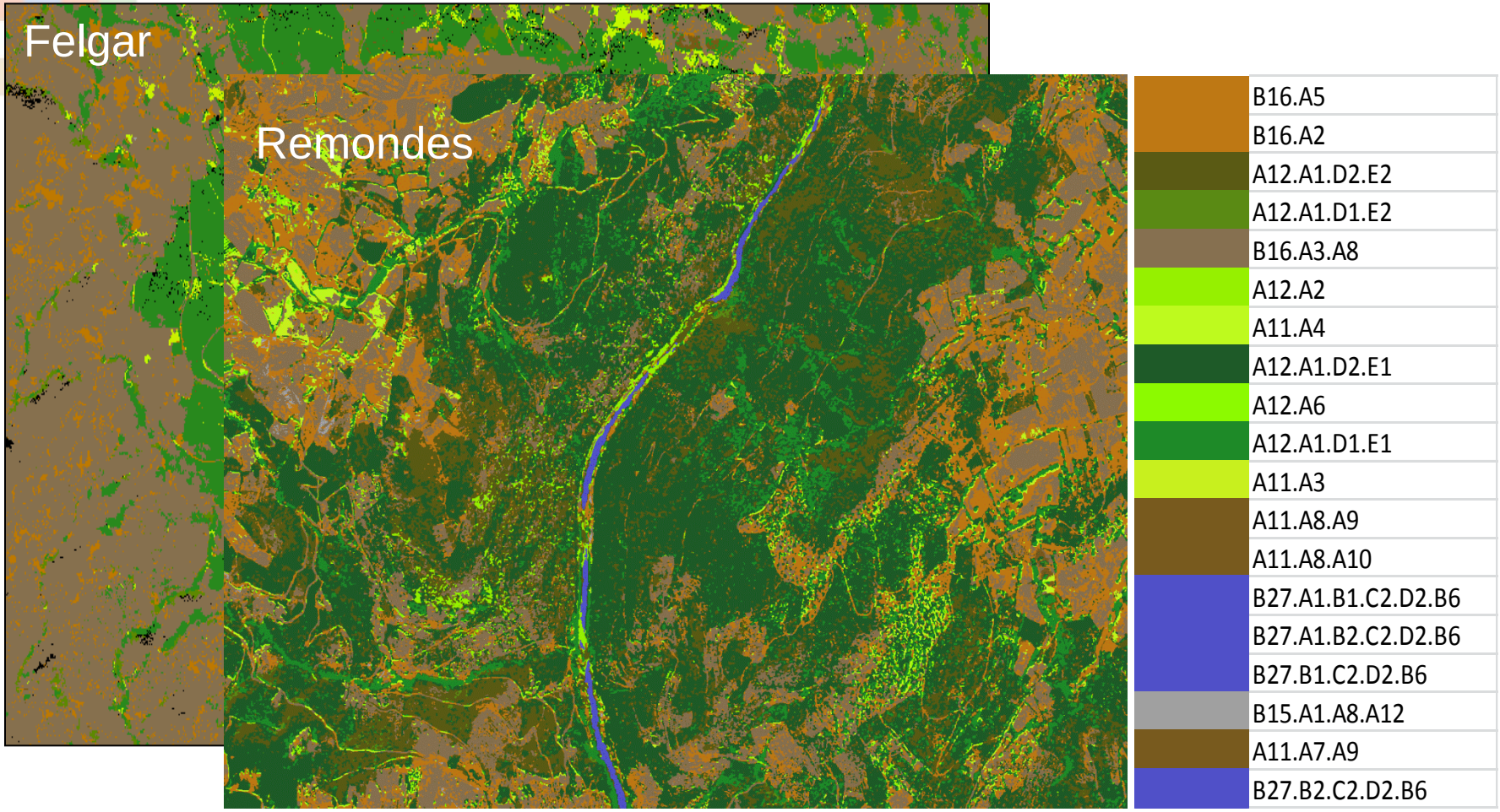
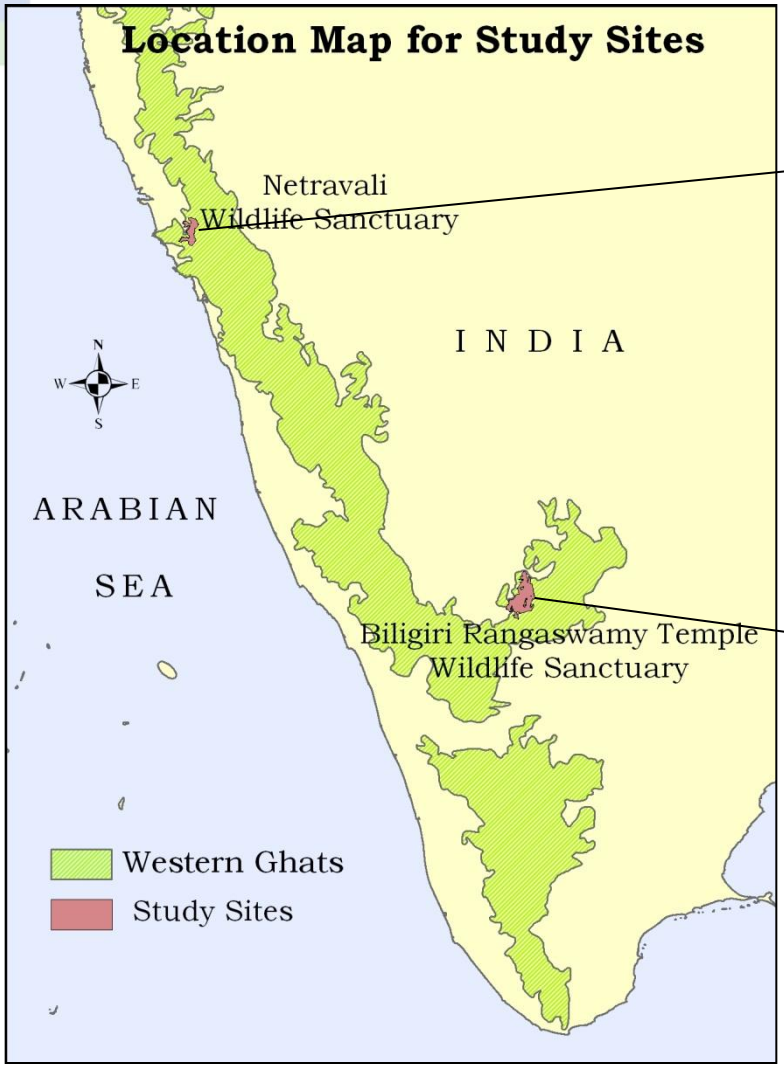
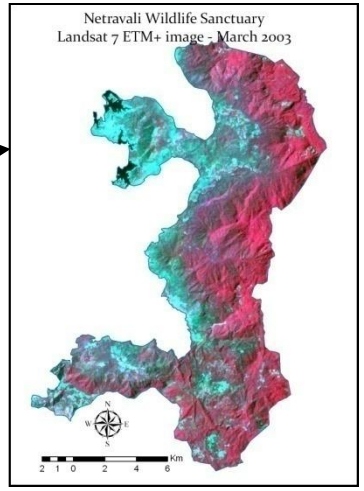
Study site in Portugal: LCLU map



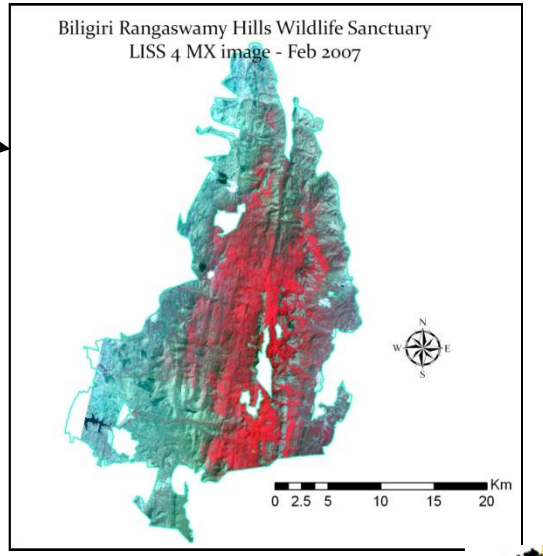
Study Sites in India: location



IN2



IN1



COOPERATION

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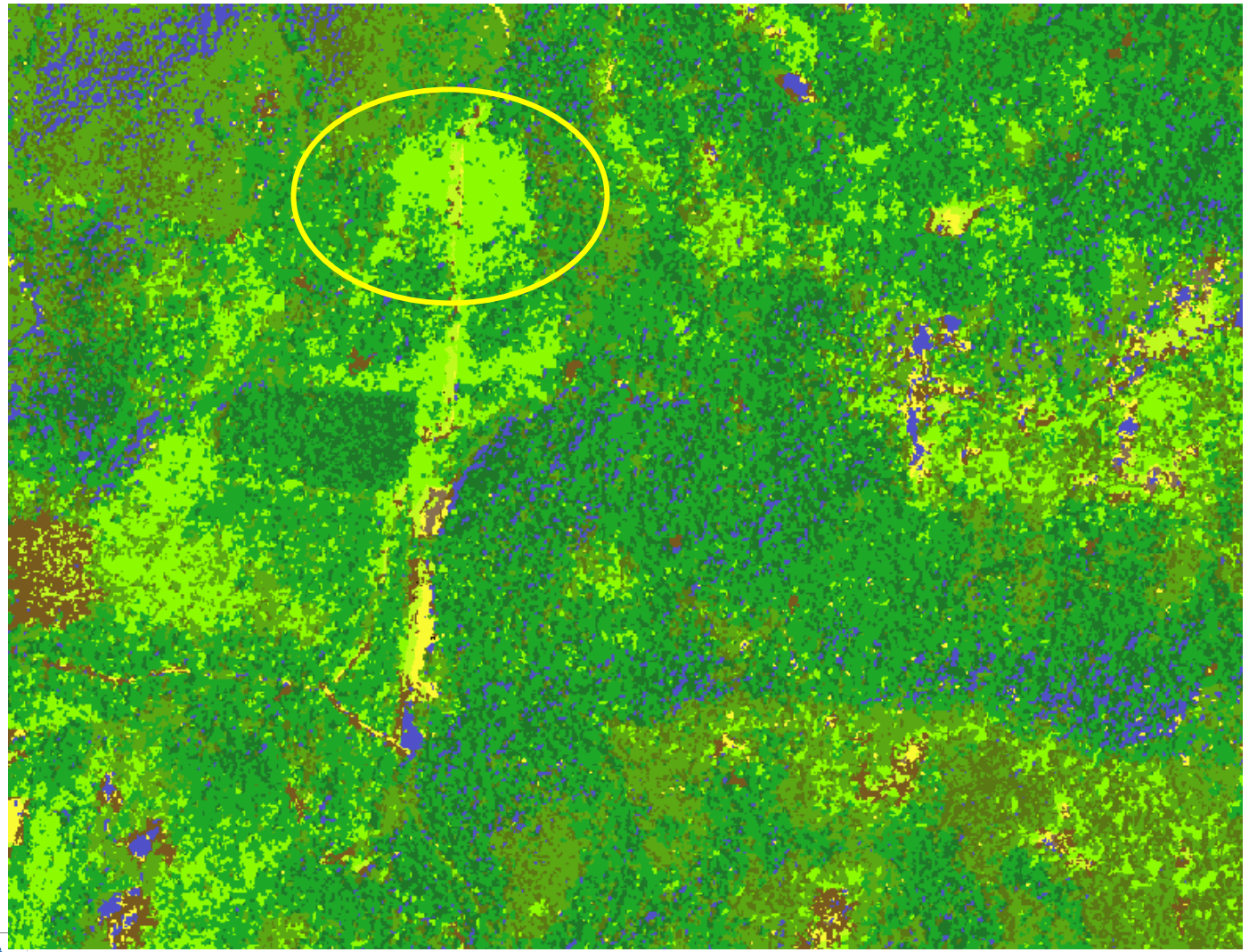
Study Sites in India: LCLU map

Invasive species identification



a) GeoEye, Jan. 2011 b) WorldView2, March. 2013

BIO_SOS main achievements

- EODHaM system products:

  - **VHR LCLU maps in FAO-LCCS taxonomy**
  - **VHR habitats maps as GHCs and Annex 1 habitats**
  - **Biodiversity indicators**
  - **Change map of LCLU and habitats**

  - Framework to translate LCLU to habitats classes
  - Open source software (python).
  - Scalable to other sensors, based on the availability of expert knowledge at different scales (e.g. UAS, WV, Landsat, Sentinel)

- It can provide scientific support to policy makers