LC taxonomies for applications to biodiversity and ecosystems

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FP7-SPACE *BIO_SOS*

Biodiversity Multi-Source Monitoring System: From Space To Species

www.biosos.eu

FP7-SPACE, 3rd call. GA 263435

1/12/2010 - 1/12/2013

HORIZON2020 *ECOPOTENTIAL*

Improving future ecosystem benefits through earth observations.

http://www.ecopotential-project.eu/

Horizon2020 - GA 641762

1/06/2015-30/05/2019

Consiglio Nazionale delle Ricerche

The outline

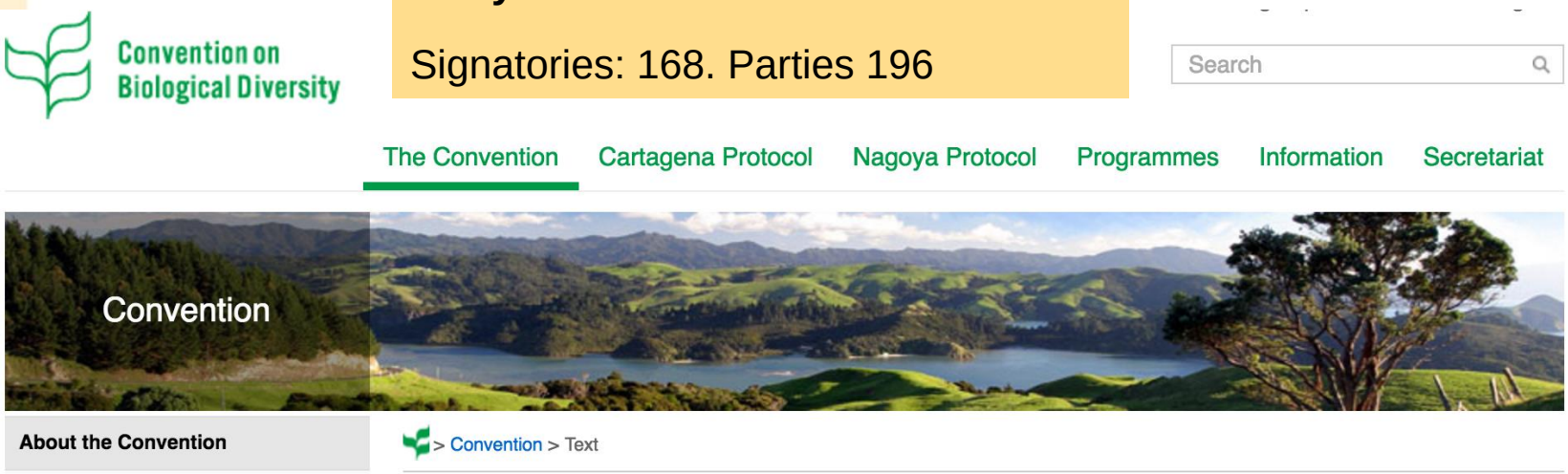
- Background: biodiversity and ecosystem conservation
- Taxonomies for Land Cover/Use (LCLU) to habitat and ecosystem mapping from remote sensing data
  - ✓ FAO-LCCS for integrating EO and in-situ data;
- The BIO_SOS methodological approach (EODHaM system) as background of the HORIZON2020 ECOPOTENTIAL
- Study cases
- Conclusions and future work

The Convention on Biological Diversity (CBD)

Rio De Janeiro, 5 June 1992

Entry into force: 29 Dec. 1993

Signatories: 168. Parties 196



Main objectives:

- ***The conservation of biological diversity;***
- ***The sustainable use of its components.***

Article 6. General Measures for Conservation and Sustainable use.

Article 7. Identification and Monitoring:

- Components of biological diversity;
- Processes and categories of actions for conservation

The EU Biodiversity Strategy to 2020

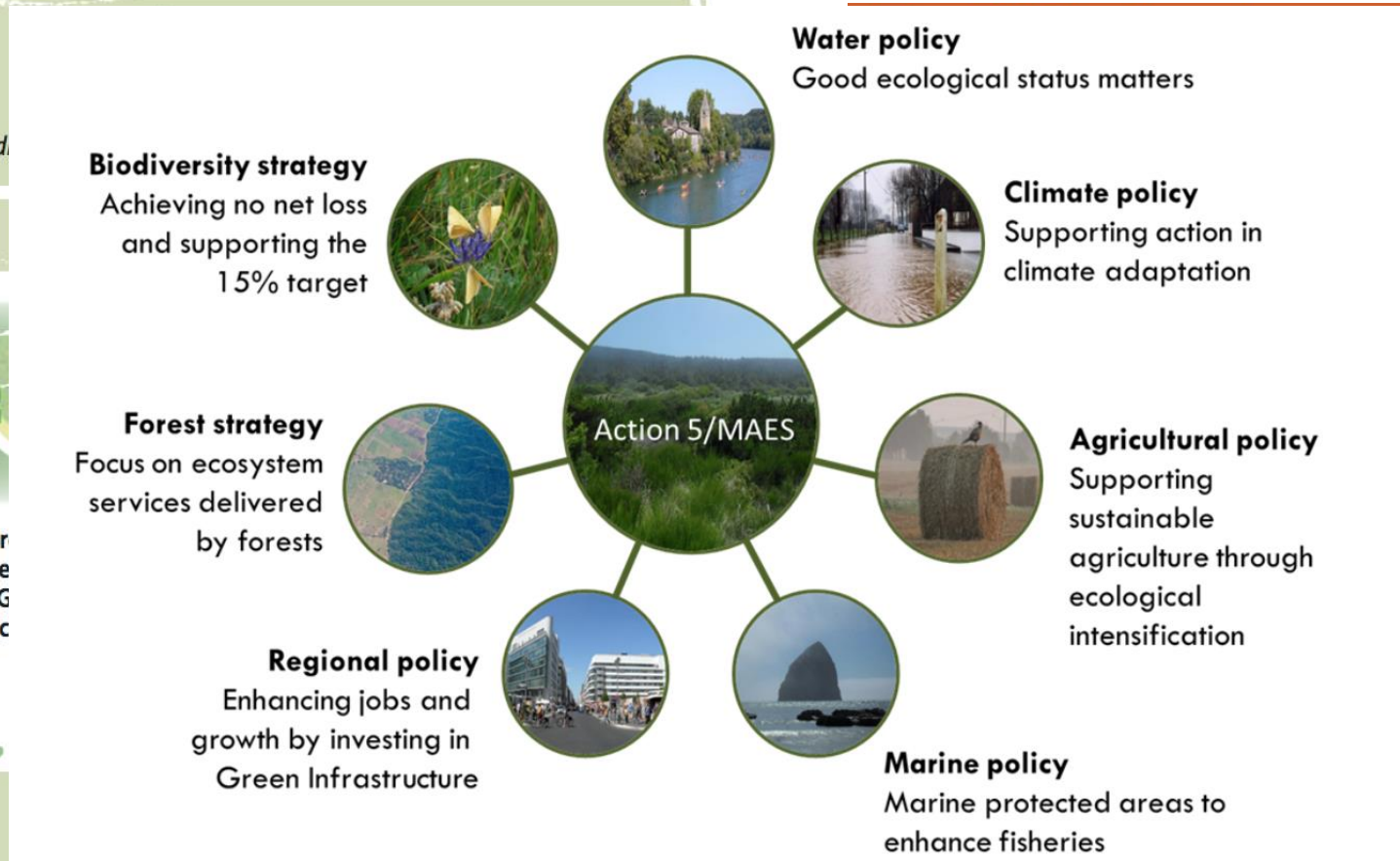


Figure 1. Example to illustrate inputs of Action 5 into other policies.

Credits: Maes et. al. 2014

Action 5 Improve knowledge of ecosystems and their services in the EU

The Habitat Directive

- The Habitats Directive (92/43/EEC) and the Birds Directive (79/409/EEC) oblige MS to report on the conservation status and distribution of species and habitats of European importance in Natura 2000 sites **every 6 years**.

- The *conservation status* report required by Art. 17 of the Habitats (92/43/EEC) directive is based on the new Standard Data Form (2011)

  - Range of habitat
  - Area covered by habitat type within range
  - Structure and functions
  - Future prospects
    - Reason for changes
    - ***Pressures/threats***

- *Users (i.e. management authorities) need:*

  - *Standardized method*
  - *Scale 1:5000 or finer;*
  - *Long-time data series* for monitoring changes
  - *Scientific support* to evaluate the impact of existing policies.

Essential Biodiversity Variables (EBV) from GEO_BON, at http://geobon.org/

EXAMPLES OF CANDIDATE ESSENTIAL BIODIVERSITY VAR

EBV class	EBV examples	Measurement and scalability	Temporal sensitivity	Feasibility
Genetic composition	Allelic diversity	Genotypes of selected species (e.g., endangered, domesticated) at representative locations.	Generation time	Data available for many species and for several locations, but little global systematic sampling.
Species populations	Abundances and distributions	Counts or presence surveys for groups of species easy to monitor or important for ES, over an extensive network of sites, complemented with incidental data.	1 to >10 years	Standardized counts under way for some taxa but geographically restricted. Presence data collected for more taxa. Ongoing data integration efforts (Global Biodiversity Information Facility, Map of Life).
Species traits	Phenology	Timing of leaf coloration by RS, with in situ validation.	1 year	Several ongoing initiatives (Phenological Eyes Network, PhenoCam, etc.)
Community composition	Taxonomic diversity	Consistent multitaxa surveys and metagenomics at select locations.	5 to >10 years	Ongoing at intensive monitoring sites (opportunities for expansion). Metagenomics and hyperspectral RS emerging.
Ecosystem structure	Habitat structure	RS of cover (or biomass) by height (or depth) globally or regionally.	1 to 5 years	Global terrestrial maps available with RS (e.g., Light Detection and Ranging). Marine and freshwater habitats mapped by combining RS and in situ data.
Ecosystem function	Nutrient retention	Nutrient output/input ratios measured at select locations. Combine with RS to model regionally.	1 year	Intensive monitoring sites exist for N saturation in acid-deposition areas and P retention in affected rivers.

Habitats as proxies

LC maps and LIDAR

Bio-geo physical indices

Techniques for habitat mapping from Space

- *Traditional*: habitats maps are generally produced by
  - In-field campaigns (*costly and sometime impracticable).*
  - Visual interpretation of *aerial ortho-photo* to extract LC information to be integrated with in-situ and ancillary data.

- *Automatic analysis of multiple-source EO data* can provide useful LC maps, however such maps are not adequately related to biodiversity in comparison to habitats (Bunce at al., 2013).

- *Issue*: which taxonomy for LC and habitat classes description?
  - **LC:** *CORINE,* ***FAO-LCCS (Di gregorio et al.,*** *, IGBP, etc.*
  - **Habitats**: *Eunis, CORINE Biotope, GHC, Annex I.*

- How LCLU classes can be translated into Habitats? **Ecological modeling at habitat level**

CLC3

4.2.1 - Salt marshes

coastal grasslands regulary flooded by sea water

Annex I 1410.

Mediterranean salt meadows (Juncetalia maritimi)

Annex I 7210.

Sphagnum acid bogs

Coastal Annex I / Eunis habitats

Annex I 1420. ***Mediterranean and thermo – Atlantic halophilous scrubs (Sarconetea fruticosi)***

EUNIS D5.2.

Beds of large sedges normally without free-standing water

Annex I 1310. ***Salicornia and other annuals colonizing mud and sand***

Taxonomies comparison

Landscape Ecol
DOI 10.1007/s10980-013-9863-3

RESEARCH ARTICLE

Translating land cover/land use classifications to habitat taxonomies for landscape monitoring: a Mediterranean assessment

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Received: 12 September 2012 / Accepted: 19 February 2013

Abstract Periodic monitoring of biodiversity changes at a landscape scale constitutes a key issue for conservation managers. Earth observation (EO) data offer a potential solution, through direct or indirect mapping of species or habitats. Most national and international programs rely on the use of land cover (LC) and/or land use (LU) classification systems. Yet, these are not as clearly relatable to biodiversity in comparison to habitat classifications, and provide less scope for monitoring. While a conversion from LC/LU classification to habitat classification can be of great utility, differences in definitions and criteria have so far limited the establishment of a unified approach for such translation between these two classification systems. Focusing on five Mediterranean NATURA 2000 sites, this paper considers the scope for three of the most commonly used global LC/LU taxonomies—CORINE Land Cover, the Food and Agricultural Organisation (FAO) land cover classification system (LCCS) and the International Geosphere-Biosphere Programme to be translated to habitat taxonomies. Through both quantitative and expert knowledge based qualitative analysis of selected taxonomies, FAO-LCCS turns out to be the best candidate to cope with the complexity of habitat description and provides a framework for EO and in situ data integration for habitat mapping, reducing uncertainties and class overlaps and bridging the gap between LC/LU and habitats domains for

EUNIS coniders agricultural and urban habitats

Objectives

- selection of a suitable LC taxonomy
- selection of a suitable Habitat taxonomy
- selection of the “best” pair for LC-Habitat conversion





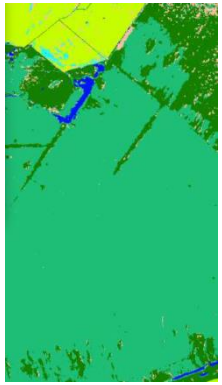

Land cover taxonomies

- IGBP
- CORINE LC
- FAO_LCCS

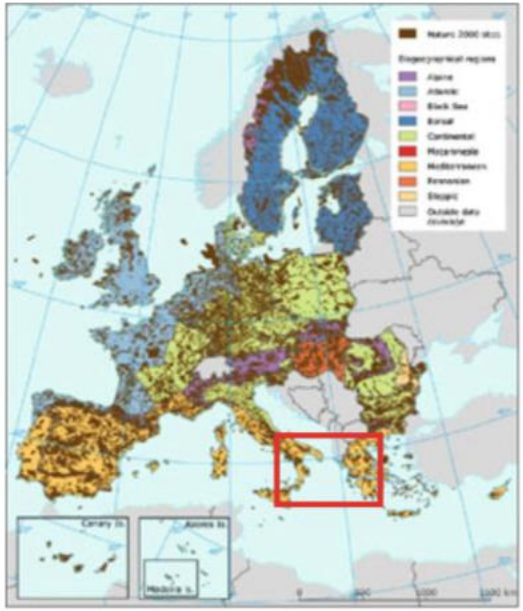
(Di Gregorio and Jansen 1998, 2005)

Habitat taxonomies

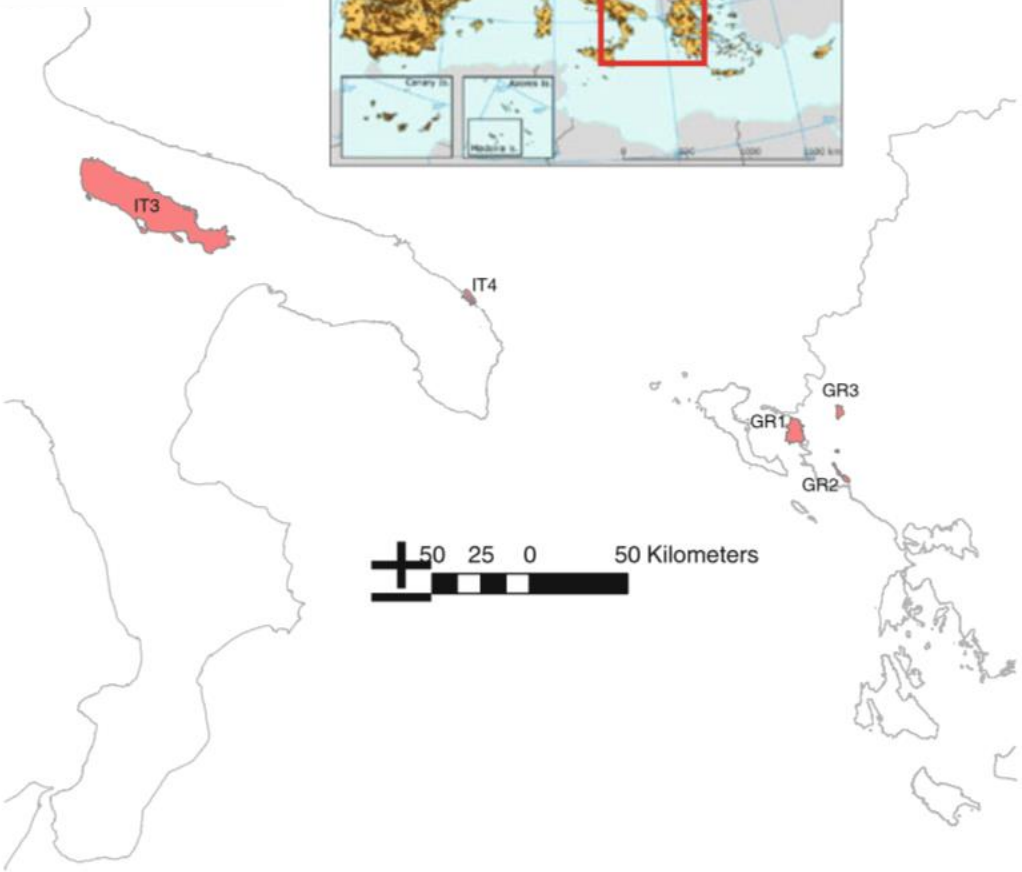
- CORINE BIOTOPES
- ANNEX I
- EUNIS
- GHC



Site name	BIO_SOS code	SCI code	SPA code	SCI area (ha)	Brief description
Murgia Alta	IT3	IT9120007	IT9120007	125880	Calcareous plateau with Mediterranean steppe grasslands
Le Cesine	IT4	IT9150032	IT9150014	2148	Coastal wetlands
Ekvoles Kalama	GR1	GR2120001	GR2120005	8481	Coastal wetlands
Elos Kalodiki	GR2	GR2120002	GR2120006	845	Inland, freshwater wetland
Stena Kalama	GR3	GR2120004		1867	River gorges



Selection of the sites. Step 1



Terminology

(Di Gregorio and Jansen, 2000)

- **Land Cover** is the observed (bio) physical coverage of the earth's surface.

(grassland is a cover term, but rangeland refers to the use of land cover)

- *Classification* is an abstract representation of the situation in the filed, based on diagnostic criteria, and should be:
  - **Scale independent**, meaning that the classes at all level of the system should be applicable at any scale or level of details
  - **Source independen**t, implying that it is independent of the means used to collect information.
- *A legend* is the application of a classification in a specific area using a defined mapping scale and specific data sets, and it is:
  - **Scale and cartographic representation dependent**;
  - **Data and mapping methodology dependent**

Good taxonomy properties

(Salafsky et al 2003)






Hierarchical	Creates a logical way of grouping classes
Comprehensive	Covers all possible objects on the scene by a class label
Consistent	All entries at a given level of the taxonomy are of the same type
Expandable	New classes can be added without changing the full hierarchy
Exclusive	Any given "object" can only be placed in one position within the hierarchy
Geographically invariant	The labeling of a same object is invariant across different locations

What about our LC taxonomies?

	IGBP	CORINE	LCCS
Hierarchical		X	X
Comprehensive		X	X
Consistent	X	Mix of LC-LU	X
Expandable		Only virtually	X
Exclusive	X		X
Geographically invariant			X






What about our Habitat taxonomies?

	Corine Biotopes	Annex I	Eunis	GHC
Hierarchical	X	X	X	X
Comprehensive	X		X	X
Consistent	X	X	X	X
Expandable				X
Exclusive	X	X	X	X
Geographically invariant	X		X	X



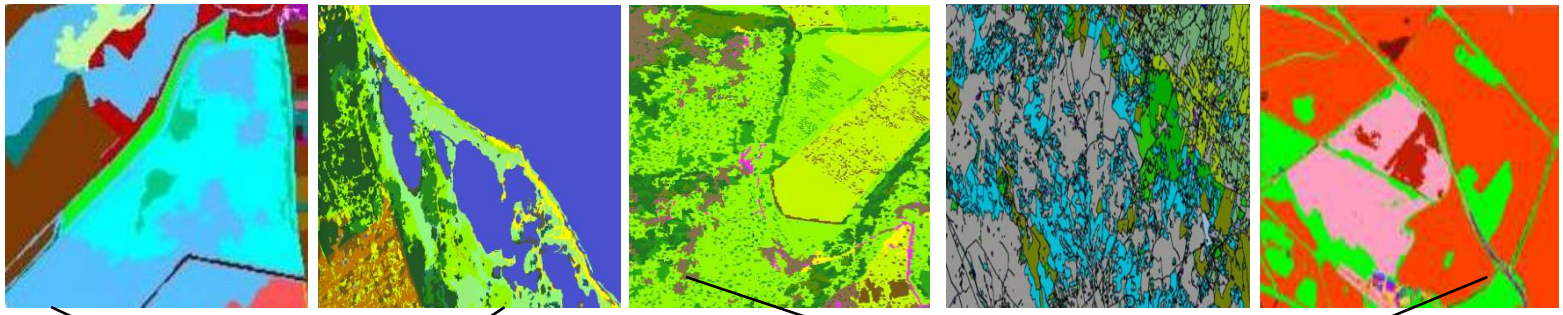



Quantitative comparison of taxonomies: step 2

5 sites : IT3, IT4, GR1, GR2, GR3

Site I | Site II | Site III | Site IV | Site V

T1
(e.g. CLC)



J(SI,SIII) **J(SIII,SV)**

The **Jaccard index** value ranges from 0 when the two sites have no common LC/LU classes to 1 when both sites have exactly the same landscape composition.

The index analyses only the presence of classes and not their coverage. For any taxonomy, this was repeated for each pair of sites.

Quantitative comparison of taxonomies: Step 3






	Corine Biot.	Annex I	EUNIS	GHC II/III	LCCS	LCCS+ ENV. ATTR
CLC3	5	10	9	11	14	10
Corine Biotopes		7	4	8	9	5
Annex I			7	5	12	10
EUNIS				6	5	3
GHC II/III					11	9
LCCS						4

FAO-LCCS version 2

- Rather than establishing land cover classes based on nomenclature, it defines a **set of independent diagnostic criteria** strictly based on vegetation physiognomy and structure (Di Gregorio & Jansen, 2005)

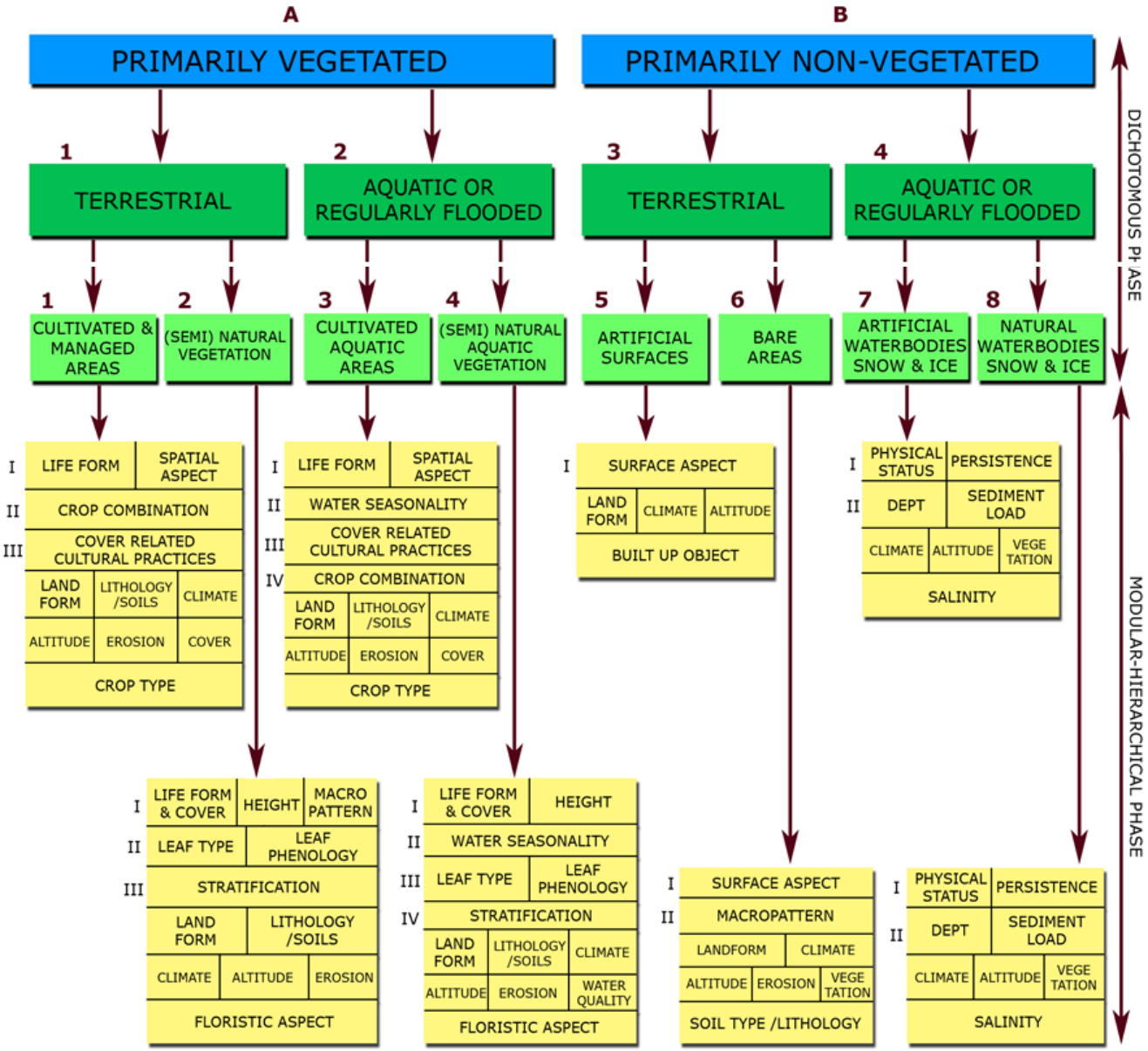
- A given land-cover class is defined by a dynamic combination of classifiers which can be combined to describe the complex semantic of each land-cover class. (Di Gregorio & Jansen, 1998)

- It provides a framework able to describe **better than CORINE** natural and semi-natural habitats (Tomaselli et. al., 2013)

- It can describe *within* class changes (e.g. in density)

- **It provides a framework, based on environmental attributes, to integrate LCLU with in-situ data and translate LCLU to habitats**

The classification is based on two phases:

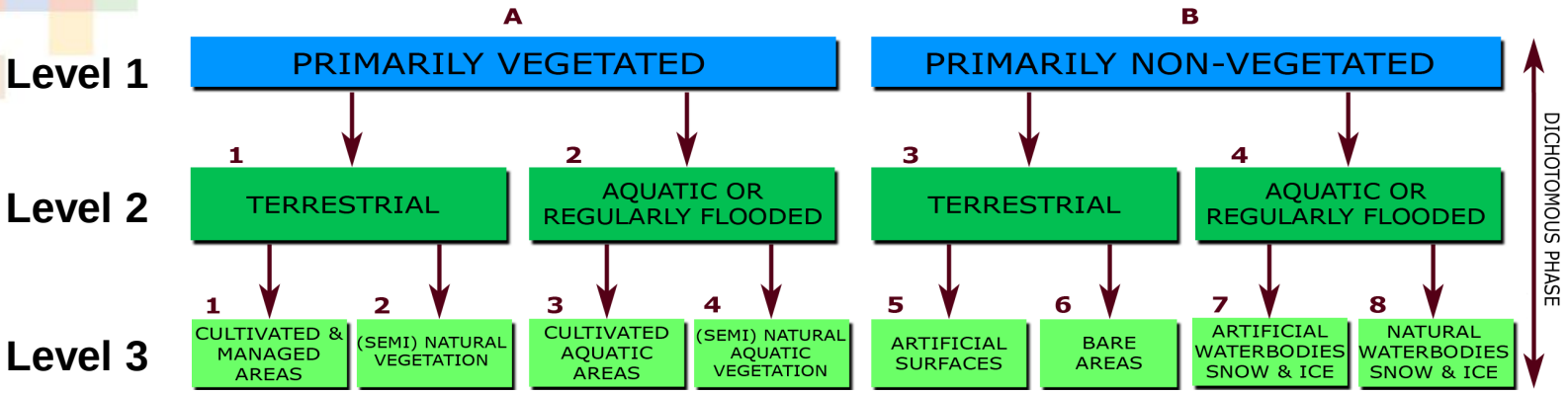


Dichotomous phase

Modular Hierachical phase

1) LCCS Dichotomous phase

A dichotomous key is used to define eight major LC types



A primarily vegetated

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

B primarily non vegetated

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

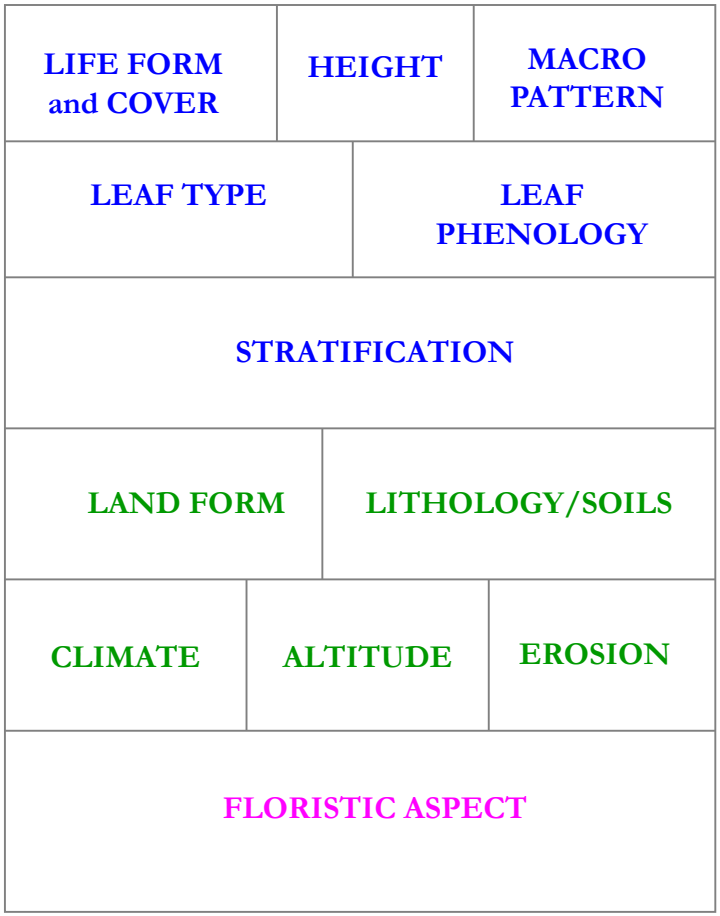
2) LCCS Modular-Hierarchical phase

- For any major LC category, a combination of a predefined set of diagnostic criteria (classifiers) based on vegetation structure and physiognomy is applied.
- For each set, the classifiers are divided into three groups:

1. pure land cover classifiers

2. environmental attributes

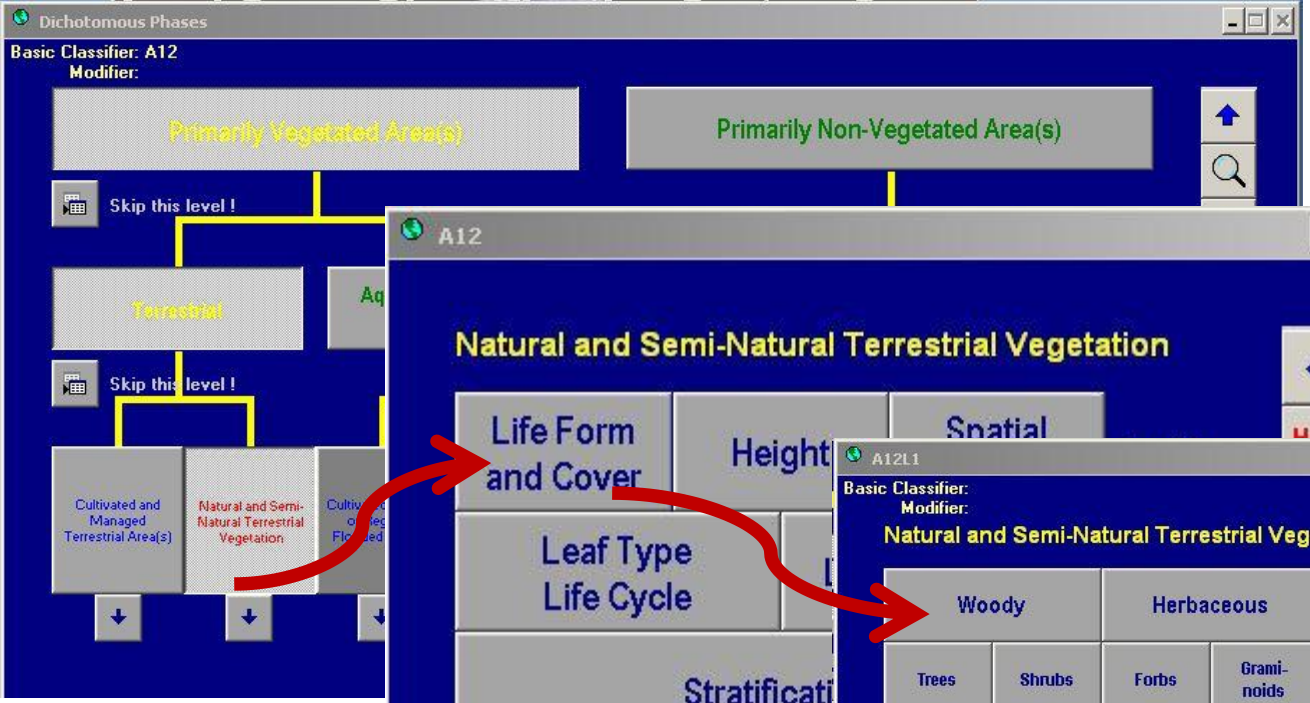
3. specific technical attributes

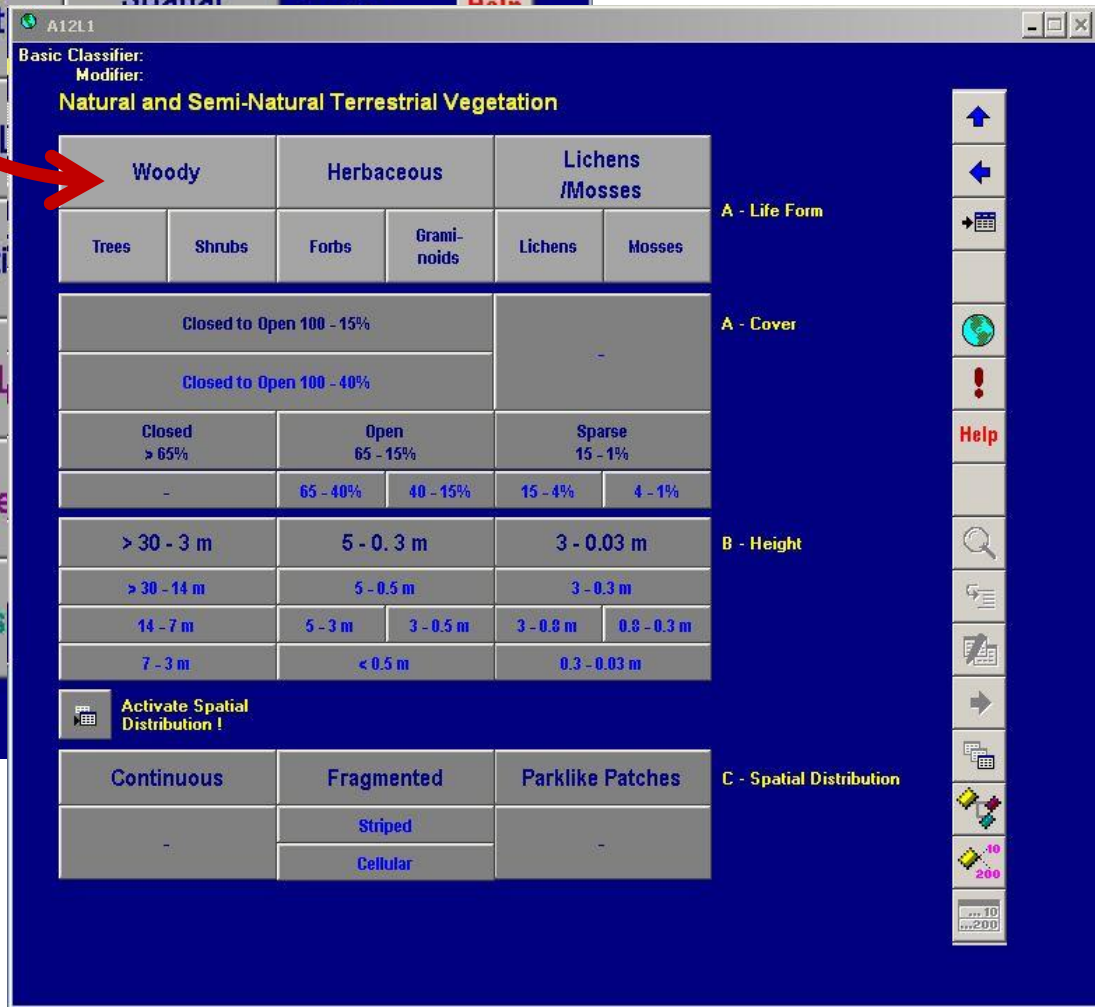


(natural / semi-natural terrestrial vegetation)

A12

http://www.africover.org/ software_down.htm





LCCS 2

http://www.fao.org/docrep/003/x0596e/X0596e02a.htm#TopOfPage

Class description

Each land cover class is described by:

- A Boolean formula, consisting of a string of classifiers used for class description,

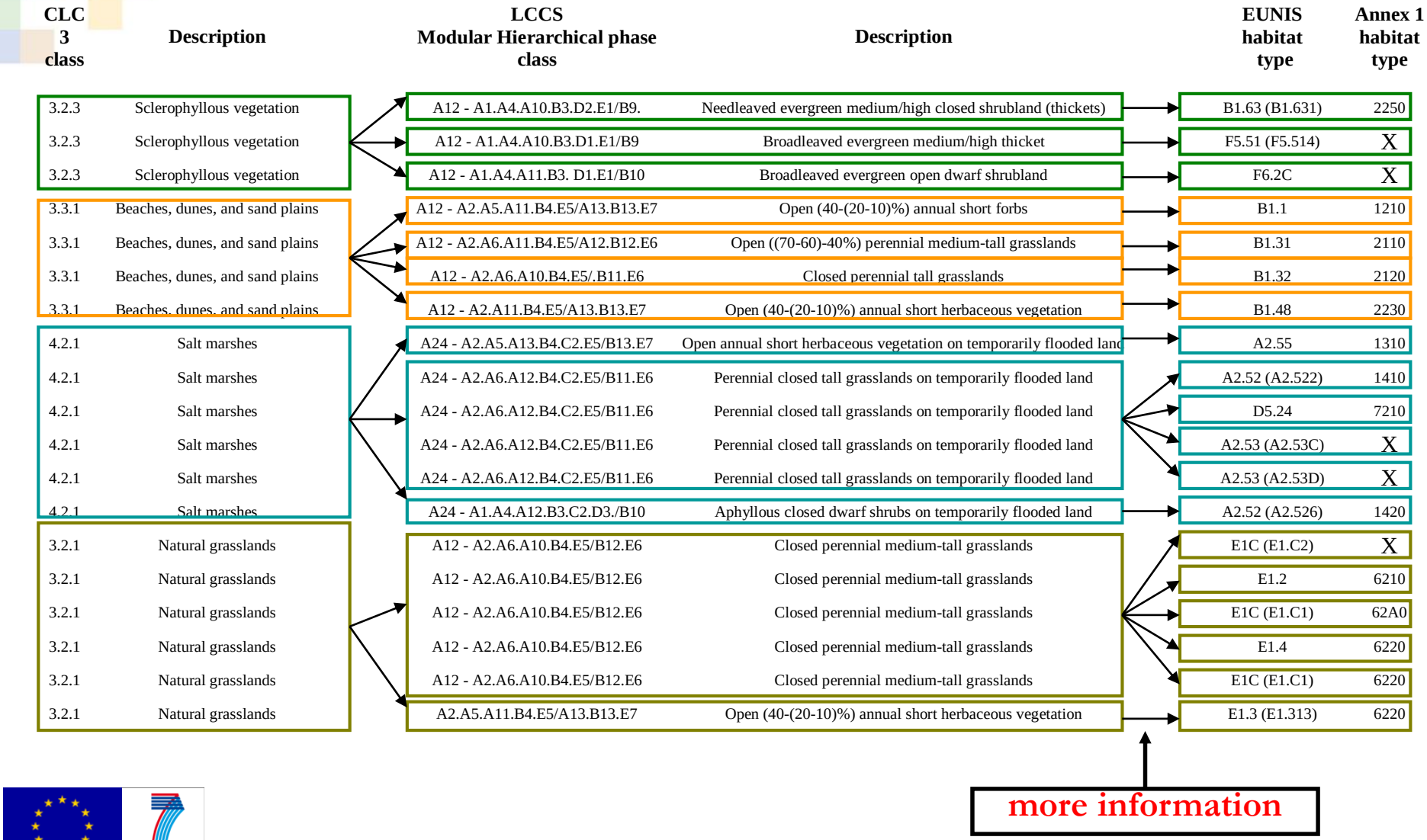
  A12/A2.A5.A11.B4-A12.B1, that is:

  - *LC type:* A12 natural terrestrial vegetated
  - *Life form:* A2 herbaceous, A5 forbs
  - *Cover: A11* open (70–60 – (20-10 %)
  - *Height: B4* tall (3-0.03m)
- The name of the land cover class “Open annual short herbaceous vegetation

Limitation for automatic LC mapping

- Phenology: perennial, annual, but **WHEN?**
- Water covererage (e.g.,temporarly flooded): but **WHEN** *(e.g., October to May?)*

One-to-one and one-to-many relations for LC to habitat mapping



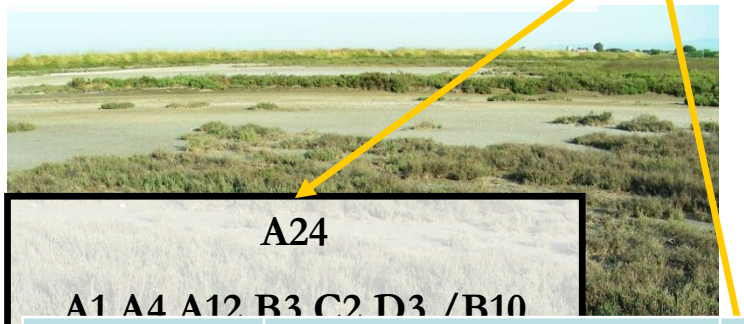
CLC3
4.2.1 - Salt marshes

FAO-LCCS2

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

ANNEX I	Lithology-Parent material	Soil sub-surface aspect	Water quality	Floristic attribute
1410	Unconsolid-Clastic sedimentary rock – Sand (M213)	Solonchaks (N12-SC)	Brakish/Saline water (R2/R3)	Juncus spp.; Carex spp
7210	Calcareous rock – Calcarenite (M233)	Histosols (N12-HS)	Fresh/Brakish water (R1/R2)	Cladium mariscus

Supercatecory	Lifeform	Field Size	Cover	Cover Modifier	Leaf Type	Phenology	Phenology Mod	Height	Height Modifier	Surface Aspect	Surface Modifier	Physical Status	Persistence	Depth	LCCS code
A11	A1	B2	NA	NA	A7	A9	NA	NA	NA	NA	NA	NA	NA	NA	A11.A1.B2_A7.A9
A12	A1	NA	A11	A12	D1	E2	NA	NA	NA	NA	NA	NA	NA	NA	A12.A1.A11.D1.E2_A12
A12	A3	NA	A11	A12	D2	E2	NA	B3	B7	NA	NA	NA	NA	NA	A12.A3.A11.B3.D2.E2_A12.B7
A12	A6	NA	A10	NA	NA	E5	E6	B4	B13	NA	NA	NA	NA	NA	A12.A6.A10.B4.E5_B13.E6
A23	A1	B4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	A23.A1.B4
A24	A1	NA	A13	A15	D1	E2	NA	NA	NA	NA	NA	NA	NA	NA	A24.A1.A13.D1.E2_A15
B16	NA	NA	NA	NA	NA	NA	NA	NA	NA	A3	A8	NA	NA	NA	B16.A3_A8
B27	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	A1	B2	C2	B27.A1.B2.C2

LCCS for changes as: class transitions and modifications

(Lucas et al. 2015)

LCCS code	LCCS description
A11.A1.B2_A7.A9	Small sized field of Broadleaved Evergreen Tree crops
A12.A1.A11.D1.E2_A12	Broad-leaved Deciduous Open (40-65%) Woody vegetation
A12.A3.A11.B3.D2.E2_A12.B7	Needle-leaved Deciduous Open (40-65%) Low Trees
A12.A6.A10.B4.E5_B13.E6	Perennial Short Closed Graminoids
A23.A1.B4	Graminoid crops
A24.A1.A13.D1.E2_A15	Broadleaved Deciduous Open (15-40%) Woody vegetation on Flooded land
B16.A3_A8	Gravel, Stones and Boulders
B27.A1.B2.C2	Turbid Shallow Artificial waterbodies

A24-A1.A4.A12.B3.C2.D3/B10

Aphyllous closed dwarf shrubs on temporarily flooded land

Class modification

A24-A1.A4.A13.B3.C2.D3/A14.B10

Aphyllous open (65-40%) dwarf shrubs on temporarily flooded land

Automatic translation: LCCS to Annex I mapping

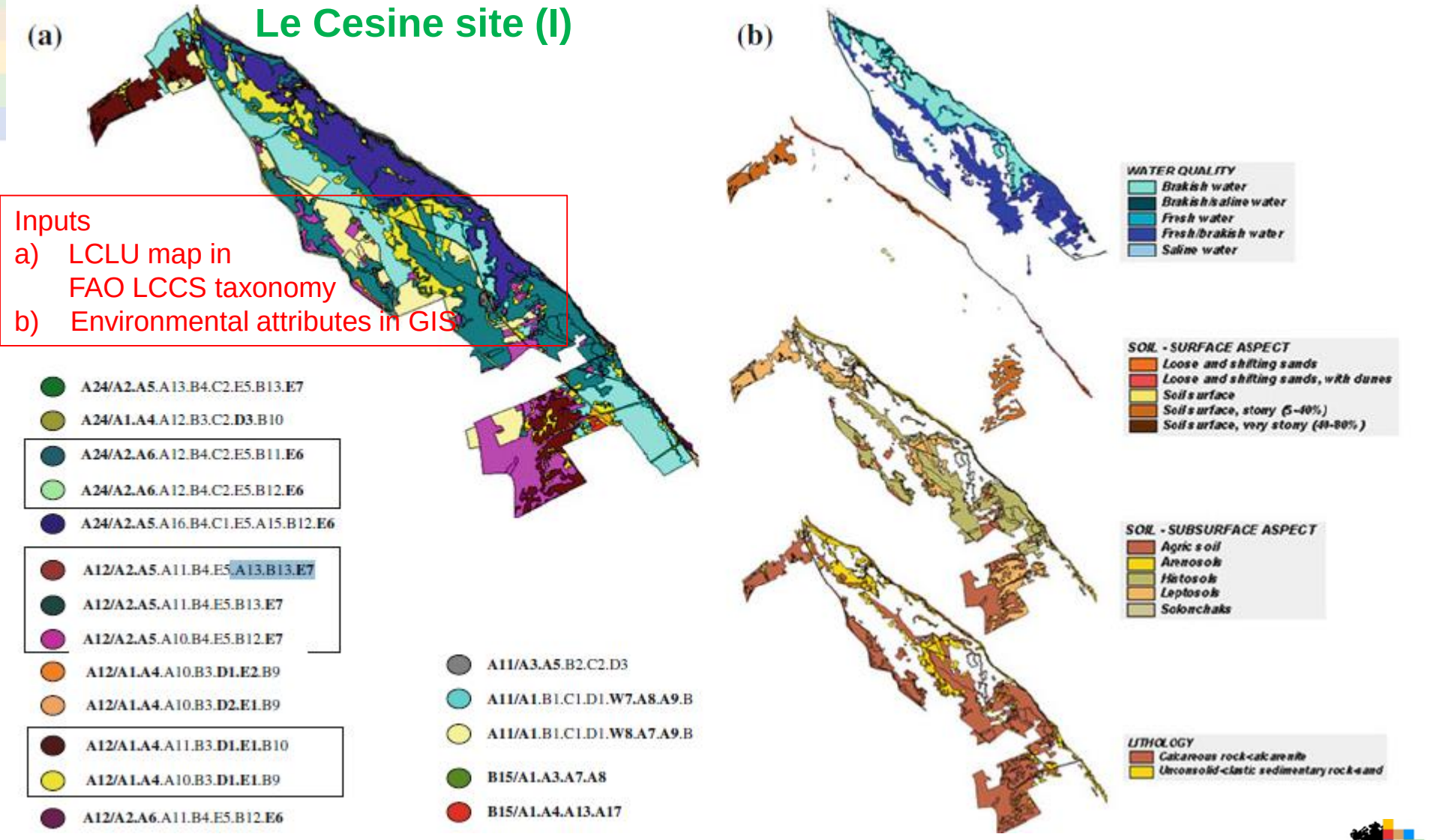
Conditions combination

CONDITION STUB (Inputs)		CONDITION ENTRIES (Y is used for TRUE Entries)																
LCCS code for inland water habitats	A24/A2.A5.E7	Y	Y															
	A24/A1.A4.D3			Y														
	A24/A2.A6.E6				Y	Y	Y	Y										
	A24/A2.A5.E6								Y									
LCCS code for other habitats	A12/A2.A5.E7									Y						Y		Y
	A12/A1.A4.D1.E2										Y							
	A12/A1.A4.D2.E1											Y						
	A12/A1.A4.D1.E1												Y	Y	Y			
	A12/A2.A6.E6																Y	
LCCS environmental attributes																		
Major landforms	Level land, Plain	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Slope classes	Flat to almost flat	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Lithology-Parent material	Calcareous rock - Calcarenite	Y				Y	Y	Y		Y	Y			Y	Y			Y
	Unconsolid- Clastic sedimentary rock - Sand		Y	Y	Y							Y	Y			Y	Y	
Soil – Subsurface Aspect	Solon chacks		Y	Y	Y		Y											
	Histosols					Y												
	Leptosols										Y		Y	Y	Y			Y
	Arenosols											Y				Y	Y	
	Acrisols									Y								
Soil – Surface Aspect	Soil surface, stony (5-40%)														Y			
	Loose and shifting sands															Y		
	Soil surface, very stony (40-80%)																	Y
	Loose and shifting sands, with dunes																Y	
Elevation	Altitude < 50m	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Water quality	Fresh water	Y						Y										
	Saline water		Y	Y														
	Brakish/Saline water				Y		Y											
	Fresh/Brakish water					Y												
	Brakish water								Y									
Climate	Subtropics – Winter rainfall	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

LCLU to habitat map translation

(Tomaselli et. al., 2013)

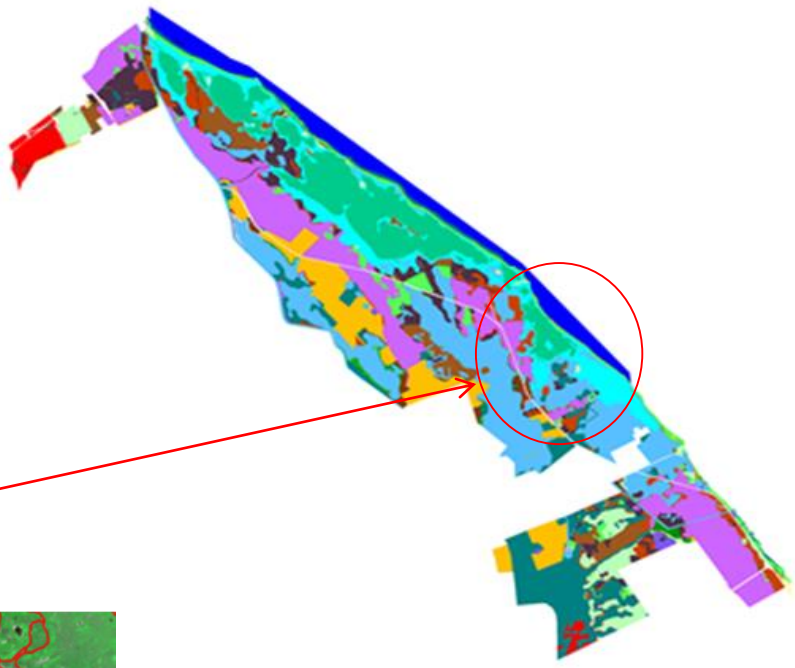
Le Cesine site (I)



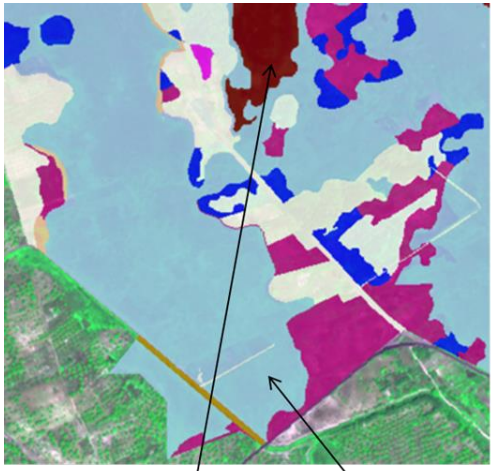
COOPERATION

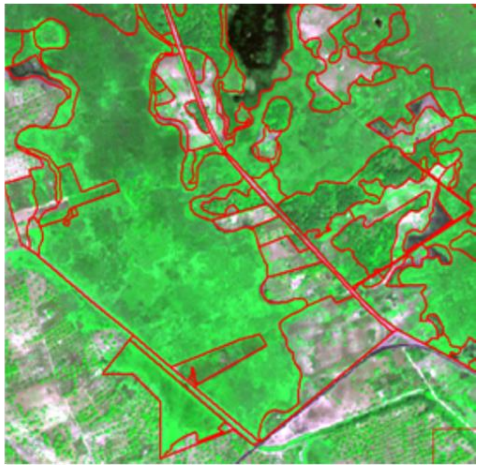
BIO_SOS

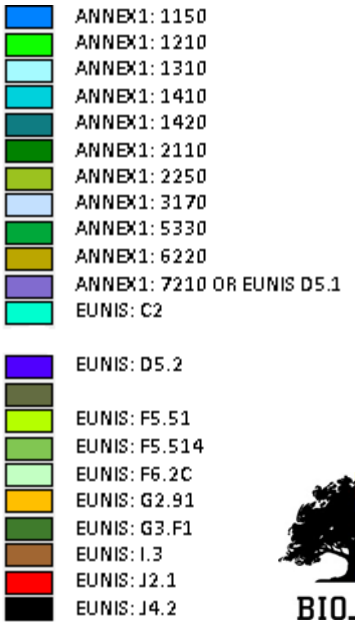
Habitat map: Annex I taxonomy, Le Cesine site (IT)



Close-up



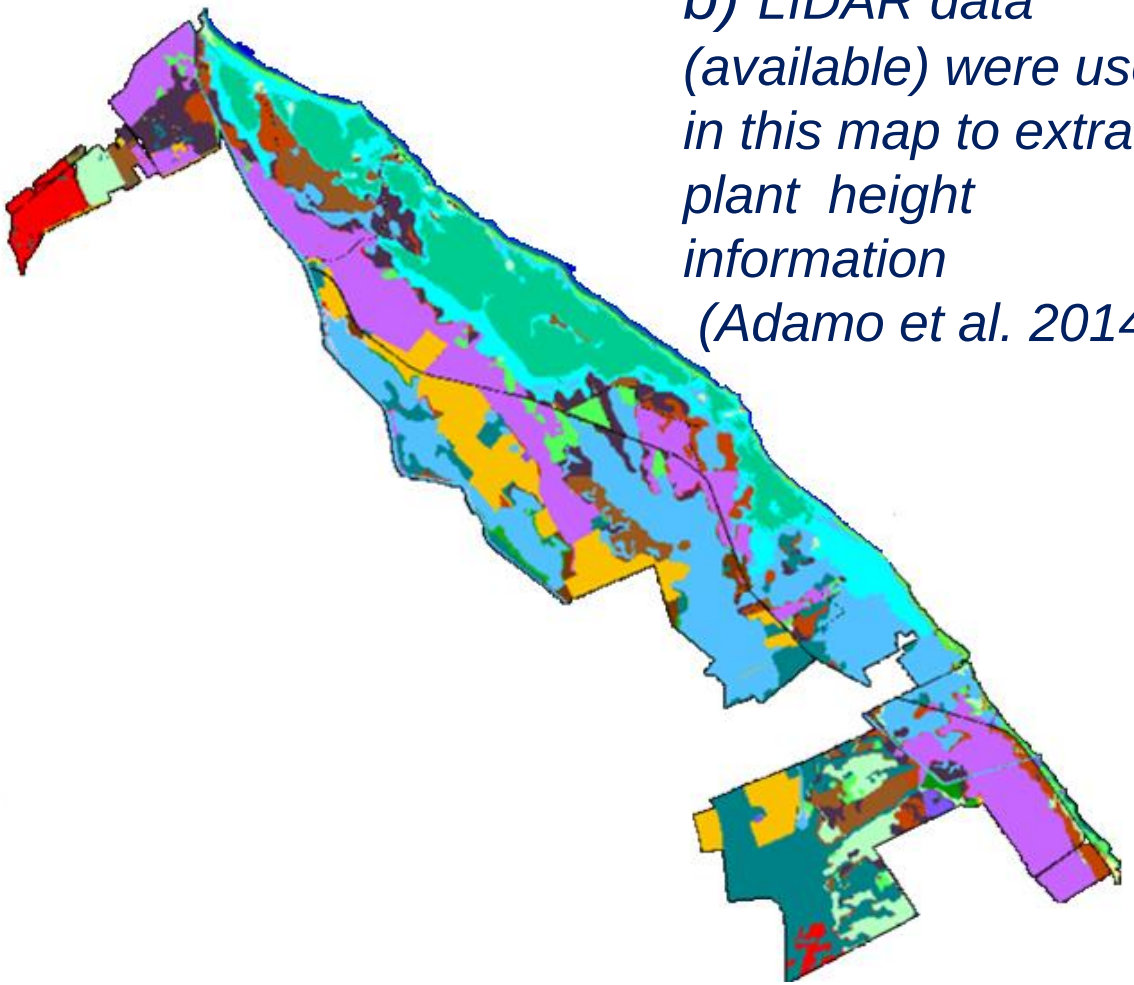




BIO_SOS

Habitat map: GHC taxonomy (Bounce et al. 2008), 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	

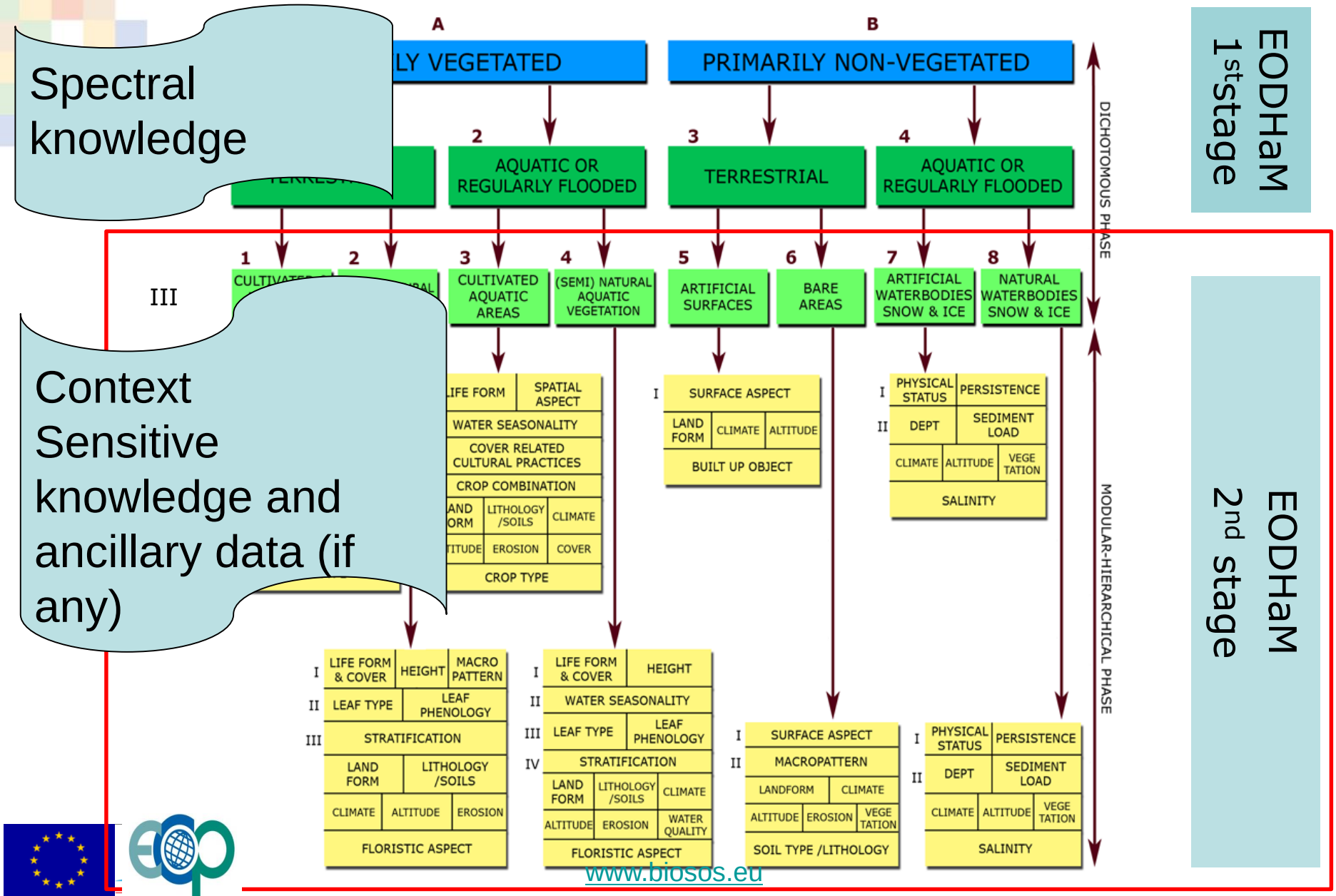


b) LIDAR data (available) were used in this map to extract plant height information (Adamo et al. 2014)

LCCS based EODHaM system (Lucas et al. 2015)

Spectral knowledge

Context Sensitive knowledge and ancillary data (if any)



Knowledge driven (deductive learning)

- Expert knowledge from remote sensing experts, botanists, ecologists, site management authorities for:
  - Image preliminary spectral segmentation (spectral knowledge);
  - Describing LCLU and habitat classes (temporal and spatial relations);
  - Translating LCLU into habitats (integration with in-situ data)

- Ontologies and semantic networks can be used for knowledge elicitation

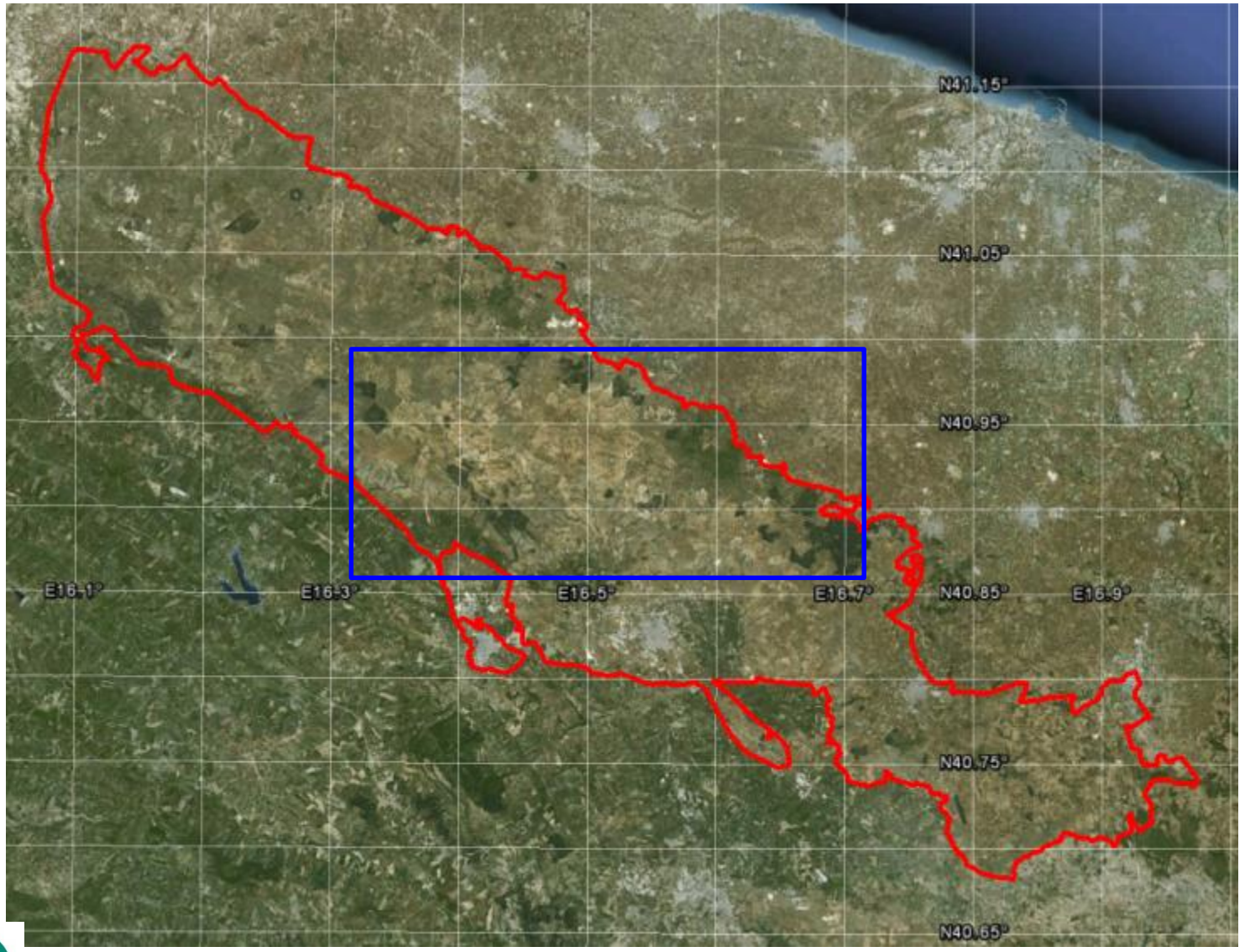
Class description is scale dependent

The methodology can be applied to any scale and image

Murgia Alta Site

Extension
≈1500 Km²

Analyzed area
≈500 Km²



LCCS Dichotomous Code	LCCS hierarchical code and class description	ANNEX I/EUNIS
	**A1.A7.A9.W8** Trees.Broadleaved.Evergreen.Orchards	X/G2.91
	A1.A7.A10.W8 Trees.Broadleaved.Deciduous.Orchards	X/G1.D4
	**A2.A7.A10.W8** Shrubs.Broadleaved.Deciduous.Orchards	X/FB.4
	**A3** Herbaceous	X/I1.3
	**A1.A3.D2.E1** Woody.Trees.Needleleaved.Evergreen	X/G3.F1
	A1.A3.A10.**D1.E2.**B7 Woody.Trees.Closed.Broadleaved.Deciduous.3-7m	91AA/G1.73
	A1.A4.A10.**D1.E2.**B9 Woody.Shrubs.Closed.Broadleaved.Deciduous.0.5-3m	X/F5.51
	**A1.A4.**A10.**D1.E1.**B9 Woody.Shrubs.Closed.Broadleaved.Evergreen.0.5-3m	X/F5.11
	A2.A6.A10.B12 Herbaceous.Graminoids.Closed.0.8-0.3m	62A0/E1.55 6220/E1.3
	A1.A5 Water.Standing	

Expert Knowledge Elicitation

LCCS/DIC	LCCS/HIER	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGO	SEP	OCT	NOV	DEC
A11 Cultivated and managed terrestrial areas	**A3.A4** Herbaceous.Graminoids												
	A3 Herbaceous												
	A2.A7.A10.W8 Shrubs.Broadleaved.Deciduous.Orchards												
	A1.A7.A10.W8 Trees.Broadleaved.Deciduous.Orchards												
	A1.A7.A9.W8 Trees.Broadleaved.Evergreen.Orchards												
A12 Natural terrestrial vegetation	**A2.A10.B12.E6** Herbaceous.Closed.0.8-0.3m.Perennial												
	A1.A3.A10.D1.E2.B7 Woody.Trees.Closed.Broadleaved.Deciduous.3-7m												
	A1.A4.A10.D1.E2.B9 Woody.Shrubs.Closed.Broadleaved.Deciduous.0.5-3m												
	A1.A3.D2.E1 Trees.Needleleaved.Evergreen.Plantations												
	A1.A4.A10.D1.E1.B9 Woody.Shrubs.Closed.Broadleaved.Evergreen.0.5-3m												

Phenology

	Dense vegetation and/or peak of biomass
	Sparse (youg) vegetation or minor green biomass
	Minor biomass with withered/dry plants (or part of plants)
	Bare soil with remnants of wuthered/dry plants

Agricultural Practices

	Ploughing
	Harvesting/Mowing

LCCS/DIC	LCCS/HIER	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGO	SEP	OCT	NOV	DEC
A11 Cultivated and managed terrestrial areas	**A3.A4** Herbaceous.Graminoids												
	A3 Herbaceous												
	A2.A7.A10.W8 Shrubs.Broadleaved.Deciduous.Orchards												
	A1.A7.A10.W8 Trees.Broadleaved.Deciduous.Orchards												
	A1.A7.A9.W8 Trees.Broadleaved.Evergreen.Orchards												

Images Dataset

Peak of Biomass
(April-May)
PoB

Post peak
(October)
PostPoB

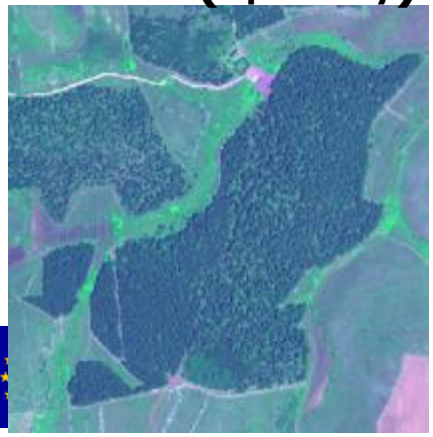
Pre Peak
(January)
PrePoB

Dry Season
(July)
DS

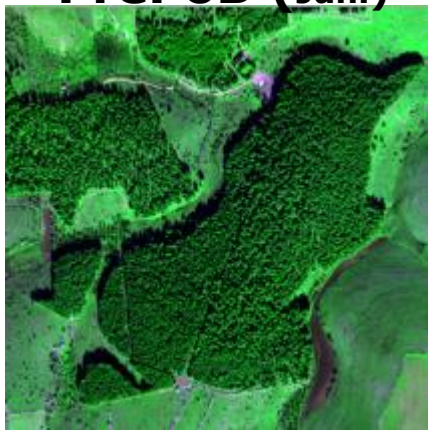
LCCS Level 1

Level 1 Temporary Classes	Spectral Rules	Logical Operators	LCCS Level 1 Final Classes
Urban	NDVI_PoB < 0.2 WBI_PoB ≥ 1. Brightness_PoB ≥ 0.15	AND	Non-Vegetated (**B**)
Barren Land	NDVI_PoB < 0.2 NDVI_PrePoB < 0.2 NDVI_PostPoB < 0.2 NDVI_DS < 0.2	AND	
Photosynthetic Vegetation	NDVI_PoB ≥ 0.2 NDVI_PrePoB ≥ 0.2 NDVI_PostPoB ≥ 0.2 NDVI_DS ≥ 0.2	OR	Vegetated (**A**)
Shadowed Vegetation	Photosynthetic Vegetation = TRUE WBI_PrePoB ≥ 1.15 WBI_PoB < 1. WBI_DS < 1.	AND	

PoB (April-May)



PrePoB (Jan.)



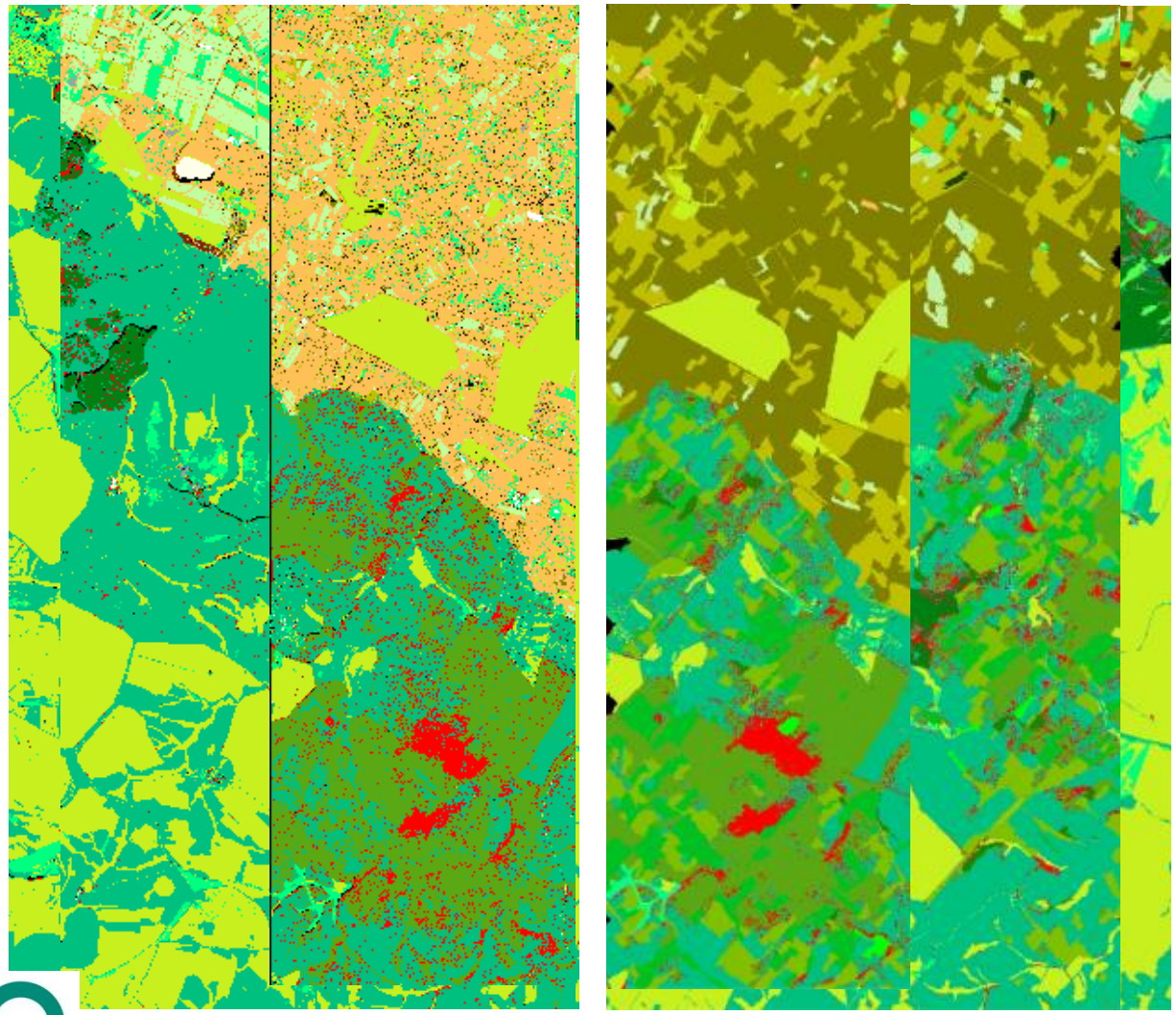
PostPoB (Oct.)

Ds (August)

SO vs LO LCCS Level 4

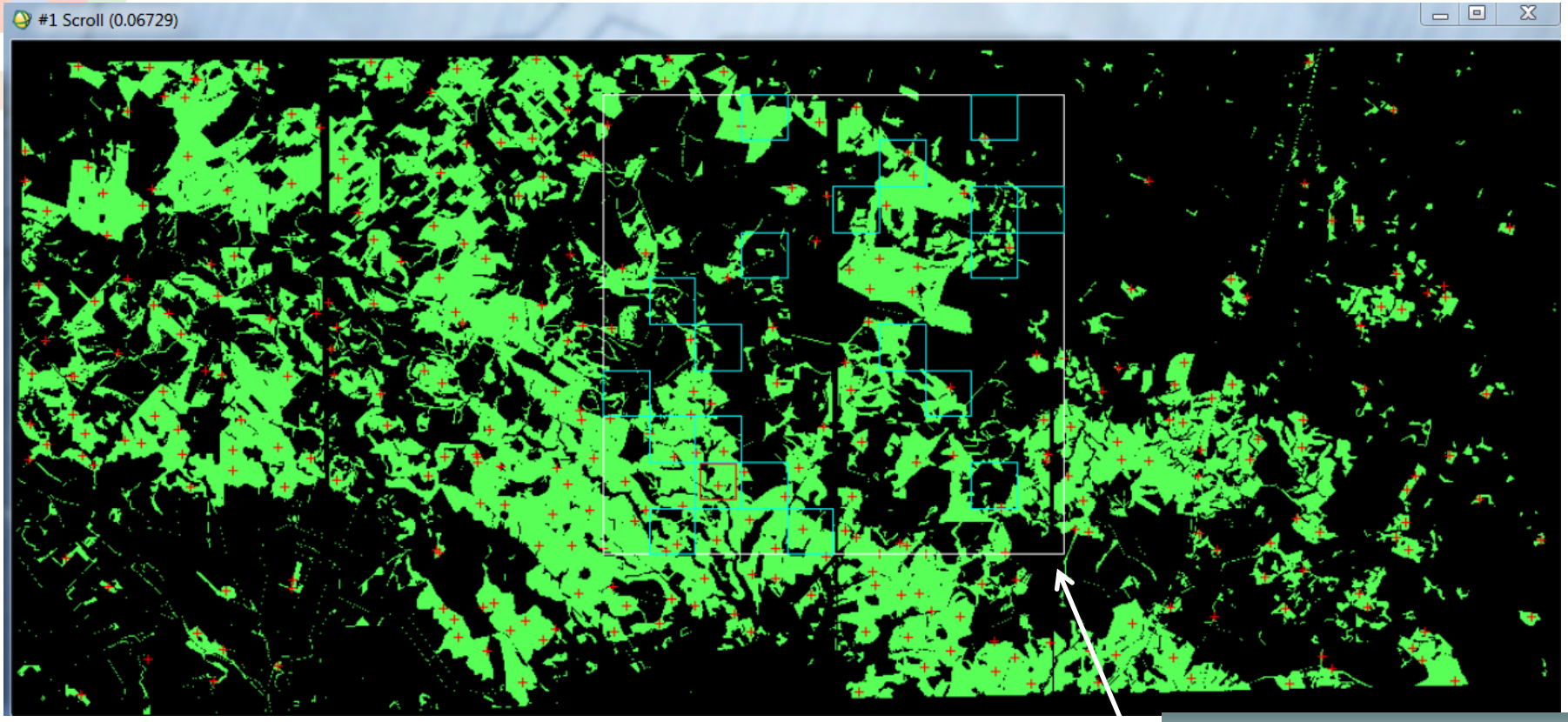
SO

LO



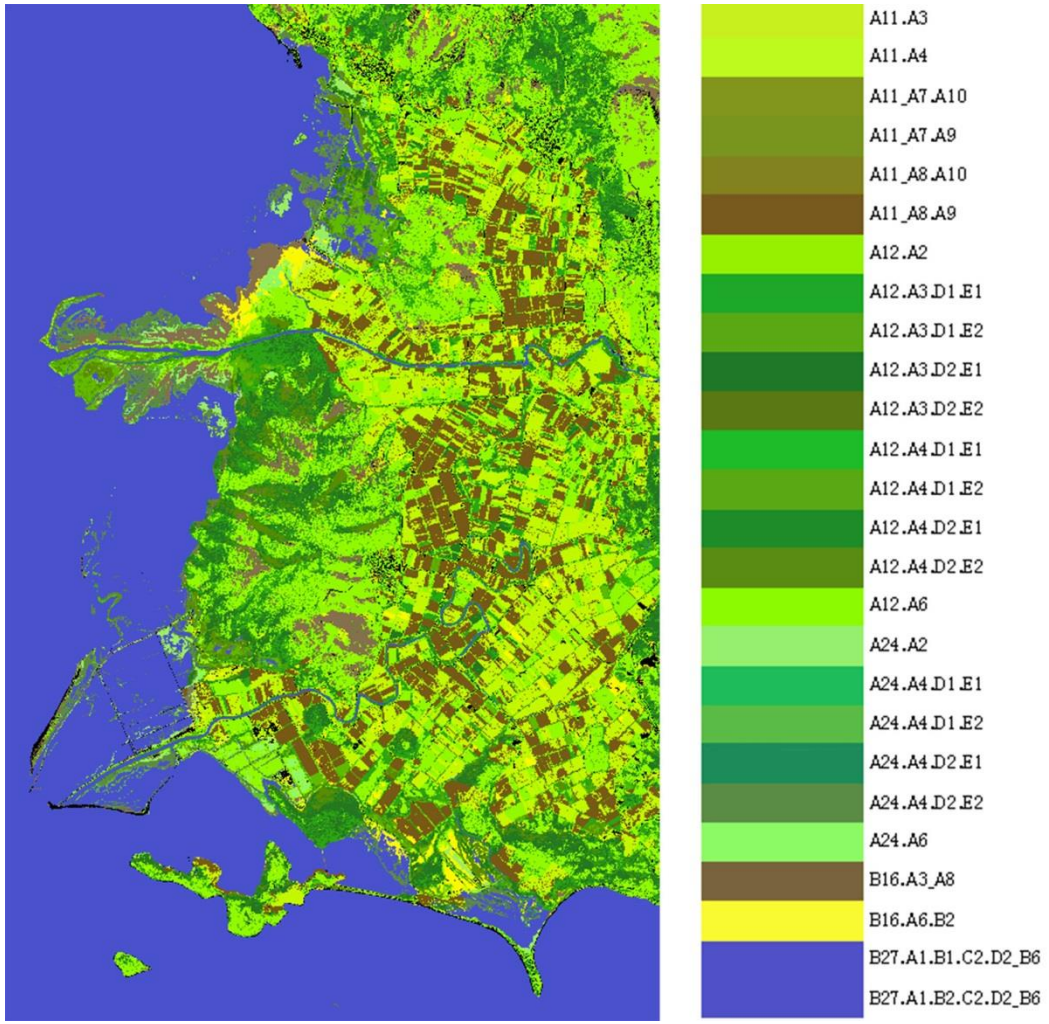
Study site in Italy: grasslands ecosystem

about 33km*15km (485 kmq) Murgia Alta(I)



350 total reference sample selected by stratified random sampling on the whole layer (strata) are overlaid as red cross

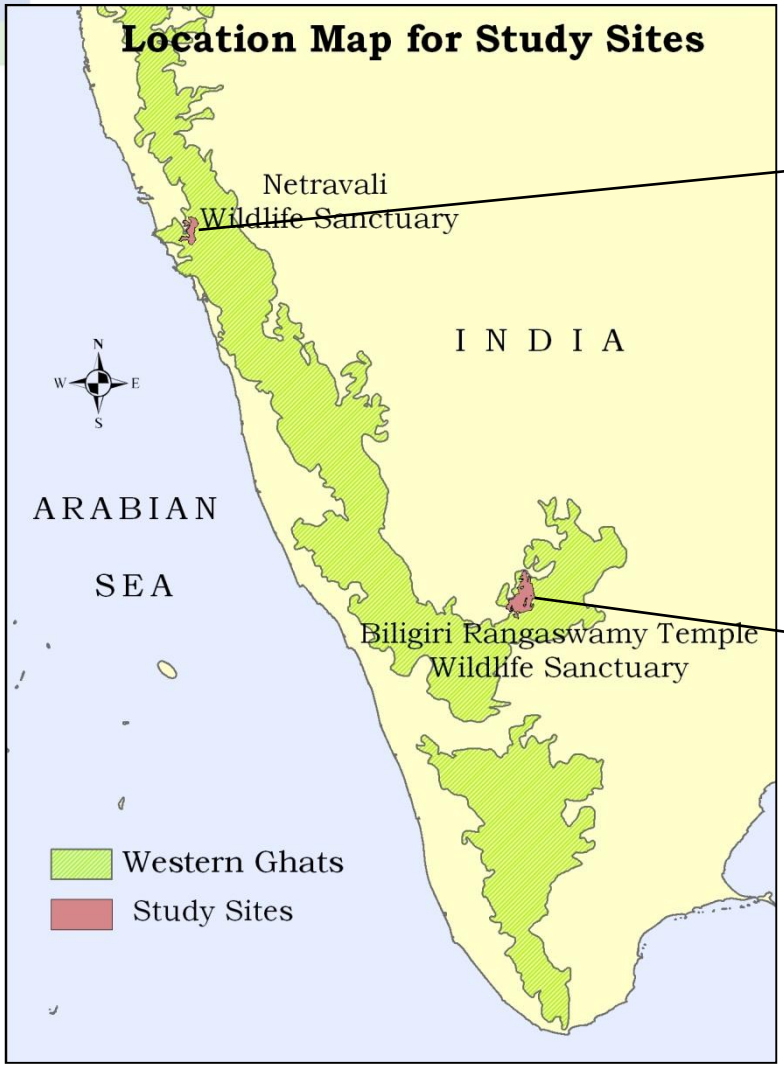
Study site in Greece: LC map

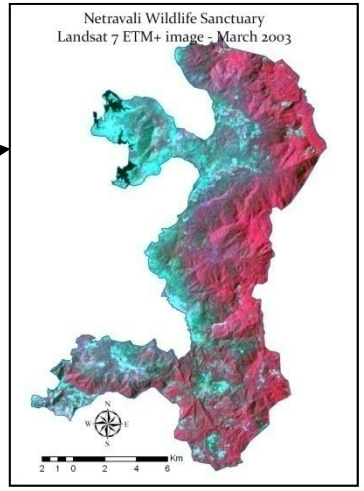


COOPERATION

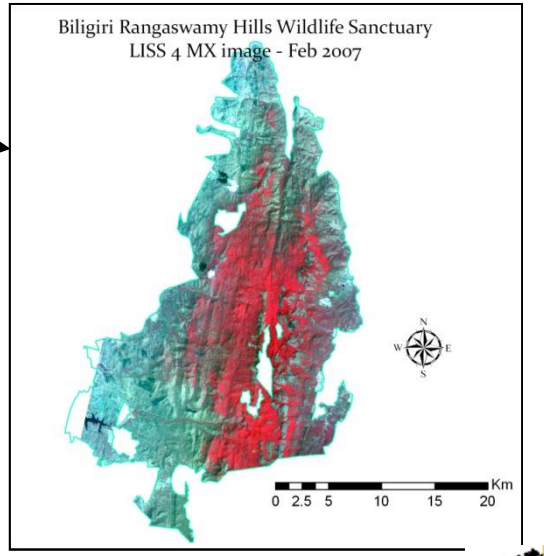
BIO_SOS

Study Sites in India: location





IN2

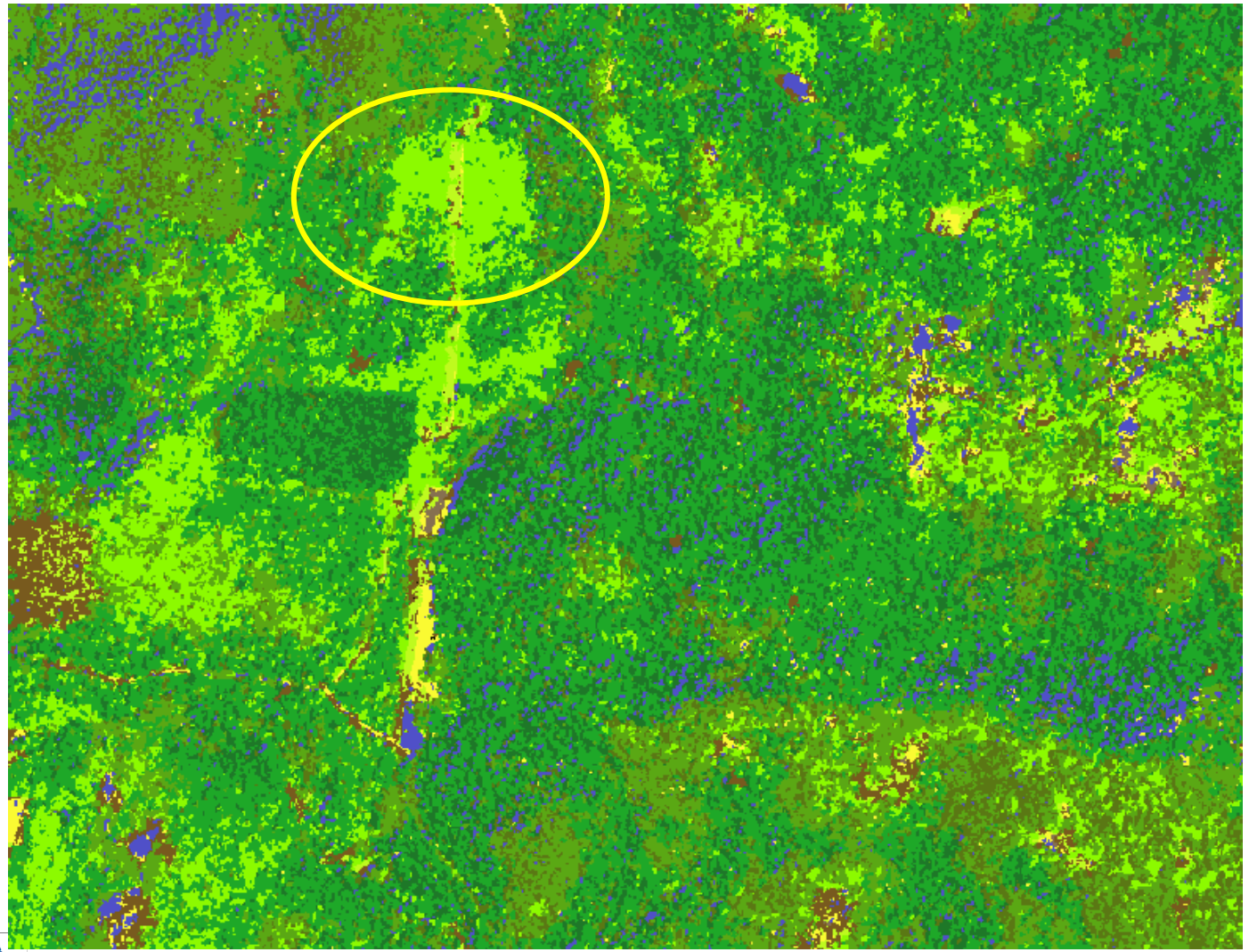


IN1

BIO_SOS

Study Sites in India: LC map

Invasive species identification



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

Gaps in EO and in-situ

for biodiversity and ecosystem monitoring

"The evolution of ecosystems properties over time can be described using simple math. response functions and the better these functions can be described, the grater insight ecologists can draw about ES dynamics"

(Kennedy at al., 2014; Front Ecol. Env. 12 (6))

Actually mainly abrupt changes of state can be detected at VHR:
as step functions

(e.g. FAO-LCCS).

An updated CORINE map will be provided this/next year:

could we solicit the collection of in-situ validation data according to other most used taxonomies for facilitating

taxonomy translations?

Recommendations

- To regularly acquire **multiple-resolution data on** Protected Areas (in Europe: the Natura 2000 sites) as *ecological focus* areas for evaluating differences in ecosystem management.

- Harmonize not only data (e.g., Landsat 8 and Sentinel 2 with VHR (super-resolution?)) but also initiative / projects

- Let focus on:
  - the assimilation of HR to VHR EO data and derived products in ecological modelling at habitat and landscape level.
  - training of land managers in the use and interpretation of EO derived products.

- Collecting ***in-situ*** data based on modelling expertise (e.g., for LCLU to habitats and ecosystem conversion).

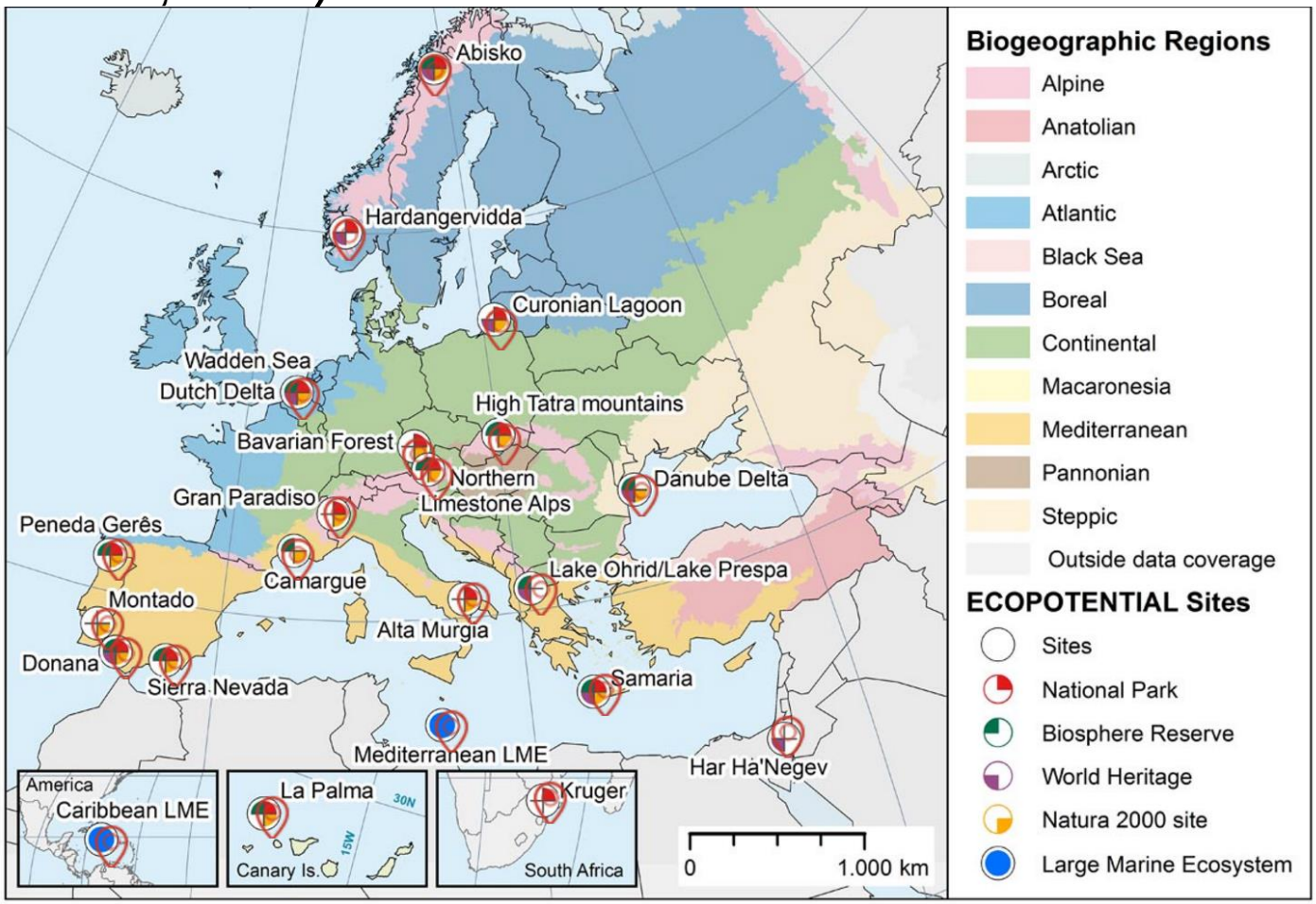
ECOPOTENTIAL: future work

- Explore FAO-LCCS3 or Land Cover Meta Language (LCML)
- Mapping and Assessment of Ecosystems and their Services (MAES et al. 2013; 2014):
  - *how to ma*
    based on t

Wales (UK),
Wadden Sea (

- EAGLE

- Comparison
  HORIZON2C



References

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- Kosmidou, V., Petrou, Z., Bunce, R.G.H., Mücher, C.A., Jongman, R.G.H., Bogers, M.M.B., Lucas, R.M., Tomaselli, V., Blonda, P., Padoa-Schioppa, E., Manakos, I., Petrou, M. (2014). Harmonization of the Land Cover Classification System (LCCS) with the General Habitat Categories (GHC) classification system: linkage between remote sensing and ecology. *Ecological Indicators*. **36**, 290-300. DOI 10.1016/j.ecolind.2013.07.025.

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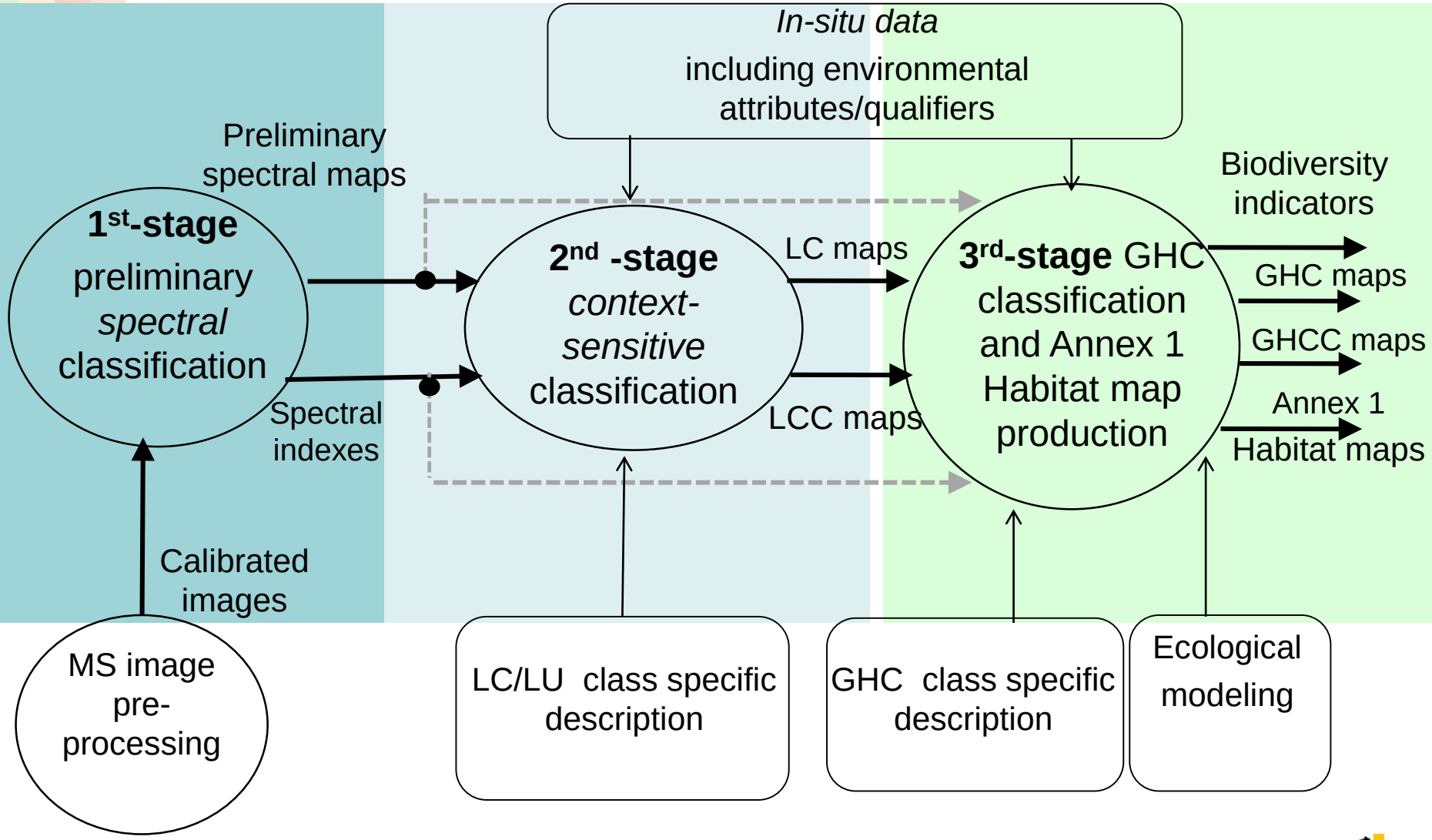
EODHaM pre-operational system



Temporal information (phenology)

from experts, so far,…from Sentinel2

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

BIO_SOS

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

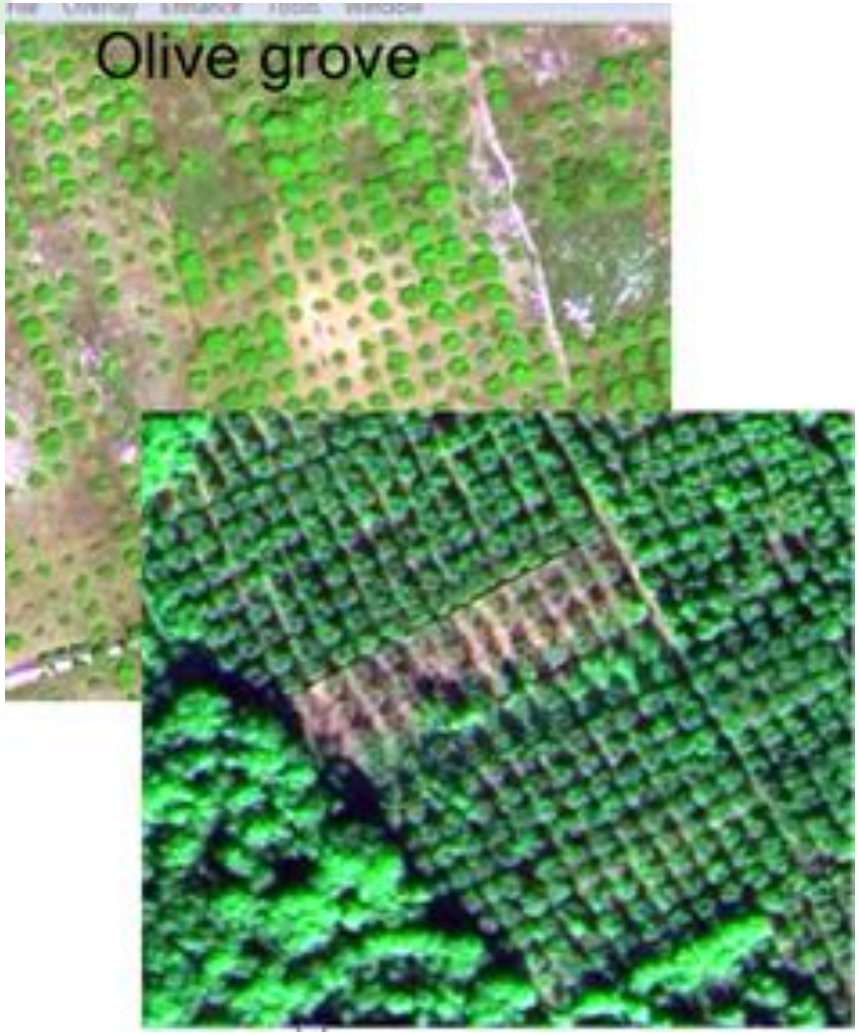
Ekvoles Kalama site, Greece

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

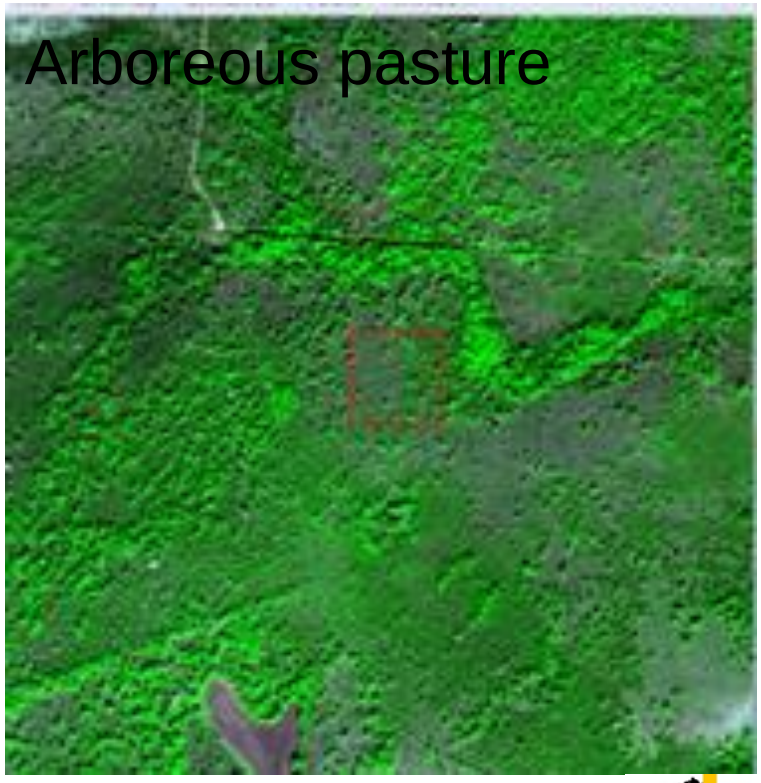
- Additional areas are being considered in Brazil and India

Core: olive trees
Context: soil and grassland

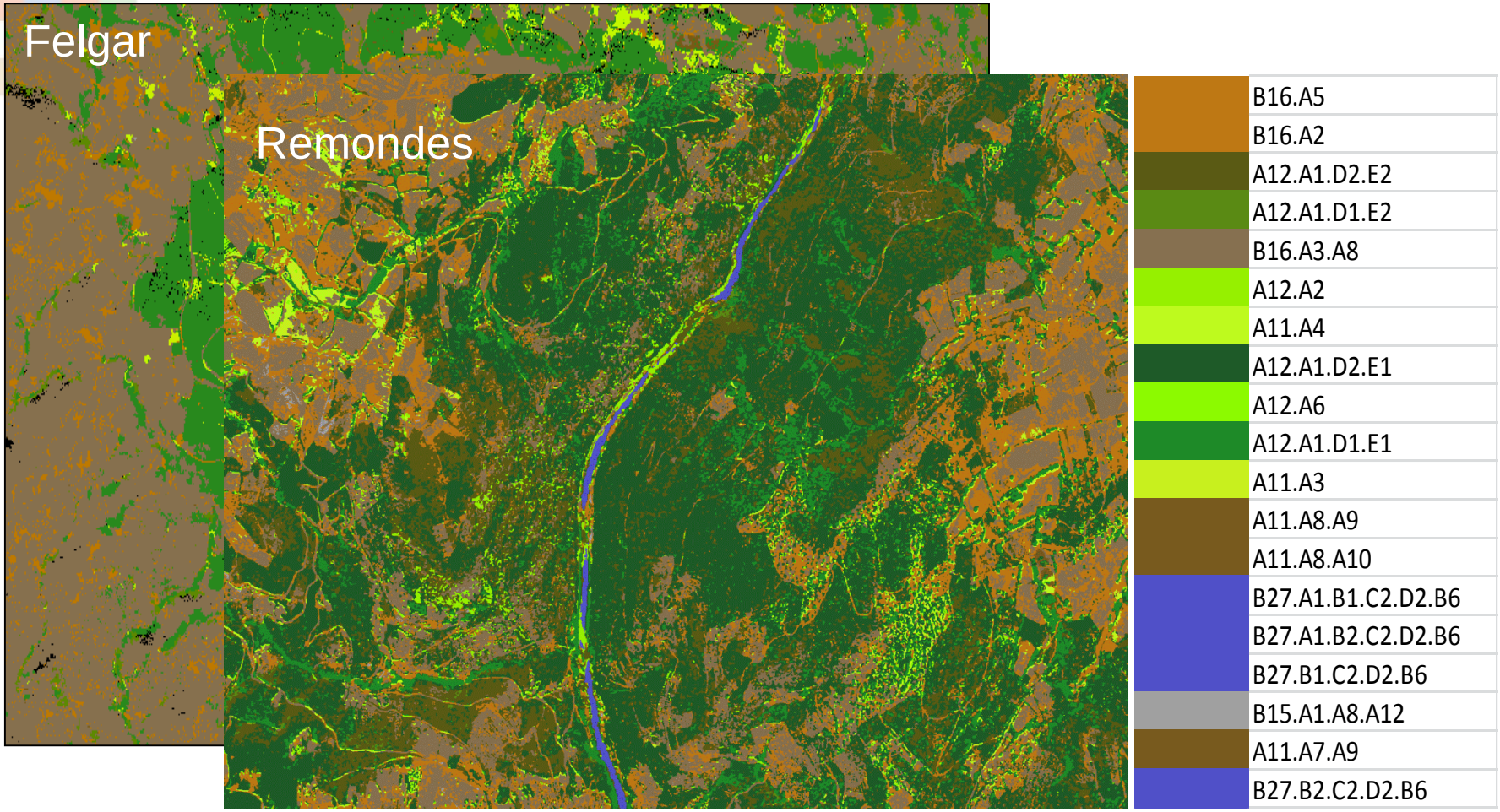


Class description is *scale dependent*

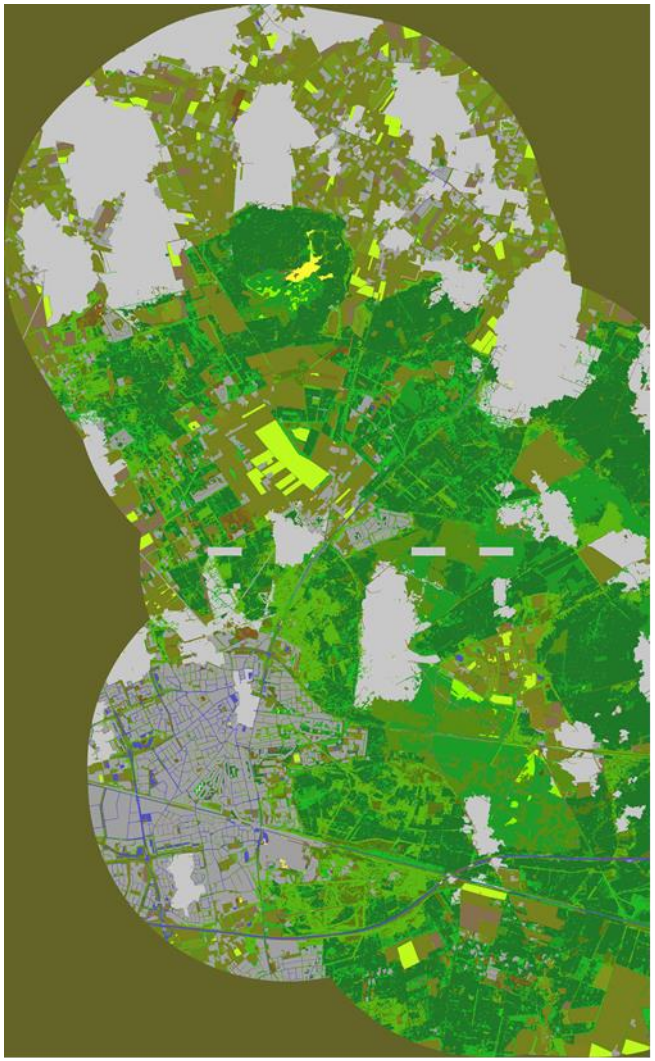
Core: deciduous trees
Context: soil and grassland



Study site in Portugal: LCLU map



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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