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GOBIERNO de CANTABRIA

Remote sensing-based spatial modelling for Natura 2000 monitoring at large scale

Teledetección y cartografía de hábitats en Cantabria

J.M. Álvarez-Martínez, *M. Recio, A. Silió-Calzada, C. Galván, B. Ondiviela, J. Barquín and J. Juanes*

GOBIERNO DE ESPAÑA
MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA

II SEMINARIO CARTOGRAFIA DE LOS HABITATS ESPAÑOLES

IEPNB
Inventario Español del Patrimonio Natural y de la Biodiversidad

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RED NATURA 2000

*Espacios, Hábitats y Especies en la **RED NATURA 2000** en Cantabria*

- Río Asón
- Río Agüera
- Río y Embalse del Ebro
- Río Camesa
- Río Miera
- Río Saja

ZEC LITORALES

- Rías Occidentales y Duna de Oyambre
- Dunas de Liencres y Estuario del Pas
- Dunas del Puntal y Estuario del Miera
- Costa Central y Ría de Ajo
- Marismas de Santoña, Victoria y Joyel

ZEC DE MONTAÑA

- Cueva de la Rogería
- Cueva del Rejo
- El Escudo y Cabuérniga
- Liébana

http://rednatura2000cantabria.ihcantabria.com/

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CONSEJERÍA DE GANADERÍA, PESCA Y DESARROLLO RURAL

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CONVENIO DE ENCOMIENDA DE GESTIÓN REALIZADA POR EL GOBIERNO DE CANTABRIA (CONSEJERÍA DE GANADERÍA, PESCA Y DESARROLLO RURAL) A LA FUNDACIÓN INSTITUTO DE HIDRÁULICA AMBIENTAL DE CANTABRIA PARA LA REALIZACIÓN DE ESTUDIOS ESPECIFICOS PARA LA REDACCIÓN DE LOS PLANES DE GESTIÓN DE LOS ESPACIOS DE LA RED NATURA 2000 EN CANTABRIA.

En Santander, a 5 de diciembre de 2014.

REUNIDOS

De una parte, la Señora Doña Blanca Azucena MARTÍNEZ GÓMEZ, Consejera de Ganadería, Pesca y Desarrollo Rural del Gobierno de Cantabria, facultada para este acto por acuerdo del Consejo de Gobierno de fecha 4 de diciembre de 2014, conforme a lo dispuesto en el artículo 33 k) de la Ley de Cantabria 6/2002, de 10 de diciembre, de régimen jurídico del Gobierno y de la Administración de la Comunidad Autónoma de Cantabria.

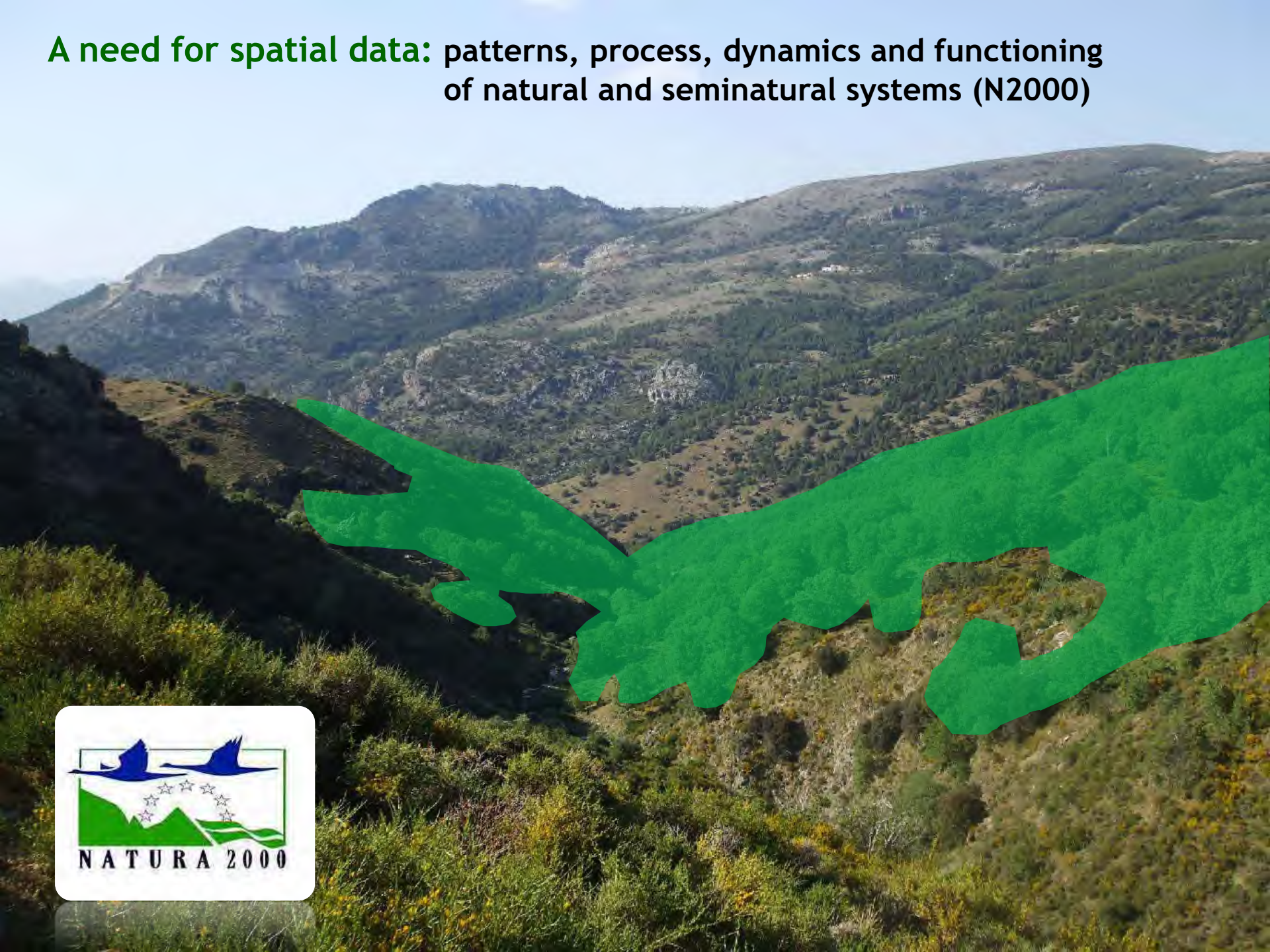
De otra parte, el Excmo. y Magfco. Señor Don José Carlos GÓMEZ SAL en nombre y representación, por su condición de Presidente, de la Fundación INSTITUTO DE HIDRÁULICA AMBIENTAL DE CANTABRIA (en adelante FIHAC), con CIF n.º G-39655170 y domicilio en Santander, en el Parque Científico Tecnológico de Cantabria, Calle Isabel Torres, 15, CP 39011, facultado para la celebración de este acto en virtud de lo establecido en el artículo 17 de los Estatutos de la Fundación.

Ambas partes se reconocen la capacidad legal necesaria para formalizar el presente convenio de encomienda de gestión y, en consecuencia,

EXPONEN

1.- La Fundación Instituto de Hidráulica Ambiental de Cantabria es una organización de naturaleza fundacional, sin fin de lucro, que tiene entre sus fines el profundizar en el conocimiento del ciclo del agua y de los sistemas asociados, ampliando las fronteras del estado del arte de las ciencias y tecnologías relacionadas, el trasladar a la sociedad y convertir en beneficios sociales concretos los logros obtenidos en el estudio del ciclo del agua y los sistemas asociados mediante el establecimiento de vías sólidas de transferencia del conocimiento, metodologías y herramientas a administraciones públicas y empresas nacionales e internacionales, el fomentar y propiciar las actividades de I+D+i en las empresas y organismos españoles y extranjeros, tanto públicos como privados, de sectores que tengan relación con los sistemas naturales del ciclo del agua o en la conservación de la biodiversidad,

A need for spatial data: patterns, process, dynamics and functioning of natural and seminatural systems (N2000)



A need for spatial data: patterns, process, dynamics and functioning of natural and seminatural systems (N2000)

SPATIAL DATASETS

CORINE Land Cover

https://land.copernicus.eu/user-corner/technical-library/upcoming-product-clc

Land Monitoring

Towards CLC+

Conceptual design and product outlines

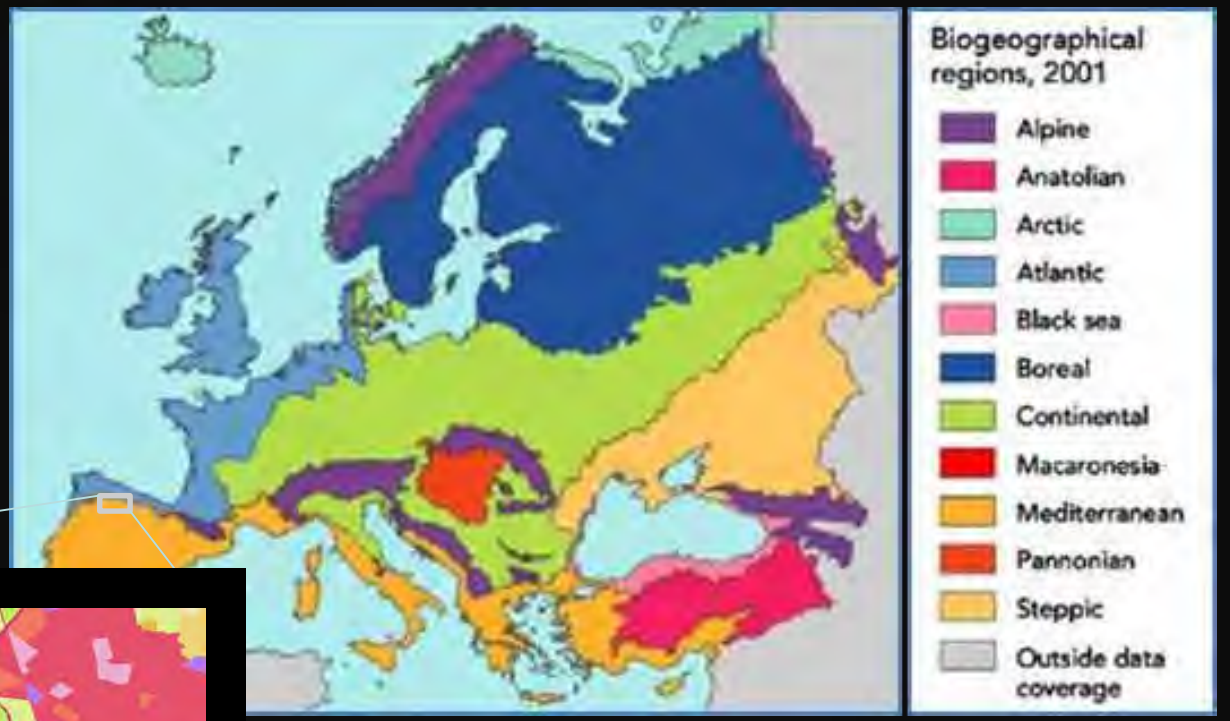
Geoff Smith
EIONET Action Group EAGLE Land Monitoring in Europe

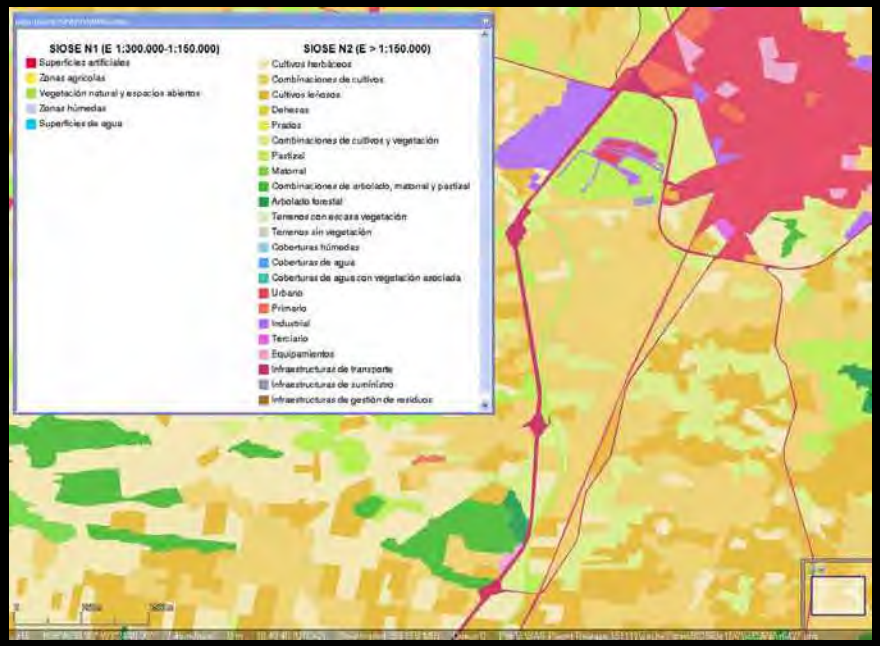
Copernicus | European Commission | European Environment Agency

LAND COVER MAPPING

Traditional inventory

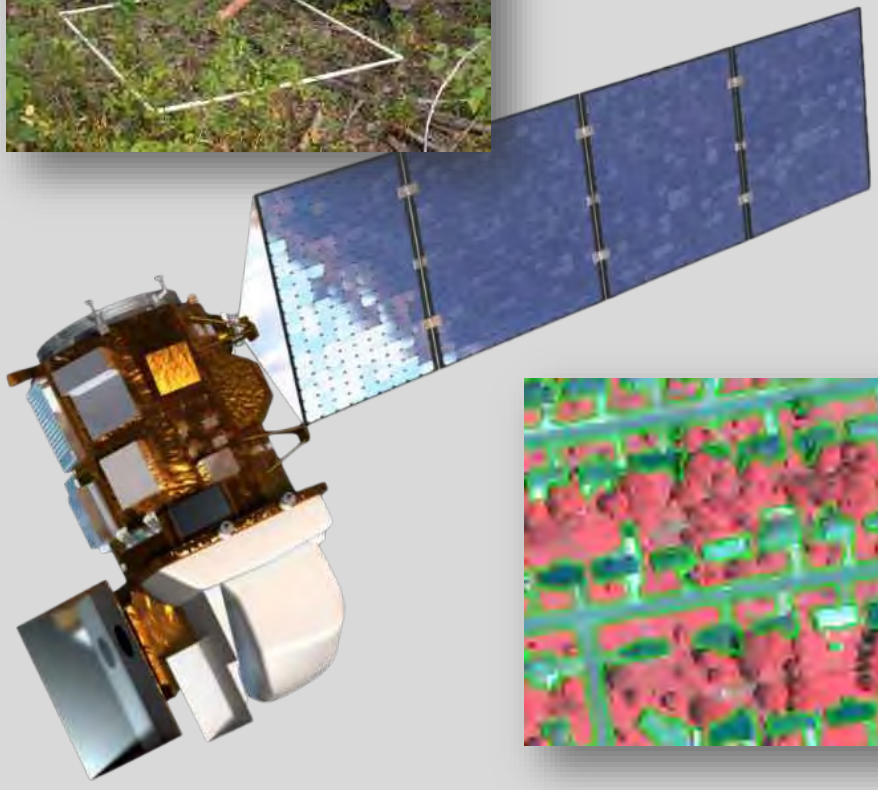
- Lack of spatial data
- Need for trained surveiers
- Mixed patches





- Scale and typology not valid…
- High cost (time, people)
- Difficult to update (no temporal resolution)

Remote sensing-based spatial modelling



A **cost-effective solution** for large scale mapping based on optimal **field surveys** (adaptive sampling), **remote sensing** and **habitat and species modelling**

5-metrs resolution PNOA

ENHANCING MONITORING

opernicus
Europe's eyes on Earth

Land Monitoring Service

Global | Pan-European | Local | Imagery and reference data

SWOT ANALYSIS

We have to get information in a quick, effective, homogeneous and dynamic manner

Cost-effective solution for large scale mapping

Álvarez-Martínez et al, 2017

Methods in Ecology and Evolution

HABITAT MAPPING

We do not end up with available tools (year 2017 and so on) and outputs…

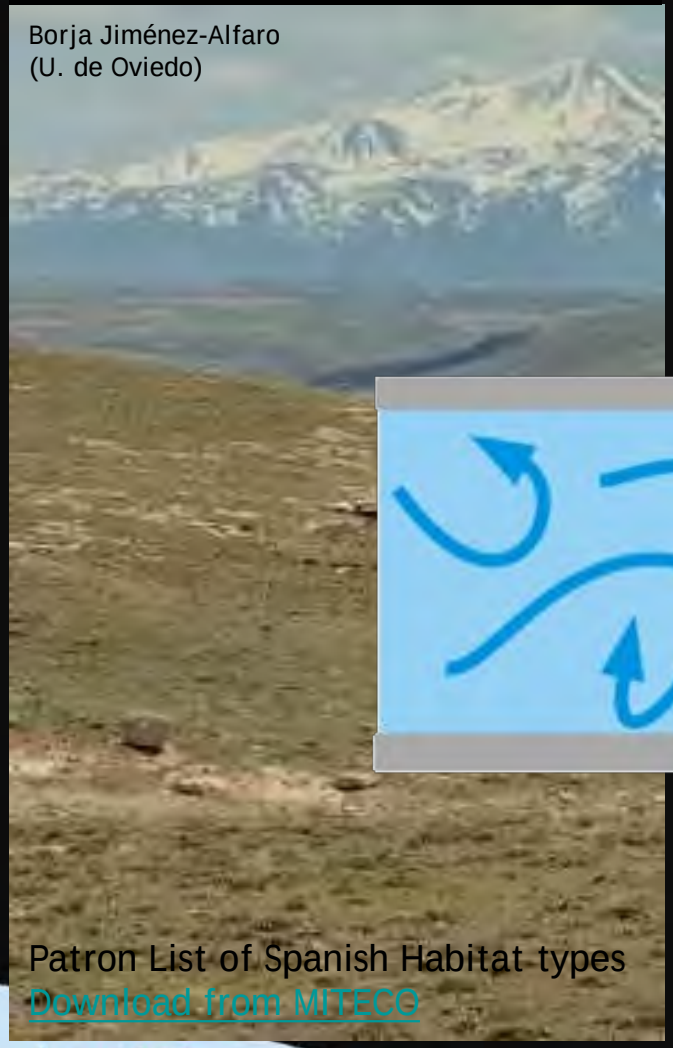
1] CLASSIFICATION TYPOLOGY Land use-land cover (LULC) ***Vegetation*** types	**2] OCCURRENCE DATA** ***Ground data*** and ***maps*** for: Training & Validation Conservation status
3] PREDICTOR LAYERS Environmental limiting factors ***Remote sensing***: resolution	**4] MODELLING PROCEDURE** ***Technique***: sensitivity analyses Data mining tolos and AI ***Purpose***: mapping, monitoring…

New modelling tools and remote sensing for vegetation mapping:

what actually matters?

1] CLASSIFICATION SYSTEM

EUNIS 2-6 level habitat types



Borja Jiménez-Alfaro
(U. de Oviedo)

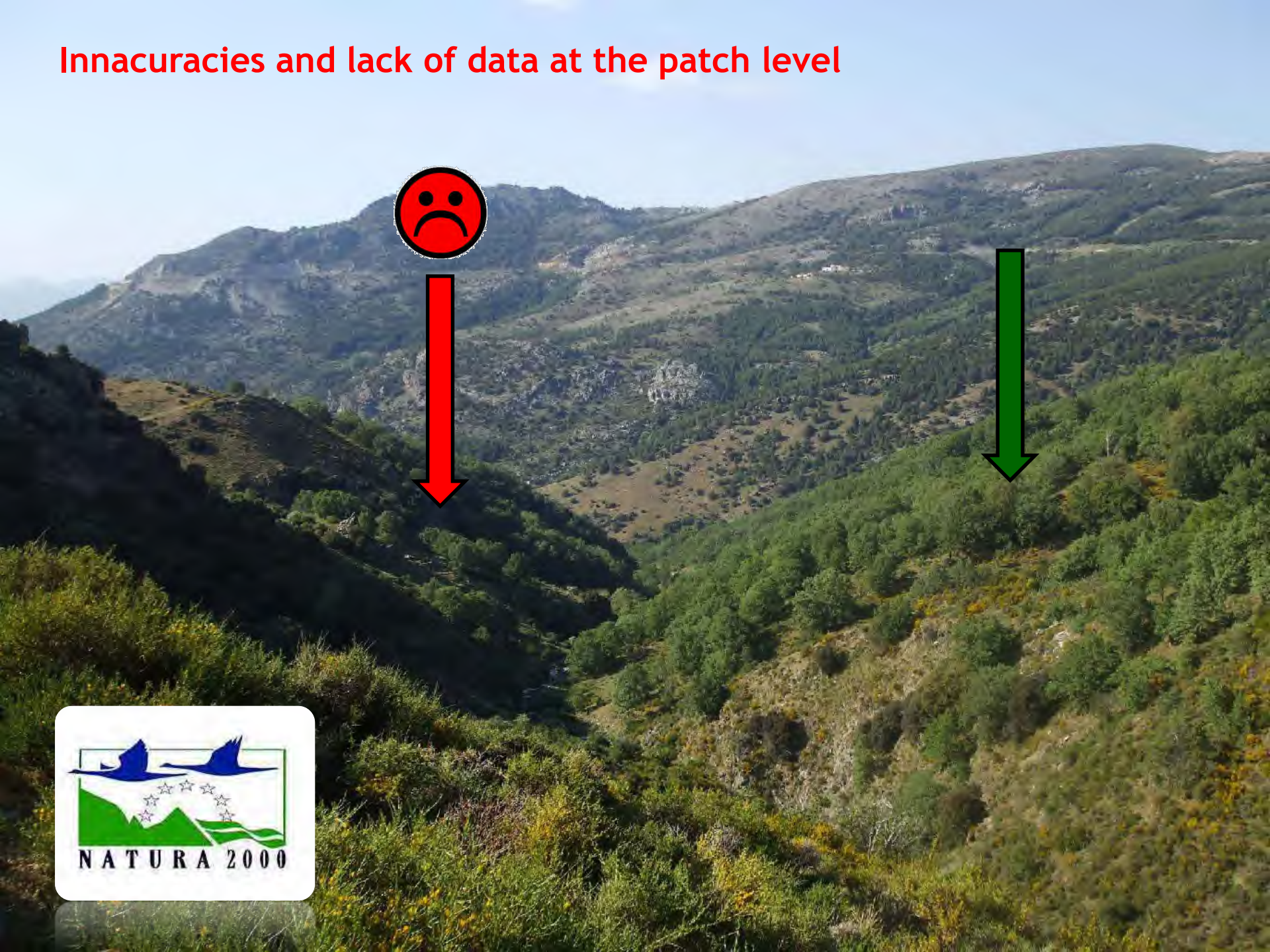
Patron List of Spanish Habitat types
Download from MITECO

EUNIS typologies in Central Anatolia

EUNIS 4 (6)

40	G1.643	231	Sub-humid oro-Cantabrian beech forests
41	G1.662	55	North-western Iberian xerophile beech woods
42	G1.7	93	Thermophilous deciduous woodland
43	G1.7B	1089	[Quercus pyrenaica] forests
44	G1.7B2	370	Cantabrian [Quercus pyrenaica] forests
45	G1.7D	48	[Castanea sativa] woodland
46	G1.862	506	Cantabrian acidophilous oak forests
47	G1.8621	77	Eastern Cantabrian acidophilous oak forests
48	G1.8622	33	Western Cantabrian acidophilous oak forests
49	G1.8623	38	Oro-Cantabrian acidophilous oak forests
50	G1.91	24	[Betula] woodland not on marshy terrain
51	G1.9151	51	Cantabrian [Betula celtiberica] woodlands
52	G1.A	33	Meso- and eutrophic oak, hornbeam, ash, sycamore, lime, elm and related woodland;
53	G1.A1	31	[Quercus] - [Fraxinus] - [Carpinus betulus] woodland on eutrophic and mesotrophic soils
68	G4.F	67	Mixed forestry plantations (plantaciones mixtas de con├iferas y caducifolios)
69	G5	27	Lines of trees, small anthropogenic woodlands, recently felled woodland, early-stage woodland and coppice
70	H2.6	102	Calcareous and ultra-basic screes of warm exposures
71	H2.641	116	Canchales calc├íreos m├┤viles orocant├íbricos
72	H2.65	34	Iberian calciphile fern screes
73	H3.21	159	Tyrrheno-Adriatic eumediterranean calcicolous chasmophyte communities
74	I	416	Regularly or recently cultivated agricultural, horticultural and domestic habitats
75	I1	101	Arable land and market gardens
76	I2	67	Cultivated areas of gardens and parks
77	I5.8	66	Comunidades alóctonas de Cortaderia, Baccharis, Buddleja, Phyllostachis, Reynoutria
78	J	132	Constructed, industrial and other artificial habitats
79	X1	115	Helechales
80	X2	31	Nanofruticedas cespitosas con G. pyrenaicum y H. sedenense

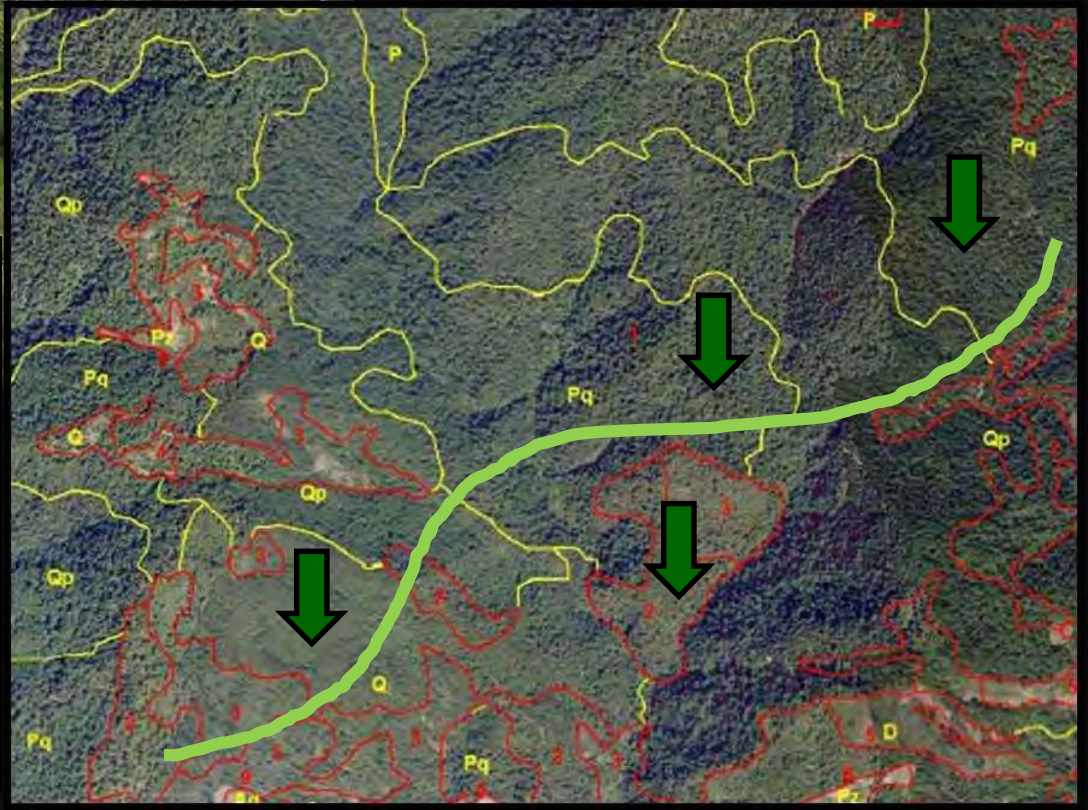
Innacuracies and lack of data at the patch level



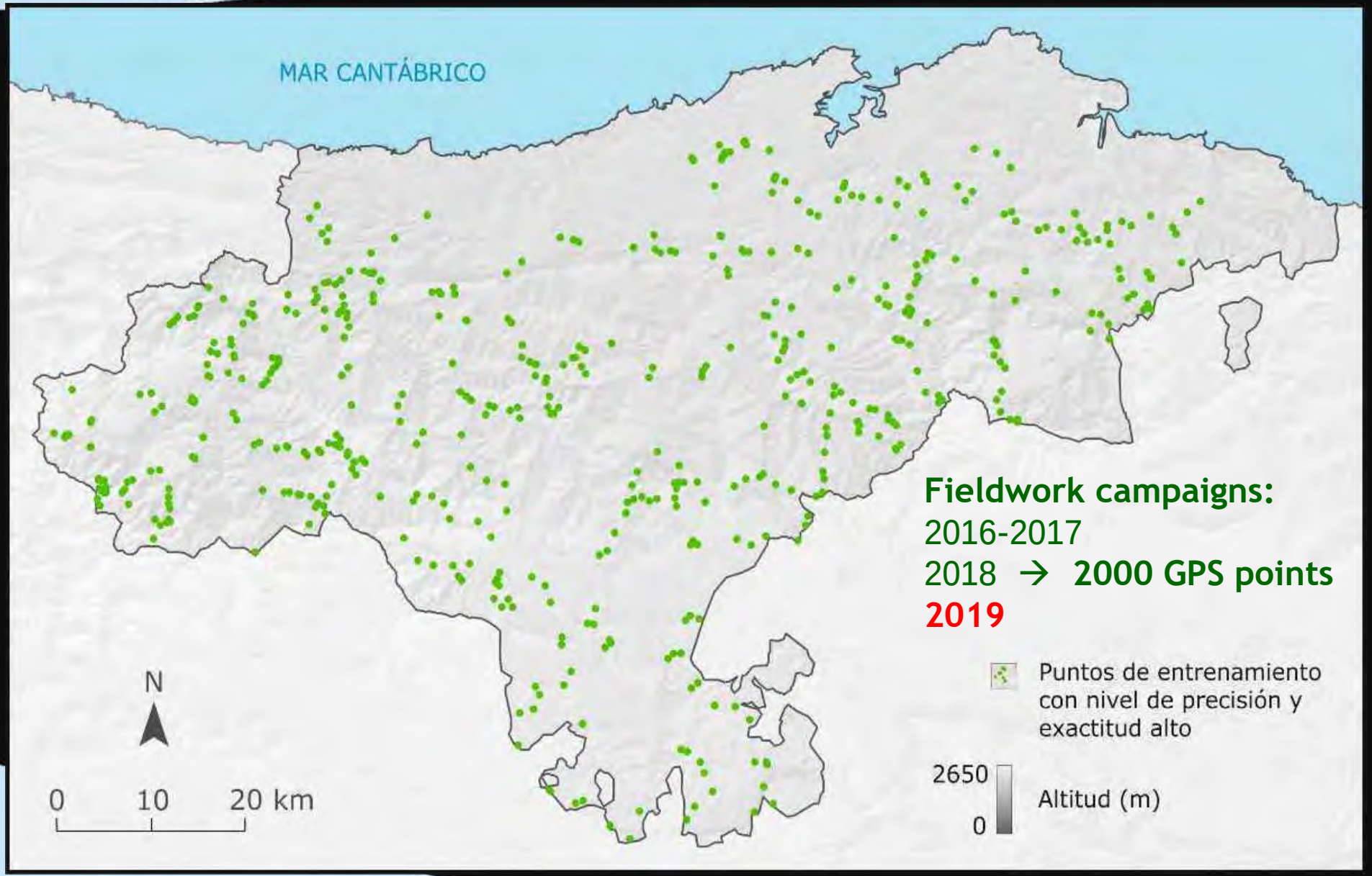
2] OCURRENCE DATA

Point-based sampling surveys

Occurrence data obtained from field surveys with (almost) no uncertainty:
Field campaigns (botanists)

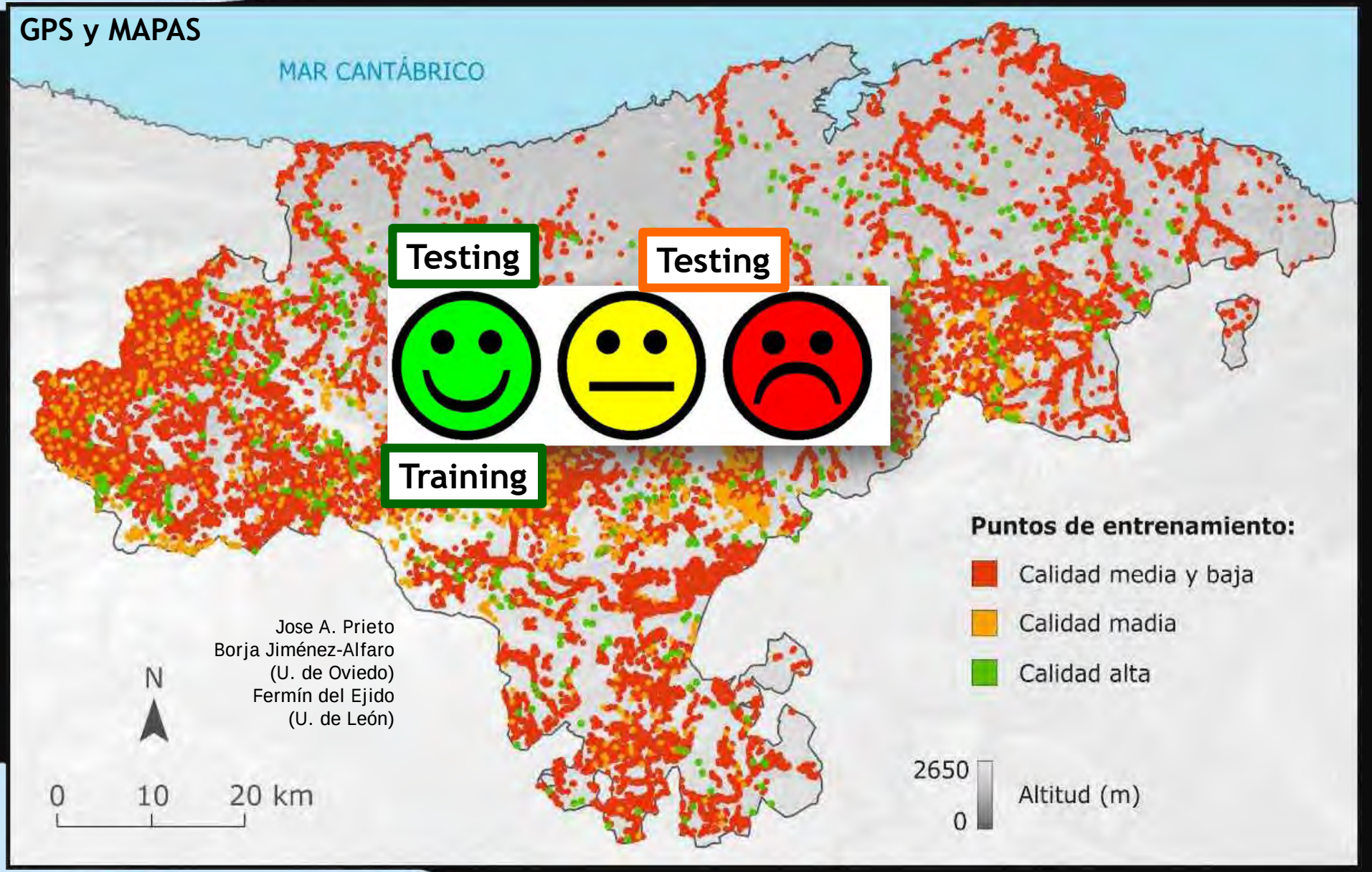


2] OCURRENCE DATA



2] OCURRENCE DATA

GPS y MAPAS



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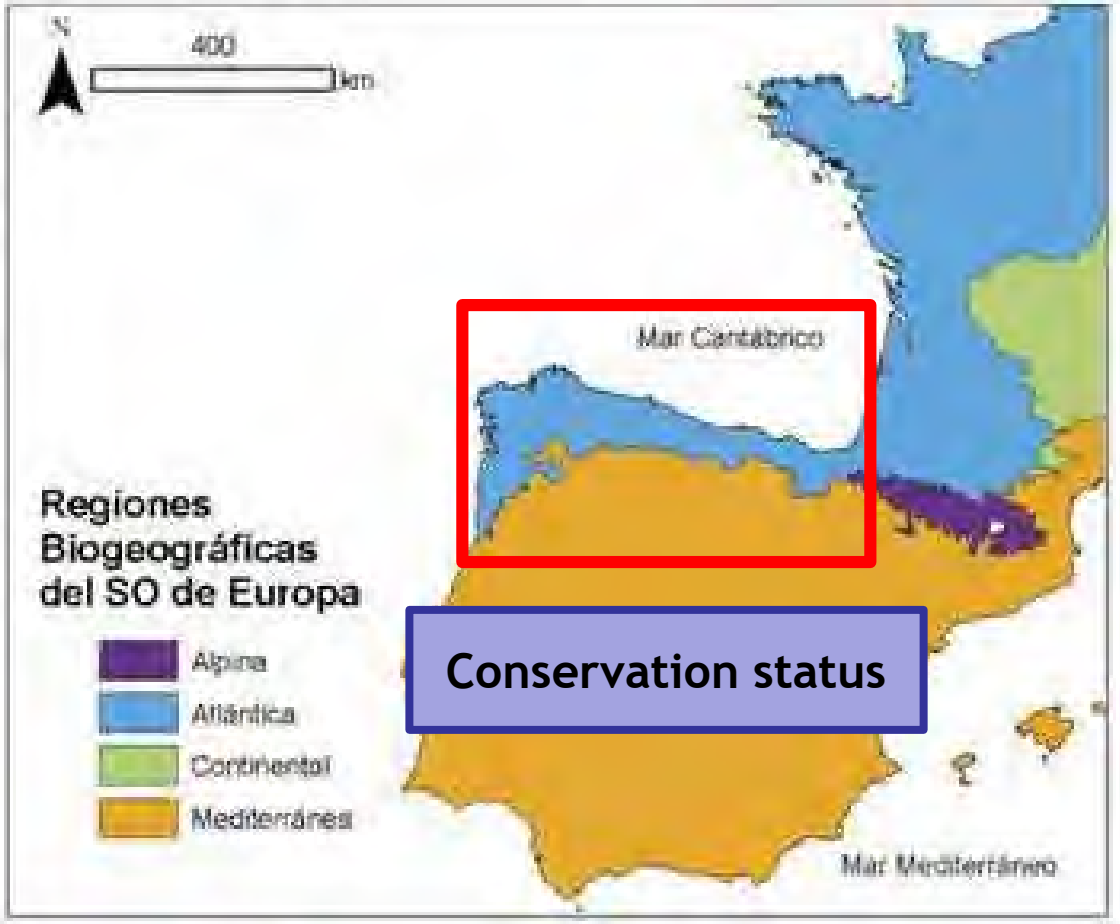
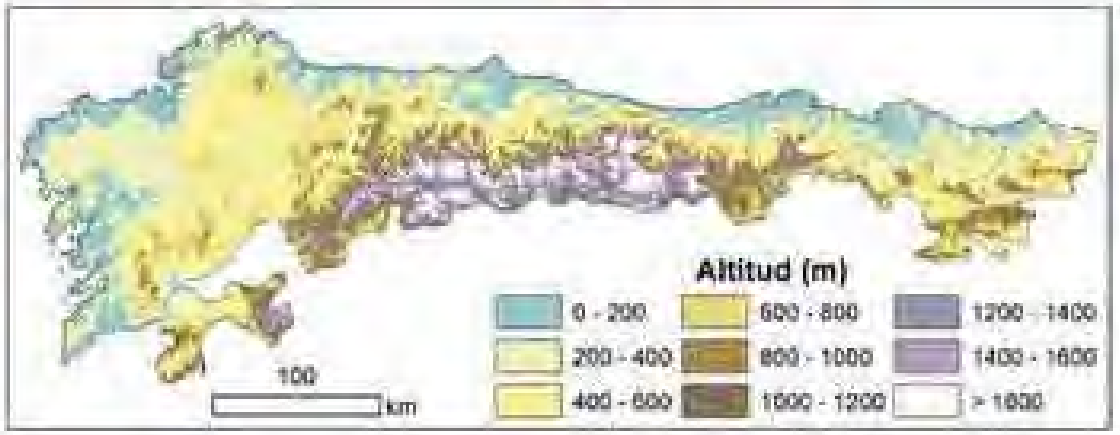
Atlantic biogeographical region (NW Spain)

Vegetation DB:
National maps
Regional programs
Fieldwork

Predictor layers
Limiting factors
Remote sensing

Monitoring and reporting





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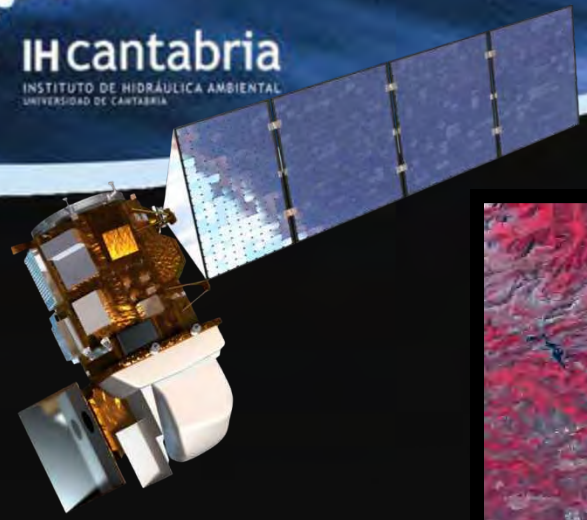
3] PREDICTOR LAYERS



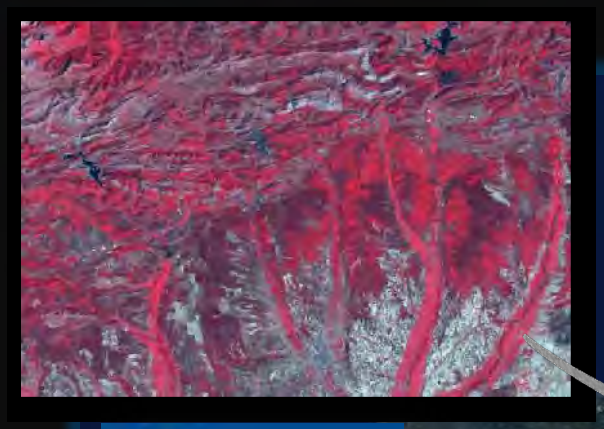
Remote Sensing (RS)

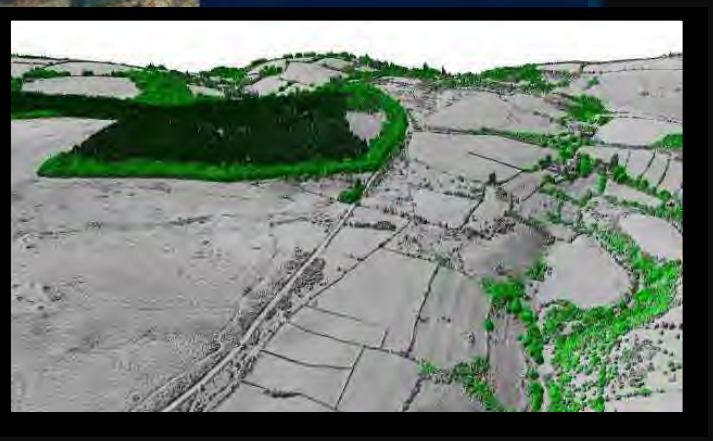
Satellite imagery:
Landsat 5TM and 8OLI 30m
Sentinel 2 A and B, 10-20m
DEIMOS-2, 4m

LiDAR PNOA derived data

Env. Limiting factors

topography, climate, soil
(digital soil mapping *)





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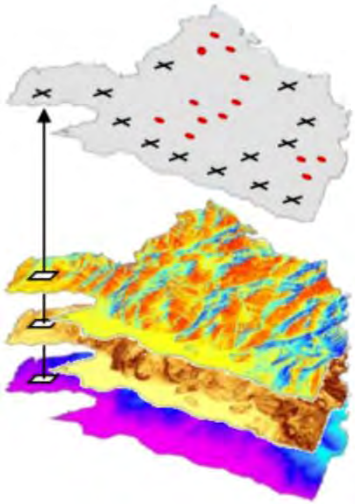
4] MODELLING

A **DATA MINING method or modelling algorithm** for habitat mapping relates occurrence data and the process-based environmental and RS predictors

OCCURRENCE DATA



PREDICTORS

1

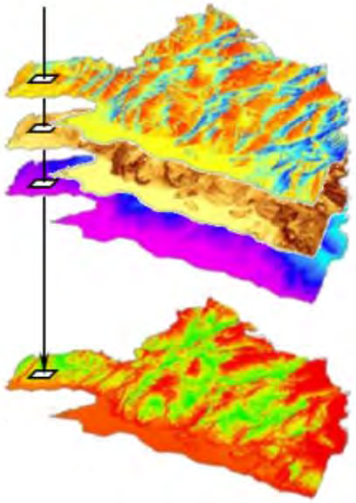
2

```
def define_model(self):
    input_shape = (self.channels, self.rows, self.columns,)
    mo = Sequential()
    mo.add(
        normalization.BatchNormalization(input_shape=input_shape, axis=1))
    mo.add(
        Conv2D(6, (1, 1), activation='relu', input_shape=input_shape))
    mo.add(MaxPooling2D((2, 2)))
    mo.add(Conv2D(12, (1, 1), activation='relu'))
    mo.add(MaxPooling2D((2, 2)))
    mo.add(Flatten())
    mo.add(Dense(self.eunis_types, activation='softmax'))
    mo.compile(loss='categorical_crossentropy',
               optimizer=keras.optimizers.Adam(),
               metrics=['acc', 'binary_accuracy'])
    return mo

def train(self, x_train, y_train, trained_model_path=None):
    x_train, y_train = self.reshape_matrices(x_train, y_train)
    file_name = None
    if trained_model_path is None:
        mo = self.define_model()
        mo.fit(x_train, y_train, epochs=100, batch_size=32, verbose=1)
        # Save trained model
        file_name = self.save_model_and_headers(mo)
    else:
        # load
        mo = load_model(trained_model_path)
    return mo, file_name
```

Deep learning

SPATIAL PREDICTIONS



MAPS

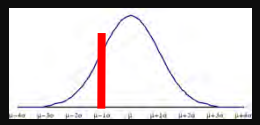
MaxEnt: SWD format, Tunning parameters, *Phillips et al (2006)*

SDM: Multiple algorithms, Bootstraping, *Naimi and Araújo (2016)*

4] MODELLING RESULTS

E 1:50 000

Local AOO



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4] MODELLING RESULTS

Habitat 1140

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Continental Shelf Research 174 (2019) 35–47

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journal homepage: www.elsevier.com/locate/csr

Mapping estuarine vegetation using satellite imagery: The case of the invasive species *Baccharis halimifolia* at a Natura 2000 site

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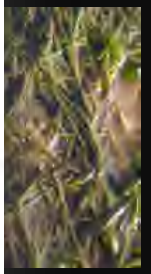
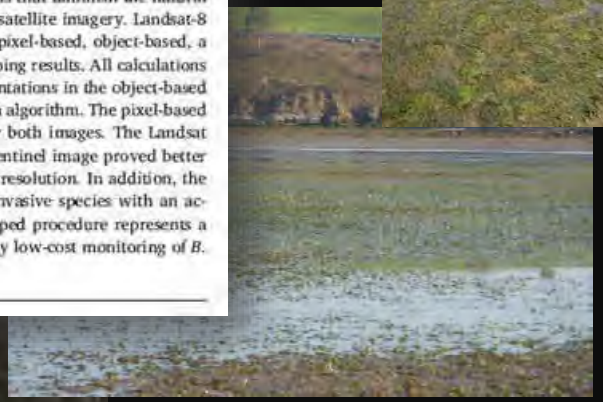
ARTICLE INFO

Keywords:
Bay of Biscay
Landsat
Sentinel
Support vector machines
Remote sensing
Mapping

ABSTRACT

The invasive shrub *Baccharis halimifolia* is a threat to the environmental health of many estuarine protected areas throughout Europe. It displaces saltmarsh vegetation and creates monospecific stands that diminish the natural diversity. This work aims to develop a procedure to map this invasive species using satellite imagery. Landsat-8 and Sentinel 2A images are compared, along with three classification approaches (pixel-based, object-based, a mixture of both), to determine which combination yields the best *B. halimifolia* mapping results. All calculations were made using open-source software, including the ORFEO toolbox for the segmentations in the object-based approach, and the Scikit-learn package for the Support Vector Machines classification algorithm. The pixel-based classifications mapped the invasive species with an accuracy of 70% or higher for both images. The Landsat image had higher accuracy in the overall classification of the vegetation, but the Sentinel image proved better suited for mapping *B. halimifolia* specifically, due to its higher spatial and spectral resolution. In addition, the procedure was implemented using a Landsat image from 2005, and mapped the invasive species with an accuracy of 72% and 88% for producers and users accuracy respectively. The developed procedure represents a valuable tool for restoration projects, allowing for retrospective analyses or relatively low-cost monitoring of *B. halimifolia's* current distribution.

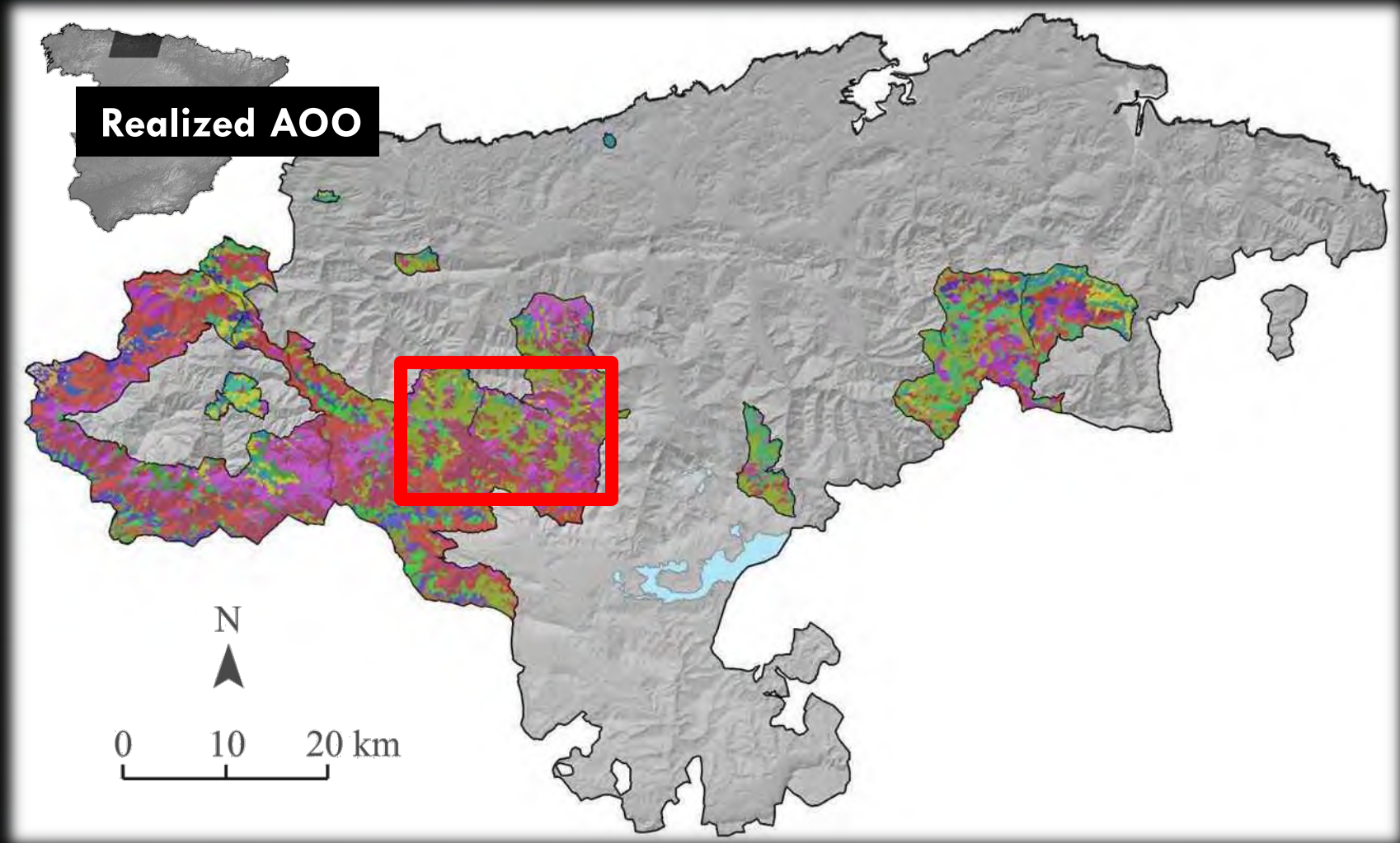




Baccharis halimifolia

4] MODELLING RESULTS

Automatic and objective: depends on the models

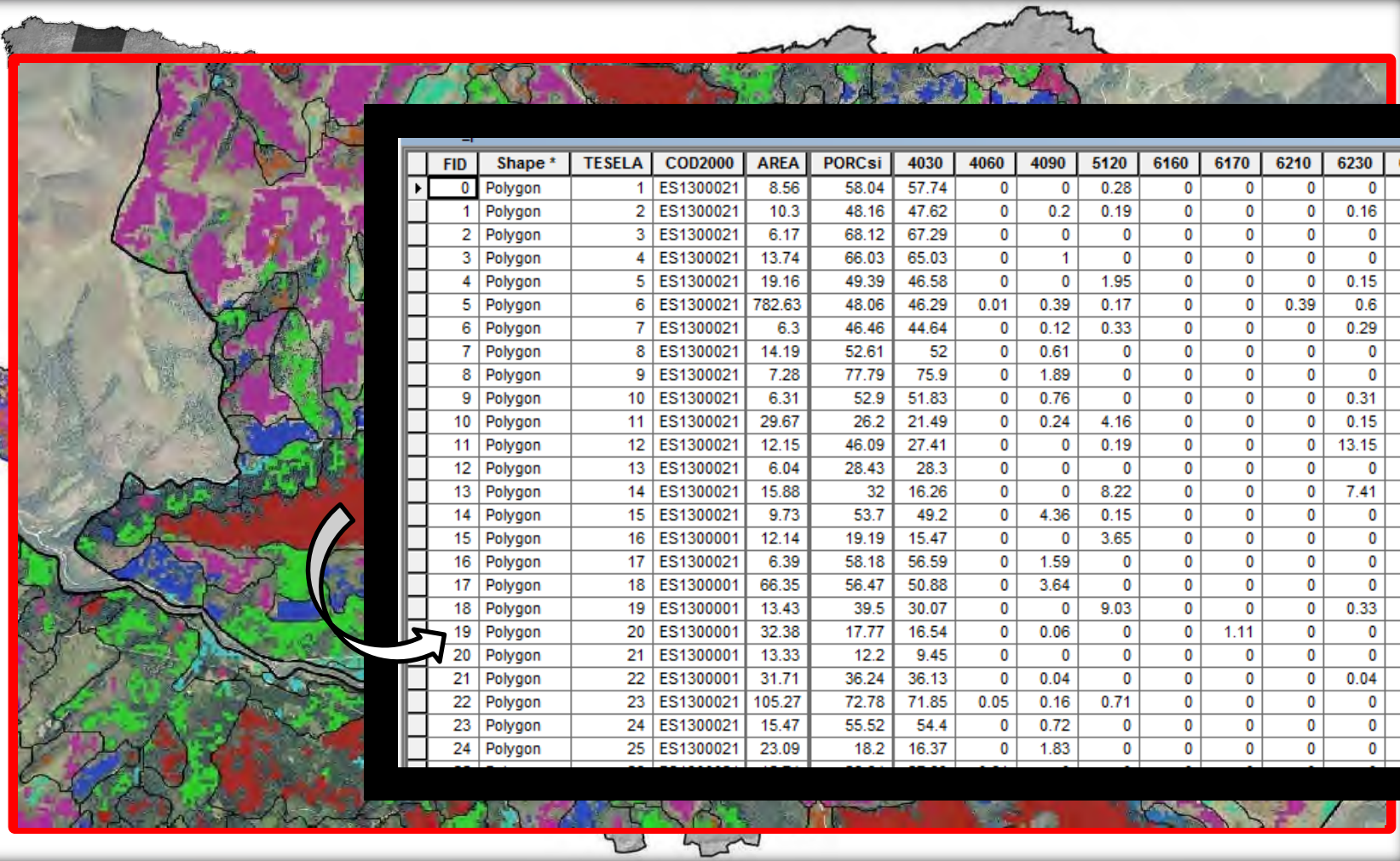


E 1:50 000

n habitats with good quality data

4] MODELLING RESULTS

Automatic and objective: depends on the models



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1	Polygon	2	ES1300021	10.3	48.16	47.62	0	0.2	0.19	0	0	0	0.16	0
2	Polygon	3	ES1300021	6.17	68.12	67.29	0	0	0	0	0	0	0	0
3	Polygon	4	ES1300021	13.74	66.03	65.03	0	1	0	0	0	0	0	0
4	Polygon	5	ES1300021	19.16	49.39	46.58	0	0	1.95	0	0	0	0.15	0
5	Polygon	6	ES1300021	782.63	48.06	46.29	0.01	0.39	0.17	0	0	0.39	0.6	0
6	Polygon	7	ES1300021	6.3	46.46	44.64	0	0.12	0.33	0	0	0	0.29	0
7	Polygon	8	ES1300021	14.19	52.61	52	0	0.61	0	0	0	0	0	0
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9	Polygon	10	ES1300021	6.31	52.9	51.83	0	0.76	0	0	0	0	0.31	0
10	Polygon	11	ES1300021	29.67	26.2	21.49	0	0.24	4.16	0	0	0	0.15	0
11	Polygon	12	ES1300021	12.15	46.09	27.41	0	0	0.19	0	0	0	13.15	0
12	Polygon	13	ES1300021	6.04	28.43	28.3	0	0	0	0	0	0	0	0
13	Polygon	14	ES1300021	15.88	32	16.26	0	0	8.22	0	0	0	7.41	0
14	Polygon	15	ES1300021	9.73	53.7	49.2	0	4.36	0.15	0	0	0	0	0
15	Polygon	16	ES1300001	12.14	19.19	15.47	0	0	3.65	0	0	0	0	0
16	Polygon	17	ES1300021	6.39	58.18	56.59	0	1.59	0	0	0	0	0	0
17	Polygon	18	ES1300001	66.35	56.47	50.88	0	3.64	0	0	0	0	0	0.81
18	Polygon	19	ES1300001	13.43	39.5	30.07	0	0	9.03	0	0	0	0.33	0
19	Polygon	20	ES1300001	32.38	17.77	16.54	0	0.06	0	0	1.11	0	0	0
20	Polygon	21	ES1300001	13.33	12.2	9.45	0	0	0	0	0	0	0	2.7
21	Polygon	22	ES1300001	31.71	36.24	36.13	0	0.04	0	0	0	0	0.04	0
22	Polygon	23	ES1300021	105.27	72.78	71.85	0.05	0.16	0.71	0	0	0	0	0
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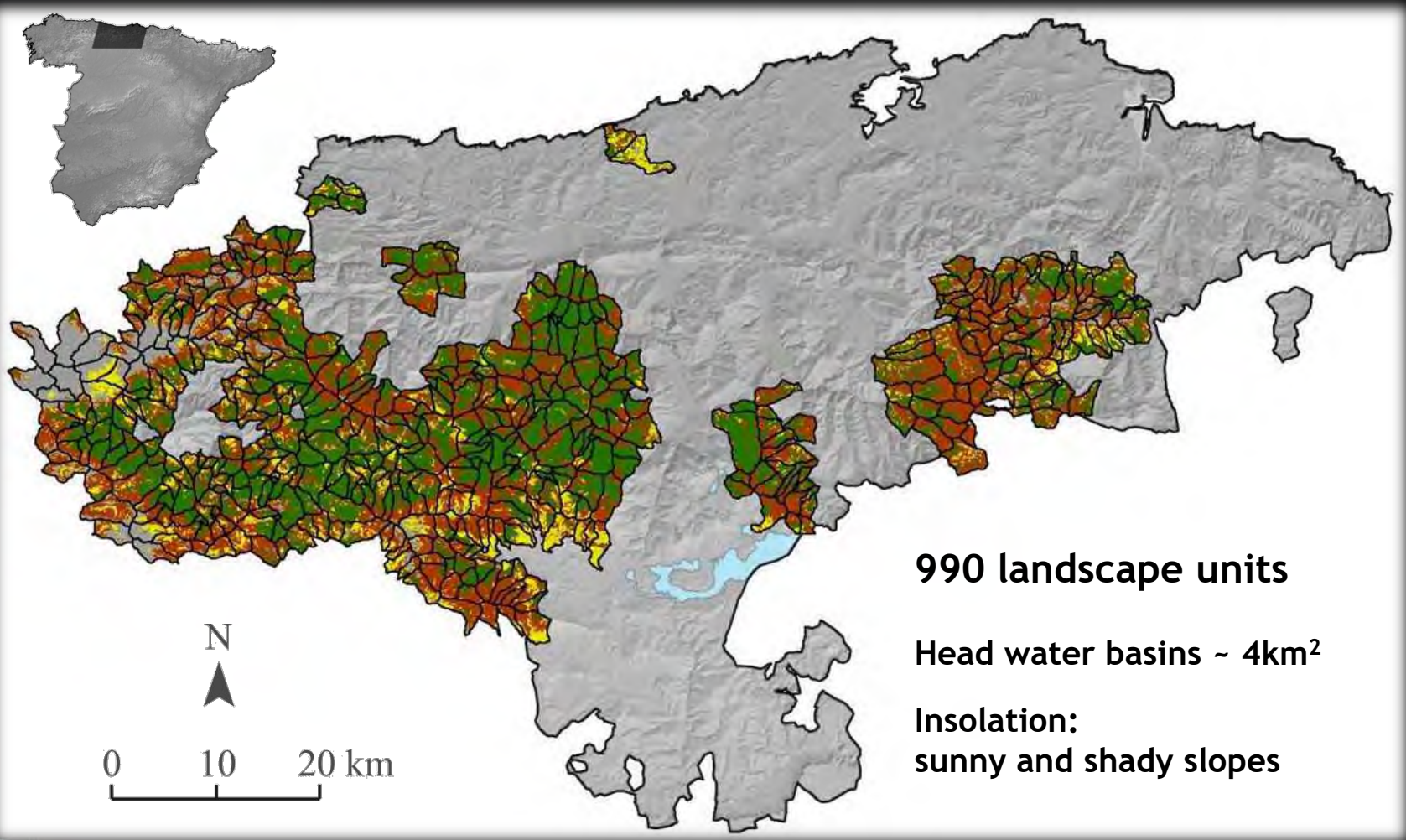
24	Polygon	25	ES1300021	23.09	18.2	16.37	0	1.83	0	0	0	0	0	0

E 1:25 000

DOMINANCE + **UNCERTAINTY**

LANDSCAPE UNITS FOR MANAGEMENT

Homogeneous units (structure and composition) driven by environmental limiting factors (topography and climate)



Álvarez-Martínez, J. M., et al (2014). Influence of land use and climate on recent forest expansion: a case study in the Eurosiberian–Mediterranean limit of north-west Spain**, Journal of Ecology**, 102, 905-919

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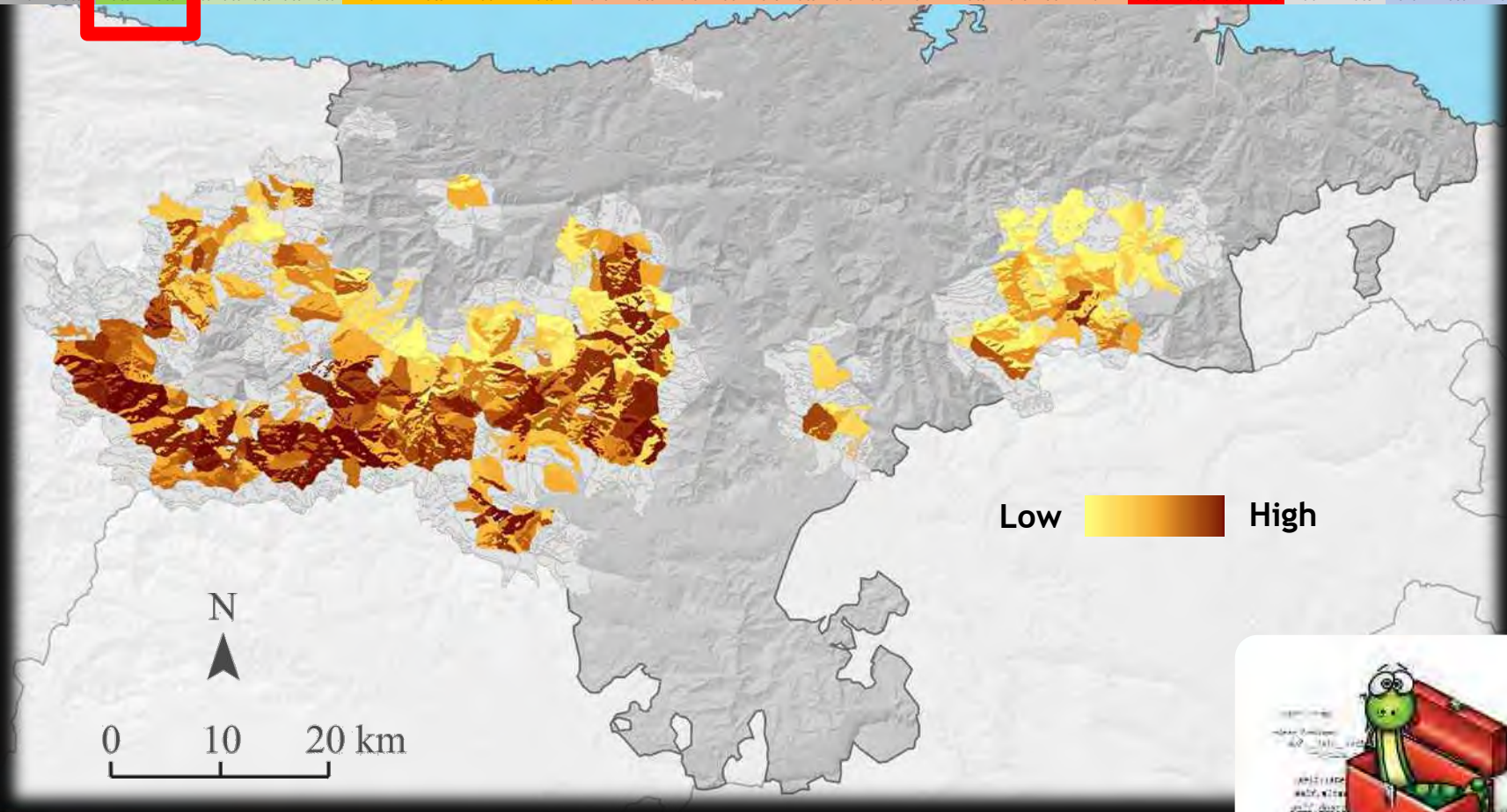
LANDSCAPE UNITS FOR MANAGEMENT

PRIORITY INDEX (for all landscape units)

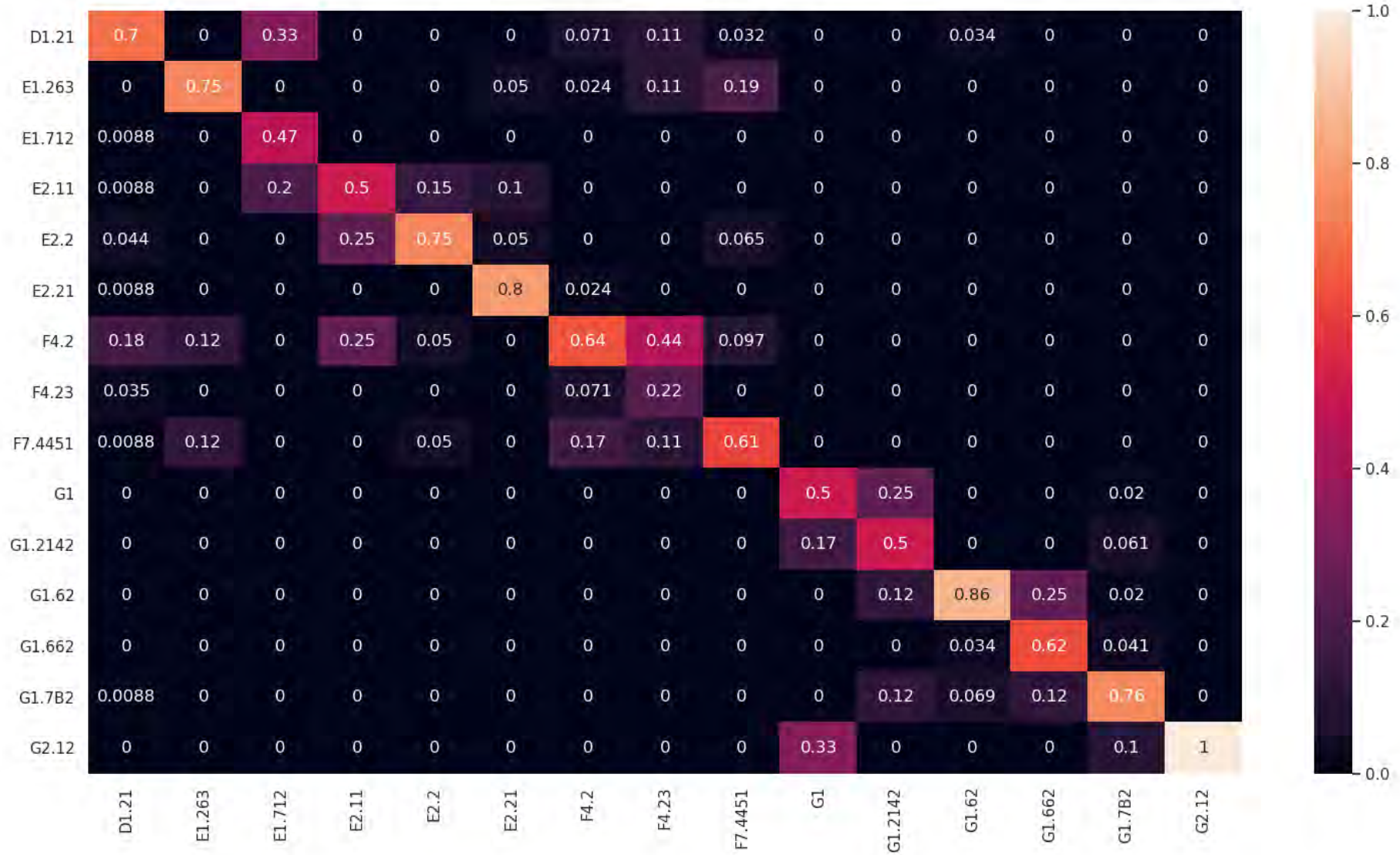
ID	LIC	AREA	PERI	area	mean	N	fAx	fAs	LPI	PAR	ndvitmaxr	ndvitxx	ndvitxd	ndvitsdx	sandm	sandd	claym	clayd	omm	omd	phm	phd	arenam	arenad	mom	mod	phh2om	firemin	firex	fired	fires	alocAx	alocAs	pMIN	pRANGE	pSUM	PRIORIZA
1	LIEBANA	0.56	0.5	0.00	0.00	00	0.00	0.00	0.00	0.00	-0.10	0.36	-0.03	-0.09	-0.17	-0.03	0.12	0.02	0.11	0.01	-0.19	-0.02	-0.17	-0.02	0.13	0.02	-0.22	-0.02	-0.52	-0.29	-0.37	0.00	0.00	0.00	0.00	0.00	**-0.47**
2	CABUERNIGA	0.23	0.3	0.00	0.00	00	0.00	0.00	0.00	0.00	-0.09	0.39	-0.03	-0.09	-0.18	-0.04	0.16	0.03	0.12	0.01	-0.20	-0.04	-0.18	-0.02	0.11	0.01	-0.24	-0.01	-0.36	-0.28	-0.11	-0.04	-0.06	-0.31	-0.68	-0.09	**-1.74**
3	ORIENTAL	1.02	0.9	0.00	0.00	00	0.00	0.00	0.00	0.00	-0.11	0.39	-0.04	-0.09	-0.20	-0.03	0.23	0.02	0.25	0.03	-0.18	-0.02	-0.22	-0.03	0.18	0.02	-0.21	-0.01	-0.98	-0.45	-1.00	-0.01	-0.08	-0.10	-0.96	-0.26	**-3.24**



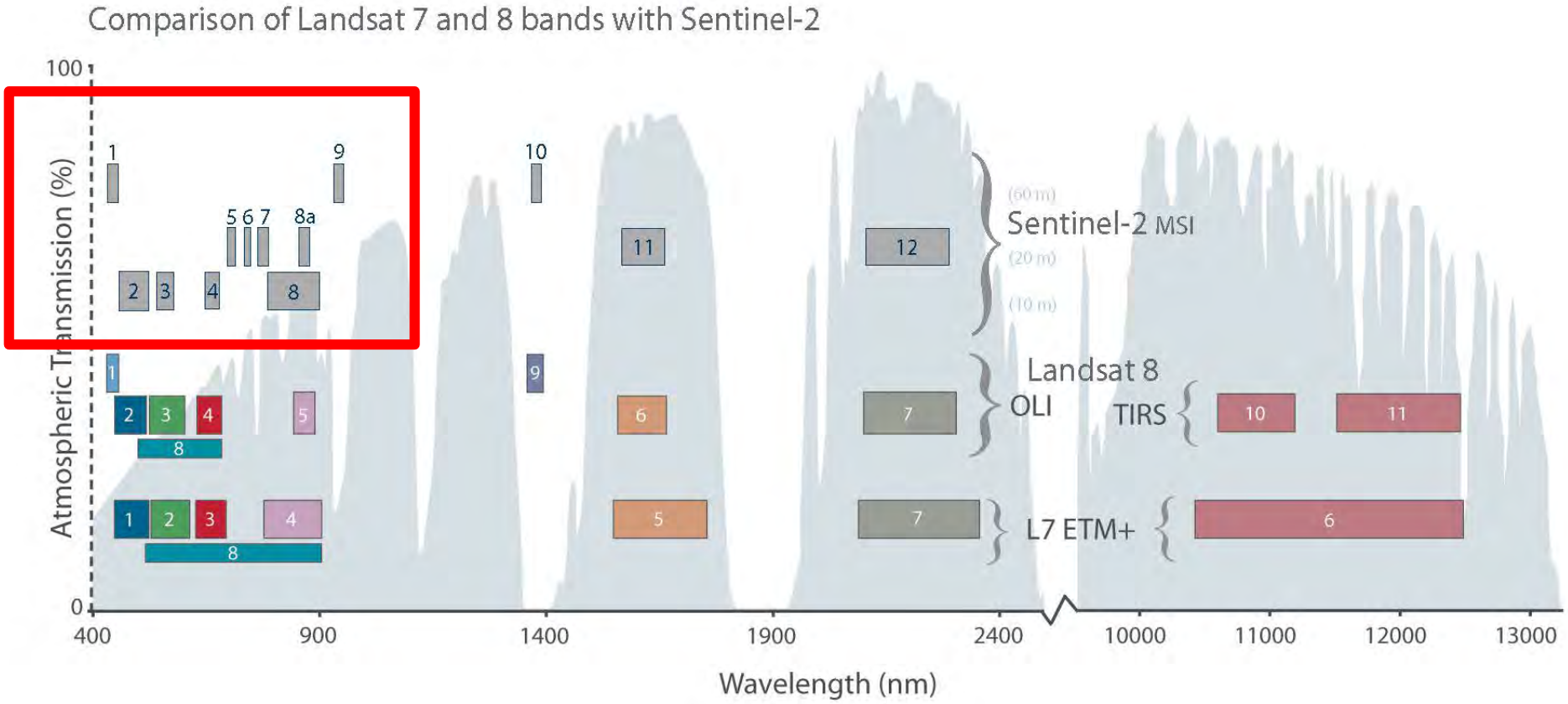
"LEGO" format tool: expandable to any variable

4] MODELLING RESULTS

VALIDATION - Confusion matrices



SENTINEL 2A IMAGERY



4] MODELLING RESULTS

High scale

Landsat 8 MVC
Landsat8 x2
Sentinel2 x2
Deimos2 x2
+LiDAR +MDT

4] MODELLING RESULTS

Landsat 8 MVC
Landsat8 x2
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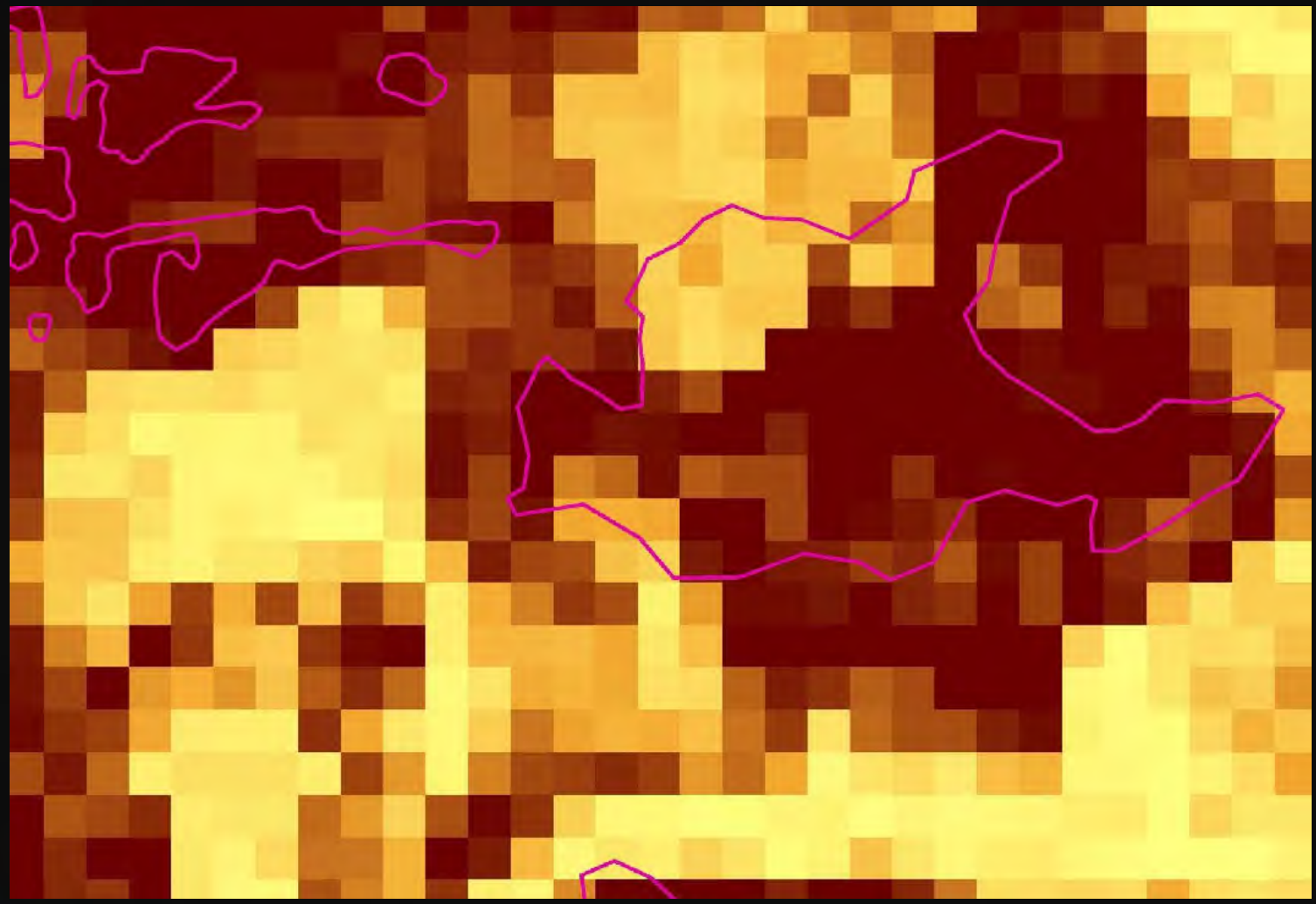
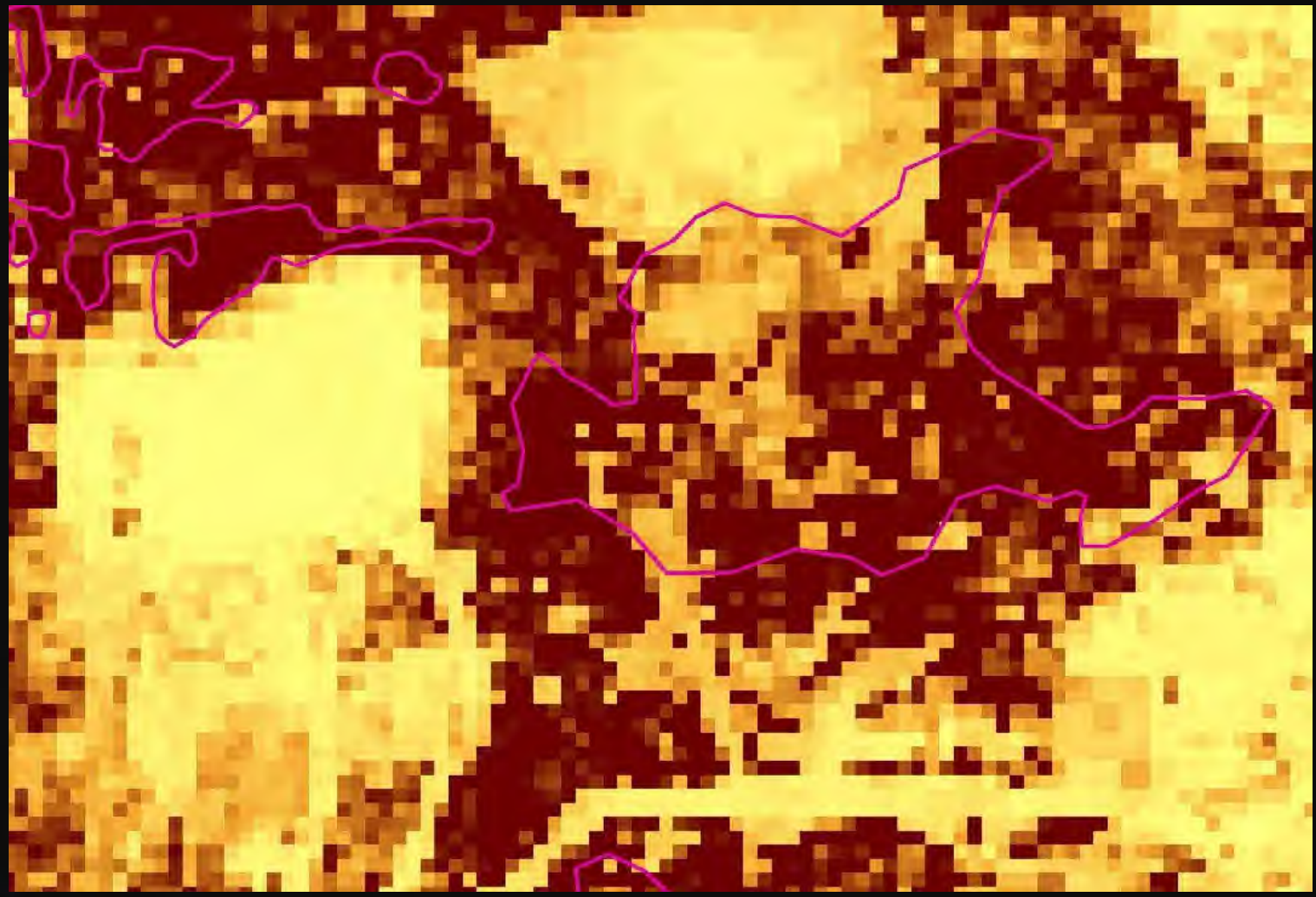


4] MODELLING RESULTS

Landsat 8 MVC
Landsat8 x2
Sentinel2 x2
Deimos2 x2
+LiDAR +MDT

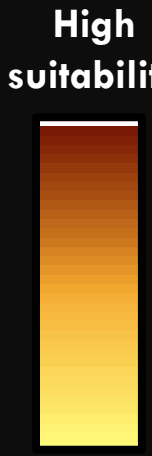


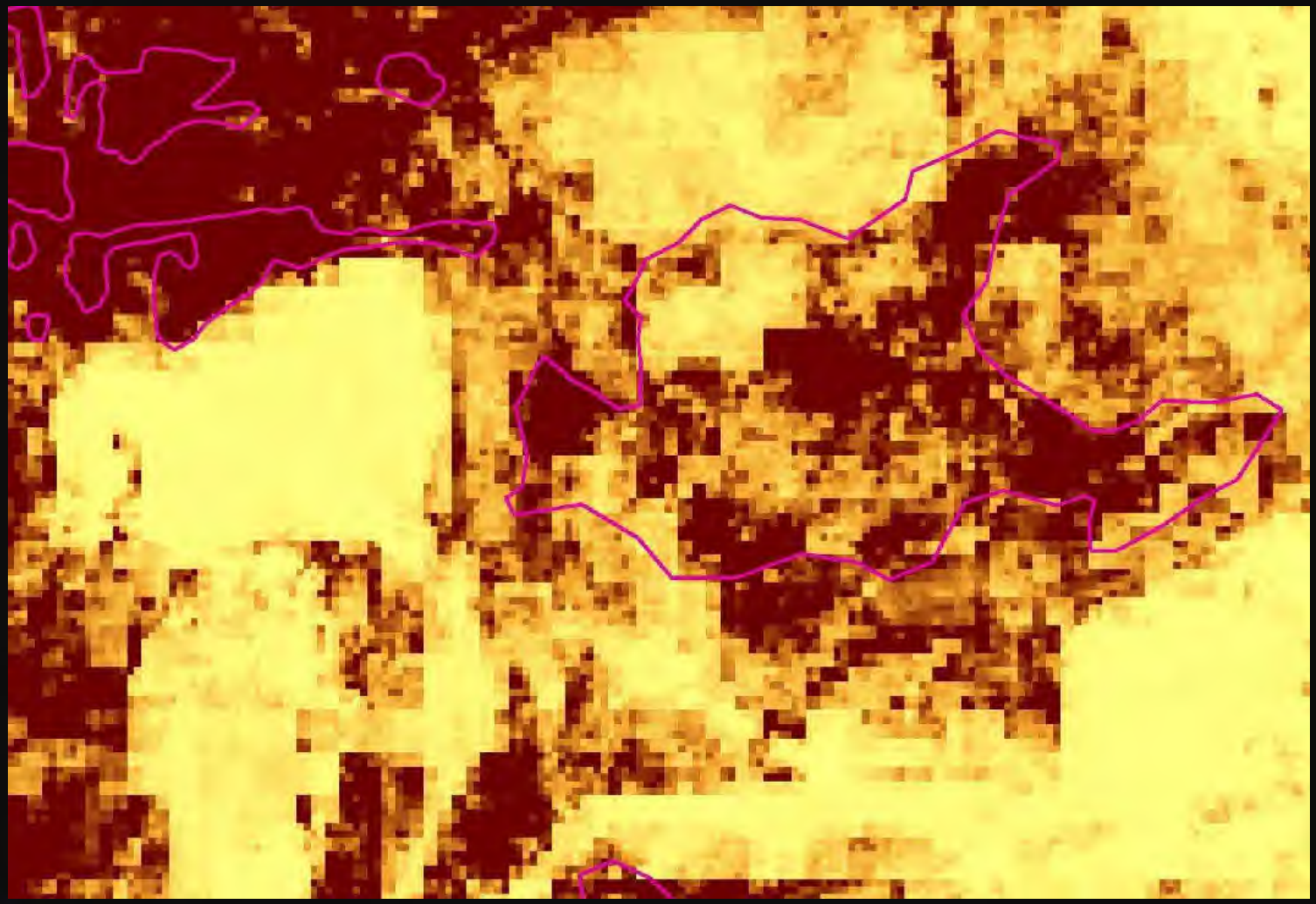
High suitability

Low suitability

4] MODELLING RESULTS

Landsat 8 MVC
Landsat8 x2
Sentinel2 x2
Deimos2 x2
+LiDAR +MDT

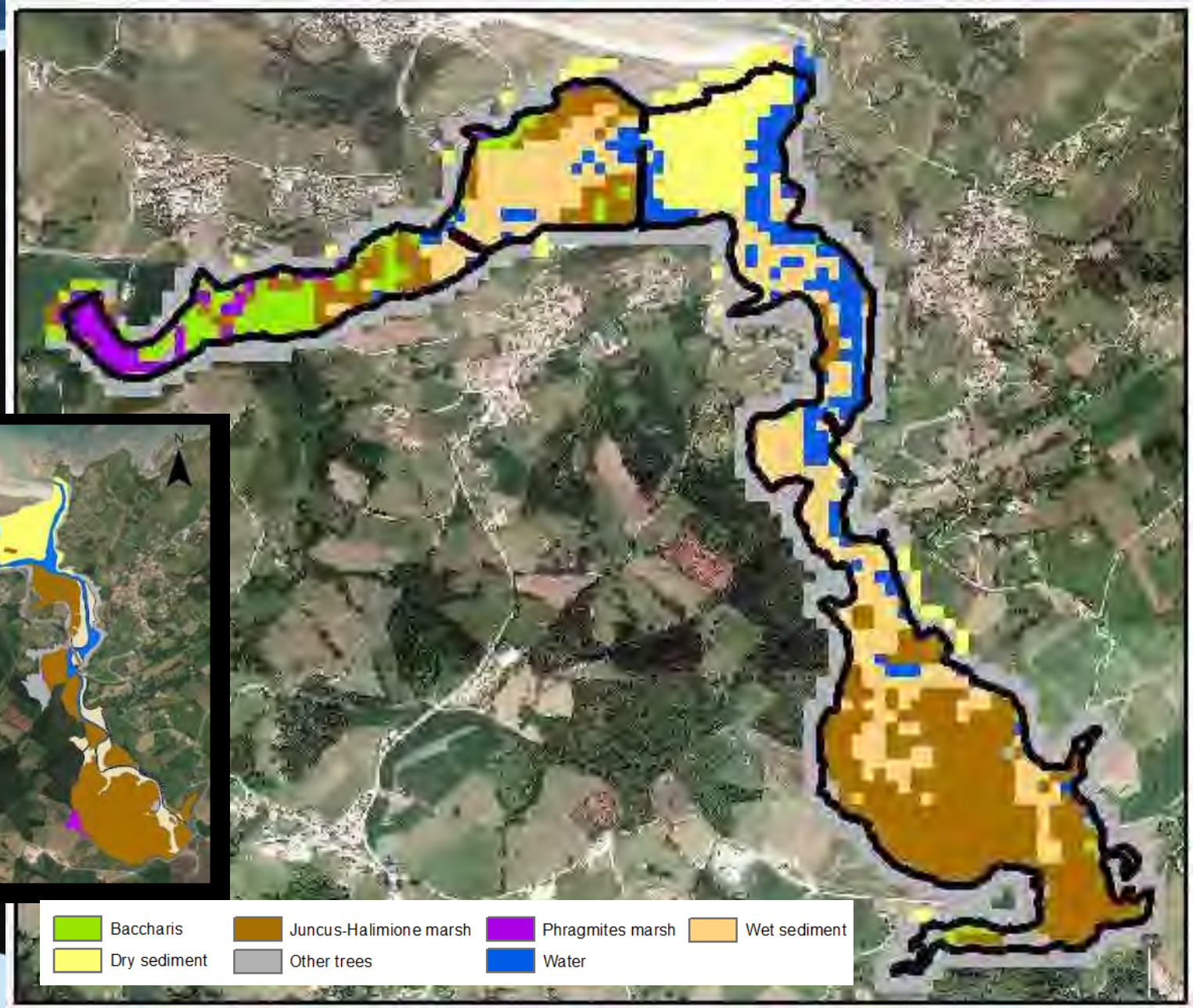




4] MODELLING RESULTS

Landsat 8

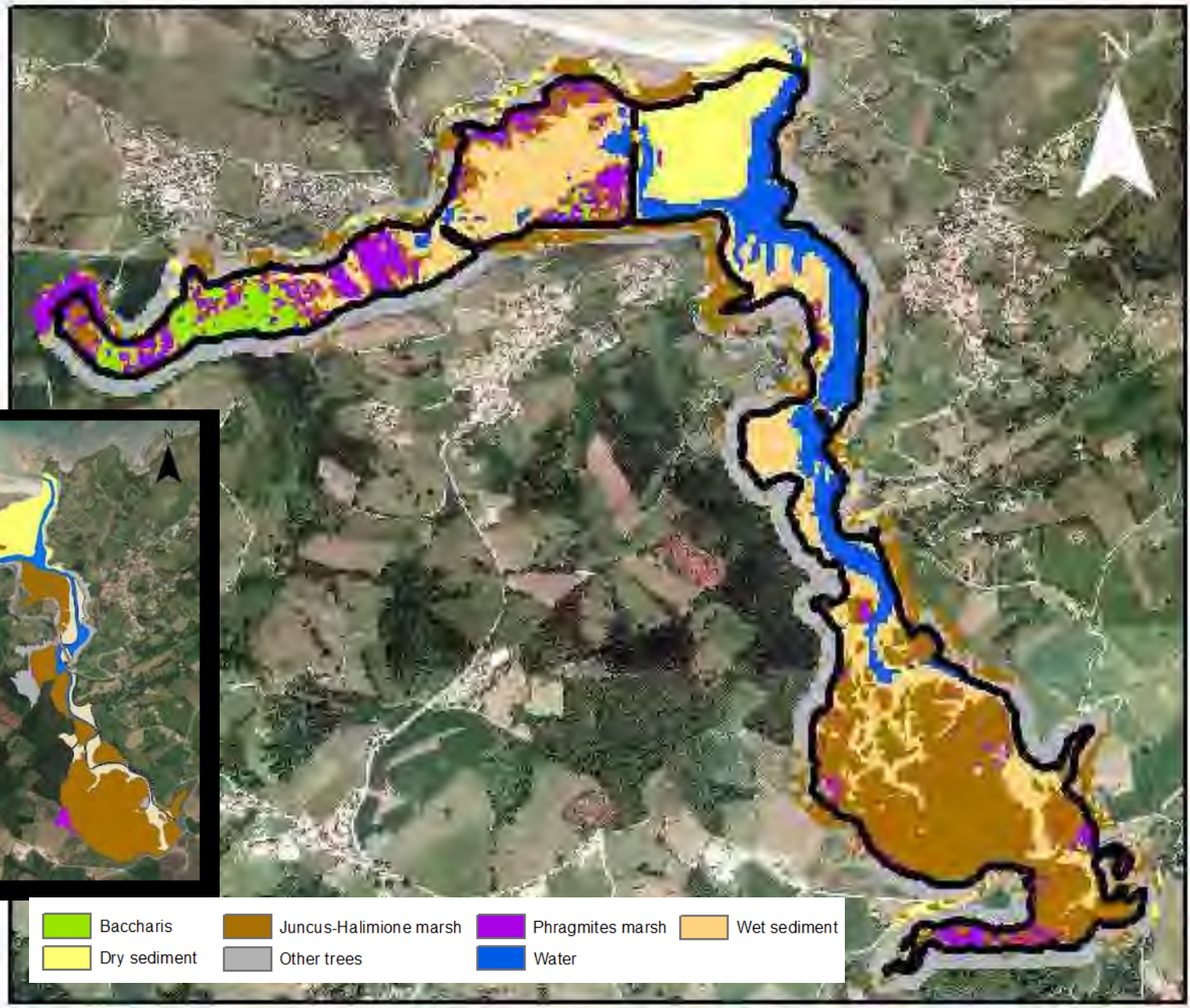
Evi2
Tasseled Cap:
Humedad
Batimetría



4] MODELLING RESULTS

Sentinel 2

Evi2 (banda 5)
Componente principal 1
Batimetría



SPECTRAL SIGNATURES

Seagrass

Set of seagrass habitats and biological conditions

Spectroscopy

ASD FieldSpec4 Spectroradiometer

Hyperspectral signatures

Set of seagrass conditions

Field

Field campaign

Laboratory

Experimental design

Multispectral signatures

Landsat 4, 5, 7, 8

Indices

Set of significant index

Training

Satellite

High resolution satellite sensor

Landsat 4, 5, 7 & 8

Multispectral imagery

Geometric and radiometric correction

Multispectral reflectance

Land/Water mask

Water index and TW limits

Emerged

Submerged

Inversion algorithms

Indices

Set of index

Classification

Cartography (Reference)

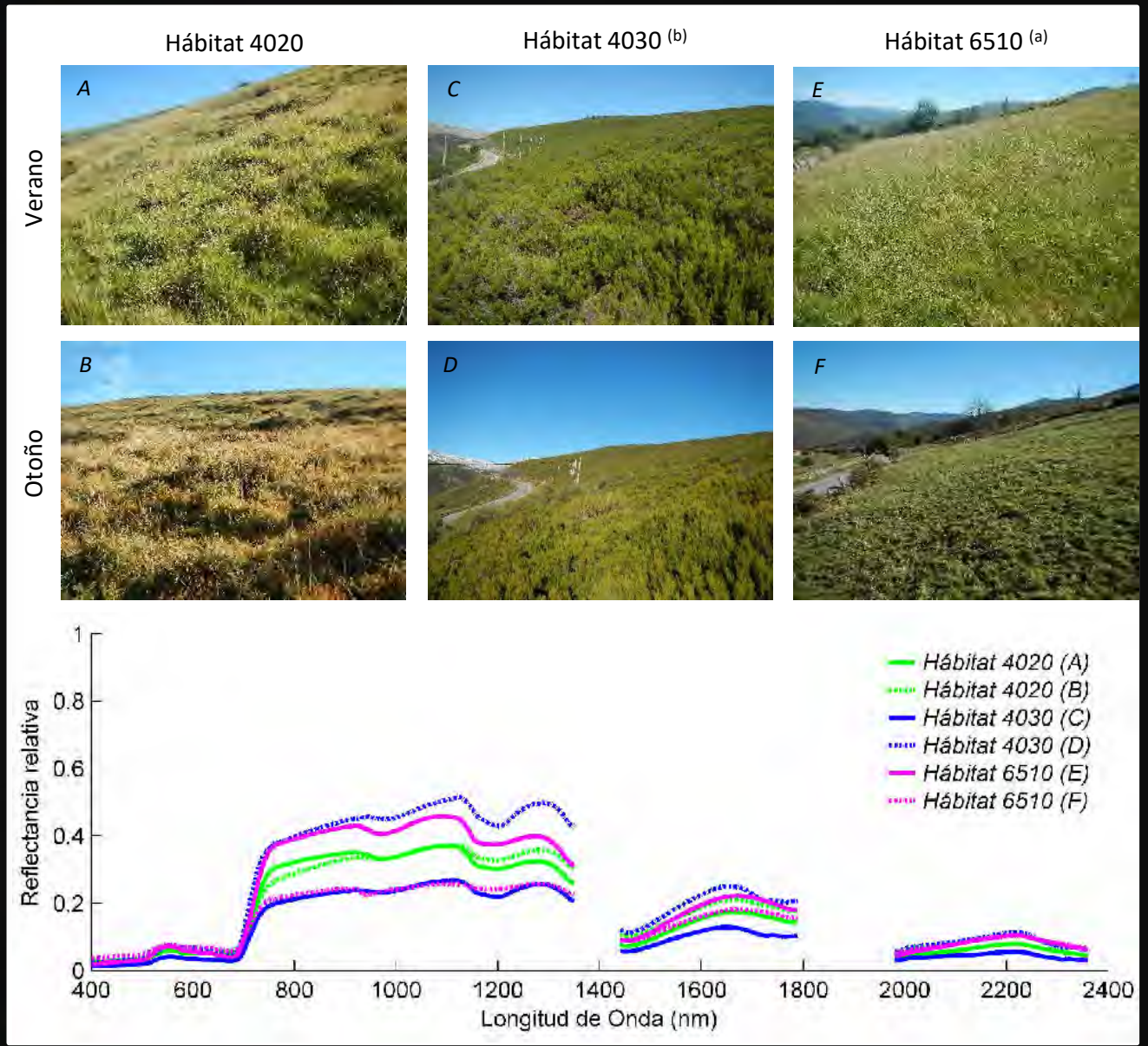
Image classification

SPECTRAL SIGNATURES

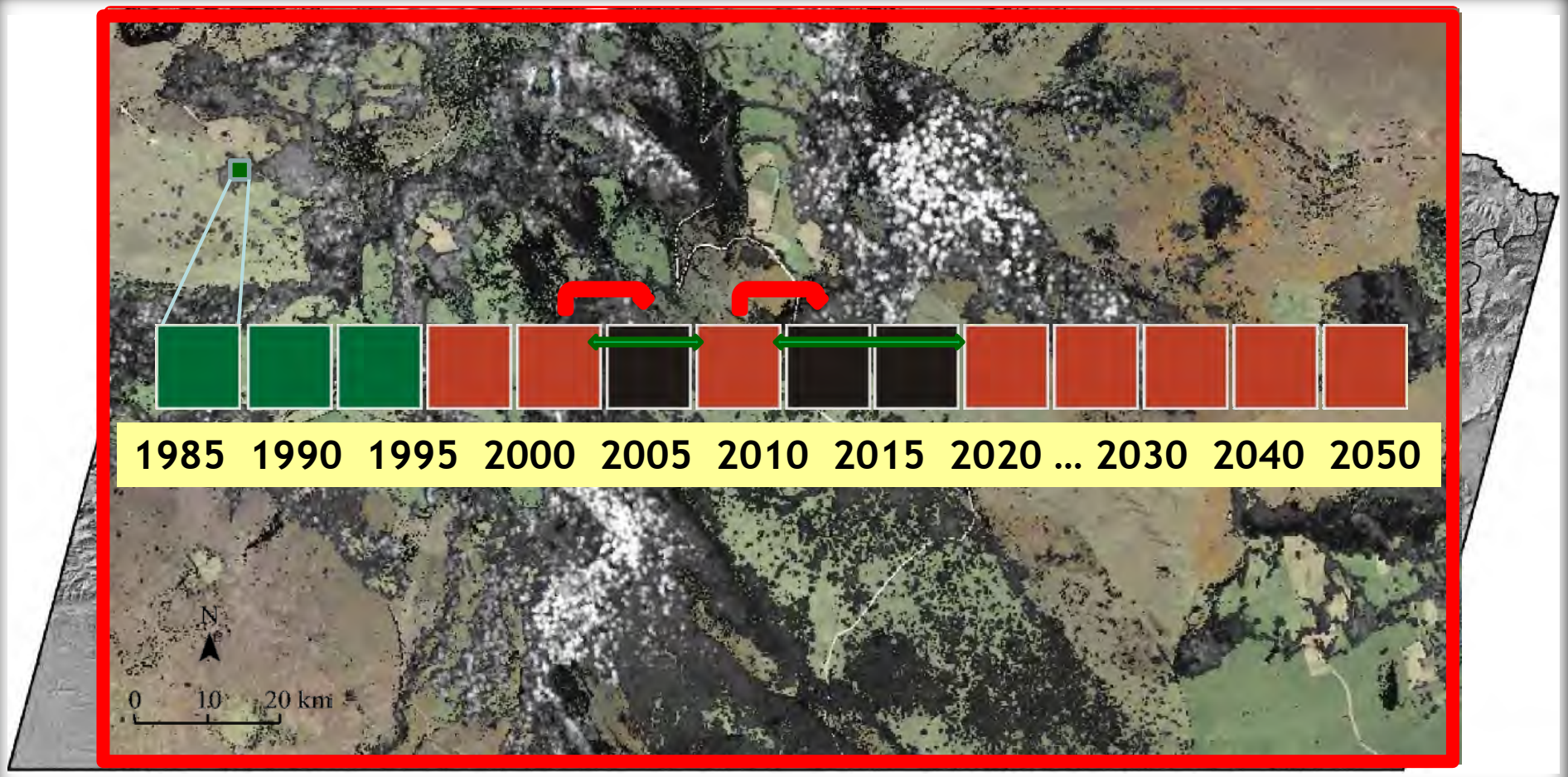
Hyperspectral Campaigns: PASTURES

SPECTRAL SIGNATURES

Spectral library: PASTURES



CONSERVATION STATUS



0 50 meters high

Vegetation structure (LiDAR derived data)
LiDAR PNOA: 0.5 p/m2, <0.5m=NoData

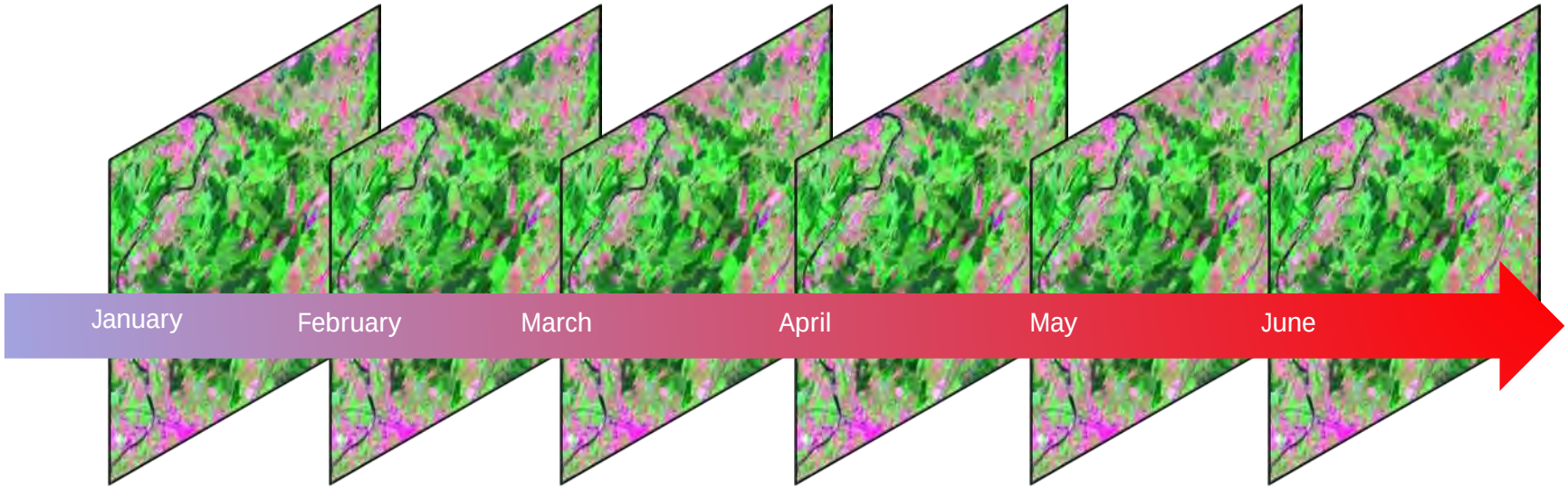
CONSERVATION STATUS

Processing in real time of data series of imagery

Landsat, MODIS and Sentinel 2

Daily data for the 2000-present period.

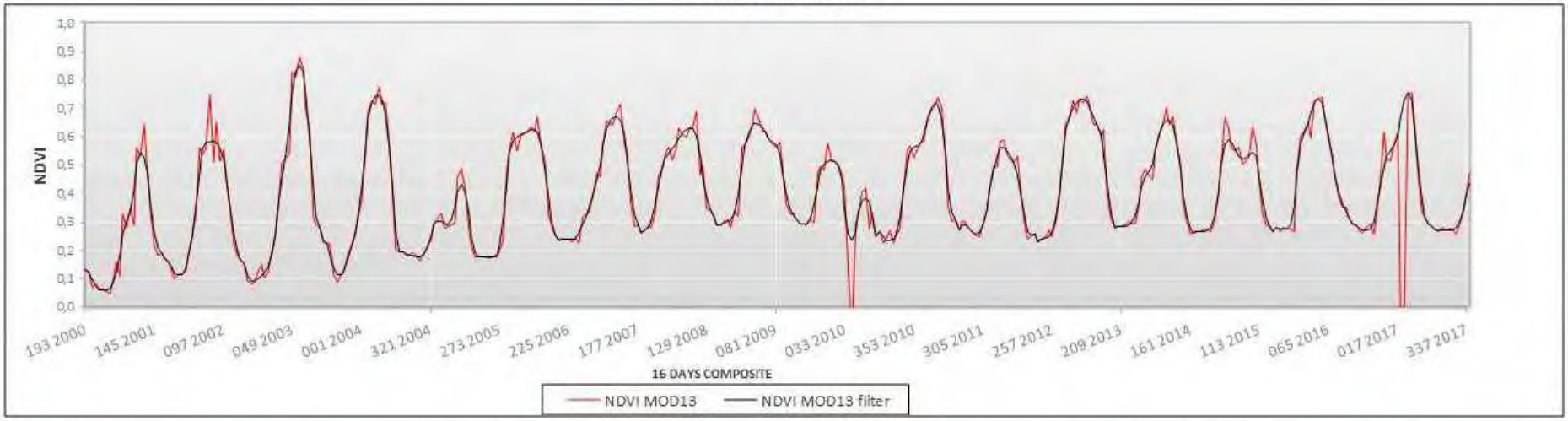
itd
medioambiente



CONSERVATION STATUS

N2K PROTECTED AREA DOÑANA NATIONAL PARK (ANDALUSIA-SOUTHERN SPAIN)

TEMPORAL PROFILE



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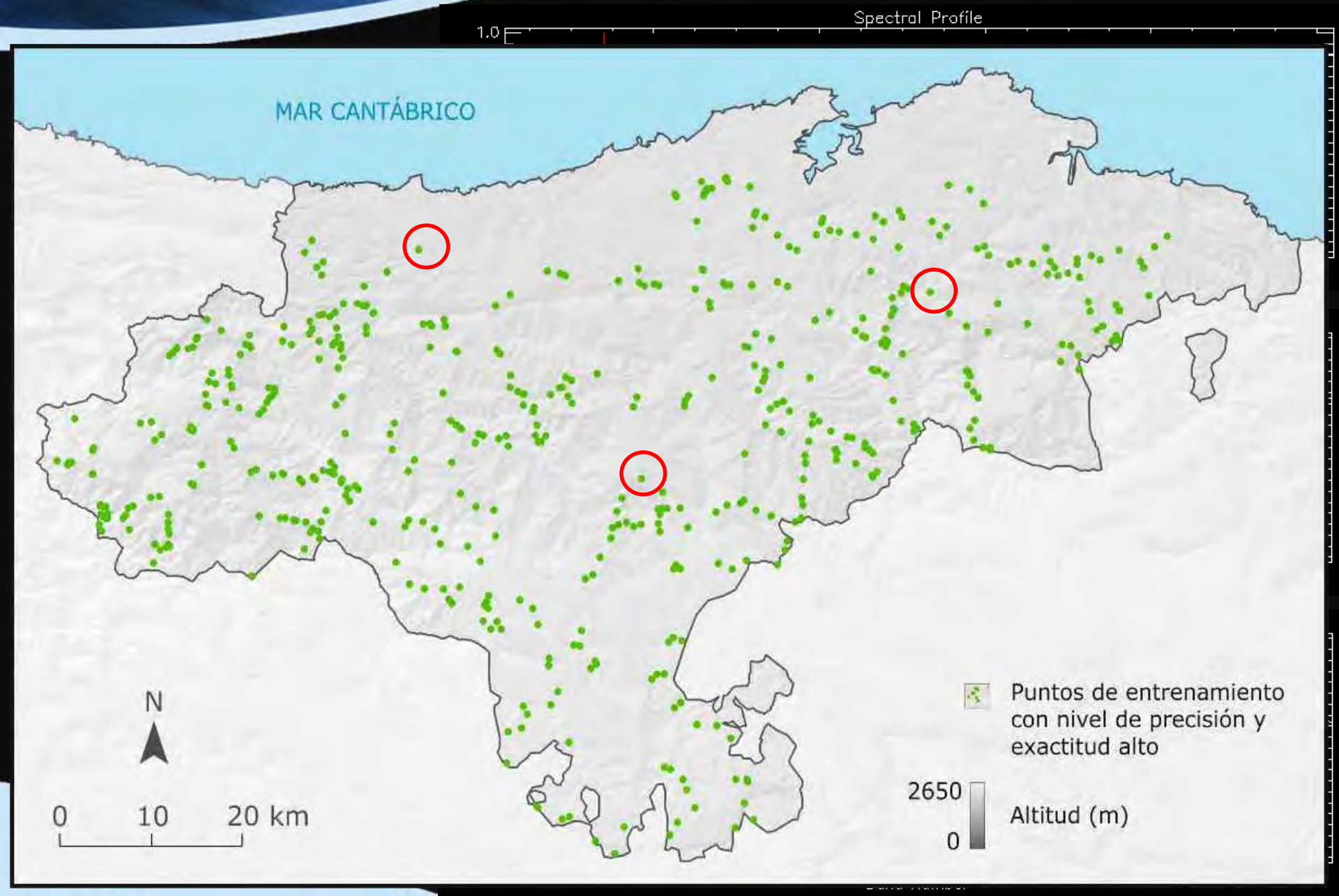
CONSERVATION STATUS



CONSERVATION STATUS

Area of Occupancy (AOO)

Estructural and functional indicators

Early warning system: identification of drivers and pressures

Common cost-effective indicators of Conservation Status through remote sensing

Non dependent of Member State data (validation!!!)

PASTURES

HABITAT	INDICATOR	VALUE	REMOTE SENSORS
6110, 6140, 6160, 6170, 6210, 6220, 6420, 6510,6520	Changes in surface by land use changes	FV: ↑ o =; U1: ↓1-5%; U2: ↓↓>5%	Y
	Relative cover of grasses	FV: >80%; U1: 60-80%; U2: < 60%	Y (LIDAR)
	Relative cover of shrubs	FV:< 15%; U1:15-30%; U2: >30%	Y (LIDAR)
	Increase of shrubs cover	FV:< 1; U1:1-5%; U2: >5%	
	Degradation of the soil (by erosion, compaction or other causes)	FV:<1%; U1:1-5%; U2: >5%	Y
	Height ofr grass		Y (LIDAR)
	flower richness		Y ?
	Primary productivity (EVI)	FV: >80% of reference U1: 60-80% of reference U2: < 60% of reference	
	Nitrophilous species (Peganum harmala, others)	FV:< 15%; U1:15-25%; U2: >25%	N
	Relative cover of chamaephytes/thorny	FV:< 15%; U1:15-25%; U2: >25%	N
6420	Wetland soil at a fixed depth		Y?

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FORESTS

INDICATOR	VALUE	REMOTE SENSORS	CONSIDERATIONS
Surface	A: ↑ o =; B: ↓1- 5%; C: ↓↓>5%	Y	Acceptable reduction according to degree of sufficiency
Size (Fragmentation)	A: >300 ha; M: 50-300 ha; B: <50%	Y	For the calculation, in the case other type of native forest contact the patch, it would be considered a continuous plot.
Distance to nearest patch (Fragmentation)	A: < 200 m; M: 200-500 m; B: >500m	Y	
Shape: Area/perimeter (Edge effect)		Y	For the calculation, in the case other type of native forest contact the patch, it would be considered a continuous plot.
Area discounting an internal buffer (Edge effect)	FV: relationship between surface without edge effect and total surface greater than 90%. U1: relationship between area without margin effect and total area less than 90% and greater than 80%. U2: relationship between surface without edge effect and total surface less than 80%.	Y	
Nº natives species of trees	A: >3; M:2; B:1	N	Variable values according to forest type
Canopy cover of native trees	A: >80; M: 50-80%; B: <50%	Y (LIDAR)	Variable values according to forest type
Understory cover	A: >50%; M:20-50%; B:<20%	Y (LIDAR)	Variable values according to forest type
Regenerate	A: >10%; M:5-10%; B:<5%	N	
Age of main species	A:irregular and + 10 trees > 70 cm (Ø); M:irregular and < 10 trees > 70 cm Ø; B: regular	N	
Old Trees	A: >10/ha; M:5-10/ha; B:<5/ha	N	
Dead wood (standing and on ground)	A: > 40 m3; M: 25-40 m3; B: <25 m3	N	
Defoliation	A: 0-10 % de defoliación o transparencia de la copa (árboles sano) M: 11-50 % de defoliación (árboles con daños leves o moderados) B: > 51% de defoliación (árboles con daños severos)	N	Study correlation with EVI
Human Print		Y	Density or afected area by forest trackss, roads, buildings, power lines, forets crops or any other intensive landuse
Distribution of trees	A:azar; M: azar; B:uniforme	N	

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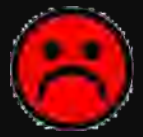
HABITAT MAPPING: SWOT


Good


Medium


Bad

(1) Could improve with photo-interpretation refinement of model outcomes
(2) This % could easily improve with further research and data

Whole TURKEY (example)	Traditional mapping system	Modelling
Economic cost	7.000.000 €	2.500.000 €
Time	5 years	2 years
Number of field-workers (2 years)	486	162
Resolution	< 1:50.000	< 1:50.000
Accuracy of mapping products	80-90%	70-80% (1)
% of habitats mapped	70%	70% (2)
Monitoring capabilities	Low, sampling	Real-time

GOBIERNO de CANTABRIA

¡Gracias!

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