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Assessing Loss of Biodiversity in Europe Through Remote Sensing: The Necessity of New Methodologies

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1. Introduction

There is a global consensus on the idea of the present loss of biodiversity is intimately linked with human development, and that the conservation and sustainable use of present biological diversity is paramount to current and future generations of all life on Earth (Duro et al. 2007).

The United Nation Convention on Biological Diversity (CBD, http://www. biodiv.org, last accessed May 2011) lays down that countries are responsible for conserving their biological diversity and for using their biological resources in a sustainable manner. It expands until 2020 with the global *Strategy Plan for Biodiversity 2011-2020 and the Aichi biodiversity targets* (http://www.cbd.int/2011-2020, last accessed May 2011) to promote effective implementation of the CDB and to stem biodiversity loss by 2020. It compels the contracting countries to develop scientific and technical capacities to provide the appropriate measures in order to prevent and halt the pace of biodiversity loss all around the world.

It was during 90s and 2000s when scientific community became conscious that habitat destruction is the most prominent driver of biodiversity loss (Dirzo and Raven 2003)and together with degradation and fragmentation represent the most important factors leading to worldwide species decline and extinction (Chhabra et al. 2006; Soule and Terborgh 1999).

To improve the current conservation efforts and draw new strategies around the commitments under the CBD, it is crucial that our progress is monitored (Pereira and Cooper 2006). Biodiversity monitoring should be focused on trends in the abundance and distribution of populations and habitat extent (Balmford et al. 2005) and be carried out at different scales, regional and global and even local (Pereira and Cooper 2006).

There are several biophysical features influence species distributions, population sizes and ranges like land cover, primary productivity, temporal vegetation dynamics, disturbance events or climate (Hansen et al. 2004). All of them could be used as biophysical predictors of biodiversity at different scales. Remote sensing has been shown to be effective in some extent to measure and mapping those indicators and it has become a powerful tool for ecological studies because it allows monitoring over significant areas (Kerr and Ostrovsky 2003).

Remote sensing technologies contribute to biodiversity monitoring both direct and indirectly and they have been intensively improved in the last two decades, especially since the beginning of 2000s when the very high spatial resolution sensors were launched. Medium spatial resolution images from sensors on satellites make especially available information related to biophysical factors. In this sense, Landsat TM and ETM+ sensors are widely used in ecological investigations and applications because they have several advantages)(Cohen and Goward 2004): 30m of spatial resolution that facilitates characterization of land cover and land cover change; measurements acquired in all major portions of the solar electromagnetic spectrum (visible, near-infrared, shortwave-infrared); more than 30 years of Earth imaging and a temporal resolution of 16 days makes possible a complete analysis of the dynamic of the ecosystem; moderate cost (actually, all Landsat data from the USGS_ U.S. Geological Survey_ archive are free since the end of 2008). Anyway, to some extent, indirect measures that rely on remote sensing of biophysical parameters are, especially for national-level analyses, not enough accurate when the aim is the analysis of some aspects of biodiversity.

In a direct way, hyperspatial and hyperspectral sensors potentially supply land elements like individual organisms, species assemblages or ecological communities. Finally, LIDAR and RADAR technologies make possible to map vegetation structure (Lefsky et al. 2002; Zhao et al. 2011). Direct measures of biodiversity are becoming feasible with this kind of sensors although processes are still expensive and time-consuming, at least to regional levels.

Then, through RS it is possible to estimate in some extent habitat loss and fragmentation and trends in natural populations. At global and regional level the keystone is how translating remote-sensing data products into real and accurate knowledge of habitats and species distributions and richness. Subsequently, at present it is recognized that remote sensing technologies are especially crucial for conservation-related science (Kerr and Ostrovsky 2003) but they are still challenging. In addition, what is finally missing are global and regional standards for developing methodologies so systematic monitoring can be carried out (Strand et al. 2007).

2. Land-cover versus habitat data

Land cover is the observed physical cover of the Earth's surface (bare rock, broadleaved forests, etc…) (Eurostat 2001). Land cover data are usually derived by using multispectral remotely sensed data and statistical clustering methods. Remotely-sensed land cover data have been used at different scales (local, regional and global) as: i) input variables in biosphere –atmosphere models simulating exchanges of energy and water between land surface and the atmosphere and in terrestrial ecosystem models simulating carbon dynamics at global scales; ii) input variables in terrestrial vegetation change assessments; iii) proxies of biodiversity distribution (DeFries 2008; Hansen et al. 2004; Thogmartin et al. 2004).

On the other hand, *habitat* is a three-dimensional spatial entity that comprises at least one interface between air, water and ground spaces, it includes both the physical environment and the communities of plants and animals that occupy it, it is a fractal entity in that its definition depends on the scale at which it is considered" (Blondel 1979). *Natural habitats* means terrestrial or aquatic areas distinguished by geographic, abiotic and biotic features, whether entirely natural or semi-natural (EU Habitats Directive, 92/43/EC). The identification of one habitat implies a holistic perspective and involves not only the expression of the vegetation (land cover) but also the species and other biophysical parameters like topography, aspect, soil characteristics, climate or water quality.

Blondel's definition of habitat was adopted in different habitat classifications at European level like CORINE Biotopes (Devillers et al. 1991), Classification of Paleartic Habitats (Devillers et al. 1992), the database PHYSIS of the Institut Royal des Sciences Naturelles de Belgique, or in the EUNIS program - *Habitat* of the European Environment Agency (EEA).

We can understand habitat monitoring as the repeated recording of the condition of habitats, habitat types or ecosystems of interest to identify or measure deviations from a fixed standard, target state or previous status (Hellawell 1991; Lengyel et al. 2008). Habitat monitoring has two attributes (Lengyel et al. 2008; Turner et al. 2003): i) it can cover large geographical areas, then it can be used to evaluate drivers of biodiversity change over different spatial and temporal scales; being specially interesting at regional scales; ii) it provides information on the status of characteristic species because many species are restricted to discrete habitats; then if the link between some key species and discrete habitat types has been previously established, habitat monitoring can be used as a proxy for simultaneous monitoring of several species.

Nature resources management and biological conservation assessments require spatially explicit environmental data that come from remote sensing or derived thematic layers. Most of these studies assume that the selected geospatial data are an effective representation of the ecological target (such as habitat) and provide an appropriate source of information to the objectives (McDermid et al. 2009). For example, biodiversity has been frequently studied indirectly through associations with land cover, which represents that mapping land cover has been often used as a surrogate for habitats (Foody 2008). The suitability of these assumptions is a current scientific concern and a dynamic research issue (Glenn and Ripple 2004; McDermid et al. 2009; Thogmartin et al. 2004).

Some studies (McDermid et al. 2009) have evaluated the suitability of general-purpose land cover classifications and compared to other data sources like vegetation inventory or specific-purpose maps: they show the constraints of general-purpose remote sensing land cover maps for explain wildlife habitat patterns and recommend the use of specific-purpose databases based on remote sensing along with field measurements. Then, traditional or general-purpose land cover maps may not be appropriate proxies of habitats, as we will show after assessing the suitability of the CORINE Land Cover product (European Environment Agency, http://www.eea.europa.eu/publications/COR0-landcover, last accessed May 2011) in Europe on this target (Section 4). Multi-purpose land cover maps meeting the needs of a large number of users but they are not specifically designed to represent the habitat of one/some key specie/-s. Furthermore, land-cover classifications used for wildlife habitat mapping and modeling must be appropriate spatial and thematic resolution to identify reliably the habitats that the target species potentially occupy (Kerr and Ostrovsky 2003).

Thus, the identification of habitats through remote sensing must be suited the characteristics of each habitat type, rather than follow general or standard images processing approaches. For example, binary and one-class classifiers have been used in the implementation of the European Union's Habitat Directive (Boyd et al. 2006; Foody 2008). Moreover, it should be based on *in situ* and ancillary measurements (Kerr and Ostrovsky 2003) and also on ecological expert knowledge that allow finding the relationship between key species and their potential habitats.

There are some ongoing challenges with this issue "*habitat monitoring*": the identification of the habitats as ecological units and not simply as land covers and the assessment and quantification of habitats degradation and fragmentation. Currently, one of the main scientific challenges and one of the big issues are if we are able to identify proper and accurately habitats from remote sensing at landscape level: the mapping and monitoring of the territory in terms of its habitats. We have to say not yet, at least not only with remote sensing technologies and with an adequate budget and an optimal time. We also need ancillary information, ecological expert knowledge, field work and other auxiliary tools like landscape ecology indices.

3. European efforts for habitats mapping and monitoring

There are different scientific and legislative agreements that define habitats in Europe (Groom et al. 2006). The European Union's Habitats Directive since 1992 sets the rules in Europe for developing a coherent ecological network, called *Natura 2000,* which is the centerpiece of the EU nature and biodiversity policy (http://ec.europa.eu/environment/nature/natura2000/index_en.htm, last accessed May 2011). The aim of the network is to assure the long-term survival of Europe's most valuable and threatened species and habitats. It is comprised of Special Areas of Conservation (SAC) designated by Member States under the Habitats Directive, and also incorporates Special Protection Areas (SPA) designed under the Birds Directive (Directive 2009/147/EC)). Habitats Directive describes two kind of habitat, from the viewpoint of their conservation status (See Annex 1 of the Directive): i) *natural habitat types of Community interest*, habitat types in danger of disappearance and whose natural range mainly falls within the territory of the European Union; ii) *priority natural habitat types*, for the conservation of which the Community has particular responsibility (Appendix 1, Table 13). The establishment of this network of protected areas also fulfills a Community obligation under the UN Convention on Biological Diversity.

The characteristics and identification of the different habitat types included in the Habitats Directive were firstly described in the Manuel d'Interprétation des Habitats de l'Union Européenne -EUR 15/2 that has been revised several times from 1999 until the present (http://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm#interpretation, last accessed May 2011). The manual enhances that habitat interpretation should be flexible and revised especially in regions with fragmented landscapes that has also a high anthropic influence. Consequently many European regions have developed their own handbooks for the interpretation of the habitats at regional level (Ramil Rego et al. 2008) (Italy: http://vnr.unipg.it/habitat/; France: http://natura2000.environnement.gouv.fr/habitats/cahiers.html; last accessed May 2011) and their own methodologies for habitats mapping and monitoring (Izco Sevillano and Ramil Rego 2001; Jackson and McLeod 2000). At present various methodologies are being used with different fieldwork efforts and levels of complexity and, in some cases, with critical limitations for appropriate and accurate monitoring.

The 2020 EU Biodiversity Strategy (http://www.consilium.europa.eu/uedocs/cms_Data/docs/pressdata/en/ec/113591.pdf, last accessed May 2011), urges countries to conserving and restoring nature. Countries are responsible of the habitats and species conservation and they must adopt measures to promote it and report about repercussions of this measures on their conservation status. The target 1 of the strategy lay down "*To halt the deterioration in the status of all species and habitats covered by EU nature legislation and achieve a significant and measurable improvement in their status so that, by2020, compared to current assessments: (i) 100% more habitat assessments and 50% more species assessments under the Habitats Directive show an improved conservation status; and (ii) 50% more species assessments under the Birds Directive show a secure or improved status*". Indirectly it requires the development of methodologies to get this goal in an appropriate and accurate way. Any loss of protected habitats must be compensated for by restoration or new assignations with the same ecological value and surface area.

Through its 17th Article, Habitat Directive forces countries to monitor habitat changes every six years and to assess and report to the European Union on the conservation status of the habitats and wild flora and fauna species of Community interest: the mapping of the distribution area, the trends, the preservation of their structure and functions together with the future perspectives and an overall assessment.

Then, to meet the requirements of global and regional biodiversity targets such as the *Strategy Plan for Biodiversity 2011-2020 and the Aichi biodiversity targets, the 2020 EU Biodiversity Strategy* or the European *Natura 2000* Network, the development of more cost and time effective monitoring strategies are mandatory (Bock et al. 2005).

At the moment, the first habitats reports were submitted in electronic format to the European Environmental Agency (www.eunis.eea.europa.eu, last accessed May 2011) (EEA) until March 2008, through an electronic platform on the Internet. This platform is managed by the EEA and the European Environment Information and Observation Network (EIONET) (http://bd.eionet.europa.eu/, last accessed May 2011). Currently, this information was supplied by 25 of the 27 countries that currently comprise the European Union (all except Bulgaria and Romania).

We have developed a map (Figure 1) about the distribution of habitats of Community interest derived from this information. The data were compiled, refined and standardized in

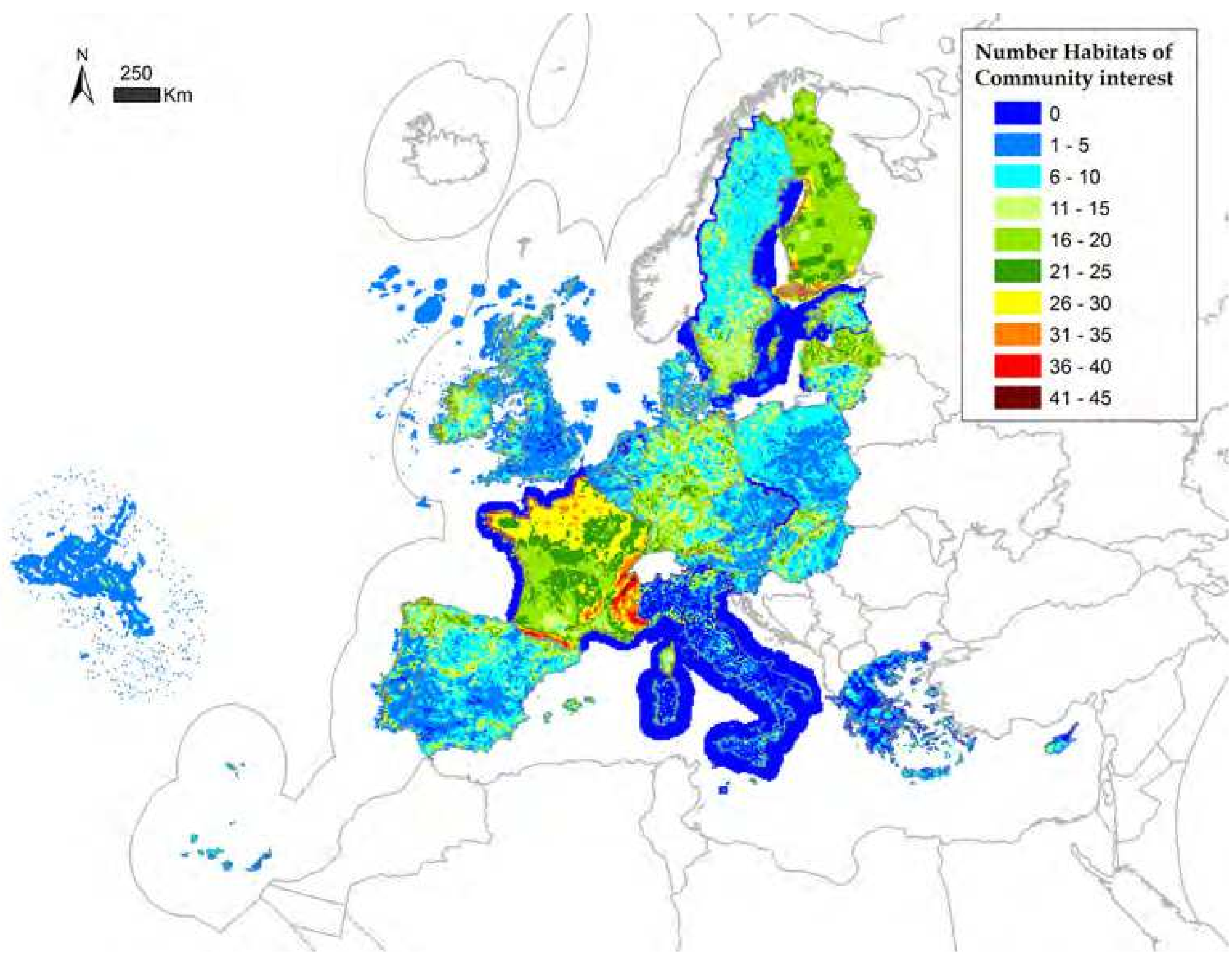

Fig. 1. Distribution of habitats of Community interest in Europe (Source: Developed from EIONET 2011)

a database using the *ETRS 1989 Lambert azimuthal equal-area* projection system (following INSPIRE Directive). All the spatial data of the habitats of Community interest, derived from each country, were harmonized and represented in a 10 km^2 UTM grid (Universal Transverse Mercator Projection) following the recommendations of the European Commission (EuropeanCommission 2006). The output map follows the EUNIS (European Nature Information System) classification system and represents finally all the European habitats of Community interest.

The EUNIS system constitutes a pan-European classification proposed by the EEA (www.eunis.eea.europa.eu, last accessed May 2011). It is developed and managed by the European Topic Centre for Nature Protection and Biodiversity (ETC/NPB in Paris), and covers the whole of the European land and sea area, i.e. the European mainland as far east as the Ural Mountains, including offshore islands (Cyprus; Iceland but not Greenland), and the archipelagos of the European Union Member States (Canary Islands, Madeira and the Azores), Anatolian Turkey and the Caucasus (Davies et al. 2004). It represents a common classification scheme for the whole of European Union, as it is compatible with the units of protection established in the strategy of *Natura 2000*-protected areas. It covers all types of habitats from natural to artificial, from terrestrial to freshwater and marine. EUNIS is also cross-comparable with CORINE Land Cover (Bock et al. 2005; Moss and Davies 2002) (Appendix 1, Table11).

4. The CORINE land cover map as a proxy of biodiversity: difficulties and constraints

The *CORINE land cover* project (EEA, 1999, http://www.eea.europa.eu/publications/COR0-landcover, last accessed May 2011) constitutes the first harmonized European land cover classification system, based on photo-interpretation of Landsat images. The minimum unit for inventory is 25 ha and the minimum width of units is 100m. Only area elements (polygons) are identified. Areas smaller than 25 ha are allowed in the national land cover database as additional thematic layers, but should be generalized in the European database. The CORINE land cover (CLC) nomenclature is hierarchical and distinguishes 44 classes at the third level, 15 classes at the second level and 5 classes at the first level. Third level is mandatory although additional national levels can be mapped but should be aggregated to level 3 for the European data integration. Any unclassified areas appear in the final version of the dataset (See CLC Legend in Appendix 1, Table 12).

Because of general land cover maps may not be suitable proxies of habitat maps, we have analyzed the spatial inconsistencies between a remote-sensed land cover map (CORINE Land Cover 2000) and some selected habitats of the map obtained from EIONET (Figure 1) which represents the spatial distribution of the natural and semi-natural habitats in the European Community. CORINE Land Cover is cross-comparable with habitats of Community interest (Council Directive 92/43/EEC) through the EUNIS system (www.eunis.eea.europa.eu, last accessed May 2011) (Tables 1 and 2). The comparative analysis was done using a 10 km^2 UTM grid which is the base of the EIONET map. Spatial gaps and contradictions that arise between both sources, when land cover maps are used to assess biodiversity status, were evaluated through the analysis of coincidences at the cells of the grid between both databases.

The CORINE Land Cover (CLC) map was analyzed and compared at the third level in the European context and at the fifth level at the scale of Spain (Table 3 and 4). Following

Corine Land Cover codes (3rd level)	Correlation with habitat of Community interest
311	9120 9180* 91E0* 91F0 9230 9330 9340 9380
312	9410
321	6170 6410 6510
322	4020* 4030 5130
323	5130
331	2120 2130*
332	8130 8220
411	7230
412	7110* 7120 7130*
421	1310
423	1140
511	3260 3270
512	3150
521	1150*
522	1130

[*], Priority natural habitat types as Habitats of the Council Directive 92/43/EEC

Table 1. Correspondences between Corine Land Cover classification (3rd level) and habitats of Community interest

Corine Land Cover codes (5th level)														
31110	**31120**	**31150**	**31210**	**32100**	**32110**	**32111**	**32111**	**32112**	**32120**	**32121**	**32122**	**32210**	**32312**	**33110**
Correlation with habitat of Community interest														
9330 9340 9380	9120 9180* 9230	91E0* 91F0	9410	6510	6410	6170 6410	6170 6410	6170 6410	6410 6510	6410 6510	6410 6510	4020* 4030 5130	5130	2120 2130*
Corine Land Cover codes (5th level)														
33210	33220	41100	41200	42100	42300	51110	51210	52100	52200					
Correlation with habitat of Community interest														
8130	8220	7230	7110* 7120 7130*	1310	1140	3260 3270	3150	1150*	1130					
[*], Priority natural habitat types as Habitats of the Council Directive 92/43/EEC														

Table 2. Correspondences between Corine Land Cover classification (5th level) and habitats of Community interest

similarities with a gap analysis (Jennings 2000; Scott et al. 1993), spatially explicit correlations was carried out and five thresholds representing the grade of inconsistency between both maps were set: i) less than 10% of coincidences represent a **total gap**; ii) coincidences between 10-30%, **very high gap**; iii) coincidences between 30-50%, **high gap**; iv) coincidences between 50-90%, **moderate gap**; v) coincidences upper 90% represent **no gap**.

At European level (Table 3), and by countries, some relevant habitats showed:

- *Habitat 2130* and 2120* (correspondence with CLC 331 class BEACHES, DUNES AND SAND PLAINS): at European level it shows a moderate gap. By countries: TOTAL GAP in Finland; VERY HIGH GAP in Denmark; HIGH GAP in UK and Sweden. Netherlands, Lithuania y Latvia present a right correspondence.
- *Habitat 1150** (correspondence with CLC 521 class COASTAL LAGOONS): at global level it shows a very high gap. By countries: TOTAL GAP in Cyprus, Slovenia, Finland, Ireland, Latvia, Malta and UK (Null values Cyprus, Finland, Latvia and Malta); VERY HIGH GAP in Denmark, Spain, Estonia, Portugal y Sweden; HIGH GAP in Italy, France, and Germany. Only Lithuania presents a right correspondence. It is important to note and comment on null values in Finland, Cyprus, Slovenia, Latvia and Malta.
- *Habitat 1130* (correspondence with CLC 522 class ESTUARIES): at European level it shows a high gap. By countries: TOTAL GAP in Denmark, Slovenia, Estonia, Finland, Italy, Lithuania and Poland; VERY HIGH GAP in Sweden and Greece; HIGH GAP in Germany, France, Ireland and UK; only Portugal shows a right correspondence. It is important to note and comment on null values in Denmark, Slovenia, Estonia, Lithuania and Poland.
- *Habitat 4020** (correspondence with CLC 322 class MOORS and HEATHLANDS): at European level it shows a high gap. By countries: VERY HIGH GAP in France; MODERATE GAP in Spain and Portugal; right correspondence in UK.
- *Habitat 7110** (correspondence with CLC 412 class PEATBOGS): at European level it shows a high gap. By countries: TOTAL GAP in Slovakia, Slovenia, Spain, France, Hungary, Italy, Poland and Portugal; VERY HIGH GAP in Austria, Netherlands, Czech Republic; HIGH GAP in Belgium, Latvia and UK; right correspondence in Ireland. They are serious inconsistencies (represented by null values) in Portugal, Hungary, Italy and Slovenia.
- *Habitat 7130* (correspondence with CLC 412 class PEATBOGS): at European level it shows a moderate gap. By countries: TOTAL GAP in Spain, France and Portugal (France and Portugal with null values); MODERATE GAP in UK; right correspondence in Sweden and Ireland.
- *Habitat 9180** (correspondence with CLC 311 class BROAD-LEAVED FORESTS): at European level it shows a moderate gap. By countries: VERY HIGH GAP in Finland; HIGH GAP in Austria; right correspondence in Poland, Luxemburg, Hungary, Lithuania, Italy, Greece, France, Estonia, Spain, Slovenia, Slovakia and Belgium.
- *Habitat 91E0** (correspondence with CLC 311 class BROAD-LEAVED FORESTS): at European level it shows a moderate gap. By countries: HIGH GAP in Austria; right correspondence in Poland, Luxembourg, Hungary, Lithuania, Greece, France, Estonia Spain, Slovenia and Slovakia.

At European level, the type of habitats (among the evaluated set) with a worse representation on CLC map are coastal lagoons (1150*), mires and bogs (7110*, 7120, 7230), water courses (3260 and 3270), heaths (4020* and 4030), *Molinia* and lowland hay meadows (6410 and 6510) and siliceous rocky slopes (8220). The different types of broadleaved forests show an acceptable representation, although a very important question is that CLC does not

HAB	COUNTRIES																							
	BE	CZ	DK	DE	EE	IE	EL	ES	FR	IT	CY	LV	LT	LU	HU	MT	NL	AT	PL	PT	SL	SK	FI	SE	UK
1130	57,38	-	0,00	28,99	0,00	34,44	13,64	37,93	41,38	5,00	-	-	0,00	-	-	-	70,59	-	0,00	56,45	0,00	-	1,45	13,19	43,28
1140	78,26	-	42,86	63,57	0,00	62,50	0,00	25,64	94,09	0,00	-	-	-	-	-	-	84,75	-	-	2,63	0,00	-	-	0,00	57,67
1150*	-	-	24,72	44,71	17,39	6,45	55,81	17,24	41,38	48,84	0,00	0,00	100,00	-	-	0,00	-	-	50,00	15,15	0,00	-	0,00	14,72	2,01
1310	21,74	-	-	72,94	4,35	19,83	53,16	30,45	43,57	44,30	25,00	6,25	-	-	-	0,00	57,89	-	0,00	64,79	33,33	-	-	2,78	41,33
2120	79,17	-	-	62,82	66,10	72,90	38,57	73,13	62,09	58,42	-	98,00	100,00	-	-	-	100,00	-	77,27	93,18	-	-	4,92	32,26	49,30
2130*	72,00	-	32,88	60,47	66,10	73,87	-	72,92	60,09	63,64	-	95,83	100,00	-	-	-	92,00	-	62,96	81,91	-	-	5,68	32,26	43,51
3150	22,22	45,83	26,34	41,83	92,31	82,35	52,38	20,74	27,16	39,29	50,00	55,59	100,00	-	58,11	-	73,57	22,42	71,43	28,72	54,55	46,05	68,36	92,37	62,03
3260	7,53	-	-	12,89	7,58	8,96	22,22	7,63	10,83	26,42	-	11,76	18,75	-	16,79	-	33,80	30,65	7,94	6,52	56,14	36,17	12,56	17,97	2,81
3270	41,38	-	-	65,56	-	40,00	-	14,98	11,82	24,24	-	30,93	84,62	-	73,18	-	100,00	68,97	52,35	38,57	56,25	50,00	-	-	-
4020*	-	-	-	-	-	-	-	88,05	19,26	-	-	-	-	-	-	-	-	-	-	61,36	-	-	-	-	100,00
4030	18,94	-	49,01	12,96	28,57	18,19	-	91,12	22,19	16,67	-	-	9,33	0,00	0,00	-	66,45	8,70	0,11	64,79	-	4,55	10,03	3,30	81,51
5130	5,77	-	-	13,92	61,62	31,91	-	100,00	23,81	31,79	-	0,00	9,09	0,00	0,00	-	79,49	55,56	14,29	-	14,71	6,12	-	4,78	81,08
6170	-	-	-	91,07	-	-	88,31	84,89	94,64	97,98	-	-	-	-	-	-	-	87,27	83,33	-	84,85	83,33	-	82,34	91,14
6410	0,55	-	31,31	29,48	65,63	36,39	-	72,44	10,61	70,50	-	14,74	1,62	0,00	41,83	-	3,17	40,58	2,01	64,89	37,25	32,50	0,00	3,15	64,86
6510	1,15	-	-	23,39	58,04	61,90	50,00	78,31	9,93	73,49	-	10,16	2,41	5,71	36,20	-	16,67	35,06	4,76	89,47	45,07	20,32	0,00	1,71	15,93
7110*	47,73	24,36	50,00	61,36	78,74	100,00	-	0,74	1,86	0,00	-	42,00	75,68	-	0,00	-	16,22	13,92	7,01	0,00	0,00	4,17	65,77	81,95	43,46
7120	37,14	40,43	65,63	54,31	85,45	97,01	-		1,78	0,00	-	42,00	76,00	-	-	-	61,54	16,88	6,10	0,00	-	10,00	62,10	84,62	43,46
7130	-	-	-	-	-	96,74	-	6,58	0,00	-	-	-	-	-	-	-	-	-	-	0,00	-	-	-	100,00	57,00
7230	13,33	6,38	42,29	25,52	67,15	31,46	0,00	4,46	10,29	4,62	-	31,51	45,57	0,00	59,33	-	11,76	14,47	27,35	-	18,75	4,84	5,63	16,11	3,31
8130	-	-	-	-	-	-	-	39,59	51,38	34,15	-	-	0,00	-	-	-	-	66,67	-	26,32	-	-	-	-	-
8220	0,00	0,45	-	0,88	0,00	7,46	0,00	21,24	10,52	58,55	6,67	0,00	0,00	-	0,00	-	-	28,79	0,00	18,78	78,95	11,11	2,71	48,85	55,93
9120	59,77	-	-	98,08	-	-	-	99,69	94,98	-	-	-	-	-	-	-	78,26	-	-	-	-	-	-	-	98,80
9180*	95,06	-	-	85,87	100,00	-	100,00	97,96	95,00	93,08	-	83,83	98,97	100,00	100,00	-	-	47,01	93,41	-	96,00	93,66	27,12	88,26	81,51
91E0*	66,81	-	85,53	83,75	97,62	60,73	100,00	90,75	95,00	88,45	-	83,83	97,95	96,77	98,54	-	76,79	44,05	92,31	83,33	100,00	92,93	56,51	70,57	87,95
91F0	85,71	-	-	91,97	100,00	-	58,82	76,92	99,10	86,21	-	83,83	100,00	-	99,68	-	62,50	75,72	96,75	68,42	100,00	99,05	-	100,00	-
9230	-	-	-	-	-	-	-	91,19	94,43	-	-	-	-	-	-	-	-	-	-	87,37	-	-	-	-	-
9330	-	-	-	-	-	-	-	92,33	91,54	91,11	-	-	-	-	-	-	-	-	-	91,62	-	-	-	-	-
9340	-	-	-	-	-	-	65,71	76,74	89,88	86,76	-	-	-	-	-	0,00	-	-	-	93,09	100,00	-	-	-	-
9380	-	-	-	-	-	-	100,00	98,77	96,02	100,00	-	-	-	-	-	-	-	-	-	87,50	-	-	-	-	-
9410	-	-	-	100,00	-	-	100,00	-	95,60	99,21	-	-	-	-	-	-	-	97,12	94,74	-	100,00	100,00	-	-	-

Countries: Belgium [BE], Czech Republic [CZ], Denmark [DK], Germany [DE], Estonia [EE], Ireland [IE], Greece [EL], Spain [ES], France [FR], Italy [IT], Cyprus [CY], Latvia [LV], Lithuania [LT], Luxembourg [LU], Hungary [HU], Malta [MT], Netherlands [NL], Austria [AT], Poland [PL], Portugal [PT], Slovenia [SL], Slovakia [SK], Finland [FI], Sweden [SE], United Kingdom [UK]

HAB: Annex I Habitats of the Council Directive 92/43/EEC of 21 May 1992, on the conservation of natural habitats and of wild fauna and flora (Table 13, Appendix 1)

Total gap: less than 10% of coincidences
Moderate gap: coincidences between 50-90%
Very high gap: coincidences between 10-30 %
No gap: coincidences upper 90%
High gap: coincidences between 30-50%

Table 3. Spatial correlations between Corine Land Cover cartography (3rd level) and CD 92/43/EEC habitats cartography in the EU Countries (units in percentage)

identify differences between forest compositions, i.e. the correspondence at the third level is with the broad CLC 311 class (broad-leaved forests) (Table1). Similar situation occurs with many other habitats like dunes whose correspondence is with CLC 331 class *Beaches, dunes and sand plains*, or alluvial forests.
This constrains many possibilities in the use of CLC at the third level to monitor biodiversity. For instance, the CLC 311 class (Broad-leaved forests) could correspond to *Eucalyptus globulus* or any native broad-leaved forests as *Quercus robur*, both phenomena with very different implications for biodiversity (Pereira and Cooper 2006).
Also, the finer the nomenclature detail, the worse the spatial correlations are. As the scale is finer and CLC is considered at 5th level (for example at Spain level) results get worse and inconsistencies increase.
At Spain level (Table 4) and using a 10km grid results show:

- TOTAL GAP: water courses (3260), mires and bogs (7110*, 7120, 7130, 7230) and alluvial forests (91E0*).
- VERY HIGH GAP: sandflats and coastal lagoons (1140, 1150*), lakes and water courses (3150, 3270), alpine calcareous grasslands (6170), rocky habitats (8130, 8220) and forests of *Ilex aquifolium* (9380).
- HIGH GAP: estuaries (1130), salt marshes (1310) and dry heaths (4030).
- MODERATE GAP: dunes (2120, 2130*), *Molinia* and lowland hay meadows (6410, 6510), woolands of *Quercus spp*. (9230, 9330, 9340).
- GOOD CORRELATION: sclerophyllous scrubs (5130), atlantic forests (9120, 9180*).

HAB	CLC	HAB	CLC
1130	37,93	7110*	0,74
1140	25,64	7120	0,00
1150*	18,39	7130	6,58
1310	31,82	7230	4,46
2120	72,50	8130	16,30
2130*	71,88	8220	17,31
3150	14,74	9120	98,44
3260	8,75	9180*	91,84
3270	17,51	91E0*	8,79
		9230	77,98
4020*	60,90	9330	72,79
4030	45,53	9340	58,21
		9380	19,63
5130	100,00		
6170	22,81		
6410	70,00		
6510	71,93		

Red	**Total gap**: less than 10% of coincidences
Orange	**Very high gap**: coincidences between 10-30 %
Yellow	**High gap**: coincidences between 30-50%
Green	**Moderate gap**: coincidences between 50-90%
Blue	**No gap**: coincidences upper 90%

Table 4. Spatial correlations between Corine Land Cover cartography (5th level) and CD 92/43/EEC habitats cartography in Spain (units in percentage)

It is relevant that at Spain level CLC map shows important inconsistencies with bogs and mires (7110*, 7120, 7130, 7230), water courses (3260), alluvial forests (91E0*) or coastal lagoons (1150*).

Total, very high and high gaps should be considered as important inconsistencies which enhance the limited capacity of the CLC map for representing natural and semi-natural habitats and reveal the inappropriate use of the CLC map as a biodiversity proxy, both at European and regional level. In some cases gaps can be explained because of the CLC methodology which makes not possible to identify habitats with less than 25ha or linear features below 100m in width. Also, discrepancies among countries could be attributed to differences among the skills and expert knowledge of image interpreters.

Then, though theoretically possible (Groom et al. 2006; Hansen et al. 2004), the use of some components of the complex habitat entity, such land covers, as a surrogate parameter of a particular habitat is uncertain and it should be previously evaluated.

5. Different approaches on the habitat identification through RS in the context of Europe

The lack of a simple and direct relationship between habitats and any biophysical feature detected by RS restricts the possibilities for automated image classification processes to habitat identification. In this sense, the current wide range of remote sensing techniques and products have supported many suggestions at different scales and using different approaches. The rationale underlying for all of them is the idea of selecting key variables and algorithms to the identification of the habitat entity, integrating knowledge from ancillary data sources. Some of these approaches are mentioned and briefly described in the next paragraphs. Also we propose a new methodology (based on a previous model proposed in Martinez et al., 2010(Martínez et al. 2010)) which presents some key concepts to be consider in a future standardized process.

5.1 Decision rules implemented through a Geographical Information System (GIS): the example of the European PEENHAB project (Mücher et al. 2004; Mücher et al. 2009)

The overall objective of the European PEENHAB project was to develop a methodology to identify spatially all major habitats in Europe according to the Annex I of the Habitats Directive (231 habitats, (EuropeanCommission 2007). This should result in a European Habitat Map with a spatial scale of 1: 2,5M and a minimum mapping unit of 100km^2 with a minimum width of 2,5km. It was expected that this European Habitat Map was the main data layer in the design of the Pan-European Ecological Network (PEEN), which is widely recognized as an important policy initiative in support of protected *Natura 2000* sites.

PEENHAB proposed a new methodology to allow the spatial identification of individual habitats to European scale, based on specific expert knowledge and the design of decision rules on the basis of their description in Annex I. Habitats were identified by a combination of spatial data layers implemented in a GIS decision rule. The methodology was implemented following five steps: i) the selection of appropriate spatial data sets; ii) the definition of knowledge rules using the descriptions of Annex I habitats; iii) the use of additional ecological expert knowledge; iv) the implementation of the models for the individual habitats; v) validation (Mücher et al. 2009).

The spatial datasets used as ancillary data were: CORINE land cover database, biogeographic regions, distribution maps of individual plant species, digital elevation models, soil databases and other geographic and topographic data.

For example, for the Annex I habitat "Calcareous Beech Forest (code 9150)", first a rule was defined that selects the broadleaf forests from the CORINE land cover database, then a second rule was used to select the beech distribution map from the Atlas Florae Europaeae, and a third rule identified the calcareous soils from the European soil database. The combination of these three filters will form the decision rule that delimitates the spatial extension of calcareous beech forest.
The main advantage of this approach is the suggestion of using specific knowledge, implemented as a GIS decision rule, to identify individual habitat maps as they are described in Annex I of Habitats Directive. The approach use remote sensing data in an indirect way (through the use of CORINE land cover and other input variables) along with other suitable ancillary data. Results are appropriate at European scale in order to set guidelines for the strategic design of the Pan-European Ecological Network.

5.2 Object oriented approaches (Bock et al. 2005; Díaz Varela et al. 2008)

Bock et al. (2005) have proposed an object-oriented approach for EUNIS habitat mapping using remote sensing data at multiple scales with good results. The approach performs well when applied to high resolution satellite data (Landsat 30m) for the production of habitat maps at regional level with coarse thematic resolution; also it performs extremely well when applied to very high spatial resolution data (Quickbird 0,7m) for the production of local scale maps with fine thematic resolution.
The use of a multi-scale segmentation (implemented in the software package eCognition, Definiens, http://www.definiens.com) allow for the accurate classification of habitat types, which occur at different scales: for example, large-scale woodland habitat can be detected at coarser segmentation levels, while small-scale habitats such as woodland corridors can be detected at finer segmentation levels.
The main advantages of the object-oriented approaches to habitats mapping are: i) the ability to integrate ancillary data into the classification processes, related to shape, texture, context, etc.; ii) the option of developing knowledge-based rules in the classification process. Both questions make especially possible the accurate identification of habitats with similar spectral properties. Some results that show the advantage of these issues are (Bock et al. 2005): i) the effective separation of different grassland types like calcareous and mesotrophic grassland habitats to a high degree of accuracy through the use of geological data; ii) the use of multi-temporal remote sensing data to distinguish among arable lands, manage grasslands and semi-natural habitats.

5.3 The use of binary classifications by decision trees (DT) (Boyd et al. 2006; Foody et al. 2007; Franklin et al. 2002; Franklin et al. 2001)

Some studies have shown binary classifications as one of the more appropriate methods to identify habitats in the territory. Binary classifications can be implemented by non-parametric Decision Trees (DT) algorithms. Some of these studies have focused on the mapping of one specific thematic class (Boyd et al. 2006; Foody et al. 2007) hypothesizing that non-parametric algorithm would be more suitable to habitats of conservation interest because of the scarce spatial distribution usually associated to them (the size of the training sample will be smaller). Other studies have combined that kind of techniques (binary classifications by DT) in hybrid approaches (Franklin et al. 2001). The hybrid approaches assumes that parametric algorithms like standard maximum likelihood (ML) are the best option with spectrally different habitats while applies non-parametric algorithms to other complex habitats, in a so-called Integrated Decision Tree Approach (IDTA). The IDTA (Franklin et al. 2001) consist on a process with a simple set of classification decision steps, readily understood and repeatable. The approach allows mixing unsupervised, supervised and stratification decision rules such that requirements for training data were minimized.

The general advantages of this kind of approaches are: i) those linked to the use of non-parametric algorithms (Tso and Mather 2009), for example less restrictions with the size of the training sample; ii) the use of key input variables combined with key algorithms defined following specific characteristics of individual habitats; iii) The use of a type of geospatial input data (nominal, ordinal, interval or ratio data like forest inventory maps, biophysical and derived maps) that are difficult to incorporate into a statistical classifier.

5.4 New model based on the identification of ecological-units and on the selection of habitat-key variables (Advances from Martinez et al., 2010)

The methodology proposed in this model is summarized in Figure 2. The approach includes two main steps: the adaptation of an international classification scheme and the generation of *ecological unit* maps. The concept of *ecological unit* goes farther than land cover notion: through ecological expert knowledge it is possible identify in the study area ecological units directly related to Annex I habitats (Table5). Each ecological unit is linked to a distinctive set of characteristic habitats through ecological expert knowledge. Consequently, the system allows identifying and assessing the habitats listed in Annex I of Habitats Directive 92/43/EC through the identification of land covers by remote sensing.

Ecologically significant units of analysis were defined (Table 5), based on the *EUNIS* pan-European classification proposed by the EEA and the CORINE Biotopes System of Classification (www.eea.europa.eu, last accessed, May 2011). By using these systems, the approach can be applicable to other European regions and it will produce cross-comparable results.

The generation of *ecological unit* mapping is based on the selection of key input variables (spectral, derived and ancillary variables) as a function of the main characteristics of the target habitats and on the use of a standard maximum likelihood classification (MLC) algorithm (Swain and Davis 1978). The target habitats are those defined in the Annex I of the Habitats Directive for the Atlantic Biogeographical Region. Because of the *not direct* correspondence between spectral classes and habitat types, we propose the combination of ecological expert knowledge to find the relationship between both of them (step 1) along with the selection of suitable input variables (step 2) in order to achieve the best possible classification of habitats.

The study area was the Biosphere Reserve of *Terras do Miño* in the Northwest of Iberian Peninsula (Figure 3).The classification process was undertaken by the use of multi-temporal Landsat ETM+ images and ancillary data.

Input variables were rectified to the Universal Transverse Mercator Projection (UTM 29T) using the European Datum 1950 (ED50) and resampled to 30m grid size. Training samples were taken by fieldwork. They were located with a global positioning system (GPS) differential receiver. Training sites were selected as to be large and representative enough to characterize each target class and provide efficient and unbiased estimators using stratified sampling. At least 50 additional points per ecological unit were surveyed on the field for results assessment. These data were not used in the training process.

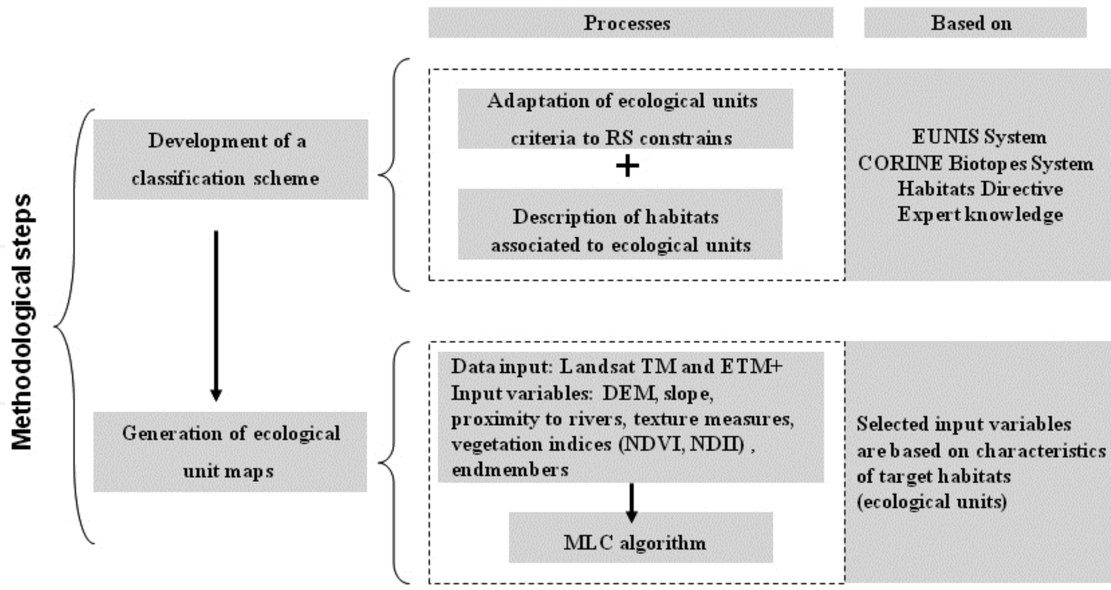

Fig. 2. Flowchart of the methodological steps for the model applied to Biosphere Reserve *Terras do Miño*

Early spring (March 26, 2002), late spring (May 26, 2001) and summer (August 17, 2002) images were selected for this model to account for the seasonal trends in vegetation communities. Images were geometrically registered using ground control points (GCP), first order transformations and nearest neighbor interpolation. The August 2002 image was geo-referenced to 1/25,000 digital maps, produced by the National Geographical Institute of Spain and used as a reference for geometrical correction of the other images. Atmospheric correction was based on the dark-object technique proposed by Chavez(Chavez 1996). Correction for effects of ground slope and topographic orientation was computed using the Lambertian cosine method initially proposed by Teillet et al. (Teillet et al. 1982) and later modified by Civco (Civco 1989). To model illumination conditions a Digital Elevation Model (DEM) was generated using contour lines from 1/5000 digital cartography. The thermal band was not included in the classification processes.

It was hypothesized that derived and ancillary variables would provide critical information for landscape classification and enable the identification of complex habitats. For example, topographic features and vicinity to fluvial corridors have an important influence on the distribution of natural and semi-natural habitats; therefore, the discrimination of this type of habitats should be favored by those variables.

The input dataset for classification processes included satellite derived variables (reflectance, vegetation indices, texture measures and spectral mixture analysis) along with continuous ancillary data. Reflectance bands were included using principal components transform (Mather 2004) in order to reduce the dimensionality of the dataset and optimize the number of training samples. Vegetation indices were: NDVI (Normalized Difference Vegetation Index) (Rouse et al. 1974) and NDII (Normalized Difference Infrared Index; using Landsat TM Band 5) (Hunt and Rock 1989). Texture measures (homogeneity using Band 3 of each Landsat ETM+ image) were calculated using the co-ocurrence matrix as designed by Haralick et al. (Haralick et al. 1973). The co-ocurrence matrix was computed from a window of 3x3 pixels, which was considered an optimum size for measuring neighbor conditions. Linear spectral mixture analysis (SMA) (Mather 2004) generated endmember spectra, which are defined as the proportion of each pixel covered by a basic spectral class. The included endmembers were water, soil, green vegetation (GV), and

ECOLOGICAL UNIT		NATURA 2000 Code (Main Habitat)
Natural –Seminatural Landscape		
Standing Water		3110/3120/3130
Running Water		3140/3150/3160
W	Water courses	3260/3270
Inland no-wooded wetlands		
WH	Bogs (Raised and blanket bogs) and Atlantic wet heaths	7130/7110*/7120 7230, 4020*
HM	Tall and mid-herb humid meadows	6430,6410
Inland wooded wetlands		
RF	Alluvial and riparian forests	91D0*/91E0*/91F0
Other natural and seminatural forests		
DF	Deciduous oak forests	9230
Rocky habitats and other heaths		
DH	Siliceous rocky habitats and dry heaths	4030/8220
Anthropic Landscape		
Forest plantations		
P	*Pine sp.* groves	
E	*Eucalyptus sp.* plantations	
Transformed rural landscape		
TF	Rural system mainly made up of pastures	
TR	Rural system mainly made up of corn and pasture in rotations	
BL	Bare land	
Traditional rural landscape		
CG	Traditional rural mosaic with fenced fields, dominated by crops and grasslands	6410/6510
WG	Traditional rural mosaic with fenced fields, dominated by wet grasslands	6410/6510
Man-made landscape		
Ur	Urban areas (villages, towns)	
ME	Mining exploitations	
I	Communication infrastructures	
B	Buildings for agricultural, forestry and industrial use	

Table 5. Ecological units directly related to CD 92/43/EEC habitats in the proposed model

non_photosynthetic vegetation (NPV). SMA models the reflectance of each pixel as a linear combination of reflectance of those four components. It was assumed constrains of no negative values and that the four components explained the whole variation of reflectance, although the model was allowed to produce a residual image.

Slope gradient was calculated from the DEM. Proximity to rivers was calculated from the 1/5000 river map using raster processing.

Results were assessed by cross-tabulation with a sample of pixels included in test plots. Global, user and producer accuracies were evaluated using an error matrix (Congalton and Green 2009). Additionally the Kappa analysis (Congalton and Green 2009) was used to evaluate the accuracy of the results: we used KHAT statistic to measure how well the remotely sensed classification agrees with the reference data, the Z statistic to determine the significance of a matrix error and the Z pairwise comparison to decide if two KHAT values are significantly different.

CODE	VARIABLES	GA (%)	KHAT
MLC_1	PCs (may+march+august)	75,56	0,733
*MLC_2	PCs (may+march+august) + NDVI (my,ag) + $NDII_5$ (my,ag) + prox. streams + SLOPE+ Homogeneity- B_3 (my, mz, ag)+ WATER (endmember-mz)+ FMo 3x3	82,75	0,811

Legend: [GA] Gloabl accuracy (%). [MLC]: Maximun likelihood classification, [*] without *Bare Land* class, [PCs]: Principal Components,
[FMo]: modal filter

Table 6. Global accuracies for parametric multi-temporal processes (MLC algorithm)

CODE	GA (%)	KHAT	Z	PAIR-WISE Z SCORES**
MLC_1	75,56	0,733	50,126*	
MLC_2	82.75	0,811	62,089*	3,496569*

Legend: [MLC]: Maximun likelihood classification [*] Significant at the 95% confidence level. [**] Comparison with MLC_1

Table 7. Kappa analysis for parametric multi-temporal processes (MLC algorithm)

The results of this model showed 82.75% global accuracy after the application of a modal filter. The best result provided a Kappa value (Congalton and Green 2009) of 0.811 with a Z value indicating very good agreement between classification results and the reference data.

Tables 6 and 7 shows the accuracy assessment for two processes: i) one of them based on the principal components of the three images (MLC_1); ii) the second one also includes the group of ancillary and derived variables (MLC_2). Some variables like slope, distance to rivers, NDVI, NDII and homogeneity showed its valuable potential (Table 9). The combination of all of them in the best MLC trial produced a significant increase in global accuracy along with an increase on user and producer accuracies for the most part of the classes of habitats (Table 8). MLC_2 showed user and producer accuracies above 70% and 80% in the most part of habitats. Only WH and forests showed producer or user accuracies less than 60%.

ECOLOGICAL UNITS	MLC1		MLC2	
	user	producer	user	producer
WG	60,41	87,00	74,22	95,00
TR	97,19	100,00	96,30	100,00
CG	84,62	74,00	85,85	87,50
HM	43,94	72,5	73,81	77,50
DF	59,74	44,23	76,39	52,88
RF	52,88	55,0	59,84	73,00
WH	53,33	26,67	73,91	56,67
P	97,92	90,38	96,23	98,08
E	94,74	90,0	90,91	100,00
TF	84,26	91,0	91,01	81,00
TI	100,00	91,67	100,00	91,67
W	100,00	100,00	100,00	100,00
ME	100,00	100,00	100,00	83,33
Ur+I+B	83,33	100,00	86,96	100,00
BL	66,67	30,0	----	----
DH	82,28	81,25	83,56	76,25

Legend: [MLC]: Maximun likelihood classification

Table 8. User and producer accuracies for parametric multi-temporal processes (MLC algorithm)

Variables	Global accuracy	Improvement in multi-temporal***	Kappa analysis		
			KHAT	Z	Pair-wise Z scores***
DEM + Slope	76,05	0,49	0,738	50,792*	0,256709
Prox. to streams	76,34	0,78	0,742	51,213*	0,412576
NDVI and NDII**	77,91	2,35	0,758	53,603*	1,248175
Homogeneity**	77,22	1,66	0,751	52,467*	0,867394
Endmember Water	75,75	0,19	0,735	50,442*	0,102807

Legend: [*] Significant at the 95% confidence level. [**] Three images. [***] In relation to the trial with principal components of the three images

Table 9. Improvement in global accuracy for multi-temporal analyses after adding to the classification the layers showed in the table.

The contribution of topographical variables and vegetation indices to the habitat mapping accuracy is appropriate for the analyses; the combination of vegetation indices was relevant in the analyses, with improvements in global accuracy (to a maximum of 2.35% of accuracy increase when both NDVI and NDII were combined in the process) (Table 9). The topographical variables (Slope and MDE) improved also the global accuracy of multi-temporal classifications, although to a lesser extent than variables like homogeneity. Texture measures and SMA components did not provide significant improvements in global accuracy in parametric methods. However they showed to be suitable for improving the discrimination of some particular classes like HM, WH or Ur. Therefore, they could be considered as interesting and helpful variables for nonparametric methods in order to get good discrimination of some classes.

The special interest of this approach comes from the use of an international classification system (EUNIS) that will allow cross-comparable spatial and temporal assessments and make the methodology extrapolated to other regions. The definition of ecological units goes farther than the simple *land cover* idea and it allows the definition of a direct relation win AnnexI habitats and consequently with species. Finally the use of a standard maximum likelihood algorithm based on the selection of key input variables makes possible the accurate identification of many ecological units.

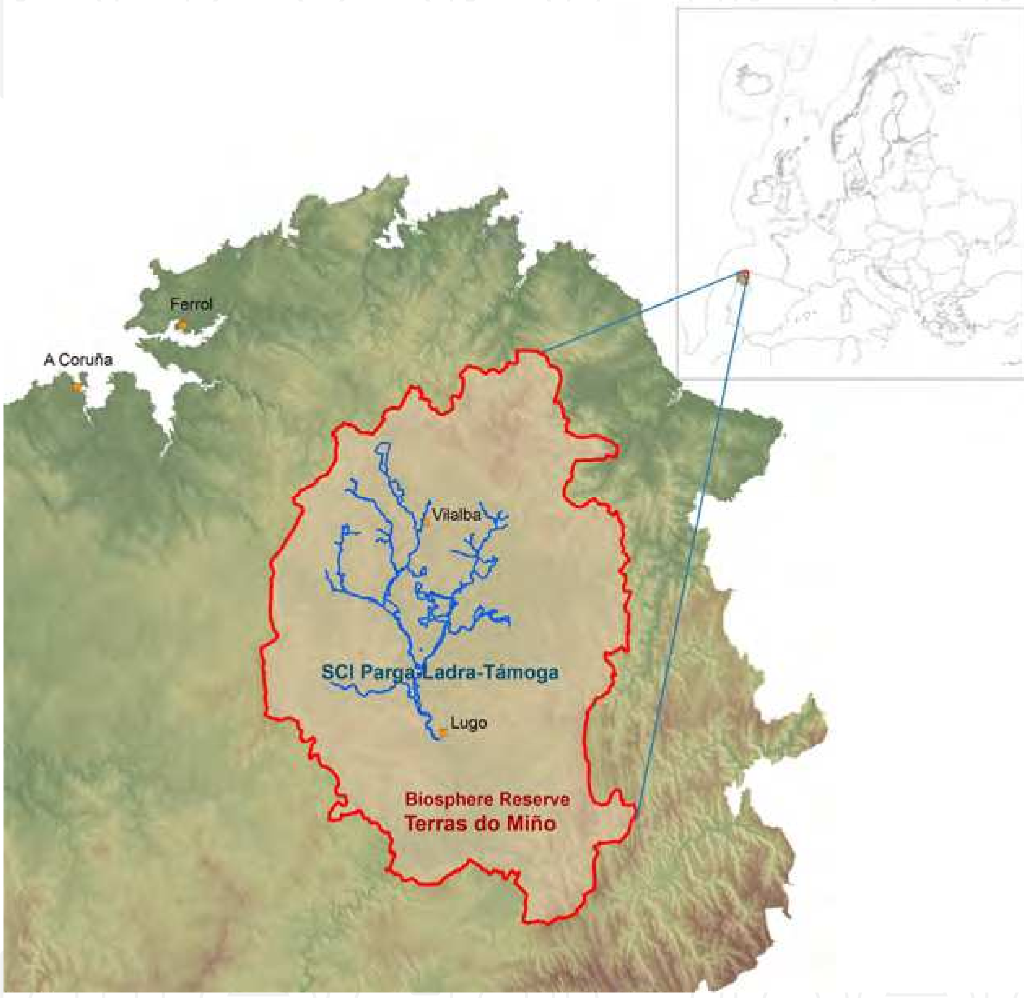

Fig. 3. Localization of the Biosphere Reserve *Terras do Miño* and de SCI *Parga-Ladra-Támoga* in Galicia (NW Spain)

The output classification of this model and the CLC map (5th level) were spatially compared with a habitat map of the Site of Community Importance (SCI) Parga-Ladra-Támoga in the Northwest of Iberian Peninsula (which belongs the Biosphere Reserve of *Terras do Miño).* This map was elaborated by photo interpretation through aerial photography with different scales ranging from 1/20000 until 1/2000 (Ramil et al. 2005). It also based on expertise fieldwork and its minimum mapping unit was 0,5ha. The map was the reference to evaluate this site as a candidate to belong to *Natura 2000* ecological network.
Again, spatial inconsistencies between both sources (CLC and the model applied to Biosfere Reserve *Terras do Miño*) were evaluated using this map by the analysis of coincidences in the cells of two different grids (UTM based): 1 and 10 km^2.

HAB	10 KM GRID (UTM) CLC	10 KM GRID (UTM) MODEL	1 KM GRID (UTM) CLC	1 KM GRID (UTM) MODEL
3110	0,00	77,78	0,00	35,14
3120	0,00	100,00	0,00	100,00
3130	0,00	83,33	0,00	70,00
3140	0,00	100,00	0,00	100,00
3150	0,00	100,00	0,00	80,00
3160	0,00	100,00	0,00	50,00
3260	6,67	73,33	1,40	5,83
3270	6,67	66,67	2,41	9,64
4020*	90,91	100,00	18,63	88,24
4030	91,67	100,00	26,16	78,48
6410	38,46	100,00	1,78	100,00
6430	-	100,00	-	91,29
6510	46,15	100,00	2,08	100,00
7110*	0,00	100,00	0,00	89,47
7230	0,00	100,00	0,00	100,00
8220	0,00	100,00	0,00	100,00
91D0*	-	100,00	-	88,89
91E0*	0,00	100,00	0,00	78,88
91F0	0,00	100,00	0,00	96,97
9230	100,00	100,00	30,77	99,04

(red)	**Total gap**: less than 10% of coincidences
(orange)	**Very high gap**: coincidences between 10-30 %
(yellow)	**High gap**: coincidences between 30-50%
(green)	**Moderate gap**: coincidences between 50-90%
(blue)	**No gap**: coincidences upper 90%

Table 10. Spatial correlations between CD 92/43/EEC habitats cartography, Corine Land Cover cartography (5th level) and the MODEL *Terras do Miño* in the SCI Parga-Ladra-Tamoga (NW Spain)

At 10km CLC shows a total gap in the most part of the habitats (Table 10). Only heaths and the woodlands with *Quercus spp.* (9230) have good correspondence. At 1 km CLC shows total or very high gap in any case. On the other hand, the model of *Terras do Miño* shows good results at 10km. At 1km, the most part of the habitats present good correspondence or moderate gap. Only two habitats present total gap which corresponds to water courses (3260 and 3270) which can be assigned to the constraints of the spatial resolution of the images.

Results show that, although both sources (CORINE and the model) are based on LANDSAT images with 30m of spatial resolution, the inclusion of decisive variables in the classification processes along with the identification of ecological units was crucial. And it is again proved that it is uncertain to use CLC as a proxy of habitat maps.

6. Conclusions

To meet the requirements of European policies such as *Natura 2000* Network and the 2020 EU Biodiversity Strategy the development of more cost and time effective monitoring strategies are mandatory. Remote sensing (RS) techniques contribute significantly to biodiversity monitoring and several approaches have been proposed to get on-going requirement for spatially explicit data on the ecological units, and the value and threats against natural and semi-natural habitats (Bock et al. 2005; Weiers et al. 2004), but no definite nor any that has been standardized across Europe.

The major obstacles to get standardized scientific monitoring methodologies for habitat monitoring form a complex patchwork. The immense versatility of RS, the full range of RS techniques and products, has led to numerous potential approaches but all of them are dependent of many factors: i) firstly the large variability in the quality of input variables, their semantic, thematic and geometrical accuracy; many approaches have assumed the suitability and representativity of the selected geospatial data; ii) secondly, the possible variability of the spectral, spatial and temporal resolutions; iii) finally, the availability of suitable RS and ancillary data.

There is no a simple relationship between habitats and biophysical parameters like land covers (Groom et al. 2006). *Habitat classes* are not the same that *land cover classes* and the inconsistencies and gaps when a land cover map, as CORINE Land Cover, is used as a surrogate of a habitat map are significant and it should be evaluated in each case. It is necessary to develop *ad hoc* criteria to get the objective of identifying and monitoring habitats from remote sensing. It should be found the optimal way (cost effective and in an acceptable time, and with an optimal level of accuracy) to get from one unit of land cover (which can definitely be detected directly by remote sensing) to a unit of habitat (which may be, at least not in a direct way).

At the European Community level the appropriate criteria for getting that relation should be achieved through EUNIS system (Martínez et al. 2010; Moss and Davies 2002) since it is a common denominator that is compatible with the requirements of Annex I of the Habitat Directive. It will support the standardization because it makes possible cross-comparable data: at spatial and temporal levels.

In regard to habitat identification through RS recent researches have suggested different relevant considerations and requirements: study areas specific approaches; ecological expert knowledge implemented as decision rules; the implementation/inclusion of key input variables selected following specific characteristics of individual habitats; the integration of ancillary data into the classification processes, related to shape, texture, context; the use of non-parametric algorithms implemented through binary classifications or decision trees that allow to include nominal, derived and ancillary geospatial data and also are advantageous with scarce training samples; (Bock et al. 2005; Boyd et al. 2006; Foody et al. 2007; Franklin et al. 2001; Kerr and Ostrovsky 2003; Martínez et al. 2010; Mücher et al. 2009).

On the other hand, insufficient integration at different scales is one of the constraints of the current biodiversity monitoring programmes (Pereira and Cooper 2006) and it is also urgent to advance in this issue. Remote sensing analyses of ecological phenomena at global scale are too general to meet regional and local monitoring requirements. Medium and high spatial resolution remotely sensed data, like Landsat TM and ETM+ sensors, have been widely used in ecological investigations and applications, because their suitability at regional and landscape scales. But there is a mismatch between broad-scale remote sensing and local scale field ecological data (Kerr and Ostrovsky 2003): the synoptic view of the remote sensing should be enhanced with *in situ* data and regional assessments should combine high spatial resolution satellite RS with on-the ground monitoring, and aerial photography or very high spatial resolution satellite RS in studying some habitats which are best monitoring at small scales (Hansen et al. 2004; Pereira and Cooper 2006).

To conclude, the upcoming standardized methodology should incorporate these recommendations. For habitat mapping through RS, expert knowledge and field measurements should be combined with key input variables and optimal algorithms related to each individual target habitat, implemented in a decision structure like a tree. At European level the new methodology should be based on the EUNIS system that meets the objectives and requirements of the Habitat Directive, the Convention of Biological Diversity and the new 2020 biodiversity targets. It should also look at the new possibilities of medium and high resolution satellite images.

7. Appendix 1

CLC 311 - Forest and semi natural areas / Forests / Broad-leaved forest

HC 9120 - Atlantic acidophilous beech forests with *Ilex* and sometimes also *Taxus* in the shrublayer (*Quercion robori-petraeae* or *Ilici-Fagenion*)

EUNIS CORRELATION: G1.62, G1.6

HC 9180* - *Tilio-Acerion* forests of slopes, screes and ravines

EUNIS CORRELATION: G1.A, G1.A4

HC 91E0* - Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion*, *Alnion incanae*, *Salicion albae*)

EUNIS CORRELATION: G1.1, G1.2

HC 91F0 - Riparian mixed forests of *Quercus robur*, *Ulmus laevis* and *Ulmus minor*, *Fraxinus excelsior* or *Fraxinus angustifolia*, along the great rivers (*Ulmenion minoris*)

EUNIS CORRELATION: G1.2, G1.22, G1.223

HC 9230 - Galicio-Portuguese oak woods with *Quercus robur* and *Quercus pyrenaica*

EUNIS CORRELATION: G1.7, G1.7B

HC 9330 - *Quercus suber* forests

EUNIS CORRELATION: G2.1, G2.11

HC 9340 - *Quercus ilex* and *Quercus rotundifolia* forests

EUNIS CORRELATION: G2.1, G2.12

HC 9380 - Forests of *Ilex aquifolium*

EUNIS CORRELATION: G2.6

CLC 312 - Forest and semi natural areas / Forests / Coniferous forest

HC 9410 - Acidophilous *Picea* forests of the montane to alpine levels (*Vaccinio-Piceetea*)

EUNIS CORRELATION: G3.1

CLC 321 - Forest and semi natural areas / Scrub and/or herbaceous vegetation associations / Natural grasslands

HC 6170 - Alpine and subalpine calcareous grasslands

EUNIS CORRELATION: E4.4,

HC 6410 - *Molinia* meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*)

EUNIS CORRELATION: E3.5, E3.51

HC 6510 - Lowland hay meadows (*Alopecurus pratensis*, *Sanguisorba officinalis*)

EUNIS CORRELATION: E2.2

CLC 322 - Forest and semi natural areas / Scrub and/or herbaceous vegetation associations / Moors and heathland

HC 4020* - Temperate Atlantic wet heaths with *Erica ciliaris* and *Erica tetralix*

EUNIS CORRELATION: F4.1

HC 4030 - European dry heaths

EUNIS CORRELATION: F4.2

HC 5130 - *Juniperus communis* formations on heaths or calcareous grasslands

EUNIS CORRELATION: F3.1, F3.16

CLC 323 - Forest and semi natural areas / Scrub and/or herbaceous vegetation associations / Sclerophyllous vegetation

HC 5130 - *Juniperus communis* formations on heaths or calcareous grasslands

EUNIS CORRELATION: F3.1, F3.16

CLC 331 - Forest and semi natural areas / Open spaces with little or no vegetation / Beaches, dunes, sands

HC 2120 - Shifting dunes along the shoreline with *Ammophila arenaria* ('white dunes')

EUNIS CORRELATION: B1.3, B1.32

HC 2130* - Fixed coastal dunes with herbaceous vegetation ('grey dunes')

EUNIS CORRELATION: B1.4

CLC 332 - Forest and semi natural areas / Open spaces with little or no vegetation / Bare rocks

HC 8130 - Western Mediterranean and thermophilous scree

EUNIS CORRELATION: H2.5, H2.5

HC 8220 - Siliceous rocky slopes with chasmophytic vegetation

EUNIS CORRELATION: H3.1

CLC 411 - Wetlands / Inland wetlands / Inland marshes

HC 7230 - Alkaline fens

EUNIS CORRELATION: D4.1

CLC 412 - Wetlands / Inland wetlands / Peat bogs

HC 7110* - Active raised bogs

EUNIS CORRELATION: C1.4, D1.1, G5.6

HC 7120 - Degraded raised bogs still capable of natural regeneration

	EUNIS CORRELATION: D1.1, D1.121
	HC 7130 - Blanket bogs (* if active bog)
	EUNIS CORRELATION: D1.2
CLC 421 - Wetlands / Maritime wetlands / Salt marshes	
	HC 1310 - *Salicornia* and other annuals colonizing mud and sand
	EUNIS CORRELATION: A2.5
CLC 423 - Wetlands / Maritime wetlands / Intertidal flats	
	HC 1140 - Mudflats and sandflats not covered by seawater at low tide
	EUNIS CORRELATION: A2.1, A2.4, A2.6
CLC 511 - Water bodies / Inland waters / Water courses	
	HC 3260 - Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation
	EUNIS CORRELATION: C2.1, C2.1B, C2.2, C2.28, C2.3, C2.34
	HC 3270 - Rivers with muddy banks with *Chenopodion rubri pp* and *Bidention pp* vegetation
	EUNIS CORRELATION: C3.5, C3.53
CLC 512 - Wetlands / Inland waters / Water bodies	
	HC 3150 - Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition* -type vegetation
	EUNIS CORRELATION: C1.3, C1.33
CLC 521 - Wetlands / Marine waters / Coastal lagoons	
	HC 1150* - Coastal lagoons
	EUNIS CORRELATION: A1.3, A2.2, A2.3, A2.4, A2.5, A3.3, A5.1, A5.2, A5.3, A5.4, A5.5, A5.6, A7.1, A7.2, A7.3, A7.4, A7.5, A7.8, C1.5, C3.4
CLC 522 - Wetlands / Marine waters / Estuaries	
	HC 1130 - Estuaries
	EUNIS CORRELATION: A1.2, A1.3, A1.4, A2.1, A2.2, A2.3, A2.4, A2.5, A2.6, A2.7, A3.2, A3.3, A3.7, A4.2, A4.3, A5.1, A5.2, A5.3, A5.4, A5.5, A5.6, A7.1, A7.3, A7.4, A7.5, A7.8 ,X01

Table 11. Correspondences between Corine Land Cover classification (3rd level) and habitats of Community interest, and correspondences between habitats of Community interest (HD) with EUNIS classification (only overlap, same and narrow relation) (Source: www.eunis.eea.europa.eu, last accessed May 2011)

CODE	DENOMINATION
31110	Forest and semi natural areas / Forests / Broad-leaved forest / Evergreen broad-leaved woodlands
31120	Forest and semi natural areas / Forests / Broad-leaved forest / Deciduous and marcescent forest
31150	Forest and semi natural areas / Forests / Broad-leaved forest / River forest
31210	Forest and semi natural areas / Forests / Coniferous forest / Needle coniferous forests
32111	Forest and semi natural areas / Scrub and/or herbaceous vegetation associations / Natural grasslands / High-productive alpine grasslands / High-productive alpine grasslands of temperate-oceanic climate areas

32112	Forest and semi natural areas / Scrub and/or herbaceous vegetation associations / Natural grasslands / High-productive alpine grasslands / Mediterranean high-productive grasslands
32121	Forest and semi natural areas / Scrub and/or herbaceous vegetation associations / Natural grasslands / Other grasslands / Other grasslands of mild-oceanic climate
32122	Forest and semi natural areas / Scrub and/or herbaceous vegetation associations / Natural grasslands / Other grasslands / Other mediterranean grasslands
32312	Forest and semi natural areas / Scrub and/or herbaceous vegetation associations / Sclerophyllous vegetation / Mediterranean sclerophyllous bushes and scrubs / Not very dense Mediterranean sclerophyllous bushes and scrubs
33110	Forest and semi natural areas / Open spaces with little or no vegetation / Beaches, dunes, sands / Beaches and dunes
33210	Forest and semi natural areas / Open spaces with little or no vegetation / Bare rocks / Steep bare rock areas (cliffs, etc.)
33220	Forest and semi natural areas / Open spaces with little or no vegetation / Bare rocks / Rocky outcrops and screes
41100	Wetlands / Inland wetlands / Inland marshes
41200	Wetlands / Inland wetlands / Peat bogs
42100	Wetlands / Maritime wetlands / Salt marshes
42300	Wetlands / Maritime wetlands / Intertidal flats
51110	Water bodies / Inland waters / Water courses / River and natural water courses
51210	Water bodies / Inland waters / Water bodies / Lakes and lagoons
52100	Water bodies / Marine waters / Coastal lagoons /
52200	Water bodies / Marine waters / Estuaries

Table 12. Corine Land cover European Nomeclature

CODE	**DENOMINATION**
1130	Estuaries
1140	Mudflats and sandflats not covered by seawater at low tide
1150*	Coastal lagoons
1310	*Salicornia* and other annuals colonizing mud and sand
2120	Shifting dunes along the shoreline with *Ammophila arenaria* ('white dunes')
2130*	Fixed coastal dunes with herbaceous vegetation ('grey dunes')
3110	Oligotrophic waters containing very few minerals of sandy plains (*Littorelletalia uniflorae*)
3120	Oligotrophic waters containing very few minerals generally on sandy soils of the West Mediterranean, with *Isoetes spp.*
3130	Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*
3140	Hard oligo-mesotrophic waters with benthic vegetation of *Chara spp.*
3150	Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition* -type vegetation
3160	Natural dystrophic lakes and ponds
3260	Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation
3270	Rivers with muddy banks with *Chenopodion rubri pp* and *Bidention pp* vegetation
4020*	Temperate Atlantic wet heaths with *Erica ciliaris* and *Erica tetralix*

4030	European dry heaths
5130	*Juniperus communis* formations on heaths or calcareous grasslands
6170	Alpine and subalpine calcareous grasslands
6410	*Molinia* meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*)
6430	Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels
6510	Lowland hay meadows (*Alopecurus pratensis*, *Sanguisorba officinalis*)
7110*	Active raised bogs
7120	Degraded raised bogs still capable of natural regeneration
7130	Blanket bogs (* if active bog)
7230	Alkaline fens
8130	Western Mediterranean and thermophilous scree
8220	Siliceous rocky slopes with chasmophytic vegetation
9120	Atlantic acidophilous beech forests with *Ilex* and sometimes also *Taxus* in the shrublayer (*Quercion robori-petraeae* or *Ilici-Fagenion*)
9180*	*Tilio-Acerion* forests of slopes, screes and ravines
91D0*	Bog woodland
91E0*	Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion*, *Alnion incanae*, *Salicion albae*)
91F0	Riparian mixed forests of *Quercus robur*, *Ulmus laevis* and *Ulmus minor*, *Fraxinus excelsior* or *Fraxinus angustifolia*, along the great rivers (*Ulmenion minoris*)
9230	Galicio-Portuguese oak woods with *Quercus robur* and *Quercus pyrenaica*
9330	*Quercus suber* forests
9340	*Quercus ilex* and *Quercus rotundifolia* forests
9380	Forests of *Ilex aquifolium*
9410	Acidophilous *Picea* forests of the montane to alpine levels (*Vaccinio-Piceetea*)
[*], Priority natural habitat types as Habitats of the Council Directive 92/43/EEC (Annex 1)	

Table 13. Habitats of Community interest (Council Directive 92/43/EEC) denomination

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9. References

Balmford, A., Bennun, L., et al. (2005). The Convention on Biological Diversity's 2010 Target. *Science,* 307, pp. (212-213),ISSN 1095-9203

Blondel, J. (1979). *Biogéographie et Écologie*,Masson,ISBN 2225639213,Paris.

Bock, M., Panteleimon, X., et al. (2005). Object-oriented methods for habitat mapping at multiple scales. Case studies from Northern Germany and Wye Downs, UK. *Journal for Nature Conservation,* 13, pp. (75-89),ISSN 1617-1381

Boyd, D. S., Sánchez-Hernández, C., et al. (2006). Mapping a specific class for priority habitats monitoring from satellite sensor data. *International Journal of Remote Sensing,* 27, pp. (2631-2644),ISSN 1366-5901

Civco, D. L. (1989). Topographic Normalization of Landsat TM digital imagery. *Photogrammetric Engineering and Remote Sensing,* 55,9, pp. (1303-1309),ISSN 0099-1112

Cohen, W. B. and Goward, S. N. (2004). Landsat's role in ecological applications of remote sensing. *BioScience,* 54, pp. (535-545),ISSN 0006-3568

Congalton, R. G. and Green, K. (2009). *Assessing the accuracy of remotely sensed data. Principles and practices*,Taylor & Francis Group,ISBN 978-1-4200-5512-2,Boca Raton.

Chavez, P. S. (1996). Image-based atmospheric corrections revisited and improved. *Photogrammetric Engineering and Remote Sensing,* 62,9, pp. (1025-1036),ISSN 0099-1112

Chhabra, A., Geist, H. J., et al. (2006). Multiple impacts of land-use/cover change,In: *Land-use and land-cover change. Local processes and global impacts*, Lambin, E. F. and Geist, H. J., pp.(71-116), Springer-Verlag, ISBN 3-540-32201-9, Berlin

Davies, C. E., Moss, D., et al. (2004). *EUNIS habitat classification revised 2004*, European Environment Agency, European Topic Centre on Nature Protection and Biodiversity: pp. (310),

DeFries, R. S. (2008). Terrestrial Vegetation in the Coupled Human-Earth System: Contributions of Remote Sensing. *Annual Review of Environment and Resources,* 33, pp. (369-390),ISSN 1543-5938

Devillers, P., Devillers-Terschuren, J., et al. (1991). *CORINE biotopes manual. Vol.2. Habitats of the European Community*,Office for Official Publications of the European Communities,Luxembourg.

Devillers, P., Devillers-Terschuren, J., et al. (1992). *Habitats of the European Community, Central Europe, Northern Europe. A preliminary List*,IRSNB,Brussels.

Díaz Varela, R. A., Ramil Rego, P., et al. (2008). Automatic habitat classification methods based on satellite images: A practical assessment in the NW Iberia coastal mountains. *Environmental Monitoring and Assessment,* 144, pp. (229-250),ISSN 1573-2959

Dirzo, R. and Raven, P. H. (2003). Global state of biodiversity and loss. *Annual Review of Environmental and Resources,* 28, pp. (137-167),ISSN 1543-5938

Duro, D. C., Coops, N. C., et al. (2007). Development of a large area biodiversity monitoring system driven by remote sensing. *Progress in Physical Geography,* 31,3, pp. (235-260),ISSN 1477-0296

EuropeanCommission (2006). *Assessment, monitoring and reporting under article 17 of Habitats Directive. Explanatory Notes & Guidelines. Final Draft 5*: pp. (64)

EuropeanCommission (2007). *The InterpretationManual of EuropeanUnionHabitats - EUR27*,DG Environment,Brussels.

Eurostat (2001). *Manual of concepts on land cover and land use*,Office for Publications of the European Communities,ISBN 92-894-0432-9,Luxembourg.

Foody, G. M. (2008). GIS: biodiversity applications. *Progress in Physical Geography,* 32,2, pp. (223-235),ISSN 1477-0296

Foody, G. M., Boyd, D. S., et al. (2007). Mapping a specific class with an ensemble of classifiers. *International Journal of Remote Sensing,* 28, pp. (1733-1746),ISSN 1366-5901

Franklin, S. E., Peddle, D. R., et al. (2002). Evidential reasoning with Landsat TM, DEM and GIS data for landcover classification in support of grizzly bear habitat mapping. *International Journal of Remote Sensing,* 23,21, pp. (4633-4652),ISSN 1366-5901

Franklin, S. E., Stenhouse, G. B., et al. (2001). An Integrated Decision Tree Approach (IDTA) to mapping landcover using satellite remote sensing in support of grizzly bear habitat analysis in the Alberta Yellowhead Ecosystem. *Canadian Journal of Remote Sensing,* 27, pp. (579-592),ISSN 1712-7971

Glenn, E. M. and Ripple, W. J. (2004). On using digital maps to assess wildlife habitat. *Wildlife Society Bulletin,* 32, pp. (852-860),ISSN 0091-7648

Groom, G., Mücher, C. A., et al. (2006). Remote sensing in landscape ecology: experiences and perspectives in a European context. *Landscape Ecology,* 21, pp. (391-408),ISSN 1572-9761

Hansen, A. J., DeFries, R. S., et al. (2004). Land use change and biodiversity: a synthesis of rates and consequences during the period of satellite imagery,In: *Land Change Science: observing, monitoring and understanding trajectories of change on the Earth's surface*, Gutman, G., Janetos, A. C.et al, pp.(277-300), Springer Verlag, ISBN 978-1-4020-2561-7, New York

Haralick, R. M., Shanmugan, K., et al. (1973). Textural features for image classification. *IEEE Transactions on Systems, Man and Cybernetics,* 3, pp. (610-621),ISSN 0018-9472

Hellawell, J. M. (1991). Development of a rationale for monitoring,In: *Monitoring for conservation and ecology*, Goldsmith, F. B., pp.(1-14), Chapman and Hall, ISBN 0412356007, London

Hunt, E. R. and Rock, B. N. (1989). Detection of changes in leaf water content using near and middle-infrared reflectances. *Remote Sensing of Environment,* 30, pp. (43-54),ISSN 0034-4257

Izco Sevillano, J. and Ramil Rego, P. (2001). *Análisis y Valoración de la Sierra de O Xistral: un modelo de aplicación de la Directiva Hábitat en Galicia*,Consellería de Medio Ambiente. Xunta de Galicia,ISBN 84-453-3158-2,Santiago de Compostela.

Jackson, D. L. and McLeod, C. R., Eds. (2000). *Handbook on the UK status of EC Habitats Directive interest features: provisional data on the UK distribution and extent of Annex I habitats and the UK distribution and population size of Annex II species*, NHBS,

Jennings, M. D. (2000). Gap analysis: concepts, methods, and recent results. *Landscape Ecology,* 15, pp. (5-20),ISSN 1572-9761

Kerr, J. T. and Ostrovsky, M. (2003). From space to species: ecological applications for remote sensing. *TRENDS in Ecology and Evolution,* 18,6, pp. (299-305),ISSN 0169-5347

Lefsky, M. A., Cohen, W. B., et al. (2002). Lidar Remote Sensing for Ecosystem Studies. *BioScience,* 52,1, pp. (19-30),ISSN 0006-3568

Lengyel, S., Déri, E., et al. (2008). Habitat monitoring in Europe: a description of current practices. *Biodiversity and Conservation,* 17,14, pp. (3327-3339),ISSN 1572-9710

Martínez, S., Ramil, P., et al. (2010). Monitoring loss of biodiversity in cultural landscapes. New methodology based on satellite data. *Landscape and Urban Planning,* 94, pp. (127-140),ISSN 0169-2046

Mather, P. M. (2004). *Computer processing of remotely-sensed images. An introduction*,John Wiley & Sons, Ltd,ISBN 0-470-84918-5,West Sussex.

McDermid, G. J., Hall, R. J., et al. (2009). Remote sensing and forest inventory for wildlife habitat assessment. *Forest Ecology and Management,* 257, pp. (2262-2269),ISSN 0378-1127

Moss, D. and Davies, C. E. (2002). *Cross-references between the EUNIS habitat classification and the nomenclature of CORINE Land Cover*, European Environment Agency and Centre for Ecology & Hydrology pp. (21),

Mücher, C. A., Hennekens, S. M., et al. (2004). *Mapping European habitats to support the design and implementation of a pan-European Ecological Network. The PEENHAB project*,Alterra,ISBN 1566-7197,Wageningen, The Netherlands.

Mücher, C. A., Hennekens, S. M., et al. (2009). Modelling the spatial distribution of Natura 2000 habitats across Europe. *Landscape and Urban Planning,* 92, pp. (148-159),ISBN 0169-2046

Pereira, H. M. and Cooper, H. D. (2006). Towards the global monitoring of biodiversity change. *TRENDS in Ecology and Evolution,* 21,3, pp. (123-129),ISBN 0169-5347

Ramil Rego, P., Rodríguez, M. A., et al. (2005). La expresión territorial de la biodiversidad. Paisajes y hábitats. *Recursos Rurais,* 2, pp. (109-128),1698-5427

Ramil Rego, P., Rodríguez Guitián, M. A., et al. (2008). *Os Hábitats de Interese Comunitario en Galicia. Descrición e Valoración Territorial.*,Universidade de Santiago de Compostela - IBADER,ISSN 1988-8341,Lugo.

Rouse, J. W., Haas, R. W., et al. (1974). Monitoring vegetation systems in the Great Plains with ERTS. *Third earth resources techonology satellite-I symposium, Volume 1: technical presentation*, ISBN CI-08791, Washington D.C., NASA SP-351.

Scott, J. M., Davis, F., et al. (1993). *Gap Analysis: a geographical approach to protection of biological diversity*,Wildlife Society,ISBN 0084-0173.

Soule, M. E. and Terborgh, J. (1999). *Continental conservation: scientific foundations of reserve networks*,Washington, D.C.

Strand, H., Höft, R., et al., Eds. (2007). *Sourcebook on remote sensing and biodiversity indicators*, Secretariat of the Convention on Biological Diversity, ISBN 92-9225-072-8, Montreal

Swain, P. H. and Davis, S. M. (1978). *Remote sensing: the quantitative approach*,McGraw-Hill,ISBN 9780070625761 New York.

Teillet, P. M., Guindon, B., et al. (1982). On the slope-aspect correction of multispectral scanner data. *Canadian Journal of Remote Sensing,* 8,2, pp. (84-106),ISSN 1712-7971

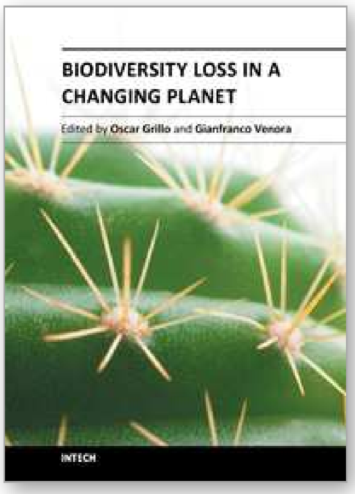
Thogmartin, W. E., Gallant, A. L., et al. (2004). A cautionary tale regarding use of the National Land Cover Dataset 1992. *Wildlife Society Bulletin,* 32,3, pp. (970-978),ISSN 0091-7648

Tso, B. and Mather, P. M. (2009). *Classification methods for remotely sensed data*,Taylor & Francis Group,ISBN 978-1-4200-9072-7,Boca Raton.

Turner, W., Spector, S., et al. (2003). Remote sensing for biodiversity science and conservation. *TRENDS in Ecology and Evolution,* 18,6, pp. (306-314),ISSN 0169-5347

Weiers, S., Bock, M., et al. (2004). Mapping and indicator approaches for the assessment of habitats at different scales using remote sensing and GIS methods. *Landscape and Urban Planning,* 67,1-4, pp. (43-65),ISSN 0169-2046

Zhao, K., Popescu, S., et al. (2011). Characterizing forest canopy structure with lidar composite metrics and machine learning. *Remote Sensing of Environment,* 115, pp. (1978-1996),ISSN 0034-4257



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Every ecosystem is a complex organization of carefully mixed life forms; a dynamic and particularly sensible system. Consequently, their progressive decline may accelerate climate change and vice versa, influencing flora and fauna composition and distribution, resulting in the loss of biodiversity. Climate changes effects are the principal topics of this volume. Written by internationally renowned contributors, Biodiversity loss in a changing planet offers attractive study cases focused on biodiversity evaluations and provisions in several different ecosystems, analysing the current life condition of many life forms, and covering very different biogeographic zones of the planet.

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