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ASSESSMENT OF THE SPANISH LAND COVER INFORMATION TO ESTIMATE FOREST AREA IN GALICIA[1]

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ABSTRACT

We assess the Land Cover and Use Information System of Spain (SIOSE) as a cartographic source of reference for regional planning. As a case study, we quantify forest area in Galicia, and carry out a comparative analysis between an updated version of the SIOSE and other widely used digital land-use maps. Our results show that the overall level of agreement across the territory of the existing forest area among the land-cover maps varies from 0.1% to 36%. We also show the congruency between the proposed updated SIOSE and the National Forest Inventory with differences between 1% and 5%.

Keywords: Forest cover, spatial information, cartographic harmonisation, SIOSE.

RESUMEN

Evaluamos el Sistema de Información sobre Ocupación del Suelo de España (SIOSE) como fuente cartográfica de referencia para la planificación regional. Como caso de estudio, cuantificamos el área forestal en Galicia y realizamos un análisis comparativo de una versión

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actualizada del SIOSE con otras fuentes cartográficas. Nuestros resultados muestran que el nivel general de concordancia de la superficie forestal entre las distintas fuentes varía entre 0,1% y 36%. Así como una elevada coincidencia entre la actualización propuesta del SIOSE y el Inventario Forestal Nacional, con diferencias entre 1% y 5%.

Palabras claves: Área forestal, información espacial, armonización cartográfica, SIOSE.

I. INTRODUCTION

The identification and mapping of forest area are extremely important for environmental research and the development of land management and natural resources policies. The study of biomass, carbon capture and sequestration, environmental impacts, and forest and biodiversity conservation depend on detailed knowledge of the forest area available. Similarly, policies on land use planning, such as reforestation, prevention and mitigation of forest fires, reducing rural exodus, incentives for the forest industry, or conservation of endangered habitats, among others, require information about forest area, its location and characteristics (e.g., species, age, type of ownership) (e.g., Cruickshank et al., 2000; Ciencialia et al., 2008; Vázquez de la Cueva and Rodríguez, 2008; Gallaun et al., 2009; Martínez et al., 2009; Seebach et al., 2011). However, existing land cover maps have often different spatial and temporal scales, classification systems and methodologies, and considerable efforts have been made in the literature to assess and compare this information (Latifovic et al., 2004; Waser and Schwarz, 2006; Wu et al., 2008)

This article assesses the harmonisation in the quantification of forest areas via available sources, which in recent times have been using photo interpretation and cartographic techniques. In Spain the detailed description of the forest characteristics has been gathered in National Forest Inventories including digital cartography from the publication of the Second National Forest Inventory (1986-1996). Recently, the Fourth National Forest Inventory (IFN4) has become available for some Spanish Autonomous Communities (CCAA). IFN4 significantly improves the quality of the information from the Third National Forest Inventory (IFN3) (1995-1998), particularly regarding the scale used (1:25,000) and the minimum mapping units. In addition, the database structure has been improved and it is more manageable and has a much higher operating capacity (MAGRAMA, 1999).

At European level, information is available on the discrimination of land uses, including forest land, through the coverage of the CORINE Land Cover (CLC) project for the years 1990 (CLC90), 2000 (CLC00), and 2006 (CLC06). However, despite the great progress achieved by having the CLC as a source of comparable information between countries, the lack of resolution of CLC highlights an obvious need for more information at state and regional level (IGN, 2011). This is due to the fact that the CLC has a reference scale of 1:100,000, which does not provide sufficient resolution for studies that require a certain level of detail, and does not allow an accurate measurement of the area occupied by different land uses. In addition, the CLC reference information, the drawing scale and minimum mapping units, 25 hectares (ha), have a great impact on accuracy, which in turn affects the results obtained (Felicísimo and Sánchez, 2002; Herrero, 2011; Chas-Amil et al., 2013).

Consequently, cartographic sources have arisen at Spanish Autonomous Community level (e.g. Land Cover and Use Map (USO_25) in the case of Galicia) or State level like the Land Cover and Use Information System of Spain (SIOSE). The SIOSE, launched by the National Geographic Institute (IGN), was created to generate a database of land cover and use for the whole of Spain, by combining the information available from the different CCAA and the Central Government.

The SIOSE has a first version with cover data referring to the year 2005 (SIOSE05) and the last update is referred to 2011. The main attributes of the SIOSE are its higher resolution and accuracy compared to other cartographic options for land cover, such as the CLC mentioned in the previous paragraph. The SIOSE reference scale is 1:25,000, and, therefore, constitutes the first continuous layer for the whole of Spain at that level of detail. It uses a data model that can integrate existing nomenclatures in other sources, such as the CLC or IFN4. But with the special feature that the territory is divided into polygons with one or more covers associated, with the only restriction being to represent a minimum area of between 0.5 and 2 ha depending on the elements to be mapped. These represent great advantages, if you compare these attributes of the SIOSE with graphic features of other cartographic sources. However, SIOSE05 is not problem-free. Exploiting the database information is laborious. Due to the complexity of the data model, it is not possible to graphically represent the mixed covers in polygons, i.e. those characterised by grouping multiple land cover. Therefore, this makes it impossible to obtain the graphical part of the different land uses as these are only reflected through cover percentages in the database. For this reason, the information regarding each land cover can only be extracted alphanumerically and the graphical part cannot be extracted. This fact affects the ability to have the delimitation of the polygons from any use cover (e.g. forestry, agriculture, urban) and to perform geoprocessing tasks that with other cartographic sources would be possible.

The aim of this paper is to assess SIOSE05 as a cartographic source of reference for regional planning in Spain and, more specifically, forest area planning. Given the main limitation of this source we have already mentioned, this paper develops an update of the information of SIOSE05, through the use of orthophotos from the National Plan for Aerial Orthophotography (PNOA), which mainly refer to the years 2007 and 2008. This allows us to define, as precisely as possible, the forest area, generating an SIOSE05 update, which we will call SIOSE07-08. In addition, this paper carries out a comparative analysis of the forest area extracted from the SIOSE07-08 and other existing cartographic sources in order to assess the harmonisation and reliability in the spatial information on the forest area obtained with the various sources.

As a case study for the forest area assessment, we chose Galicia (NW of Spain) due to the impact of the forestry sector on this region. In terms of timber cutting, Galicia produces nearly 7 million m^3 annually, 57% of the Spanish total (MAGRAMA, 2012). Furthermore, the forest area in Galicia has seen steady growth in recent years (IGE, 2013) due in part to favourable climate conditions and socio-economic circumstances that encourage the gradual exodus from rural areas (Balsa, 2012; Corbelle et al., 2012). This exodus has a direct impact on loss of usable agricultural area (Corbelle and Crecente, 2009) and, therefore, on spontaneous plant colonisation followed by herbaceous and shrub formations that in the absence of external disruptions, can lead to forest growth. We also analyse the spatial

differences in this region's forest area, which allows us to assess the real situation and different behaviour in this respect of the different Galician provinces and counties.

The updated SIOSE05 map developed in this paper (SIOSE07-08) is able to provide detailed information on forest cover taking into account the complex landscape of Galicia which, in the most part, is occupied with mixed cover. In the case of Galicia, the high fragmentation and discontinuity of uses (Diaz-Manso et al., 2007) forced us to consider many different polygons, although many of these were small, for the proper delimitation of the forest area. Our results compare information on forest area from SIOSE05 and its updated version, SIOSE07-08, USO_25, CLC06, and IFN4. The choice of Galicia as a case study facilitates the inclusion of data from IFN4 as it is currently one of the Spanish regions for which this information is available.

The paper is organised as follows. In the first section we introduce the data used and the methodology applied. In the second section, we present the main results of the quantification of forest areas in Galicia with the different cartographic sources used. The final section summarises the main points and we offer some conclusions.

II. MATERIALS AND METHODS

II.1. Data

The review conducted for the analysis of the forest area of Galicia was based on the Land Cover and Use Information System of Spain 2005 (SIOSE05), which is free to access via the web platform of the National Centre for Geographic Information (CNIG) under the National Geographic Institute (IGN). The SIOSE layer provides detailed information about the distributions of various types of land cover on a scale of 1:25,000 (IGN, 2011). The minimum mapping unit is 2 ha for agrarian, forest, and natural areas, and the minimum width of linear elements is 15 meters (m) (table 1). The SIOSE layer does not classify a given polygon within a fixed hierarchical nomenclature, but rather allows assigning one or more covers to the same polygon, using shares of occupation. Single cover is when the whole surface of the polygon is homogeneous and exceeds the minimum area requirement; and mixed cover is when it is comprised of a mixture of covers that in turn can be simple or mixed, in which case the information is indicated via cover percentages and attributes. Therefore, SIOSE05 provides more complex information on land cover and use than traditional thematic classifications, and it is much more versatile in its operation as it allows the association of one or more land covers for a single polygon. This could increase the semantic richness, as the queries can be adapted to the users' needs.

The other cartographic sources consulted in this paper, chosen for having similar time reference points are:

- CORINE Land Cover (CLC) for the year 2006 (CLC06)
- Land Cover and Use Map of Galicia for the year 2003 (USO_25).
- Fourth National Forest Inventory (IFN4) developed for Galicia from 2008-2009.

Access to this information varied due to the different organisations that manage them. The layers with free access were CORINE Land Cover via the web platform of the National Centre for Geographic Information (CNIG) under the National Geographic Institute. Free access to the Galician Land Cover and Use Map was granted by the Instituto de Estudos do Territorio (IET)-Xunta de Galicia. Finally, access to IFN4 was given on a DVD produced by the Ministry of Agriculture, Food and Environment (MAGRAMA). Each of these layers has its own particular characteristics that we explain briefly and are summarised in more detail in table 1.

CORINE Land Cover (CLC) is a vector layer with a reference scale of 1:100,000 which focus on generating a continuous base for land use across Europe, which is the responsibility of the European Environment Agency, and is used for spatial analysis and management of European policies. The minimum mapping unit is 25 ha for polygons and land cover nomenclature is organised hierarchically on several levels of information. In the Spanish case, the level of disaggregation has been reduced in the different versions, moving from 5 levels and 64 classes in CLC90 to 3 levels and 44 classes in CLC06. The graphical features of CLC are therefore very general for a study that requires a certain level of detail since as it is designed for European scale, it does not allow accurate measurement of land use. In addition, the reference information as well as the mapping scale and the minimum mapping units greatly determine the accuracy, thereby affecting the results. The advantage of this layer is that it allows comparative studies between European countries and a time evolution in the period 90-06, as data is available relating to 1990, 2000, and 2006.

The Land Cover and Use Map of Galicia 1: 25,000 (USO_25) provides a description of the situation of land use and cover at the Galician level, so that it can detect, quantify and assess the uses, as well as integrate existing cartographies in a single operational base for this region. In this case, we chose to describe most of Galicia via mixed classes (area units with more than one cover), increasing the level of conceptual disaggregation of the CLC's legend and trying to capture the existing combination of uses in Galicia.

The Fourth National Forest Inventory (IFN4) is the result of a nationwide project designed to obtain information on the situation, ownership and protection, nature, legal status, likely development and production capacity of all kinds of assets of the Spanish forest (MAGRAMA, 2011). The IFN4 also represents a significant improvement over the Third National Forest Inventory (IFN3) as it has been based on the cartography of the Forest Map of Spain at 1:25.000 (MFE25) carried out on aerial orthophotos of the PNOA instead of on the Forest Map of Spain 1:50.000 (MFE50). The minimum mapping unit has been reduced from 2.5 ha to 1 ha in polygons for woodland forest use and 6.25 ha to 1 ha in polygons for non-wooded forest land. Moreover, it improves the digitisation of information regarding IFN3 which, due to the existence of minimum mapping units, sometimes areas that were not correctly assigned to the corresponding class. Therefore, it has substantially improved the accuracy in the characterisation of the territory. The IFN4 also presents a much more manageable database structure than the SIOSE05 and has a capacity for more direct and functional operation insofar as forest area is concerned.

Table 1
SUMMARY OF THE CHARACTERISTICS OF THE CARTOGRAPHICAL SOURCES USED

	CLC	**USO_25**	**IFN4**	**SIOSE05**
Geodetic reference system	CLC90-00: ED50 CLC06: ETRS89	ED50	ETRS89	ETRS89
Cartographic projection	UTM	UTM	UTM	UTM
Data capture	CLC90: Landsat-TM CLC00: Landsat7 CLC06: Imágenes SPOT4	Landsat-TM, Spot-P and ortophoto SIGPAC (0.5m). Burn areas cartograhy, Comunal Forest, Protected areas, IFN3, Forest Map of Spain, etc.	PNOA aerial ortophoto, Forest Map of Spain 1:25.000	Landsat TM, SPOT5 with HRG sensor and PNOA. Numeric Topographic Base 1:25.000, Cadastre, Forest Map of Spain, etc.
Scale	1:100 000	1:25 000	1:25 000	1:25 000
Minimum mapping unit	25 ha for polygons and the minimum width of linear elements is 100 m	>5 ha for agrarian and forest areas	1 ha for wooded forest and 1 ha for non-wooded forest	2 ha for agrarian, forest, and natural areas, and the minimum width of linear elements is 15 m
Nomenclature	CLC90: 5 levels and 64 classes CLC00: 5 levels and 85 classes. CLC06: 3 levels and 44 classes	48 classes	3 levels and 1 sub-level in level 3, 64 classes	Object oriented data model: 40 simple classes, and 45 mixed classes
Time reference	CLC90: 1990 CLC00: 2000 CLC06: 2006	2003	2004-2007	2005
Access to the data	Free (1)	Free cesion	DVD (2)	Free (1)

Note: (1) Centro Nacional de Información Geográfica (CNIG): http://centrodedescargas.cnig.es/CentroDescargas/; (2) MAGRAMA (2011).

II.2. METHODS

II.2.1. Updating the SIOSE05

The Land Cover and Use Information System of Spain (SIOSE), as already explained in the previous section, displays two types of polygons, on the one hand, those with one cover (single cover) and on the other, polygons with different covers (mixed covers). In single polygons the land cover is homogeneous and, therefore, its spatial quantification is not a problem, however, in mixed covers the surface is disaggregated by different land cover percentages. To select the polygons corresponding to the forest area, we reviewed the relationship between the abbreviations and the type of cover to which they refer (table 2). Extracting the information from the SIOSE05 layer is quite complex, and is not the result of a direct process but rather, it is necessary to filter the tables that make up the cover. In addition, it displays two fundamental entities, the polygon (geometry) and the cover (semantics) associated to the polygon. This means that the areas obtained for each mixed polygons do not allow the accurate distinction of the actual limit of the forest area, which poses a problem of graphic and cartographic representation of the data, making it necessary to re-digitize the entire forest area that is in mixed cover.

For that reason, we developed a graphical review of the layer of forest use extracted from SIOSE05. We isolated forest polygons with partial or complete content of forest area on a new layer, and proceeded to re-digitize them. The polygons of SIOSE05 with forest content were redefined and updated based on photo interpretation. If there is complexity in the mixture of land use covers, as it is the case in Galicia, adopting a visual analysis approach is often recommended (Chuvieco 2010). This photo interpretation was carried out using the latest available orthophotos of the National Plan for Aerial Orthophotography (PNOA 2007-2008 © National Geographic Institute - Xunta de Galicia). Except on the most south-western coastline, the rest of the region has a more up-to-date source of information than that indicated by the SIOSE05. The western half of Galicia has an update year of 2008 and most of the eastern half is projected as of 2007, except for a strip in the northwest that is from 2006. Additionally, by using orthophotograms with a resolution of 0.25 m, we have an increased ability to identify small surfaces than if we use Landsat (30 m) or SPOT (2.5 m) as in the case of CLC, USO_25 and SIOSE05.

The scale used to display the orthophotos was 1:5000 or 1:3000 depending on the complexity of the landscape, using the more detailed scale in densely populated areas to detect very small forest formations. After that, in order to correctly outline the perimeters, the smallest forest areas were digitized at a scale of 1:2000 or 1:1000. Once the forest polygons were digitized, we applied topological rules to depurate them. This process allowed us to eliminate any potential overlap of forest polygons, which would cause an overestimate of the forest area in the region. Lastly, random checks were made of the resulting layer in which we graphically tested its definition and how it corresponded with the image offered by the PNOA. Once the polygons were digitized and we had created or deleted those that were considered necessary, topological screening was performed aimed at removing overlapping errors of polygons that would lead to an erroneous increase in forest area. As a result, we achieved an updated layer of SIOSE with a more precise delimitation of Galician forest

area mainly in reference to the period 2007-2008 (SIOSE07-08). This updated SIOSE layer provides detailed information on land cover and better captured the complex landscape of Galicia, where most land use classes are mixed.

II.2.2. Comparative with other cartographic sources

When making the comparison between different cartographic sources, we had to pay special attention to the differences between them in relation to the reference systems, definitions of forest area, the source of the data (satellite or aerial images) or the spatial resolutions that can affect the homogeneity and consistency of the data obtained. As these layers come from different bodies, referring to different years, the reference systems adopted differ. The USO_25 layer uses the geodetic reference system ED50 (European Datum 1950), while the CLC06, IFN4 and SIOSE05 use the Global European Geodetic Reference System, ETRS89. To process the various layers we had to reproject the layer where necessary from ED50 to ETRS89, which is the one recommended by INSPIRE (EC, 2010) as a common framework for all Spatial Data Infrastructures (SDI) in Europe. To perform this task, as recommended by the IGN (2007a, 2007b, 2007c), the transformation process of ED50 to ETRS89 was performed using the NTv2 (National Transformation Version 2) grid, using as a specific parameter the option of the Iberian Peninsula.

It was also necessary to perform an analysis of the nomenclatures to establish comparisons between the different sources. Table 2 presents the codes considered for each source in this paper, which include what is usually considered forest area, excluding pastures. As the CLC, USO_25, and IFN4 legends are similar we can carry out a detailed analysis of the areas of each category. We must highlight the loss of information for land management at regional level that occurs in the CLC06 compared to previous versions, CLC90 and CLC00, due to the use of the nomenclature at level 3 instead of level 5. In the case of SIOSE05, table 2 presents the names of the single covers comparable to the nomenclature of the other sources.

There are also technical factors that complicate the comparison between layers, such as different minimum mapping units (between 0.5 ha and 25 ha), the different scales (from 1:25.000 to 1:100,000) or the various sources of information used (satellite images, cartographic reference sources, etc.). On a recurring basis, we found Landsat and SPOT images as information sources. In all cases, we used various applications and methods based on topological analysis to correct the errors detected. From the information regarding the forest polygons obtained from each cover, we moved on to their analysis with ArcGIS ® 10.0, based on geoprocessing procedures. The polygons selected from each layer were combined using the Dissolve option and with the resulting layers from this geoprocess, intersections were made with layers of provinces and counties of Galicia, created from the municipal limits downloaded from the website of the National Centre for Geographic Information (CNIG). This allowed us to obtain information on forest area for that level of spatial detail. In the case of SIOSE05, we developed a specific process in order to disaggregate the alphanumeric information at regional level, because, as there are mixed polygons, it is not possible to allocate the total value of the area of the polygon but rather, the percentage value indicated in the table. On the other hand, as there are polygons that can belong to more than one county, the layer was cut along this territorial division and then we operated at table level.

Table 2
HARMONISATION OF CODES OF THE CLC, USO_25, IFN4, AND SIOSE05 FOREST LAYERS

CLC				USO_25	IFN4	SIOSE05
Códigos 3-5	**90**	**00**	**06**	**2003**	**2008-2009**	**2005**
311 Broad-leaved forest			X			310Wooded forest 311Broad-leaved species: 312 Deciduous forest (FDC) 313 Perennifolias (FDP) 316Coniferous (CNF)
3111		X		3111Eucalypt	Wooded forest (11-16, 171, 172, 18, 19)	
31111	X					
31112	X					
3112	X	X		3112 Castanea sativa		
3113	X	X		3113 Deciduous species		
3114		X*				
3115		X*				
3116		X*				
312 Coniferous forest			X			
3121	X	X		3121 Pinus		
3122	X*	X*				
313 Mixed forest	X	X	X	3131 Eucalypts and pinus 3132 Deciduous species and pinus 3133 Eucalypts, pinus and deciduous species 3134 Acacia, pinus and deciduous species		
322 Moors and heathland			X		Shrubs (21-27)	
3221	X	X				
3222	X*	X*				
323 Sclerophylous vegetation			X	3221 Shrubs 3222 Heather		320 Shrubs (MTR)
3231	X					
32311		X				
32312		X				
3232	X	X				
3233	X*					
324 Transitional woodland/shrub	X		X	3241 Shrubs and deciduous species 3242 Shrubs and wooded species		
3241		X				
3242		X				
3243		X				
333 Sparsely vegetated areas			X		Bare soil (451-453, 4541, 4542)	333 Bare soil (SDN)
3331	X	X				
3332	X	X				
3333	X	X				
334 Burnt areas	X	X	X		Burnt areas (431, 432)	334 Burnt areas (ZQM)

Note: (*) Classes without polygons in Galicia.

III. RESULTS

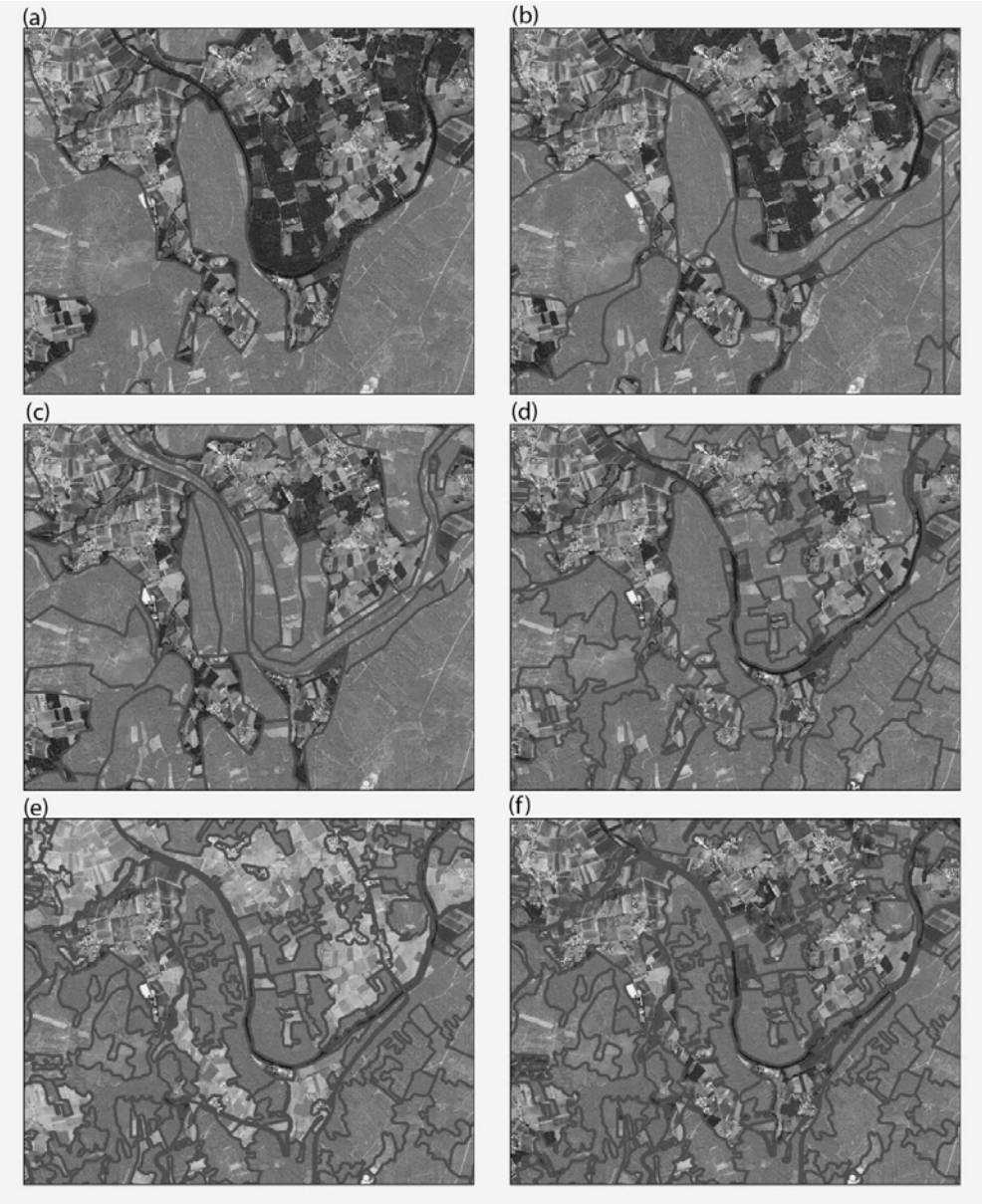
The analysis of the SIOSE05 showed that 92% of all polygons in Galicia present mixed cover. This fact emphasises the importance of disaggregating this alphanumeric information from the layer's database to perform a spatial analysis. The result of the queries on the forest area gives a total of 163,363 polygons with forest content (84% of all polygons that make up the layer in Galicia), of which only 10,349 are polygons with single forest cover, covering an area of 83,649 ha. This large proportion of polygons with mixed forest content forces us to work only with the alphanumeric portion to extract the information on area occupied by different land covers included in the polygon. This is because when working with mixed polygons, as already mentioned, the graphical part is relegated to a mere visual attribute of the tabular information.

Figure 1 compares the graphical delimitation of the forest area of the various sources used with the PNOA orthophoto of the years 2003 and 2007-2008. This figure clearly shows the possible inaccuracies present in the calculation of the forest area that may exist with the various sources. It illustrates how the SIOSE07-08 is able to more accurately delimit the forest area than the SIOSE05, which does not distinguish the cover in mixed type polygons in its graphical representation of the data. The delimitation of SIOSE07-08 shows strong similarities to that carried out by IFN4. This figure 1 also includes data from the Third National Forest Inventory (IFN3) to show how the latest version of the inventory, IFN4, has greatly improved the spatial resolution of the graphical information. In fact, on many occasions, IFN3 classifies as forest polygons elements such as streams, reservoirs, agricultural areas, grasslands, quarries, roads and built-up areas. Furthermore, the cartography of the IFN3 is very general, with very few nodes to delimit spaces that are not always regular.

An analysis of SIOSE07-08 shows that forest area is 1,960,311 ha, representing 66% of the total area of Galicia. Table 3 shows the results obtained from the forest area for the different cartographic sources used, and its difference in absolute values (in hectares) and relative values (in percentage terms) as regards the results obtained from SIOSE07-08. A positive (negative) value would indicate that the SIOSE07-08 forest estimates are lower (higher) than the forest area obtained from the alternative land-cover map. The data obtained from SIOSE05 and SIOSE07-08 is quite similar with a global difference of about 30,000 ha. This implies an underestimation of less than 2% of the forest area of Galicia. IFN4 is the cartographic source that gives the most forest area among all those studied, but it differs only slightly from the results of SIOSE07-08. In IFN4, the forest area is 60,000 ha higher than that obtained by SIOSE07-08, which represents a difference of only 3%. However, CLC06 and USO_25 offer significant differences in the quantification of forest area, offering results that underestimate the Galician forest area with respect to the information extracted from SIOSE07-08 by around 24% and 29%, respectively.

Table 4 shows the results of the study of data at provincial level. The comparison of CLC06 and USO_25 with SIOSE07-08 shows large differences for all Galician provinces, especially in Ourense, with a difference in relative terms of -32% and -36%, respectively. Again these two sources, CLC and USO_25, underestimate the forest area, and it is the last source that provides greater divergences as regards SIOSE07-08. The province of Ourense is also where the differences are greater between SIOSE05 and SIOSE07-08, but an under-

Figure 1
EXAMPLE OF DELIMITATION OF FOREST AREAS BY
(a) CLC06, (b) USO_25, (c) IFN3, (d) IFN4, (e) SIOSE05, AND (f) SIOSE07-08.



Note: The grey lines indicate the delimitation of the forest polygons. The shading shows the delimitation of forest cover in each case. In the case of SIOSE05, the shading encompasses both single polygons and mixed polygons with some forest content.

estimation of less than 6%. The IFN4 presents for all provinces higher values of forest area than any other source analysed, although with insignificant relative differences with respect to SIOSE07-08, ranging from 1% for the province of Pontevedra and 5% for Ourense.

Table 3
FOREST AREA (ha) IN GALICIA ACCORDING TO THE DIFFERENT SOURCES AND DIFFERENCES AS REGARDS SIOSE07-08

Sources	Forest area	Difference with SIOSE07-08	
	ha	ha	%
CLC06	1,485,796	-474,515	-24.2
USO_25	1,397,781	-562,530	-28.7
IFN4	2,020,328	60,017	3.1
SIOSE05	1,929,610	-30,701	-1.6
SIOSE07-08	1,960,311	-	-

Table 4
FOREST AREA BY PROVINCE ACCORDING TO THE DIFFERENT SOURCES AND RELATIVE DIFFERENCES AS REGARDS SIOSE07-08

Provinces	Total area	CLC06		USO_25		IFN4		SIOSE05		SIOSE07-08
	ha	ha	%	ha	%	ha	%	ha	%	ha
A Coruña	795,756	405,547	-15.3	359,270	-25.0	495,901	3.6	487,441	1.8	478,746
Lugo	985,228	494,781	-23.1	484,723	-24.7	654,649	1.7	643,995	0.1	643,672
Ourense	726,992	368,206	-32.5	349,614	-35.9	574,457	5.4	513,801	-5.8	545,262
Pontevedra	448,970	217,262	-25.8	204,174	-30.2	295,321	0.9	284,373	-2.8	292,630
Galicia	2,956,947	1,485,796	-24.2	1,397,781	-28.7	2,020,328	3.1	1,929,610	-1.6	1,960,311

Below we summarise the results of the analysis of the forest area at county level. Figure 2 shows the percentage importance of the forest area of SIOSE07-08 in relation to the total area of the different counties of Galicia. This forest distribution at county level indicates clear spatial differences throughout Galicia. The counties with a greater presence of forest cover (>80% of the total area) are those with important areas used for forestry (A Mariña Occidental and Fonsagrada in the north), for shrub formations in the mountain systems and native wooded areas mixed with plantations (Quiroga, Valdeorras and Viana in the south-east and Baixa Limia in the south) and eucalyptus and scrubland (Condado and A Paradanta in the south). The counties with the least forest area in percentage terms, with forest area of less than 50% of its total area, are A Coruña, a major metropolitan area, Ordes, Xallas and Chantada. The last three are characterised by extensive agricultural and livestock activity and great importance of arable crops intended for feed. Values between 50-60% of the total county area are found in the agricultural depressions of the province of Lugo (e.g. Terra Cha, Lugo or Sarria) and in the county of A Limia, also characterised for having important agricultural production and, in some areas, rural abandonment.

Figure 2
PERCENTAGE OF FOREST AREA AT COUNTY LEVEL (SIOSE07-08)

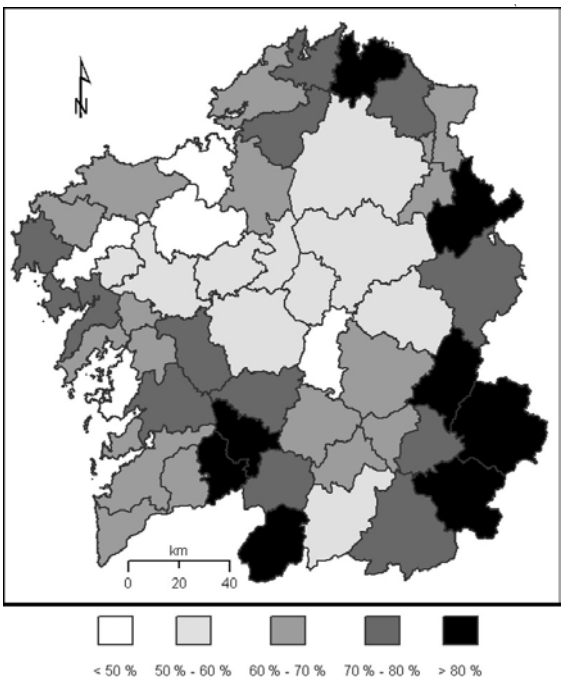


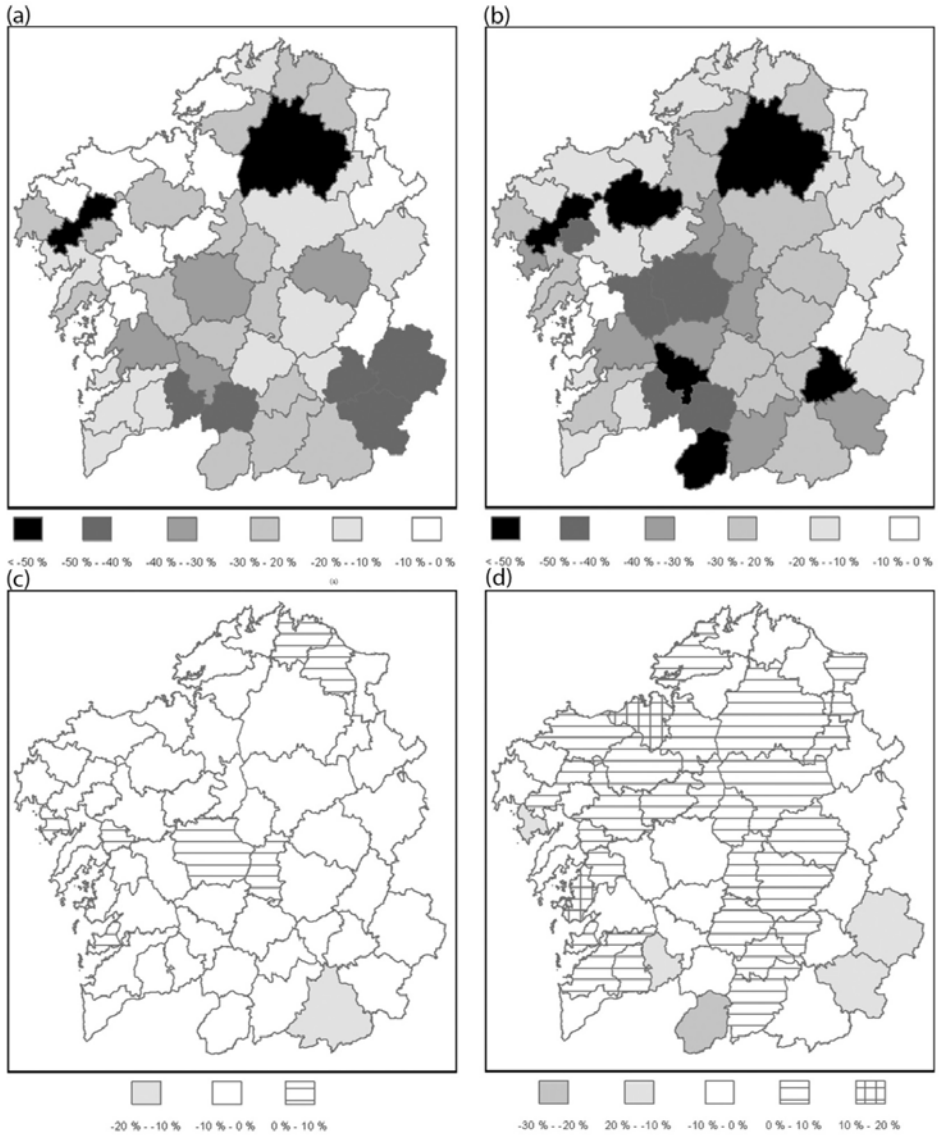
Figure 3 lists the results of the comparison of forest area at county level between the different sources analysed. Again we can highlight that the calculation for the forest area with SIOSE07-08 and IFN4 provides very similar results even at this spatial level (figure 3c), with differences between -10% and 10% in the information from these two sources. Only in the case of the county of Verín there is a difference between them of 14%.

Consistently with previous results, CLC provides a lower value of the forest area than SIOSE07-08 in all counties of Galicia, reaching in some cases differences of around 50% or even higher (figure 3a). For example, in two counties, Terra Cha and Xallas, the forest area calculated by CLC06 is 51,053 ha and 6,066 ha, respectively, while SIOSE07-08 offers 50% higher values, i.e. 103,661 ha and 17,960 ha, respectively. IFN4 confirms the results of SIOSE07-08 for these counties, providing similar data of 104,225 ha and 19,151 ha, respectively. A similar situation occurs in the comparison of the results of SIOSE07-08 with USO_25 cartography, with consistent underestimates of forest area throughout almost the whole of the Galicia counties (figure 3b). In six counties (Terra Cha, Ordes, Xallas, O Ribeiro, Baixa Limia, and Terra de Trives) the forest area estimated with USO_25 diverges from the SIOSE07-08 figure by more than 50%.

As regards SIOSE05, there are much smaller differences between this source and its update SIOSE07-08. However, in specific counties these differences (overestimating or underestimating) can reach significant values. For example, in Viana, Valdeorras, A Para-

danta, and Muros, the relative differences vary between -10% and -20%, and similarly, but with positive relative differences, for the counties of O Morrazo and A Coruña. Finally, we can highlight the case of A Baixa Limia where forest area is underestimated in relation to SIOSE05 by 21% (figure 3d).

Figure 3
RELATIVE DIFFERENCE, IN PERCENTAGE, TAKING SIOSE07-08 AS A REFERENCE, OF COUNTY FOREST AREA OF (a) CLC06, (b) USO_25, (c) IFN4, AND (d) SIOSE05



IV. DISCUSSION AND CONCLUSIONS

This study compared estimates of forest area in Galicia from different cartographic sources. This type of comparison allows us to assess the existing harmonisation and reliability of information on the forest area. It also improves the understanding of the differences and similarities offered by different sources, enabling users (e.g. land managers and researchers) to make an informed choice of the cartography that best suits their needs. This choice is crucial due to the great effect that a cartographic source can have on the results of its applications.

The SIOSE05 update performed in this paper from PNOA orthophotos (SIOSE07-08), provides a graphically higher level of detail than that of the rest of the cartographic sources analysed for two reasons: (a) the review scale ranged from 1:5,000 and 1:3,000 and the digitalisation from 1:2,000 and 1:1,000; and (b) this layer does not present minimum mapping units except those derived from the review scale of the orthophotos used. In addition, the measurement of forest area provides a recent image of the expanse of Galician forest, as it includes forest formations with lower minimum mapping units than other available sources, and it does not only obtain the information from occupancy percentages indicated in the SIOSE05 database.

SIOSE07-08 quantifies the forest area of Galicia at 1,960,311 ha, accounting for 66% of the total area of Galicia. As regards other cartographic sources studied, we can highlight that there are significant differences between the figure of CLC06 and USO_25 in quantifying the total forest area, with differences of 475,000 ha and 562,000 ha less, respectively. These sources also underestimate forest area as regards SIOSE07-08 in its assessment at provincial and county level, whereby it can reach differences of around 50% in certain counties. These sources lack many of the advantages listed for SIOSE07-08 due, among other factors, to the digitisation scale, the sources of information used and the minimum mapping units. These characteristics greatly determine the accuracy, forcing some land covers to be classified into classes that do not correspond, which affects the results obtained, as shown in this paper.

Specifically, in relation to CLC06 the differences may be due to generalisation errors derived from the working scale, 1:100,000, compared to 1:25,000 for SIOSE, and/or possible classification errors of land cover; errors that are already documented in other papers (Felicísimo and Sanchez, 2002).

The similarity we found in the quantification of forest area between IFN4 and SIOSE07-08 at the regional, provincial and county level, is a key indicator of the validity of the proposed update, SIOSE07-08. Since the National Forest Inventory is the project that provides detailed nationwide information on forests and their evolution, from both an economic and ecological point of view (MAGRAMA, 2011), IFN4 constitutes a basic reference source used for the analysis of forests. We can therefore conclude that the updating and screening of the information from SIOSE05, SIOSE07-08, is reliable, obtaining very similar data to IFN4. This result indicates that potential updates may be carried out of SIOSE05 for quantification and location of other covers (agriculture, scrub, wooded area, urban) in the territory, even though updating of existing land cover is always a challenging task (Xian and Homer, 2010; Chen et al. 2012).

Finally, this work shows that the diversity of covers and methodologies makes comparison between sources and the possibility of establishing precise data of forest area difficult. To this cartographic scenario there is a new source of information to be considered in the short term, the LiDAR (Light Detection And Ranging) data, as it will provide more accurate and detailed delimitation of the forest formations. LiDAR is an active remote sensing system based on a laser scanner that allows distinguishing and identifying forest formations and their characteristics. It also offers the possibility of measuring the height of the elements, making it possible to identify between wooded and shrub vegetation, which, clearly, has important implications in the autonomous community that we have taken as a case study in this paper, due to its aforementioned impact on the Spanish forestry sector. At present, we have the PNOA (http://www.ign.es/PNOA/caracteristicas_tecnicas.html) project in this format with a point resolution of 2 m and accuracy on the Z coordinate of 0.2 m. This new technology will provide more reliable data on forest area, facilitating the assessment of the level of quality of the remaining traditional cartographic sources analysed here.

V. REFERENCES

BALSA BARREIRO, J. (2012): "O modelo de xestión da superficie forestal en Galicia e a súa repercusión na crise incendiaria do ano 2006". *Revista Galega de Economía*, 21, 11-38.

EC (2010). INSPIRE (Infrastructure for Spatial Information in Europe). [Online]. European Commission. Available in http://inspire.jrc.ec.europa.eu/. [8 May 2013]

CHAS-AMIL, M.L., TOUZA, J. and GARCÍA-MARTINEZ, E.D. (2013): "Forest fires in the wildland-urban interface: a spatial analysis of forest fragmentation and human impacts". *Applied Geography*, 43, 127-137.

CHEN, X., CHEN, J., SHI, Y. and YAMAGUCHI, Y. (2012). "An automated approach for updating land cover maps based on integrated change detection and classification methods". *ISPRS Journal of Photogrammetry and Remote Sensing*, 71, 86-95.

CHUVIECO, E. (2010): *Teledetección Ambiental. La observación de la Tierra desde el espacio*. Editorial Ariel, S.A. 586 pp.

CIENCIALA, E., TOMPPO, E., SNORRASON, A., BROADMEADOW, M., COLIN, A., DUNGER, K., EXNEROVA, Z., LASSERRE, B., PETERSSON, H., PRIWITZER, T., SÁNCHEZ, G. and STAHL, G. (2008): "Preparing emission reporting from forests: use of National Forest Inventories in European countries". *Silva Fennica*, 42, 73–88.

CORBELLE RICO, E. and CRECENTE MASEDA, R. (2009): "Evolución histórica de la Superficie Agrícola Utilizada en Galicia (1962-2006). Integración de fuentes estadísticas y cartográficas". *Economía Agraria y Recursos Naturales*, 9, 183-192.

CORBELLE RICO, E., CRECENTE MASEDA, R. and SANTÉ.RIVEIRA, I., (2012): "Multi-scale assessment and spatial modelling of agricultural land abandonment in a European peripheral region: Galicia (Spain), 1956-2004". *Land use policy*, 29, 493-501.

CRUICKSHANK, M.M., TOMLINSON, R.W. and TREW, S. (2000): "Application of CORINE land-cover mapping to estimate carbon stored in the vegetation of Ireland". *Journal of Environmental Management*, 58, 269-287.

FELICISIMO, A.M., and SÁNCHEZ GAGO, L.M. (2002): Thematic and spatial accuracy: a comparison of the Corine Land Cover with the Forestry Map of Spain. Proc 5th AGILE Conference on Geographic Information Science, Palma (Spain), April 25-27.

GALLAUN, H., ZANCHI, G., NABUURS, G.J., HENGEVELD, G., SCHARDT, M. and VERKERK PJ (2009): "EU-wide maps of growing stock and above-ground biomass in forest based on remote sensing and field measurements". *Forest Ecology and Management*, 260, 251-262.

HERRERO CORRAL, G. (2011): "Las interfaces urbano-forestales como territorios de riesgo frente a incendios: análisis y caracterización regional en España". Doctoral Thesis. Universidad Autónoma de Madrid.

IGE (2013): Analise da cadea forestal-madeira. Instituto Galego de Estatística, 47 pp. [In Galician].

IGN (2007a): Análisis de la problemática del cambio de datum geodésico a ETRS. Versión 1.0. Madrid. Grupo de trabajo para la transición a ETRS89. Instituto Geográfico Nacional. [In Spanish].

IGN (2007b): Análisis de los sistemas de cambio. Versión 1.0. Madrid. Grupo de trabajo para la transición a ETRS89. Consejo Superior Geográfico.

IGN (2007c): Herramientas para facilitar el cambio. Versión 1.0. Madrid. Grupo de trabajo para la transición a ETRS89. Instituto Geográfico Nacional.

IGN. (2011): Documento Técnico Sistema de Ocupación del Suelo de España (SIOSE 2005). Versión 2. [Online]. Instituto Geográfico Nacional. [In Spanish]. Available in http://www.ign.es/siose/Documentacion/Guia_Tecnica_SIOSE/Doc_tecnico_SIOSE2005_v2.pdf [8 May 2013]

LATIFOVIC, R., ZHU, Z-L., CIHLAR, J., GIRI, C. and OLTHOF, I. (2004). Land cover mapping of North and Central America-Global Land Cover 2000. *Remote Sensing of Environment*, 89, 116–127

MARTÍNEZ, J., VEGA-GARCÍA, C., and CHUVIECO, E. (2009): Human-caused wildfire risk rating for prevention planning in Spain. *Journal of Environmental Management*, 90, 1241-1252.

MAGRAMA (1999): Tercer Inventario Forestal. Galicia. [online]. Ministerio de Agricultura, Alimentación y Medio Ambiente. [In Spanish]. Available in

http://www.magrama.gob.es/es/biodiversidad/servicios/banco-datos-naturaleza/informacion-disponible/ifn3_bbdd_descargas.htm.aspx. [8 May 2013]

MAGRAMA (2011): Cuarto Inventario Forestal Nacional. Galicia. [DVD]. Ministerio de Agricultura, Alimentación y Medio Ambiente.

MAGRAMA (2012): Anuario de Estadística Forestal. 2010. [online]. Ministerio de Agricultura, Alimentación y Medio Ambiente. Available in http://www.magrama.gob.es/es/biodiversidad/estadisticas/forestal_anuario_2010.aspx. [7 May 2013]

SEEBACH, L.M., STROBL, P., SAN MIGUEL-AYANZ, J., and GALLEGO, J. (2011): "Comparative analysis of harmonized forest area estimates for European countries". *Forestry*, 84, 285-299.

VÁZQUEZ DE LA CUEVA, A., and RODRÍGUEZ MARTÍN, J.A. (2008): "Dinámica de paisajes forestales en relación a la incidencia del fuego en España peninsular: 1987-2000". *Investigación Agraria: Sistemas y Recursos Forestales*, 17, 143-154.

WASER, L.T., and SCHWARZ, M. (2006): "Comparison of large-area land cover products with national forest inventories and CORINE land cover in the European Alps". International Journal of *Applied Earth Observation and Geoinformation*, 8, 196-207.

WU, W., SHIBASAKY, R., YANG, P., ONGARO, L., ZHOU, Q. and TANG, H. (2008). "Validation and comparison of 1 km global land cover products in China". *International Journal of Remote Sensing*, 29, 3769-3785.

XIAN, G. and HOMER, C. (2010). "Updating the 2001 National Land Cover Database Impervious Surface Products to 2006 using Landsat Imagery Change Detection Methods". *Remote sensing of environment*, 16, 1676-1686.