Comparing AWIFS and MERIS images for land use-land cover mapping in Spain

Comparación de imágenes AWIFS y MERIS en la cartografía de usos y cubiertas del suelo en España

F. González-Alonso[1], S. Kaiser[1], S. Merino[2], M. Huesca[1], A. Roldán[1], J.M. Cuevas[1] y G. Ventura[1]
alonso@inia.es

[1]*CIFOR-INIA (Ministerio de Ciencia e Innovación), Ctra. A Coruña, km 7.5 Madrid 28040*
[2]*EUIT Forestal (Universidad Politécnica de Madrid),Ciudad Universitaria s/n Madrid 28040*

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RESUMEN

Dada la creciente importancia de los mapas de usos y coberturas, se considera de gran utilidad el realizar una evaluación de los beneficios y desventajas del uso de imágenes de satélite de mejor resolución espacial o espectral, de cara a la mejora de ciertas metodologías. En este trabajo se presenta la comparación de clasificaciones de la provincia de Madrid (España) realizadas a partir de imágenes AWiFS (Advanced Wide Field Sensor) y MERIS-FR (MEdium Resolution Imaging Spectrometer – Full Resolution). El algoritmo de clasificación empleado fue el de máxima probabilidad para lo que se usaron áreas de entrenamiento basadas en datos procedentes del Inventario Forestal Nacional y del CORINE Land Cover 2000. La clasificación a partir de la imagen AWiFS fue más laboriosa obteniéndose una precisión global un 10% mayor que en el caso de MERIS-FR. Sin embargo, para ciertas clases como la de bosque caducifolio, la mejor resolución espectral de MERIS-FR supuso una ventaja. Queda en mano de los investigadores decidir si los mejore resultados obtenidos con AWiFS compensan el mayor coste de las imágenes y el mayor esfuerzo de procesado.

PALABRAS CLAVE: IRS-AWiFS, ENVISAT-MERIS, clasificación supervisada, mapas de usos y coberturas, CORINE Land Cover, inventario forestal.

ABSTRACT

As global land use – land cover mapping has become of great importance, an evaluation of the benefits and disadvantages of using satellite data with either increased spatial or spectral resolution would be adequate for the improvement of methodologies. This paper describes the comparison of AWiFS (Advanced Wide Field Sensor) and MERIS-FR (MEdium Resolution Imaging Spectrometer – Full Resolution) -based classifications of the Spanish province of Madrid. Maximum Likelihood Supervised Classification was performed using training areas based on data coming from the Spanish National Forest Inventory and from the CORINE Land Cover 2000 data bases. The classification process with AWiFS was more laborious than with MERIS-FR but the overall accuracy could be increased by 10%. For some surfaces such as deciduous forests, the high spectral resolution of MERIS-FR might be an advantage. Researchers will have to decide if the better results obtained with AWiFS compensate for the higher cost of the images and the more effortful processing.

KEYWORDS: IRS-AWiFS, ENVISAT-MERIS, supervised classification, land use – land cover mapping, CORINE Land Cover, forest inventory.

INTRODUCTION

In times when many countries are concerned about the reduction of CO_2 and other greenhouse gases to satisfy the requirements of the Kyoto protocol, the availability of updated cartography at different scales becomes more and more important. International organizations such as the European Space Agency (ESA) are involved in global projects that aim to provide these products to decision and policymakers all over the world. One of the most determining projects is the currently running European GLOBCOVER project (DUP-ESA, 2006). The objective is to develop a service which will produce a 300m global land cover map for the year 2005 using mainly full resolution data acquired by the MERIS (Medium Resolution Imaging Spectometer) sensor on-board ENVISAT (Joint Research Centre – Terrestrial Ecosystem Monitoring, 2006).

As the medium spatial resolution of MERIS-FR (Full Resolution) products may restrict the process of obtaining high-quality end-products in some cases, other satellite-derived data with increased spatial resolution, such as the ones acquired by the Advanced Wide Field Sensor (AWiFS) of the Indian RESOURCESAT-1 (National Remote Sensing Agency, 2006) should be tested for their aptitude to produce high-quality land use - land cover (LULC) maps with a reasonable effort in terms of time and money. Benefits and disadvantages of using satellites with either increased spatial or spectral resolution have to be evaluated in the future to refine methodologies for LULC mapping.

As a first step in this direction, the classification described in this paper aims to supply information about pros and contras of using satellite data with different spatial and spectral resolution for the creation of forest or LULC maps at any scale for researchers and decision makers dealing with this issue. For that purpose, a classification based on an AWIFS image of the Spanish province of Madrid was performed and the results were compared with previous classification results for MERIS-FR data.

STUDY AREA

The Spanish province of Madrid (figure 1) comprises 8022 km² including the metropolitan area of Madrid in the centre surrounded by evergreen broadleaved forests (*Quercus ilex*) and shrublands, cultivated and sparsely vegetated areas in the South-East and the Sierra de Guadarrama with its evergreen and deciduous forests (Pinus sylvestris, Quercus pyrenaica etc.) in the North-West.

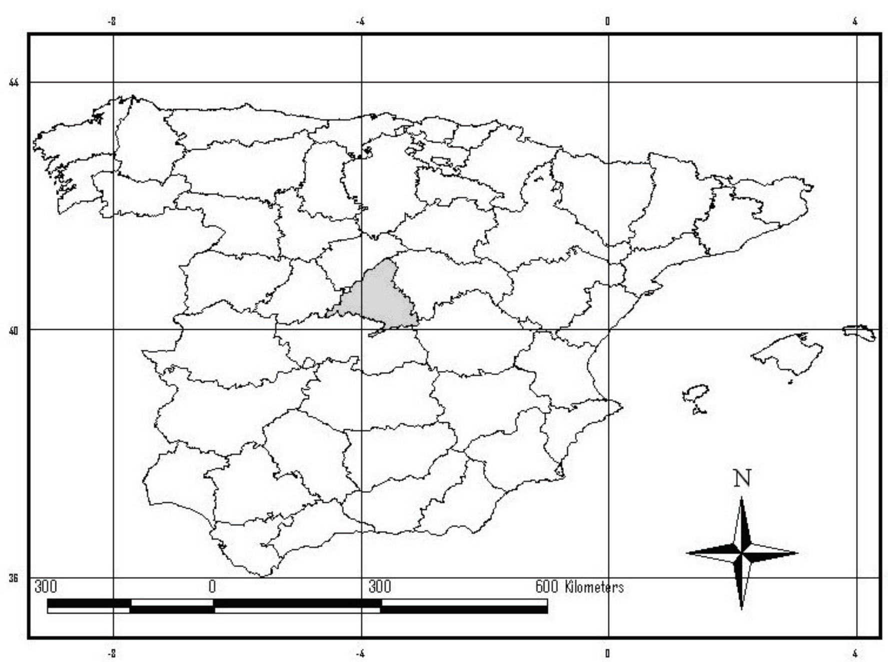

Figure 1. The province of Madrid (grey) situated in the centre of Spain

MATERIAL

The material used for the present work belongs to three main categories: (i) remotely sensed images (spaceborne products and aerial orthophotos), (ii) field data and (iii) reference cartography.

(i) The image chosen for classification was acquired on August 22, 2005 by the 10-bit AWiFS sensor. A land cover mapping product based on a medium-resolution MERIS-FR image (ESA, 2006) developed by García-Gigorro *et al*. (2007) was used for comparison with the results obtained with AWiFS data (table 1). Orthophotos of the province of Madrid provided by the SIGPAC Website of the Ministry of Agriculture, Fishing and Food (MAPA, 2006) were reviewed to validate the Regions of Interest (ROIs) defined in the classification process.

Sensor	spatial resolution at nadir	bands	spectral coverage	swath-width
AWIFS	60m	4	0,52 to 1,70 µm	740 km
MERIS	300m	up to 15	0,39 to 1,04 µm	1150km

Table 1. Characteristics of AWIFS and MERIS sensors (Euromap, 2006; ESA, 2006).

(ii) Field data came from the Third National Forest Inventory's (3-NFI) database (Ministerio de Medio Ambiente, 2004) that supplies detailed information on Spanish forests. Several forest and environmental parameters are measured every ten years at permanent sample plots located on the ground according to a regular net all over the country.

(iii) Reference cartography for the selection of ROIs was compounded by 3-NFI maps for forest classes (needleleaved forest, broadleaved forest, mixed forest and closed forest – shrublands) and the CORINE Land Cover 2000 (CLC2000) product for the remaining land cover classes considered. The aim of the European CLC2000 project is to provide land cover information that should be of homogeneous quality, strictly comparable for all the countries involved and susceptible to be updated periodically (CORINE, 1993). The maps are at a 1:1.000.000 scale with an accuracy of at least 100m for all European products and the minimum mapping unit is 25ha (Instituto Geográfico Nacional – España, 2004).

METHODOLOGY

The original AWiFS image was re-projected from its original Lambert Conformal Conic to the UTM-30N-WGS84 coordinate-system and a subset containing the province of Madrid was obtained. Maximum Likelihood Supervised Classification (MLSC) was performed. MLSC requires *a priori* knowledge of the considered LULC classes. In the present work, two cartographies were used as ground truth for both training and validation purposes: the 3-NFI maps for forest classes and the CLC2000 map for non-forest classes, as for this purpose it is the most accurate product available.

The classification process was divided into four phases: (i) legend definition, (ii) delimitation of ROIs for training and validating, (iii) supervised classification and (iv) accuracy analysis of the results.

(i) Legend categories were defined based on the European Global Land Cover 2000 (GLC2000) LULC products (Joint Research Centre, 2006) since they are FAO-based, facilitating therefore the comparison of the obtained results with other available cartographies. 3-NFI and CLC2000 classes were assembled to make up each of the GLC2000 categories, as shown in table 2.

(ii) Concerning the forest categories, ROIs were delimited on homogeneous areas on or near the ground plots locations of the 3-NFI. For that purpose, around 10% of the 3-NFI ground plots locations were selected by systematic sampling. Plots locations were checked at the SIGPAC Website (MAPA, 2006) and the ROIs that resulted to be of a land cover type that did not agree with reference cartography were discarded. By doing this, the number of ROIs considered for each forest category decreased although it increased their quality. At the end, we accounted for a number of ROIs per class that varied between 15 and 30 of around 15 pixels each. In the case of broadleaved forests, the classification was performed using three subclasses (deciduous, closed evergreen, scattered evergreen) that were combined afterwards. For non-forest categories we delineated between 30 and 50 ROIs per class, using the CLC2000 map as a base.

(iii) MLSC was performed with all four AWiFS bands. In a first step, the classification algorithm was trained using 50% of the delineated ROIs, using the remaining 50% ROIs for validation. In a second step, and provided that the first classification had resulted accurate enough, the classification algorithm

GLC-based legend	Description according to reference cartography	reference cartography used
CDBF (Closed Deciduous Broadleaved Forest)	In Spain deciduous and evergreen species. Species in Madrid: *Quercus ilex, Quercus pyrenaica, Populus nigra, Fraxinus spp*	3-NFI
MFS (Mixed Closed Forest and Shrubland)	Arborescent matorrals of 5-19% crown cover density.	3-NFI
CENF (Closed Evergreen Needleleaved Forest)	*Pinus sylvestris, Pinus pinaster, Pinus pinea, Pinus halepensis*	3-NFI
MF (Mixed Needleleaved and Broadleaved Forest)	*Pinus pinea* with *Quercus ilex* or *Q.faginea, Juniperus* spp. with *Quercus ilex* and/or *Q.pyrenaica*	3-NFI
CMI (Cultivated and Managed areas, Irrigated)	Irrigated arable land (vineyards, fruit trees & berry plantations, olive grows, annual crops associated with permanent crops, complex cultivation patterns, land principally occupied by agriculture with significant areas of natural vegetation)	CLC2000
CMN (Cultivated and Managed areas, Non-irrigated)	Non-irrigated arable land (vineyards, fruit trees & berry plantations, olive grows, annual crops associated with permanent crops, complex cultivation patterns, land principally occupied by agriculture with significant areas of natural vegetation)	CLC2000
G (Grassland)	Natural Grassland	CLC2000
UA (Urban areas)	Urban areas: continuous or discontinous urban fabric, industrial or comercial units, road and rail networks and associated land, airports, mineral extraction sites, dump sites, construction sites, green urban areas	CLC2000
CS (Closed Shrubland)	Moors & heathland, sclerophyllous vegetations	CLC2000

Table 2. Description of the GLC-based legend used for the classification of the AWiFS and MERIS Images.

was trained using 100% of the delineated ROIs.

(iv) The accuracy analysis of the first classification was performed using those ROIs that had not been used for training, as mentioned before. The second classification was analysed using the same ROIs that had been used for training. This second step was done supposed that the accuracy would be higher or at least equal to the classification trained with 50% of the ROIs.

The latter classification was finally compared to the 3-NFI and CLC2000 maps and with a MERIS-FR-based classification of the study area performed by García-Gigorro *et al*. (2007). The methodology employed to obtain the MERIS-FR product was similar to the one described in this work.

RESULTS AND DISCUSSION

Nine LULC classes were considered for the province of Madrid. The classes are mentioned in the legend of figure 2 and explained in more detail in table 2. Figure 2.1 shows the two land cover maps to be compared for the province of Madrid – the one based on AWiFS data (A) and the one based on MERIS-FR imagery (B). Figure 2.2 shows the AWiFS classification in comparison with the 3-NFI and CLC2000 reference cartographies. Table 3 provides an overview of land cover class surfaces for all the three products.

The overall and class accuracies for the classifications based on AWIFS and MERIS, using 50% of ROIs as trainers and 50% for validation, are compiled in table 4.

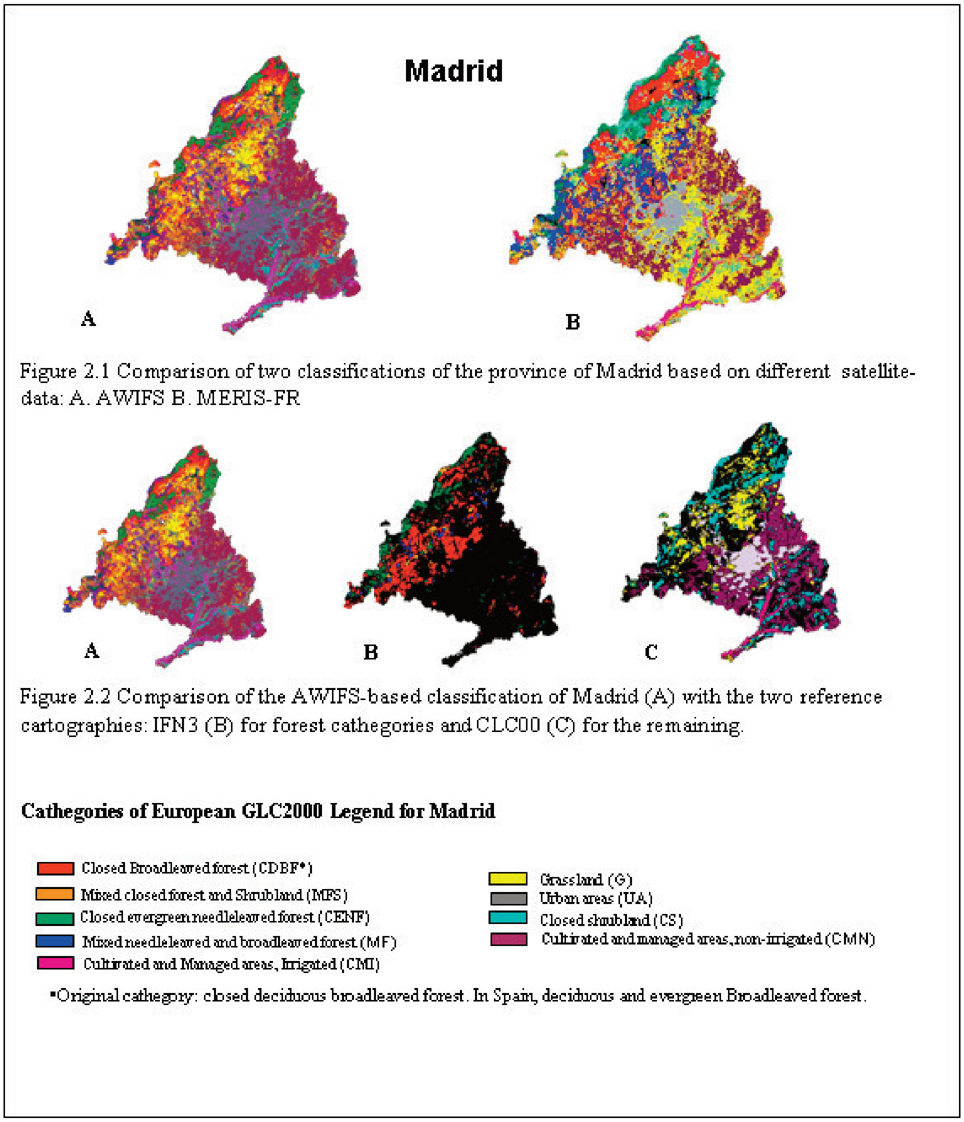

Figure 2. Classification results for AWiFS and MERIS_FR data and comparison with reference maps.

Class	AWIFS classification based on IFN&CLC	MERIS classification based on IFN&CLC	CLC2000	3-NFI
CDBF	14,17	15,35	6,79	19,60
MFS	5,82	6,11	10,80	3,14
CENF	6,79	8,62	5,59	8,50
MF	6,34	7,96	0,50	2,42
CMI	3,89	4,72	4,50	x
CMN	31,49	19,91	26,35	x
G	10,,58	18,56	13,78	x
UA	14,47	9,53	11,93	x
CS	6,45	8,47	13,91	x
water	*masked*	0,75	0,87	x

Table 3. Comparison of relative class surfaces (%) for different cartographies. For 3-NFI forest cartography, non forest surfaces are not considered.

	AWiFS overall accuracy = 74,66 % Kappa = 0,70				MERIS overall accuracy = 65,55 % Kappa = 0,58			
Clase	PA	OE	UA	CE	PA	OE	UA	CE
CDBF	46,64	53,36	49,02	50,98	66,15	33,85	78,45	21,55
MFS	45,00	55,00	30,00	70,00	9,52	90,48	7,41	92,59
CENF	80,66	19,34	90,48	9,52	70,42	29,58	62,04	37,96
MF	43,48	56,52	18,87	81,13	6,90	93,10	5,26	94,74
CMI	98,62	1,38	95,56	4,44	87,07	12,93	92,66	7,34
CMN	88,47	11,53	91,45	8,55	89,95	10,05	81,4	18,60
G	77,61	22,39	62,40	37,60	45,05	54,95	50,51	49,49
UA	93,04	6,96	95,35	4,65	94,81	5,19	89,51	10,49
CS	30,54	69,46	57,03	42,97	28,57	71,43	24,14	75,86

Table 4. Comparison of the accuracy of the two classifications for the province of Madrid. PA= producer accuracy, OE= omission error, UA= user accuracy, CE=commission error (all in %).

To consider not only class accuracies but also class areas to determine the overall accuracy, a weighted overall accuracy was calculated:

$$\text{Weighted overall accuracy} = \sum_{i=1}^{n} PA_i \cdot CA_i$$

Being PAi the Producer Accuracy for class i and CAi the proportional Class Area for class i, ranging from 0 to 1. The producer accuracy is a measure indicating the probability that the classifier has labelled an image pixel into class j given that the ground truth is class j, and it is usually expressed as a percentage. The resulting weighted overall accuracy is also expressed as a percentage. Weighting the overall accuracy made it decrease from its original 74,66 % to 72,11 %, in the case of the AWiFS-based classification and from its original 65,55% to 61,54%, in the case of the MERIS-FR-based classification.

Due to the relatively high spatial resolution of AWiFS, areas inside the patches defined by the reference polygons for a particular class may be relatively heterogeneous on the remotely sensed image – a fact that makes the selection of representative ROIs more difficult. This occurs specially in the case of the urban areas, a class that according to the CLC2000-definition includes spectrally different surfaces such as constructed areas or urban parks that are not put together in the same category in the final classification product. Depending on the characteristics of the area to classify, this might be a disadvantage of using images with a relatively high spatial resolution for mapping.

In the process of mapping, a conflict between satellite imagery and reference cartography arises. When performing a supervised classification of remotely sensed data, a land cover map composed by spectrally distinguishable classes is obtained, whilst reference products provide land use classes. As an example, 31,42% of the study area is classified as "Cultivated, non irrigated areas", being this class a mixture of what in reality is shrub lands, cultivated areas, grassland and bare soil – all spectrally similar but managed in a different way. The bare soil class does not appear in the classifications, as it is not representative according to the CLC2000 layer. Some areas with bare rocks are included in the urban areas class, as the surfaces' spectral responses are similar.

What are the benefits of using satellite data with high spatial resolution (AWiFS) rather than high spectral resolution (MERIS-FR)? The AWiFS-product provided higher accuracies for most of the classes. The most significant exception is the category deciduous forests where better results were achieved with MERIS. For that kind of photosynthetically active surfaces it may be more adequate to rely on high spectral resolution data, such as the ones provided by MERIS-FR, rather than high spatial resolution information.

An increase of 10% of the overall accuracy is achieved with AWiFS, but the task of image-classifying compared with MERIS-FR is more effortful as the extra detail of the image also increases the heterogeneity inside the LULC class areas suggested by reference cartographies. The lower cost of MERIS-FR imagery has to be taken into account as well.

CONCLUSIONS

The results reached so far suggest that AWiFS images as a good source of information for land cover mapping. Nevertheless, although accuracies obtained for AWIFS classifications are higher, MERIS data may be more adequate for some types of surfaces. If a forest map is to be developed at European scale, the characteristics of each country's land cover types have to be carefully analyzed to determine whether it is worth assuming the higher cost and more laborious process of using AWIFS instead of MERIS-FR to reach the proposed goals.

Important differences appear when comparing the classification product with the reference data, mainly due to the conflict land use vs land cover classes and the difficulty to achieve compatible legends. It would be useful to reach an agreement for the use of a global land use and land cover legend. Classes should be adaptable to the specific characteristics of the different countries involved in global scale projects.

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