Mapping invasive species (*Acacia dealbata* Link) using ASTER/TERRA and LANDSAT 7 ETM+ imagery

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Abstract

The rapid spread of invasive alien species (IAS) is now recognised as one of the greatest threats to the ecological and economic well being of the planet. This study shows a comparison between ASTER/TERRA and ETM+/LANDSAT 7 sensors data suitability for mapping the *Acacia dealbata* Link spots. The work was carried out in central Portugal (Viseu region) where the presence of invader species in pure stands is quite significant. The images were ortho-rectified and submitted to supervised classifications techniques. The achieved results showed an overall accuracy of 89.42% over the ETM+ image and 86.69% over the ASTER image. For the class *Acacia dealbata* Link, the producer's precision was 100% for both images but the user's accuracy was only 23% in ETM+ and 12% in ASTER image. The obtained results suggest good perspectives for the use of this type of satellite images in order to detect and map this invasive species.

Keywords: Alien species, Acacia dealbata, land cover classification, Landsat ETM+, ASTER

1. Introduction

The rapid spread of invasive alien species (IAS) is causing irreparable damage to global ecosystems. Variously referred to as exotic, non-native, alien, noxious, or non-indigenous weeds, these species are causing enormous damage to biodiversity and to the valuable natural agricultural systems, which we depend on (Coimbra 1999; Liberal & Esteves 1999; Aguiar et al. 2001; Aguiar & Ferreira 2005, Viana 2005). In Portugal, the establishment and spread of invasive species, particularly *Acacia dealbata* Link, has increased over time. They were introduced deliberately as silvicultural, for soil fixing, as ornamental or by another pretext, being now a serious problem for the ecosystems, with difficult control and even impossible eradication. Identifying those areas is essential to quantify the real dimension of the problem (Coimbra 1999; Liberal & Esteves 1999; Bargeron et al. 2003; Viana 2005).
With the coming in sight of new image sensors, with different characteristics, and data availability, it is important to test the potentialities for specific uses as IAS detection and mapping (Asner 1998; Bargeron et al. 2003; Leitão et al. 2003; Brundu 2005; Chikhaoui et al. 2005; Viana 2005; D'Iorio et al. 2007).
The Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) is a research facility launched on NASA's Earth Observing System, on board of TERRA satellite (previously called EOS AM-l), in December 1999. As expected ASTER data has been used in specific areas of scientific investigation, including vegetation and ecosystem dynamics, hazard

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monitoring, geology and soils, land surface climatology, hydrology, and land cover change (Abrams 2000; NASA 2004; Tangestani 2004; Chikhaoui et al. 2005; Euroimage 2008).
The Landsat programme constitutes the longest data register of the Land surface from the Space. The Enhanced Thematic Mapper-Plus (ETM+) was launched on April 15, 1999 on board of Landsat7 and, as TM sensor data, imagery have been extensively used for agricultural evaluation, forest management inventories, geological surveys, water resource estimates, coastal zone appraisals, and a host of other applications (Song et al. 2001; Darvishsefat 2003; Thenkabail et al. 2004; Peterson 2005; Viana 2005; NASA 2006; NASA 2007;).
Given the characteristics of ASTER sensor systems, which provide imagery data at higher spatial resolution (15m on VNIR) than ETM+ (30m), the same temporal resolution-16 days, and with a unique combination of wide spectral coverage, in this study we tested and compared both imagery performance in the mapping of a specific class of forest land cover (*Acacia dealbata* Link).
Study Area was a 64Km x 60Km rectangle in the region of Viseu (centre of Portugal) (see Figure 1). It's a heterogeneous area with a complex topography and fragmented land cover, with elevation in the range of 100 to 1800m; high climatic variability, with annual mean precipitation in the range of 800 to 2800 mm and annual mean temperatures of < 7.5 to 16 ºC.

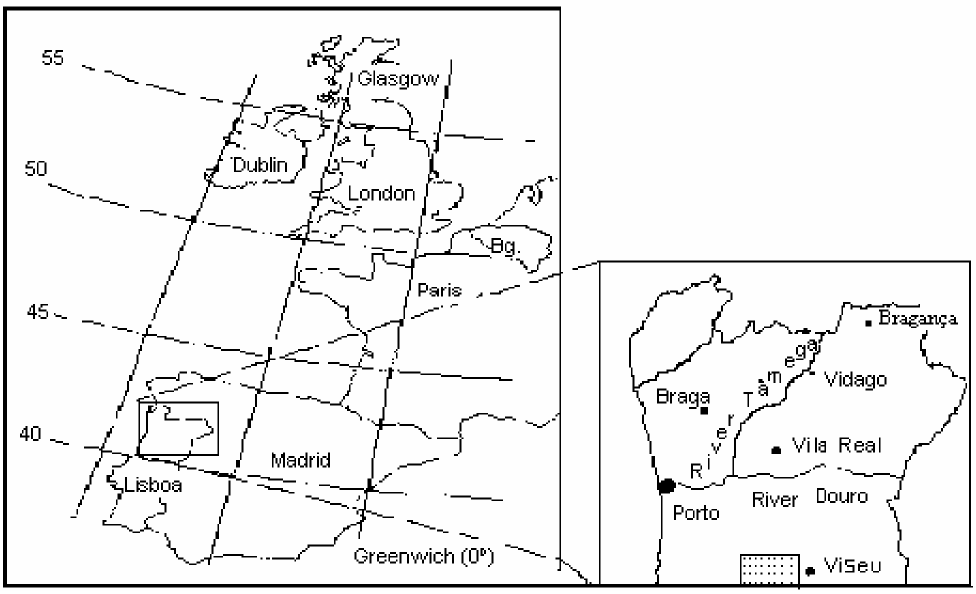

Figure 1: Study area location.

2. Methodology

2.1. Data acquisition

The study was developed using multispectral images covering Viseu's region, in Portugal, provided from the sensor ETM+/Landsat 7, and sensor ASTER/Terra (L1b format), on the VNIR bands. The acquisition date of ETM+ was on 24, January 2003, period in which these plants were flowery and ASTER on 7, October 2003, since it was the available image closest to the ETM+ acquisition date. Topographic maps 1:25000 and orthophotomap 1:10000 were used as auxiliary tools in the definition of training classes and in the validation stage. The collection of spatial information as cartographic elements e.g. land cover classes, roads and ground control points (GCP) was done by GPS. A total of 85 plots of *Acacia dealbata* were measured in a sum of 66.6 hectares, with a mean area around 0.78 hectares, later used for training classes. The GCP

were collected in road crosses, barrages or other notable points visible in the images (Lillesand et al 2004; Viana 2005, Eastman 2006).

2.2. Data processing

The conceptual framework of the research followed 5 central steps: geometric correction, Image enhancement, image transformation (vegetation indices and principal component analysis), classification and interpretation and validation. DGPS (Differential Global Positioning System) data was corrected with Pathfinder Office, image data were processed with IDRISI 32, and GIS based analyses was done with ArcGis software.
In first place the ASTER data (level 1B) of VNIR bands (1, 2, 3N), with 15m spatial resolution, in the HDF format, and ETM+ data of pan band with 15 m and multispectral band (1~5, 7) with 30 m spatial resolution were imported to IDRISI. The ASTER image and pan ETM+ images were registered with GCP, and the multispectral ETM+ bands were based on image-to-image method, using the already registered images as reference.
For image classification, it was adopted a land use/cover scheme based upon the Corine Land Cover classification (CLC2000). They were performed automatic classification methods, unsupervised models and Principal Component Analysis (Song et al. 2001, Tsai et al. 2007). Supervised classification of multispectral images was performed, running the Maximum Likelihood classifier (MLC) and the Minimum Distance to Means Classifier (MDMC) (Lillesand et al. 2004, Eastman 2006, Scally 2006). The accuracy of a classified image refers to the extent to which it agrees with a set of reference data. Thus, an error matrix was created in order to compare the accuracy of maps obtained from satellite images classification. The error matrix provides a mean to calculate the overall accuracy and to compute accuracies of each category (Congalton and Green 1999). Kappa statistic (Cohen 1960), because of its ability to provide information about a single matrix and to statistically compare matrices, was calculated in order to get another measure of agreement between the predicted values and the observed values, the, (Cohen 1960, Rosenfield and Fitzpatrick-Lins 1986, Congalton and Green 1999, Meidinger, 2003).
For land cover changes detection, it was used a pixel-to-pixel comparison of classified images, because it is a method widely used and easily understood.

3. Result

After supervised image classification, the resulting images area very alike. These results were evaluated using a set of 2304 validation points and error matrix. The overall statistics of classifications are summarised in the Tables 1 and 2.

Table 1: Producer's and User's for ETM+ and ASTER imagery classification

Land cover class	Producer's accuracy (%)		User's accuracy (%)	
	ETM+	ASTER	ETM+	ASTER
Forested areas	93.1	94.7	99.9	97.8
Meadow	81.8	56.0	96.8	84.8
Acacia dealbata	100.0	100.0	22.4	11.1

As previous presented table show, both images provided quite similar results. The best classification was achieved with the Maximum Likelihood classifier (Table 2). Although the ETM+ image achieve a higher overall accuracy, and superior user's accuracy, for all the considered land cover classes, only the Md class had higher producer accuracy (81.8% and 56.0%, respectively).

Table 2: Overall accuracy of ETM+ and ASTER imagery classification

Method	Overall accuracy (%)	Kappa statistics
ETM+ - MLC	89.42	0.8543
ETM+ - MDMC	63.53	0.5190
ASTER - MLC	86.69	0.8121
ASTER - MDMC	69.21	0.5688

For the land cover class Fr the reliability of ETM+ image (93.1%) was minor than ASTER (94.7%). In the best classification (MLC), the class “acacias” had shown a Producer’s accuracy of 100% in both ETM+ and ASTER images. This happened due to the commission error being 77.57% in ETM+ and 88.89% in ASTER image (Table 3). This means that the vector shapes considered in the creation of this spectral signature were representative of the Ac class, and had been well created, however given the nature of this land cover class (permanent leaf and closed canopy) some pixels belonged to other land cover class were classified as Ad, principally Md class in reason of their similar spectral response.
All Ad (*Acacia dealbata*) spots mapped with a DGPS were well classified by satellite image classification. However, do to small spot dimension and fragmented landscape, some Md (Meadow) were misclassified as Ad (*Acacia dealbata*) areas.

4. Discussion

In this paper/work we have compared ASTER and ETM+ data in forest applications. The accuracy of image classification and interpretation was tested and compared. The resulting conclusions are:
- ASTER data can be registered with elevated accuracy with error less than half pixel.
- ASTER is better than ETM+ data in visual surface feature identification.
- ASTER classification has the same effect as ETM+ with high accuracy;
- With ASTER it was possible to classify land cover shapes with smaller areas in reason of their superior spatial resolution.
- A superior resolution in ASTER (15m) is not an evident advantage when mapping features with reduced dimension such as Ad (*Acacia dealbata*), given that the spectral confusion, fact amplified in fractionated landscapes as in the Centre of Portugal.
- The Maximum Likelihood classifier gave better results than the Minimum Distance to Means classifier in the supervised classification, involving land cover classes (acacias) distributed in parcels with small areas.
- Given the uncertainty about follow-on Landsat ETM+ sensor, ASTER imagery could be supply suitable images for monitoring applications, with similar results.

References

Abrams, M., 2000, The Advanced Spaceborne Thermal Emission & Reflection Radiometer (ASTER): Data products for the high spatial resolution imager on NASA's Terra platform. *International Journal of Remote Sensing*, 21(5), pp. 847-859.

Aguiar, F. C., Ferreira, M. T. & Moreira, I., 2001, Exotic & Native Vegetation Establishment Following Channelization of a Western Iberian River. Regulated Rivers: *Research & Management*, 17, pp. 509-526.

Almeida, T. I. R., De Souza Filho, C. R. & Rossetto, R., 2006, ASTER & L&sat ETM+ images applied to sugarcane yield forecast. *International Journal of Remote Sensing*, 27(19), pp.4057-4069.

Atlas Do Ambiente, 1978, *Carta da Distribuição de Acácias e Eucaliptos*. Escala 1/1000000. In: Atlas do Ambiente Digital, Instituto do Ambiente. Impressa no Instituto Hidrográfico, Lisboa.

Bargeron, C. T., Moorhead, D. J., Douce, G. K., Reardon, R. C. & Miller, A. E. (Tech. Coordinators), 2003, *Invasive Plants of the Eastern U.S.: Identification & Control*. [CD-ROM]. USDA Forest Service - Forest Health Technology Enterprise Team. Morgantown, WV USA. FHTET.

Brundu, G., Camarda, I. & Satta, V., 2003, A methodological approach for mapping alien plants in Sardinia (Italy). In *Plant Invasions: Ecological Threats & Management Solutions*, Child, L.E.; Brock, J.H.; Brundu, G.; Prach, K.; Pysek, P.; Wade, P.M.; Williamson, M. (Eds.), pp. 41-62. (Leiden, The Netherl&s: Backhuys Publishers).

Chavez, P. S., Jr. (1996), Image-based atmospheric corrections revisited & improved. *Photogrammetric Engineering & Remote Sensing*. 62, pp. 1025–1036.

Chavez, P. S., Jr., 1988, An improved dark-object subtraction technique for atmospheric scattering correction of multi- spectral data. *Remote Sensing of Environment*, 24, pp. 459–479.

Chavez, P. S., Jr., 1989, Radiometric calibration of L&sat Thematic Mapper multispectral images. *Photogrammetric Engineering & Remote Sensing*. 55, pp.1285–1294.

Chikhaoui, M.; Bonn, F., Bokoye, A. I. & Merzouk, A., 2005, A spectral index for l& degradation mapping using ASTER data: Application to a semi-arid Mediterranean catchment. *International Journal of Applied Earth Observation & Geoinformation*, 7, pp.140-153.

Civco, D. L., 1989, Topographic normalization of L&sat Thematic Mapper digital imagery. *Photogrammetric Engineering & Remote Sensing*, 55, pp. 1303–1309.

Cohen. I., 1960, A coefficient of agreement of nominal scales. *Educational & Psychological Measurement*, 20(1): 37-46.

Coimbra, A. J. M., 1999, Distribuição da mimosa (Acacia dealbata Link) na área do Parque Natural da Serra da Estrela. *In 1º Encontro sobre Invasoras Lenhosas*, 16 a 18 de Novembro, Parque Nacional da Peneda-Gerês, Gerês, pp. 186-189.

CONGALTON, R.G. & K. Green., 1999, *Assessing the Accuracy of Remotely Sensed Data: Principles & Practices.* Lewis Publishers. 137 pp.

Coutinho, A. X. P., 1939, *Flora de Portugal (Plantas Vasculares)*. 2ª Edição dirigida por R. T. Palhinha. (Lisboa, Bertr& Irmãos Ltd.).

Du, Y., Teillet, P. M., & Cihlar, J., 2002, Radiometric normalization of multitemporal high-resolution satellite images with quality control for l& cover change detection. *Remote Sensing of Environment*, 82, pp. 123–134.

Eastman, J. R., 2006, *Idrisi Andes. Guide to GIS & Image Processing*. (Worcester: Clark Labs for Cartographic Technology & Geographic Analysis, Clark University).

Esri, 2004, *ArcGIS version 9.2* (Redl&s, California: ESRI).

Fensham, R. J., Fairfax, R. J., Holman, J. E. & P. J. Whitehead, 2002, Quantitative assessment of vegetation structural attributes from aerial photography. *International Journal of Remote Sensing*, 23(11), pp. 2293–2317.

Franco, J. A., 1971, *Nova Flora de Portugal (Continente e Açores).* 1ª. ed, Lisboa (Impressa na Sociedade Astória Lda).

Godinho-Ferreira, P., Azevedo, A. & Rego, F., 2005, Carta da Tipologia Florestal de Portugal Continental. *Silva Lusitana*, 13(1), pp. 1-34.

Larsson, H., 2002, Acacia canopy cover changes in Rawashda forest reserve, Kassala Province, Eastern Sudan, using linear regression NDVI models. *International Journal of Remote Sensing*, 23(2), pp. 335 339.

Leitão, P., Pinto, M. & Máguas, C., 2003, Remote sensing evaluation of post-fire sand-dune acacia forest dynamics. *In Invasão de Habitats Naturais por espécies lenhosas infestantes*, 7 de Novembro, Parque Nacional da Peneda-Gerês, Gerês.

Liberal, M. & Esteves, M., 1999, Invasão de Acacia dealbata no Parque Nacional da Peneda-Gerês. *In 1º Encontro sobre Invasoras Lenhosas*, 16 a 18 de Novembro, Parque Nacional da Peneda-Gerês, Gerês, pp 99-103.

LILLES&, T.M., KIEFER, R.W. & CHIPMAN, J.W., 2004, *Remote Sensing & Image Interpretation*, 5th edition, 765 pp. (New York, NY: John Wiley & Sons).

Lu, D. & Weng, Q., 2007, A survey of image classification methods & techniques for improving classification performance. *International Journal of Remote Sensing* Vol. 28, No. 5, pp. 823–870.

Meyer, P., Itten, K.I., Kellenberger, T., S&meier, S. & S&meier, R., 1993, Radiometric corrections of topographically induced effects on L&sat TM data in an alpine environment. ISPRS *Journal of Photogrammetry & Remote Sensing*, 48, pp. 17–28.

Montserud, R. A. & Leamans, R., 1992, Comparing global vegetation map with the Kappa statistic. *Ecological Modeling*, 62, pp. 275–293.

Peterson, E. B., 2005, Estimating cover of an invasive grass (Bromus tectorum) using tobit regression & phenology derived from two dates of Landsat ETM+ data. *International Journal of Remote Sensing*, 26(12), pp. 2491–2507.

Rosenfield, G. H. & Fitzpatrick-Lins, K., 1986, A coefficient of agreement as a measure of thematic accuracy. *Photogrammetric Engineering & Remote Sensing*, 52(2): 223-227.

Song, C., Woodcock, C. E., Seto, K. C., Lenney, M. P. & Macomber, S. A., 2001, Classification & Change Detection Using L&sat TM Data: When & How to Correct Atmospheric Effects? *Remote Sensing of Environment*, 75, pp. 230-244.

Tangestani, M. H., Mazhari, N., Agar, B. & Moore, F., 2008, Evaluating Advanced Spaceborne Thermal Emission & Reflection Radiometer (ASTER) data for alteration zone enhancement in a semiarid area, northern Shahr-e-Babak, SE Iran. *International Journal of Remote Sensing*, 29(10), pp. 2833–2850

Teillet, P.M., Guindon, B. & Goodenough, D.G., 1982, On the slope-aspect correction of multispectral scanner data. *Canadian Journal of Remote Sensing*, 8, pp. 84–106.

Toutin, T., 2004, Review article: Geometric processing of remote sensing images: models, algorithms & methods. *International Journal of Remote Sensing*, 25(10), pp. 1893-1924.

Tsai, F., Lin, E. K. & Yoshino, K., 2007, Spectrally segmented principal component analysis of hyperspectral imagery for mapping invasive plant species. *International Journal of Remote Sensing*, 28, pp. 1023-1039.

USGS, 2008, ASTER Overview. *NASA's Earth Observing System (EOS). Land Processes Distributed Active Archive Centre (LPDAAC)*. Available online at: https://lpdaac.usgs.gov/lpdaac/products/aster_overview (accessed 10 January 2009).

USGS, 2009, *Landsat Enhanced Thematic Mapper Plus (ETM+). Product information*. Available online at: http://eros.usgs.gov/products/satellite/l&sat7.php (accessed 10 January 2009).

Viana, H., 2005, *Aplicação de Tecnologias de Detecção Remota e Sistemas de Informação Geográfica na Identificação de Áreas Ocupadas com Acacia dealbata Link*. Dissertação de Mestrado em Engenharia dos Recursos Florestais. University of Trás-os-Montes e Alto Douro.

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