THE STUDY OF ANTHROPOGENIC AFFECTED WETLANDS IN SEMI-ARID ENVIRONMENTS APPLYING AIRBORNE HYPERSPECTRAL DATA

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RESUMEN: Este estudio constituye una etapa inicial de una investigación encaminada a explorar las capacidades de datos hyperespectrales del sensor DAIS 7915 para el estudio de la degradación de humedales. El trabajo presentado incluye la preparación del vuelo, preprocesamiento de los datos y clasificaciones no supervisadas de datos DAIS y Landsat ETM+ correspondientes un mismo periodo temporal, completando el estudio con un trabajo de verificación en campo. Se pretende extraer información de interés relacionada con diferentes componentes de los humedales y procesos de degradación implicados.
El área de estudio está situada en "La Mancha Alta", dentro de la región central española. Se trata de una zona semiárida caracterizada por la presencia de numerosas áreas con humedales de pequeña superficie, muchos de los cuales han sufrido importantes cambios atribuidos fundamentalmente a: drenaje artificial y regulación de cursos fluviales; contaminación severa; sobreexplotación de acuíferos y prácticas agrícolas intensivas. En la zona se distinguen tres tipos principales de humedales: *seasonal hypersaline*; *riverine permanent subsaline* y *anthropogenic affected floodplains*, que constituyen el objeto de este estudio.
Los resultados obtenidos a partir de los datos hiperespectrales ofrecen un mayor detalle espacial y espectral a la vez que permiten la extracción de información de interés referente a cambios espaciales en las cubiertas asociadas a los humedales. Estos cambios están relacionados fundamentalmente con gradientes de salinidad y humedad que afectan a las características de la vegetación y de los suelos, posibilitando la discriminación de procesos antrópicos asociados a degradación de humedales.

Palabras clave: datos hiperespectrales, humedales semi-áridos, degradación de tierras

ABSTRACT: Wetlands in semiarid regions of Spain are especially susceptible to land degradation processes. This work is a first stage of a research focused on the potential application of hyperspectral data obtained with the Digital Airborne Imaging Spectrometer DAIS 7915 sensor for wetland degradation studies.
The study area lies in the eastern part of La Mancha in Central Spain, enclosing a steppe-wetland area, which is undergoing important human induced changes. A simple unsupervised classification of the DAIS data proved to be successful in discriminating different wetland types and their associated surface cover assemblies. The sensor's discrimination power enables improved detection of wetland degradation indicators, which are often manifested in slight compositional changes of land surface covers.

Key words: hyperspectral data, semi-arid wetland, land degradation.

INTRODUCTION

The degradation and loss of wetland areas is a serious problem in many parts of the world due to population increase and the resulting pressure on agricultural land resources. Wetlands in semi-arid regions, such as in central Spain, are especially susceptible to land degradation processes. These areas are considered important for the migrating and wintering waterfowl in Spain and possibly hold the most dense wintering populations of waterfowl in the South of Europe. The demand for increased agricultural production in central Spain region (La Mancha Alta)

has led to a relative decline of traditional rain fed crops (cereals, vineyard and olive grove) and this has led to an increase in large-scale irrigation schemes with intensive exploitation of water resources. The combination of these factors is the major cause of wetland losses in this area. It has been estimated that about 60% of the wetlands areas have disappeared in the last four decades or are in the process of disappearing and only 2.8% of wetland area is relatively well preserved.

An important effort is currently taking place in order to identify areas affected by land degradation processes using remote sensing techniques (Hill, 1996; Gumuzzio *et al.*, 2000; Koch, 2000 and Schmid *et al.*, 2000). Further specific work has been carried out on salinization and wetlands related with remote sensing by Taylor *et al.* (1994) and Qingxi *et al.* (1997), respectively.

This work is a first stage of a research focused to assess the potential application of hyperspectral data obtained with Digital Airborne Imaging Spectrometer DAIS 7915 sensor for wetland degradation studies (Gumuzzio *et al.*, 2000). A specific objective of this work is to explore the capability of the hyperspectral sensor, applying an unsupervised classification followed by post-classification ground assessment, in order to discriminate and identify wetland components that serve as degradation indicators.

STUDY AREA

The area under study lies in "La Mancha Alta" which is a region characterised by numerous areas with steppe-wetlands unique in Western Europe. However, these areas are undergoing important changes due to artificial drainage and regulation, severe pollution, aquifer overexploitation and intensive agricultural practises.

The climate is semi-arid with a mean annual precipitation, evapotranspiration and temperature of 410 mm, 810 mm and 15ºC, respectively. An undulating topography shows accumulation of sediments containing soluble salts that coincide with the wetland areas in the depressions. The natural vegetation associated to the wetlands is classified as hydrophytic and halophytic. The main wetland soils are Solonchaks and Fluvisols (salic), and the upland (elevated areas around the wetlands) soils are mainly Cambisols, Calcisols and Regosols. Based on their characteristics the wetlands can be divided into three main types: *seasonal hypersaline* (Lagunilla de la Sal); *riverine permanent subsaline* (Laguna Grande of Villafranca) and *anthropogenic affected floodplain*, (Cigüela alluvial plain).

Frequently the degree of salinization of these wetland types depends on the proximity of the water table to the land surface. The vegetation cover is an important indicator of the rate and type of soil salinization and ground water fluctuations especially in seasonal hypersaline wetlands.

From all three wetland types, *seasonal hypersaline* wetlands are better conserved because of their unsuitability for agricultural use. Whereas, wetlands in floodplains are most affected by human induced activities. The upland soils are mainly used for rain fed agriculture (cereal, olive groves and vineyards).

HYPERSPECTRAL DATA ACQUISITION

The Digital Airborne Imaging Spectrometer DAIS 7915 is a 79 channel high resolution optical spectrometer operating in the wavelength range from 0.4 µm to 12.5 µm. With the exception of the 1.1 µm to the 1.4 region all atmospheric windows are covered. The DAIS 7915 scan mechanism is a Kennedy type with a cubic rotating polygon mirror. The scan mirror rotates anti clockwise with respect to the aircraft heading to provide a ground element cross track scanning motion while the forward motion of the aircraft provides a requested line-by-line scan.

Pre-flight planning included the determination of the area to be covered, time of acquisition and field arrangements during the flight, which was carried out at DLR at the end of June 2000. Flight lines were established taking into account the properties of the sensor (swath width and píxel size depending on the altitude of the aircraft), time of day (sun angle location to determine the direction of the flight lines) and area to be covered (correlating the length of the flight lines with the data recording capacity of the equipment). The spatial ground resolution of the sensor was accepted to be approximately 5 m and the swath width 3 km when the aircraft was at an altitude of 3000 m above ground level. A 33 % overlap of the flight lines was considered necessary in order to ensure the data uptake.

A day before the flight, field measurements with a GER3700 spectrometer were carried out on various points in the area of study by a team of experts from DLR. Two targets with high albedo differences (white and dark areas) were chosen for calibration purposes of the sensor. Furthermore, two homogenous areas were chosen to determine spectral curves of common saline wetland soils with vegetation.

During the over flight, we were, together with an expert, in the field with an Ashtech Reliance Global Positioning System (GPS) obtaining data in order to be able carry out geometric correction of the DAIS 7915 data. We were situated at a fixed point within the area of study and we obtained the GPS data from the base station situated in Madrid.

Pre-processing of the data was carried out by the DLR facilities. This included systematic corrections such as raw data preparation, system and DC correction, facet and vignetting correction, radiometric calibration as well as geometric and atmospheric correction.

WETLAND CHARACTERISATION

The DAIS data strips were mosaicked together using a georeferenced based mosaicking procedure with feathering along cutlines to blur the seams between overlapping areas. An unsupervised classification followed by post-classification ground assessment of the resulting classes was conducted on an area including the three types of wetlands (*seasonal hypersaline*; *riverine permanent subsaline* and *anthropogenic affected floodplains*). The purpose of this exercise was to assess the spectral separation of (1) the different wetland types, and (2) surface cover variability within each wetland type.

It was found that the isodata clustering method using 12 classes and three iterations gave a satisfactory classification result, which clearly identified the wetland types, their boundaries and transitional zones to surrounding agricultural land. Comparison of the isodata classification results obtained from DAIS with that of Landsat ETM+ for the same area and approximately the same date (DAIS and ETM+ data are only one day apart), show a remarkable improvement in discriminating wetland types (*Figure 1* and *2*).

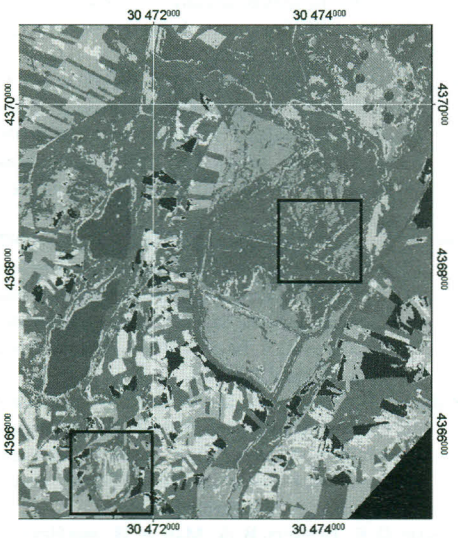

Figure 1. DAIS isodata classification result with 12 classes.
(Ver figura en color en la página 674)

Due to lower spatial and spectral resolution of ETM+, certain wetland components such as open water bodies, moist alluvial areas and dense wetland vegetation are combined in one single class (shown in red in *Figure 2*), regardless the number of classes specified for the classifier. Whereas in the DAIS classification result, these areas are separated (shown in red, dark and light green).

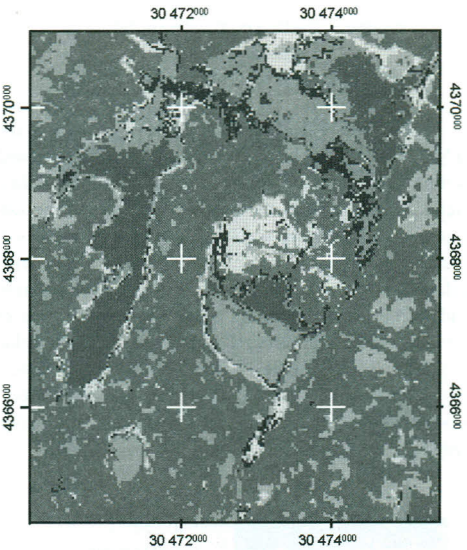

Figure 2. ETM+ isodata classification result with 10 classes.
(Ver figura en color en la página 674)

Further field inspection of two selected areas, namely Lagunilla de la Sal and Finca Pastrana (outlined in *Figure 1*) demonstrates the improved discrimination capability of the DAIS 7915 in terms of detecting distinct wetland zones. Enlargements of the DAIS classification results for the two selected sites are shown in *Figures 3* and *4* with their respective legend revised by post-classification field assessment. It was found that certain classes do not correspond to the same surface covers established in both sites.

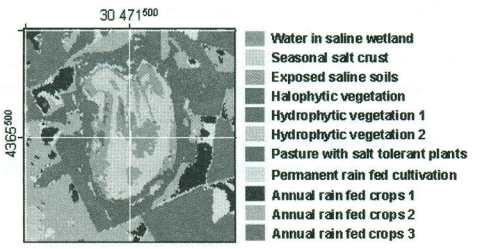

Figure 3. DAIS isodata classification of Lagunilla de la Sal.
(Ver figura en color en la página 675)

In the case of the Lagunilla de la Sal (*Figure 3*) the DAIS 7915 was able to discriminate several wetland components arranged around the centre of this saline lagoon. Starting from the moist centre part of the salt lagoon, the following sequence can be observed: salt crust area, exposed saline soils, saline soils with halophytic vegetation, soils with hydrophytic vegetation and bordering the lagoon, soils with agriculture in elevated areas. The proximity of the agricultural fields (less than 100m) from the wetland boundary indicates a progressive conversion of wetland areas into agricultural land leaving no or little room for a protective buffer zone around these salt lakes.

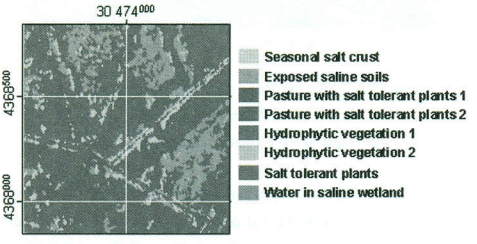

Figure 4. DAIS isodata classification of Finca Pastrana area.
(Ver figura en color en la página 675)

The Finca Pastrana wetland area (*Figure 4*) shows a somewhat different composition. Here the wetland area is dominated by water diverted from the Cigüela river which borders the Pastrana area. The alluvial floodplain has undergone the following human induced changes: wetland drainage and desiccation, tillage and cultivation, and final abandoning due to low agricultural productivity. These changes can still be observed in the distribution and density of the wetland cover types, where vegetation density and salinity are inversely related.

CONCLUSIONS

This preliminary study shows that the improved spectral and spatial discrimination power of hyperspectral sensors over conventional multispectral sensor makes the former one very suitable for wetland degradation studies where surface cover variations are often associated to very subtle changes in salinity levels, moisture content and anthropogenic influences.

A simple unsupervised classification of the DAIS sensor data provide good results in terms of separating the three wetland types present in the study area as well as in discriminating characteristic wetland cover associations related to individual wetland types. However, post-classification field inspection at selected sites, representative of two wetland types, show that some class confusion occurs between corresponding classes. This indicates that further refinement in the selection of classification method and parameters is needed to ensure correct discrimination of surface cover characteristics associated with individual wetland types.

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