ABSTRACT

Wetland delimitation, necessary for efficient management, is problematic in the case of playa-lakes. The official delimitation of Gallocanta wetland, recently drawn after an agreement between farmers and regional government, is based on its present appearance, without taking into account the fluctuations related with periods wetter than the present. This study highlights the temporal changes of the lake shore facies associated with water level fluctuations and verifies the high variability in ecologically interesting border areas under pressure from agriculture, both at present and historically. A series of Landsat images covering the range of temporal fluctuations of Lake Gallocanta has provided reliable knowledge on its variability, including the delineation of shore facies and their functional status. This information will help in the management of the wetland and related areas.

1. INTRODUCTION

Wetland delimitation, a basic step in management [1], is not an easy task because of the difficulties in establishing borders between land and water in wetlands. Remote sensing can be useful for this purpose [2].

Recently, the Spanish government, basing itself on directives in the Water Act [3], defined the administrative limits of Lake Gallocanta as a means to regulate water issues. Also, the Government of Aragon (Autonomous Community in NE Spain), in charge of the management of all the natural resources of Lake Gallocanta except water, established the administrative limits of the protected area, based on provisions in Spanish law [4]. Neither of these two delimitations are based on scientific criteria but rather on administrative arrangements. The aim of the present work is to show the contributions remote sensing would make to the delimitation of this wetland.

2. GALLOCANTA LAKE

Gallocanta is a saline endorheic wetland, the biggest playa-lake of Europe. The area was catalogued as a SPA for birds in 1987 for migratory bird protection and was included in the RAMSAR list in 1994. It is located in NE Spain, 115 km far from Zaragoza (Fig. 1) in a tectonic depression at almost 1000 m a.s.l. The extent of the lake-bed is about 14 km², though a broader extent is suggested by the outcrops of ancient lake sediments found more than 10 km away from the present shoreline [5].

The sources of water are both fresh surface runoff and saline groundwater recharge. The maximum registered water depth, 2.3 m, was recorded in 1974 [6]. The Lake dries in periods of strong evaporation. Physical, chemical and biological characteristics of the lake change according to the water level fluctuations, making the water salinity range from 15 g/L to 150 g/L [7].

Annual precipitation ranges from 650 to 320 mm, with a mean of 488 mm. The mean of the maximum monthly temperature, 21.1°C, is registered in July, and the minimum, 2.9°C, in January, with 39°C and -21°C the absolute maximum and minimum, respectively. A regular north-western wind frequently reaches more than 80 km/h [6].
Gallocanta land-water boundaries change because of water level fluctuations. These fluctuations depend on seasonal and interannual meteorological factors and on long-term climatic oscillations like ENSO [7]. In this type of wet, water level fluctuations affect the spatial distribution and status of all the structural components of the ecosystem, including the plants communities on the lake shore, which are considered of special interest for conservation under the European regulations [8]. Boundaries definition is a key issue for management purposes. Recently, the Government of Aragon has established in Galocanta Lake and its surroundings (Tab. 1). Variable lacustrine and palustrine facies and the transitional facies located in the most external areas represent components of the wetland dynamic [3]. The 27 resulting thematic maps correspond to a wide range of moisture conditions of this playa-lake; Fig. 4 is an example of these maps. The facies distribution reveals evidence of the wetland function and boundaries and is valuable for selecting agricultural use and for delineating protected areas. Moreover, the monitoring of the water extent and other hydrological variables will help to improve the hydrological balances.

We obtained 15 meaningful facies — soil surface covers — in Lake Gallocaanta and its surroundings (Tab. 1). Variable lacustrine and palustrine facies and the transitional facies located in the most external areas represent components of the wetland dynamic [3]. The 27 resulting thematic maps correspond to a wide range of moisture conditions of this playa-lake; Fig. 4 is an example of these maps. The facies distribution reveals evidence of the wetland function and boundaries and is valuable for selecting agricultural use and for delineating protected areas. Moreover, the monitoring of the water extent and other hydrological variables will help to improve the hydrological balances.

Table 1. Facies —soil surface covers— established in Gallocanta Lake and their extent as extracted from Landsat imagery supported with the field knowledge.

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Images were radiometrically corrected, orthorectified and resampled to 25 m [9]. The fusion of multispectral and panchromatic bands was performed with ETM+ images using the “à trous” algorithm in order to preserve as well as possible the spectral information [10, 11]. We applied non supervised classification, HIS and TTC transformations, and NDVI. Both field knowledge and experience in northern playa-lakes [12] were crucial in assigning thematic meaning to the spectral classes obtained by image treatment.

Figure 2. The surrounding area of Gallocanta Lake selected for remote sensing study is outlined over a Landsat image RGB 432, from Mars16, 1994.

Figure 3. Facies extent in the studied images.
The water body fluctuations and the decrease of the water extent by agricultural use are important for migratory bird protection. However, from a comprehensive ecological point of view, of special interest are those fringes temporally flooded and the wet areas which are not flooded but strongly involved in the wetland dynamics. This changing area appears as a fragile fringe of gradual transition which segregates the inner from the outer facies of the playa-lake (Fig. 5). There, the palustrine vegetation includes plants communities protected by the Habitats Directive [8]. Due to their ecological interest, these plants community areas associated with environmental factors were mapped in the field over colour orthophotographs at scale 1:2500.

4. CONTRASTING PLANTS COMMUNITY AREAS ASSOCIATED WITH ENVIRONMENTAL FACTORS

Two aerial photographs of two sites on the NE shore of Lake Gallocanta in 1989 —relatively high water level— and 2003 —relatively low water level— show the contrast between the areas covered by important plants communities as dependent on the water level of the Lake (Fig. 6). The change in the Juncus maritimus dominated community is directly related to water level fluctuations; the change in the Phragmites australis dominated community is also related to freshwater discharges from the nearby village of Gallocanta.

Figure 6. Aerial photographs of small zones in the NE shore of Lake Gallocanta showing the changing extent of two plants communities in 1989 and 2003.

As the area covered by a plants community changes in relation to environmental and human factors, a delimitation programme based on remote sensing and ground data records would be of major interest and application. Clearly the plants communities are distributed in this type of habitat according to two major environmental factors: soil moisture and soil salinity. These variables were measured directly in the soil along transects in the salt meadow in September 2005, the driest recorded season. In each plants community the survey included electrical conductivity measurements at three points and comparative moisture records at four points. Moisture was measured in three depth intervals at each point, using a TDR IMKO probe. Soil samples were collected eliminating the salt efflorescence, and the electrical conductivity was measured in a 1:10 soil to water volumetric ratio (EC 1:10 vol.). Fig. 7 shows the values of these variables averaged in each sampling point/plants community, and the distribution of plants communities defined by the dominant species. These gradients show that an
accurate mapping of areas of interest is required for wetland delimitation and management.

5. CONCLUSIONS

Landsat imagery has provided reliable knowledge of the variability of the water body extent of Gallocanta and its shoreline from 1984 to 2000. This study highlights the temporal changes of the lake shore facies associated with water level fluctuations and verifies the high variability in ecologically interesting border areas under pressure from agriculture, both at present and historically. Remote sensing observations covering temporal fluctuations of this playa-lake must be taken into account when delineating shore lines and associated facies. These fluctuations and the functional status of the facies have been reconstructed from the available remotely sensed information. In the future, remote sensing, especially when contrasted with ground data, ought to be used for Gallocanta Lake monitoring and for decision-making on conservation measures and policies.

Acknowledgements. This research was a previous step for the project AGL2006-01283, granted by the Spanish Ministry of Education and Science. Remote sensing works were funded by C.H.E (Ebro Basin Water Authority).

REFERENCES

6. CHE (Ebro Water Authority), Establecimiento de las normas de explotación de la unidad hidrogeológica “Gallocanta” y la delimitación de los perímetros de explotación de la laguna, 2002.