Assessing the degradation of saline wetlands in an arid agricultural region in Spain

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Abstract

A constellation of saline wetlands in the Spanish Monegros Desert is currently subjected to increasing agricultural pressure. Until now, no systematic study of their degradation status has been performed, and no comprehensive map of these wetlands has been available. Both subjects are addressed for the first time in this study. In addition, we set up a conceptual tool for assessing saline wetlands degradation that improves upon available methods within geomorphological, sedimentological or hydrological frameworks. A wetlands inventory was produced and updated using satellite data, field observations, and orthophotographs, together with the available disperse data about these wetlands' toponymy and location. The degraded landscape appearance of the surviving wetlands, mainly affected by agricultural intensification —dumping and farming— has been qualitatively assessed.

Systematic descriptors of these saline wetlands —escarpment, stone dumping, vegetation, and water— were selected and analyzed to identify the status and the increase in degradation of these wetlands between 1988 and 2003. At present, 50% of the wetlands registered in 1988 have disappeared. Of the remaining wetlands, 30% have been invaded by crops and stone debris has increased in 63%. The smoothing of the escarpment appears to be a key degradation symptom. In the absence of field

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monitoring programs, the integration of remote sensing and GIS with field data was a powerful tool to track recent changes and assess wetland disturbance. A baseline for comparative analyses and further agro-environmental monitoring has been established.

Keywords: aridity; landscape degradation; Monegros; playa-lakes; salinity

1. Introduction

Wetlands are among the most valuable and productive ecosystems on earth, necessitating research to ensure wise development and protection (Ramsar Convention Secretariat 2004). Worldwide, many wetlands were lost and degraded during the 20th century by human pressures (Dahl and Johnson, 1991; Davis and Froend, 1999; Tiner, 2002), especially by agricultural intensification (OECD, 1996) and loss might increase in the future (Millennium Ecosystem Assessment, 2005). In Europe, a regional overview of wetlands degradation recognized the high pressure of urban and industrial development (Stevenson and Frazier, 1999). Since the Ramsar Convention in 1971, various initiatives have been undertaken in order to increase conservation awareness about these habitats. The Medwet long-term collaborative program hopes to ensure the wise use of wetlands throughout the Mediterranean, emphasizing not only ornithology but many wetland values and functions (Costa et al., 1996). In order to protect these vulnerable environments it is necessary to monitor the changes produced, their causes and consequences (Tomàs-Vives, 1996). Wetland inventories are incorporating remote sensing and GIS techniques to conservation planning efforts in order to characterize land uses and habitats (Tiner, 2004).

Common causes of wetlands loss and degradation can be found in the study of Finlayson and Rea (1999). Arid-zone wetlands especially, for which there is little or no information, are poorly mapped (Finlayson et al., 1999). Saline wetlands in arid climates are scarce in Europe and are not well represented in inventories and conservation plans. In the Monegros Desert of northeastern Spain the saline wetlands, locally named "saladas", are playa-lakes (Castañeda et al., 2005a) and other closed saline depressions of high scientific and environmental value. Similar wetlands from other semiarid regions throughout the world have been inventoried and classified. For example, the U.S. Fish and Wildlife Service classifies these wetlands as isolated playas and salt flats (Tiner et al., 2002). The U.S. Environmental Protection Agency (2005) has included *Playa-lake* in its system of classification of wetlands in order to update the Cowardin et al. (1979) system used in the National Wetlands Inventory (Cowardin and Golet, 1995). The U.S. Geological Survey supports wetland hydrological research that promotes their restoration (Hunt et al., 1999). Endorheic systems similar to those of Monegros have been added to the South African National Wetland Inventory (Dini et al., 1998) in recognition of the significant ecological role played by pan ecosystems in southern Africa.

Southern High Plains playas incorporated into farming systems have been studied by Haukos and Smith (1994) for biodiversity purposes. Standard procedures for studying wetlands in the field are difficult to apply in playas and may require specific protocols for delineation purposes (Lichvar et al., 2004; 2006) as well as inferential study and professional judgment (Brosttoff et al., 2001).

The saladas of Monegros are scattered throughout a landscape undergoing significant transformations due to agricultural intensification that includes irrigation of new croplands. Land consolidation and new infrastructures affect the entire area (Figure

1) and some saladas have already been destroyed or are greatly affected. On the other hand, the Birds Directive and the Habitats Directive —the two main pieces of legislation of EU nature conservation policy— deal with the conservation of European wildlife, focusing on the protection of sites as well as species. These sites make up the Natura 2000 network, the cornerstone of EU nature protection policy. Half of the overall area of the Monegros saladas has been proposed for inclusion in the Mediterranean region of the expanded Natura 2000 network. However, at present there are no standardized procedures to describe the degradation status of saladas or monitor the effects of land-use management.

The aim of this research is to establish a methodology for the systematic study of saline wetlands in southern Monegros. This objective includes two main purposes: (i) to accomplish an updated and unified inventory and (ii) to depict the changes in these wetlands in the last decades by comparing current observations with historical data. We have taken advantage of remotely sensed data and a geographical information system (GIS) as a supporting tool to integrate the information recovered from different sources and scales. This study takes an eco-centric approach (Eckersley, 1992), based on habitat naturalness and preservation.

2. Study area

Saline wetlands in the Monegros desert (Figure 1), one of the most arid regions in Europe (Herrero and Snyder, 1997), are scattered throughout an agricultural landscape of about 400 km^2. The almost one hundred closed depressions, some of them hosting playa-lakes, are isolated and slightly hidden in smooth and flat karstic depressions (Figure 2) and flat-bottomed valleys. They usually stand out in the landscape due to one or more of the following characteristics: a flat bed topography with water and/or salt efflorescence, permanently wet soil related to their groundwater discharge function (Castañeda and Herrero, 2005), and halophytes.

Figure 1

The saladas play an important role in the regional hydrology, having a close connection with hypersaline aquifers (Samper and García-Vera, 1998; Castañeda and García-Vera, *in revision*) and are recognized in the EU Natura2000 network (Domínguez et al., 2006) for hosting endemism and protected species (Pedrocchi, 1998). They also provide habitats for algae and extremophile microbes.

Most of the largest saladas are bordered by a sharp escarpment from one to twenty meters in height which primarily delimits the northern and southern extent of the depressions. The common orientation of these escarpments is NW-SE. The higher the escarpment and the longer its lateral continuity the better preserved the salada, since height and continuity increase confinement and hamper agricultural invasion. Many escarpments have been smoothed to facilitate plowing towards the bottoms, increasing sedimentation, as observed in similar playa environments in the U.S. by Haukos and Smith (1994).

Figure 2

The smallest depressions are round shaped and rarely flood, have gentle margins and wet bottoms with halophytes which indicate their discharge hydrological function. The durum (*Triticum durum* Desf.) or barley (*Hordeum vulgare* L.) fields surrounding the saladas have numerous stones and boulders. Since the plowing must be deep enough to retain the scarce rains, stones are continuously removed. Stone dumping in the saladas cover the escarpment and borders of most saladas, advancing towards the mud flat or vegetated bottom. The halophytes are suffocated and geomorphologic processes are modified. Intermittent water occurrence in the saladas, an outstanding feature in this arid zone, is critical to the conservation of these habitats. Water and escarpment hinder agricultural use; as soon as the surface water evaporates, the smaller saladas are plowed, to obtain agricultural subsides.

3. Material and methods

The saladas boundaries were delineated from an April 2, 1997, Landsat image. We selected the wettest year during the last two decades, with an annual average rainfall of 535 mm for the Petris Weather Station (Figure 1) against an average of 350 mm for the period covered by that station, 1974-2006 (Figure 3). For this purpose we performed a visual interpretation of the most suitable Landsat bands (Castañeda et al., 2005b), with the assistance of topographic maps at scales of 1:25000 and 1:50000.

Figure 3

Disperse data about the saladas —some of them unpublished— were collected and those containing geographical coordinates (Pueyo-Mur, 1978; Pedrocchi, 1988; 1998; Comín and Sanz, 1989; Berga, 1993) were represented in a geographic information system together with our remotely sensed mute map. Location and toponymy from each author were revised, standardized, and compared with our map and with two non-georeferenced sketches from Balsa et al. (1991) —including one hundred saladas, all numbered and many with names—, and from Sancho and Gutiérrez (1993) —showing geomorphologic features such as karstic depressions and sinkholes—. A subsequent field campaign inspection was carried out aided by black and white orthophotographs from 1997 at 1:10000 scale.

A new geospatial saladas database was created containing only those saladas clearly identified in the field. In the lack of soil and vegetation maps, we systematically recorded in the field four features for each salada —the systematic descriptor of the saladas (SDS)—. Escarpment continuity, stone dumping, natural vegetation and crops, were considered visual indicators of status, together with the surface area of each salada, extracted from the GIS. In the lack of detailed topographic maps, escarpment continuity/smoothing was evaluated in the field.

When estimating the importance of water presence, we take into consideration the rainfall registered in the area. At the time the field work was conducted, water presence was not a degradation symptom. However, water presence has been recorded in the field because of its significance for hydrologic behavior comparisons in the advancing irrigation works scenario and also because it is often taken into account by decision makers as the only feature to indicate the saladas existence. For this purpose we studied the water presence from 1984 to 2004 using satellite images (Castañeda and Herrero, 2006).

Several categories of SDS were established to rank each descriptor, from absence to maximum observed degree (Table 1). In addition, we collected photographs that revealed the changing appearance of the saladas through the seasons during a field campaign spanning from October 2002 through June 2003, and we also grouped the saladas in different classes according to their general landscape appearance.

In order to detect possible changes in conservation status, the next step was to compare, for each salada, our SDS with the analogous observations recorded 15 years before by Comín and Sanz (1989). We matched the SDS categories from the two surveys, adopting an integrated classification —last column of Table 1—, disregarding the most detailed classification, when necessary. In order to discard the possible effects of the surface area estimations techniques, only differences > 15% in the size of the saladas were considered. Loss of confining properties of the escarpment, dumping, crop invasion, and decrease in size are considered as degrading changes in the saladas. The number of changed SDS is used to qualify the degradation for each salada.

Table 1

4. Results and discussion

4.1. Updated Inventory 2003

Agricultural intensification and irrigation works make it difficult to recognize some saladas, both in the field and in the recent earth surface images. The largest and wettest saladas, as well as those preserving their escarpment and native vegetation, were detected and delineated in the Landsat image of April 2, 1997. A first inventory was obtained containing 39 saladas ranging from 1.8 ha to 200 ha. The visual analysis of the orthophotographs and the field data recorded during 17 visits allowed a detailed drawing of the saladas borders and enlarged the remotely sensed inventory. The resulting map, labeled *Inventory 2003*, shows a total wetland area of 860 ha, distributed in 53 saladas (Figure 1).

Several saladas described in previous studies were not recognized in the Landsat image, mostly because of farming, as confirmed in the field. Many small saladas without geographic references recorded by Balsa et al. (1991) and not detected by us in the satellite image, were located in the orthophotographs. Vestiges of saladas were also detected on the ortophotographs from arrangements of terrain features or from differences in vegetation and soil color, evidencing the destruction of many of the depressions mapped by Balsa et al. (1991) or by Sancho and Gutiérrez (1993). These two sketches were not integrated into the GIS due to the lack of georeferenced points. The saladas listed by Pedrocchi (1988), Comín and Sanz (1989), and Balsa et al. (1991) contained 95, 85, and 100 saladas, respectively; in which 48%, 33% and 76% of the saladas were given names. Pueyo-Mur (1978), Berga (1993) and Pedrocchi (1998) monitored a limited number of saladas, less than 25, primarily including those with more water presence.

The coordinates given to each salada differ between authors. Although they all used 1:50,000 topographic maps, they followed different criteria to assign coordinates: the NW vertex, along the North limit, or at its inner point. Therefore, several saladas came to be represented by the same point; in other cases the same salada was located at different points. Other differences came from the poor legibility and physical degradation of some revised documents. Location ambiguities and toponymy disagreement were clarified by consulting non-georeferenced sketches from Balsa et al. (1991) —drawing a hundred saladas, all numbered and many with names— and from Sancho and Gutiérrez (1993) —depicting geomorphologic features such as karstic depressions and sinkholes—. The most complete toponymy, from Balsa et al. (1991), was maintained for our *Inventory 2003*, in which “clota” was the term used for the nameless saladas. This updated inventory contained those 53 saladas clearly identified in the field and the toponymy used by the different authors.

Only 31 of the inventoried saladas —those with more water presence and those with marked boundary— are shown on the official topographic maps; they were qualified as marshes in the legend, 14 of them without a toponym. The absence of some saladas in these maps is not related to size but to cultivation. This can be attributed to the method of production of these maps based on photointerpretation.

4.2. Assessment of the ***condition class*** *of the saladas*

The maps shown in Figure 4 represent the distribution of the SDS recorded in 2003. As visual indicators, they provided sound information about the status of the 53 saladas. More than 75% of them present an easy access due to their smoothed escarpment; of these, 28% are not recognizable as saladas at the time of inventory because they are incorporated into the plowed area or are affected by roads and subsurface pipe drains installed by the irrigation works in progress. Some 90% of the studied saladas show stone dumping; 80% are invaded by crops to some degree. The saladas least invaded by crops are the ones that contain water most often.

Figure 4

Flooding and soil salinity in the borders were traditionally the limitations for cultivation around the saladas. However, at present, the SDS recorded in this study reveal a breaking-down of these limits, perhaps attributable to the availability of machinery and to subsidies from the European Union —Common Agricultural Policy— that reward low input extensive crops.

It is not clear from the data presented how the SDS recorded reveal a breakdown in flooding and soil salinity at the borders: no border flooding or soil salinity data are presented or discussed. No data are presented to support how machinery or crop subsidies would affect flooding/soil salinity.

To carry out comparative analyses and describe this environment, the saladas were classified in the field according to their landscape appearance by means of external expert judgment. Six categories or condition classes describing the degree of conservation were established, from *unrecognizable* to *pristine* —third column in Table 2—. These condition classes are a useful reference for understanding and monitoring these habitats.

The inventoried saladas average 16 ha in surface area, with 77% less than 20 ha; those larger than 20 ha are of playa-lake type. Condition class was strongly correlated with salada size (Figure 5). The *unrecognizable* saladas averaged 6 ha, and the average size for each category increased steadily, reaching 43 ha for those with *pristine* landscape appearance. For all the saladas, 26% were classified in the *pristine* or *slightly disturbed* landscape appearance groups. These well-preserved saladas range from 234 ha to 8 ha in size, contained water in 1988 and 2003, and had the highest historical water occurrence (Castañeda and Herrero, 2005). This is the case of Salineta, with 23 ha and the maximum water and salt occurrence (Figure 2b). Decades ago, this salada was a profitable site for artisan salt production, an activity with limited habitat disturbance that caused local people to appreciate the value of saladas.

Figure 5

4.3. Saladas degradation: observed changes between 1988 and 2003

While in 1988 Comín and Sanz (1989) described 85 saladas, only 40 of them were recognized by us in 2003 and many saladas have become unrecognizable in the field. However, examination of the saladas’ shape and size in the Landsat image and the orthophotograph shows past borders faded by tillage. In contrast, 13 saladas described in 2003 did not appear in that inventory. Table 2 shows the changes observed in the 40 saladas recorded in both inventories, together with their condition class as established in the *Inventory 2003*.

Taking into account the established 15% threshold for changes in the saladas size, 38% of the saladas have decreased in extent. All belong to the saline closed depressions type, locally named "clotas" and "hoyas", which do not exhibit surface water yearly but do have a cover of halophytes. Fully 23% of the saladas show escarpment degradation, i. e., a *confining* escarpment has changed into a *smooth* or non-confining escarpment, probably due to flattening to allow farming or for machinery to pass. Of all these degraded saladas, Agustín, Farnaca, and Benamud, ranging from 70 ha to 12 ha in size, are the most relevant in terms of the halophytic and endemic plants they host (Domínguez et al., 2006). Thus, 43% of the saladas retained their *confining* escarpment, and 34% retained their *smooth* escarpment.

Saladas with no detectable changes between 1988 and 2003 in terms of cropping have been grouped in three categories: *not* cultivated, *partially* cultivated and *totally* cultivated, involving 10%, 50%, and 10%, of the whole sample set, respectively. This leaves 30% of the saladas that were affected by new cropping. These are also grouped in three categories: (1) *not* cultivated in 1988 and *partially* cultivated in 2003; (2) *partially* cultivated in 1988 and *totally* in 2003; (3) *not* cultivated in 1988 and *totally* cultivated in 2003. These saladas rank from 12 ha to 70 ha, in size. Some of them, such as Camarón and Pueyo, are playa-lakes and host water yearly; others, like Agustín, host significant halophytic plants, both in extent and diversity. Almost all of them have a smooth escarpment and four were unrecognizable in 2003, totally incorporated to farming.

Waste dumping has increased in recent years, as has the presence of industrial machinery and construction traffic. From 1988, dumping has affected 63% of the saladas regardless of their size and water presence; less than the 8% remain free of dumping, due to cultivation. All told, 92% of the saladas exhibit dumping in the center and/or borders, covering the halophilous vegetation to some degree.

The last column of the Table 2 summarizes the number of SDS features changing between 1988 and 2003, with only five saladas qualified with 0, i.e., without any change in their initial appearance. All the other saladas have some form of effective degradation in one to three of their features. As observed, these changes (degradation) are not exclusively related to their size, though the smaller saladas certainly look in the field to be the ones most damaged. Almost all the saladas holding water in both years also demonstrate less features changed. All the saladas with 3 changing SDS did not hold water in both years; almost those saladas holding water in both years have only 1 feature changed The standing water observed during the humid period of the field campaign (January to May) hampers the plowing of the saladas; however, some of them have been tilled in June, when water evaporates.

Endemism and priority Natura2000 habitats, all of which are represented in the study area, have not been used here to categorize the saladas interest since biodiversity is a common feature. Other factors such as the saladas location with respect to the current installation of new irrigated schemes, or with respect to protected areas, ought to be taken into account in further analyses and be incorporated into the irrigation system design.

Table 2.

5. Conclusions.

The saladas, usually considered agricultural wasteland or barren terrain from the point of view of productivity, have undergone a siege of agricultural intensification constrained only by spots of flooding and extreme salinity. The traditional dry farming around these saline wetlands is also changing over to irrigation, increasing their degradation. For monitoring and conservation purposes, we have looked at the inventory and described the status of these arid-zone wetlands, for which there is little or no information. The updated Inventory 2003 has been developed to better understand the saladas system of Monegros. The field inspections allowed grouping the saladas in several condition classes according to their landscape appearance. This grouping illustrated the degree of conservation of the saladas and built a baseline for comparative analyses and further monitoring.

The systematic descriptors of the saladas (SDS) were established to assess in more detail their status as of 2003. These descriptors showed the high percentage of saladas that had been disturbed to some degree —affecting their escarpment and native vegetation— and those unrecognizable as functional wetlands because the soil surface features related with groundwater discharge had been eliminated. Comparing our SDS with similar observations from other authors 15 year ago, we obtained factual information on the saladas' degradation, i. e. the observed changes between 1988 and 2003. This degradation, though more visible in the smallest saladas, affects all of them regardless of their size or the presence of water. Escarpment smoothing, crop invasion, stone and debris dumping, and decrease in size have affected 23%, 30%, 63%, and 38% of saladas, respectively.

This study attempted to perform a systematic overview of the saladas to quantify features otherwise difficult to measure in the field, and to contrast the results spatially and temporally. This work increases knowledge about these wetlands and can be a baseline for agro-environmental monitoring purposes.

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Table 1. Systematic descriptors of the saladas (SDS) as recorded in the inventories of 1988 and 2003, and their aggregation —sketched by dot lines— into simplified categories for comparison.

Systematic descriptor	Original records		Categories of SDS
	1988	**2003**	
Escarpment	Significant*	Very significant	Confining escarpment
		Significant	
	Smooth or not significant	Smooth	Smooth escarpment
		Very smooth	
	Plain depression		
		Unrecognizable	
Dumping	Absent	Absent	Without stone dumping
	Present	In escarpment	With stone dumping
		In center	
		Completely covered	
Cropping	Not cultivated	Not cultivated	Not cultivated
	Slopes cultivated	Partially cultivated	Partially cultivated
	Bottom cultivated	Totally cultivated	Totally cultivated
	Totally cultivated		
Surface area	ha	ha	Decreased
			Invariable
			Increased
Water presence	Dry	Without water	Without water
	Flooded	With water	With water

(*) large and /or high.

Table 2. The 40 compared saladas: name, extent, condition class, and features registered in, along with water presence observations. Changes between 1988 and 2003 are outlined in grey; (+): saladas detected in Landsat TM images.

Salada name after Balsa et al. (1991)	Size (ha)	Condition class in 2003	Escarpment			Dumping			Cropping						Size		Water		Number of SDS with change
			smooth	confining	change to smooth	without	with	new from 1988	without	partially	totally	change to partially	change from partial to totally	change from not to totally	without change	decrease	with W in 1988	with W in 2003	
Agustín$^+$	68.1	disturbed					*										*	*	2
Alforjeta II$^+$	2.3	advanced destruction	*								*				*				1
Amarga Alta $^+$	22.3	slightly disturbed		*			*										*	*	1
Amarga Baja$^+$	7.1	pristine		*			*			*							*	*	1
Balsa$^+$	2.9	disturbed									*				*				2
Benamud$^+$	19.9	disturbed				*				*									2
Berzas	8.8	heavily disturbed	*												*			*	2
Camarón$^+$	44.7	pristine		*													*	*	2
Catio I	2.3	advanced destruction									*								3
clota-19$^+$	1.7	unrecognizable	*								*								1
clota-50$^+$	2.5	advanced destruction	*																3
clota-51	4.1	disturbed	*							*									2
clota-52$^+$	2.8	advanced destruction	*							*									2
Corral Viejo	4.9	disturbed	*				*												2
Correo	4.6	disturbed	*												*				2
Farnaca$^+$	12.2	disturbed								*									3
Gramenosa$^+$	10.7	pristine		*					*								*		2
Gros	3.9	disturbed								*									3
Guallar$^+$	15.0	pristine		*						*							*	*	1
Herrero	3.2	disturbed	*							*									2
Hoya del Pez	2.5	unrecognizable					*								*				2
La Playa$^+$	234.5	pristine		*					*								*	*	1
Larga	10.4	disturbed					*			*									2
Lisonfer	5.5	disturbed								*									3
Muerte$^+$	17.9	pristine		*						*							*	*	1
Nieves$^+$	7.0	unrecognizable	*				*												2
Pez$^+$	8.3	pristine		*		*				*							*	*	0
Piñol$^+$	15.7	pristine		*			*		*								*	*	0
Pitamar	4.2	unrecognizable	*								*				*				1
Pito$^+$	67.2	pristine		*						*							*	*	1
Pueyo$^+$	24.3	pristine		*													*	*	2
Rebollón$^+$	16.1	slightly disturbed		*						*					*		*	*	1
Rollico$^+$	40.3	slightly disturbed		*						*							*	*	1
Salineta$^+$	22.7	pristine		*					*								*	*	1
Valdecarreta$^+$	6.9	disturbed	*				*			*					*		*		0
Valdespartosa$^+$	14.8	disturbed	*												*				2
Vinagrero I$^+$	5.0	advanced destruction		*						*									1
Vinagrero II$^+$	5.0	advanced destruction		*			*			*					*				0
Yesera I$^+$	3.1	advanced destruction	*				*								*				1
Zaborros$^+$	9.0	advanced destruction		*		*					*				*				0

Figure captions

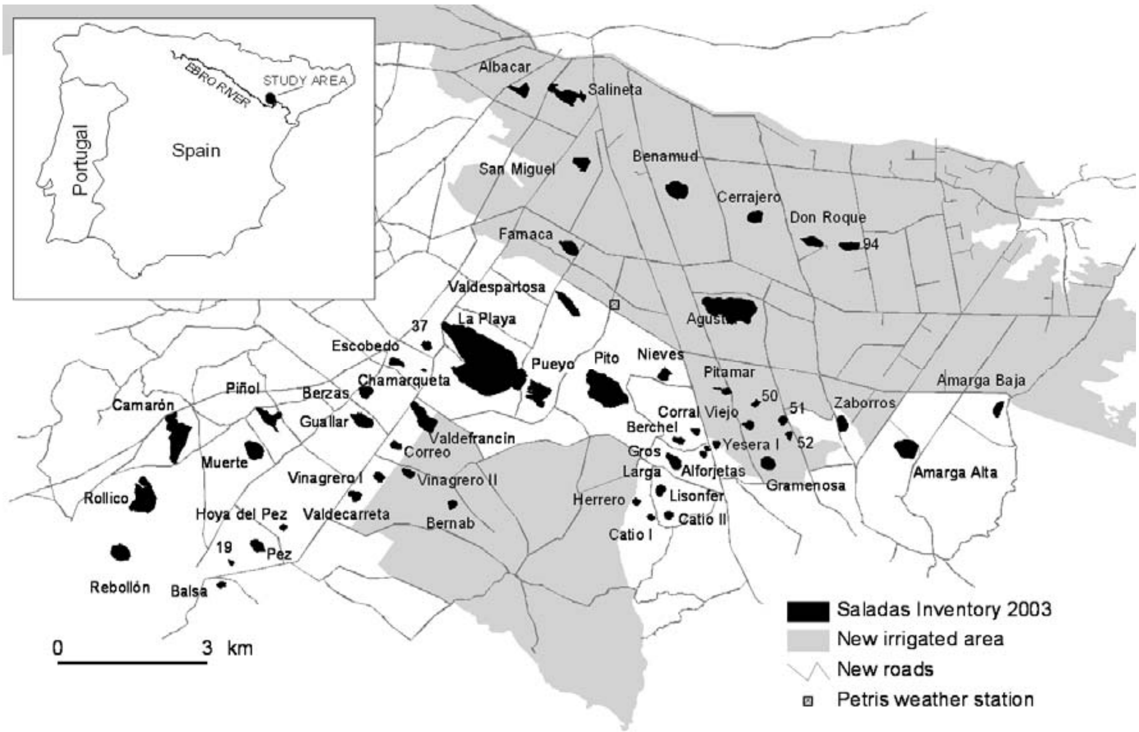
Figure 1. Location of the Monegros playa-lakes.

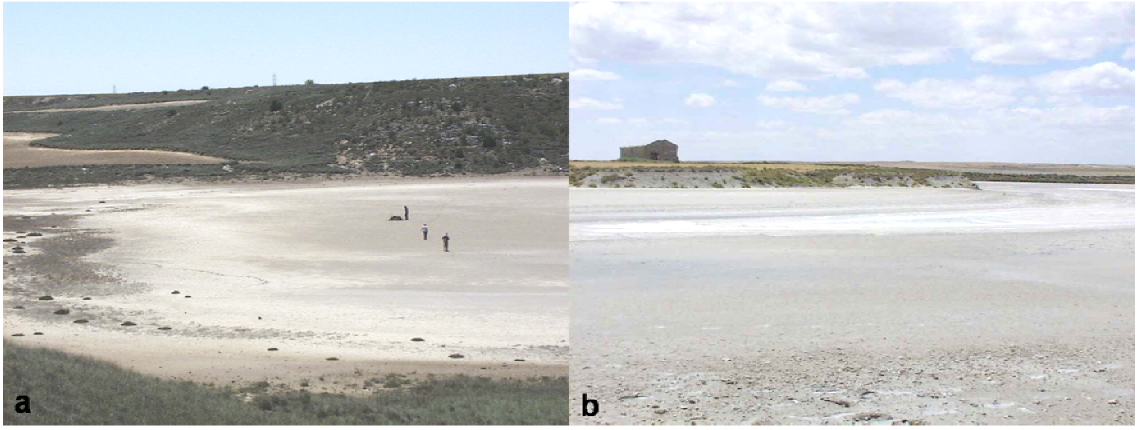
Figure 2. Different height of the escarpment bordering the saladas: (a) in Pez, the native vegetation is better preserved when the escarpment is big; (b) the Salineta bottom and escarpment in a dry period.

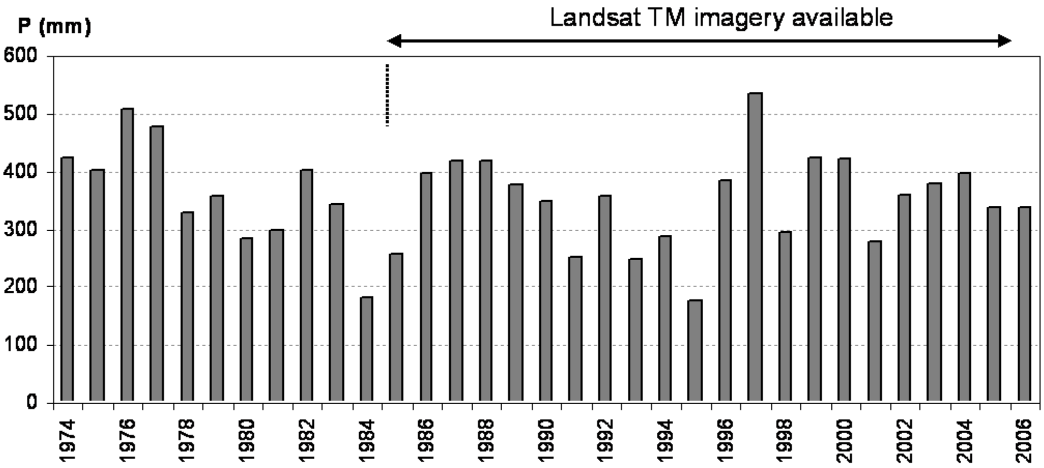
Figure 3. Annual rainfall for the Petris Weather Station, located in the study area, from 1974 to the present and period covered by Landsat TM satellite.

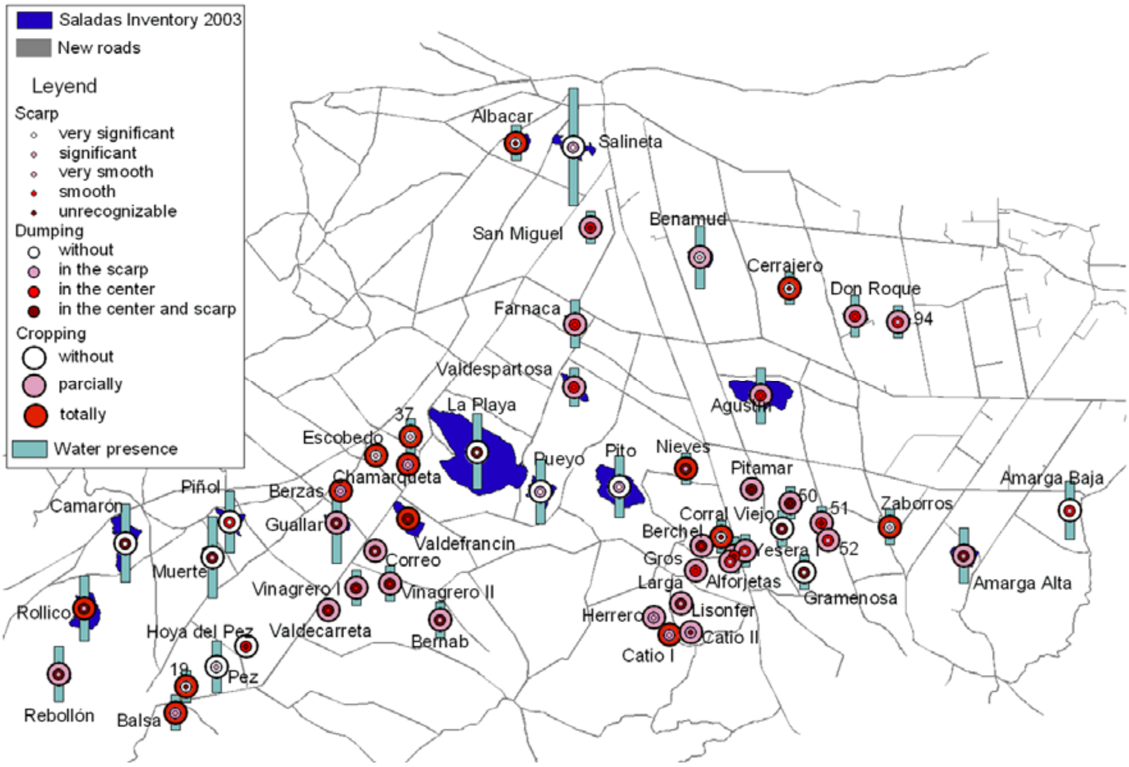
Figure 4. The status of the *Inventory 2003* illustrated by means of the Systematic Descriptors of the Saladas: escarpment, stone dumping, crop invasion, and water presence. Water presence was obtained from a series of satellite observations (Castañeda and Herrero, 2006).

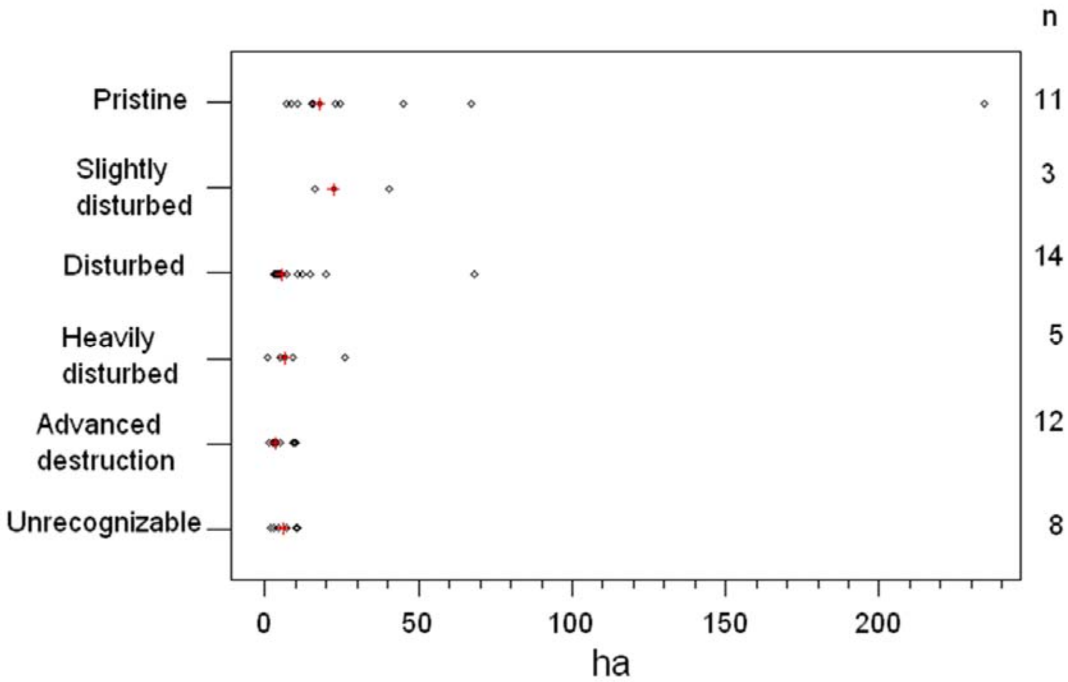
Figure 5. Classes established to group the landscape appearance of the saladas in the *Inventory 2003*: number of saladas (n), surface extent and median (red plus), in ha, in each condition class.


STUDY AREA
EBRO RIVER
Spain
Portugal
Albacar
Salineta
San Miguel
Benamud
Cerrajero
Don Roque
94
Famaca
Valdespartosa
Agustín
37
La Playa
Escobedo
Pueyo
Pito
Nieves
Chamarqueta
Pitamar
50
51
Piñol
Berzas
Camarón
Corral Viejo
Zaborros
Amarga Baja
Guallar
Berchel
Valdefrancín
Yesera I
52
Correo
Gros
Muerte
Alforjetas
Larga
Vinagrero I
Vinagrero II
Gramenosa
Amarga Alta
Lisonfer
Rollico
Herrero
Hoya del Pez
Valdecarreta
Catio II
Bernab
Catio I
19
Pez
Rebollón
Balsa
0
3 km
Saladas Inventory 2003
New irrigated area
New roads
Petris weather station


a
b


Landsat TM imagery available
P (mm)
600
500
400
300
200
100
0
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006


Saladas Inventory 2003
New roads
Leyend
Scarp
very significant
significant
very smooth
smooth
unrecognizable
Dumping
without
in the scarp
in the center
in the center and scarp
Cropping
without
parcially
totally
Water presence
Albacar
Salineta
San Miguel
Benamud
Cerrajero
Don Roque
94
Farnaca
Valdespartosa
La Playa
Agustín
37
Escobedo
Chamarqueta
Pueyo
Pito
Nieves
Pitamar
Amarga Baja
Camarón
Piñol
Berzas
Guallar
Valdefrancín
Correo
50
51
52
Zaborros
Corral Viejo
Berchel
Yesera I
Gros
Larga
Alforjetas
Gramenosa
Amarga Alta
Muerte
Vinagrero I
Vinagrero II
Rollico
Hoya del Pez
Valdecarreta
Bernab
Herrero
Lisonfer
Catio II
Catio I
19
Pez
Rebollón
Balsa


n
Pristine
11
Slightly disturbed
3
Disturbed
14
Heavily disturbed
5
Advanced destruction
12
Unrecognizable
8
0
50
100
150
200
ha