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QUANTIFYING VISIBLE LAND DEGRADATION OF SALINE WETLANDS IN AN ARID REGION OF NE SPAIN[1]

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Introduction

The saline wetlands in the Monegros Desert, NE Spain (Figure 1) are a unique European landscape and have high scientific and ecologic interest. This vulnerable semiarid territory is undergoing significant landscape transformations due to farm consolidation, new irrigation, and other kinds of agricultural intensification. Yielding to pressure from ecology activists and the European Union, parts of this area were declared under protection and included in the Natura 2000 network, but with poor practical results.

These wetlands, located in the center of the Ebro Basin, lie on a gypsiferous Miocenic platform more than 100 m above the Ebro River level. This arheic area, with the highest degree of aridity in Europe (Herrero and Snyder, 1997), host endemic plants (Cervantes and Sanz, 2002) and other organisms adapted to brines or other extreme environmental factors. About one hundred saline depressions, locally named saladas were inventoried by Balsa et al. (1991), Comin and Sanz (1988) and Pedrocchi (1988). Some of them are playa-lakes similar to the sebkhas in the deserts of North Africa and southwest United States.

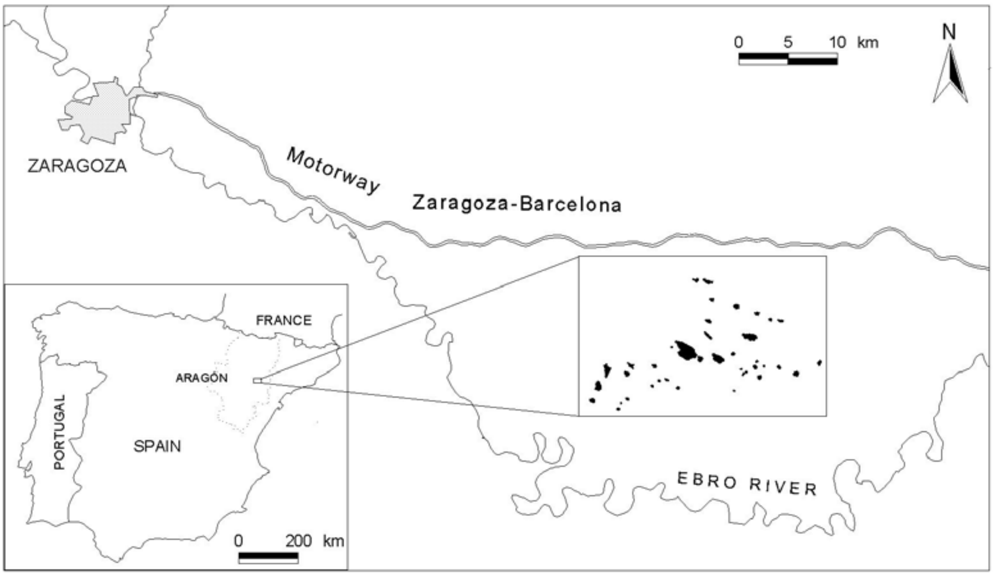

Figure 1. Location of the studied area.

Scientists fear that flows from new irrigated districts on conterminous lands will produce irreversible alterations, disturbing the natural hydrological cycles and the natural salinity, and polluting with agrochemicals. Several saladas are already artificially flooded, but the current degradation affecting most of these wetlands comes from the dumping of boulders

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removed from plowed fields, land consolidation, heavy machinery traffic, new linear infrastructures for agricultural intensification, mainly irrigation, and more recently from urban debris. The degradation of the landscape and the habitats are easily observed, since some of these playa-lakes have disappeared and others have deteriorated in appearance.

This article aims to study the present status of the saladas and to quantify their visible degradation with the help of a Geographical Information System (GIS). For this purpose we analyze the changes that have occurred in the last decades and we establish indices to evaluate the condition of the saladas in terms of conservation status and vulnerability.

Materials and Methods

An inventory of the saladas initiated by Castañeda (2002) using remote sensing was completed with field observations of 53 saladas in 2003. The observed features include (i) the geometry of the talus of the depression, (ii) the cover caused by stone dumping, and (iii) the farming invasion, among others. The location of the saladas, their names and the recorded observations have been compared with the unpublished inventories of Pedrocchi (1988), and Comín and Sanz (1988) using a GIS. Then, an external expert has labeled each salada according to its current conservation into one of six levels ranging from “very good” to “unrecognizable”.

Our methodology, otlineded in Figure 2, has two steps: (i) an analysis of the perceptible changes in the saladas and (ii) an appraisal of their present condition using indices that facilitate the quantification of the field observations and their systematic study.

In order to analyze the noticeable changes in the saladas over the last decades, we have categorized each of the three features mentioned above. The current status of these features in the 2003 inventory is compared with that described in the Comín and Sanz (1988) inventory, the oldest available inventory having systematic descriptions of the talus, dumping and crops invasion. The comparison required that categories of these three features from the two inventories were homogenized and simplifed in certain cases. The aim here is to detect the most striking land degradation symptoms.

For assessing the present condition of the saladas two indices were established: the Conservation Index (CI) and the Vulnerability Index (VI). The VI was defined two ways, the Current Vulnerability Index, CVI, and the Predictable Vulnerability Index, PVI, parallel dynamic descriptors of land transformations.

The Conservation Index is calculated as a linear combination of the three features described in the inventory and mentioned above. The main feature is the talus because the steeper and more continuous it is, the greater the difficulty for agricultural machinery to pass, impeding dumping and farming and facilitating conservation. To construct this index, each feature is codified for its spatial analysis in a Geographic Information System; then each feature is weighted according to the authors’ field knowledge. The weights establish the relative importance of each feature and were confirmed using a Spearman rank correlation in a group of 25 saladas, and verifying the resultant CI with the remaining 28 saladas.

The two vulnerability indices were established to quantify the degree of exposure to degradating elements and were calculated as linear combinations. For calculating CVI, the elements were: distance to the new roads, the size of each salada, as obtained from the GIS, and water occurrence as obtained from satellite data. Similar to the CI, these features were categorized and codified. For the PVI, the plan of the future protected areas and the new irrigated lands are analyzed as a whole. Taking into account that 50% of the platform is going to be transformed in irrigated lands, the PVI modifies the CVI using a factor F which represents the salada location: (i) within the irrigated area, (ii) out of it but closer than 500 m to the irrigated area rim, or (iii) farther than 500 m to this rim. No weights were applied to the features in these vulnerability indices because of its predictive character and the lack of field data about the relative importance of each feature.

Finally, the Conservation Index was crossed with the two vulnerability indices to obtain the present condition of the saladas. Since there are two vulnerability indices, there are also two Conditions: the Current Condition (CC) and the Predictable Condition (PC), which quantify saladas condition in terms of conservation and vulnerability, both currently and what is happening as irrigation works are in progress.

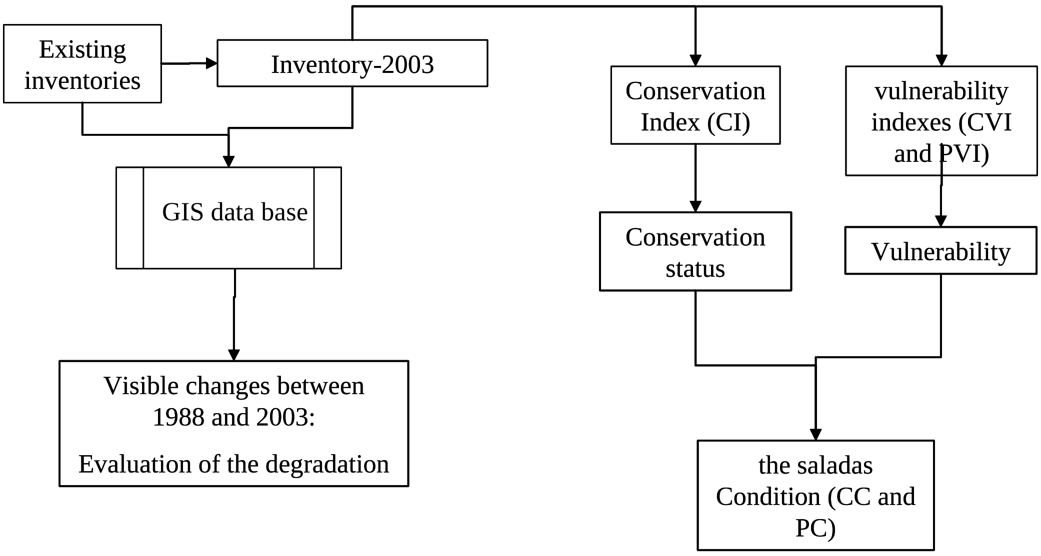

Figure 2. Sketch of the methodology used to study the degradation of the saladas.

Results

The saladas studied in 2003 have suffered a noticeable degradation since 1988, in terms of changes in talus, dumping and agricultural invasion. First, 23% of the saladas have seen their talus change from what could be described as "confining" to "smooth", losing their enclosed and isolated disposition. This loss can be attributed to the use of machinery, intensive earth removal, and dumping over the talus. Second, 30% of the saladas pass from "uncropped" in 1988 to "cropped" in 2003, with the smaller saladas the more severely affected. Third, 63% of the saladas pass from "free of dumping" in 1988 to a "stone dump" status in 2003. This brings the current total to 92% those saladas that have stones covering the halophile vegetation to some degree. The remaining 8% are cropped.

The Conservation Index was established as: CI = 3 × {talus} + 2 × {crops} + 1.5 × {dumping}, where {talus}, {crops} and {dumping} are the codified features, weighted according to its importance as observed in the field and corroborated by the Spearman ranks coefficient. The CI, ranging from 0.5 to 26.5 and divided into five intervals, labels the conservation status of the saladas from *very good* to *very bad*. Sadly, 50% of the saladas are in a *bad* or *very bad* conservation status, in the main these are the smaller saladas and those invaded by crops. Then, 30% are in a *medium* conservation status; these saladas have occasional brine and enjoy developed halophile vegetation covering all the bottom; finally, 20% are in e a *good* or *very good* status, an are the largest saladas as well as those with the most water occurrence.

The CVI was established as: CVI = {distance to roads} + {size} + {water occurrence}, where {distance to roads}, {size} and {water occurrence} are the codified features. The resultant vulnerability index, ranging from 3 to 15, is grouped in three categories: *low*, *medium* and *high*. A 60% of the saladas have a high vulnerability, and are those saladas which are smaller and with lower water occurrence; only 13% have a low vulnerability, and are the largest, of playa-lake type, and located out of irrigation areas.

The PVI ranges from 6.0 to 22.5 and is sub-divided in four risk categories, from *low* to *very high*. As expected, this index reveals that an elevated number of saladas are exposed to a degradation risk. So, 73% have a *high* or *very high* vulnerability, including some larger saladas which are soon to be incorporated into irrigated lands.

The Current Condition of the saladas, obtained by crossing the CI with the CVI, represents a more factual evaluation because it includes simultaneously their conservation status and their risk of degradation. Five condition categories were established, ranging from *very bad* to *very good*. We find that 58% of the saladas are in a *bad* or *very bad* condition. Again, these are the smaller saladas and those with a lower water occurrence; some of them cannot be recognized and others are very affected by dumping. Presently, 31% are in *good* or *very good* condition. The Predictable Condition, obtained by crossing the CI with the PVI, indicates that the projected irrigation works increase the risk of degradation since 69% of the saladas are now classified as *bad* or *very bad* condition; these are saladas of any size, most of them within or very close to the irrigated area (Figure 3), and they are going to disappear as their conservation is incompatible with land transformations.

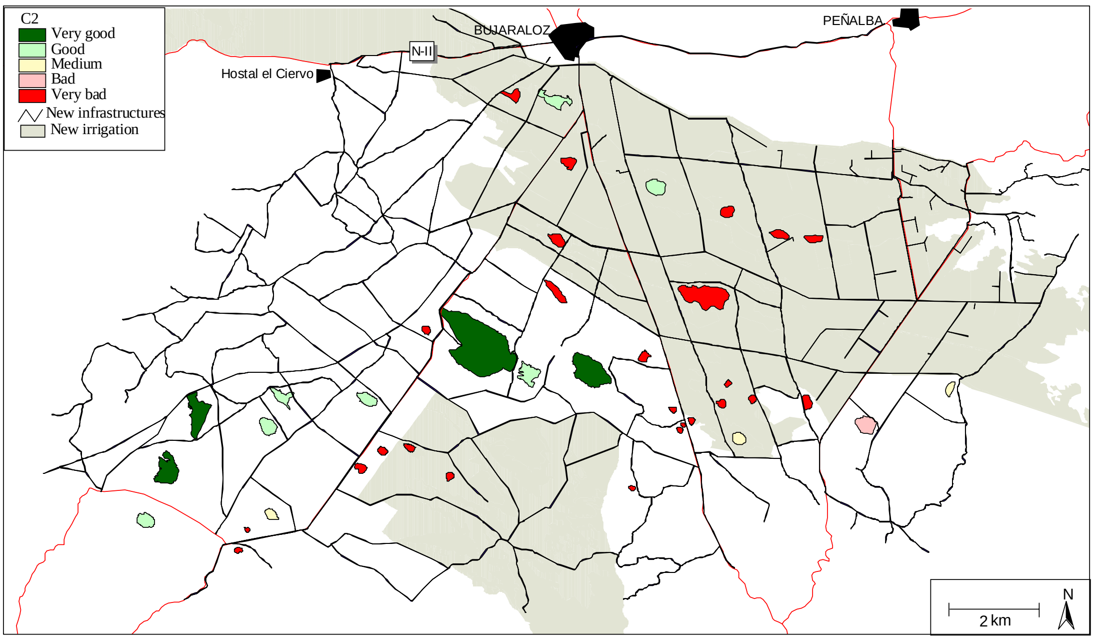

Figure 3. Predictable Condition of the saladas included in the study.

Conclusions

The integration of current field observations, unpublished historical data, remotely sensed and other geographic data, into a geographic information system has permitted us to form a consistent evaluation of land degradation in this area of high ecological value. A current inventory with systematic field observations was performed, the changes in the saladas in the last decades were registered, and several indices were established to quantify their status and systematize their study.

In spite of high environmental and scientific interest in these wetlands, the degradation of the landscape and the habitats are plainly evident; some of these playa-lakes have disappeared and others have deteriorated in appearance due to land consolidation or new infrastructures for agricultural intensification, mainly irrigation.

Results show changes in the saladas such as: a loss of halophile vegetation due to increased agricultural invasion for 30% of them, the suffocation of halophytes and other organisms as a result of dumping over the talus and inside the depressions for 63% of the cases, and a smoothing of the edge of the depression for 23% of the saladas.

Overall, 69% of the saladas will be destroyed. This is the plain traslation of having been evaluated in *bad* and *very bad* condition, in terms of conservation and vulnerability because of their inclusion or closeness to the area to be irrigated. Some of them are the largest saladas, valuable habitats supporting halophile vegetation with scarce representation in Europe.

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