A METHODOLOGY FOR WETLAND CLASSIFICATION ATTENDING TO THE CAPACITY FOR ARTIFICIAL AQUIFER RECHARGE. APPLICATION TO THE COCA-OLMEDO WETLANDS, DUERO BASIN (SPAIN)

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Abstract

A specific system to classify wetlands attending to their suitability for aquifer recharge-based restoration is proposed. The system is based on several approaches, highlighting wetland's relationship with the aquifer, current state of conservation, typology of environmental impacts that have affected the wetland, hydrogeological conditions, presence of water and viability of aquifer recharge. This paper arises from the PhD of the first author.

Keywords

Artificial recharge of aquifers, wetlands, Cubeta of Santiuste, Coca-Olmedo wetlands, Arenales.

INTRODUCTION

Interactions between the human being and aquatic ecosystems date from ancestral times. Anthropic actions have contributed to the high dynamism of water landscapes, resulting in very diverse environments. In this respect, Spain is the country of the EU that presents the greatest diversity wetland types *(Casado & Montes, 1995).*

Wetlands are particularly valuable from the scientific point of view, since they represent 'living laboratories' for the study of multiple natural processes. In addition, wetlands are important for ecological and socio-economic reasons. However, the reality of wetlands is often misunderstood by human beings, who at times find it difficult to adequate themselves to aquatic ecosystems *(González, 1989, 1992 a, b, c.).*

Wetland recovery through artificial aquifer recharge is a relatively new idea, or at least, one that has generally been hinted but not implemented *(MAPA, 1999, Galán et al, 2001; Fdez. Escalante and López, 2002).* Artificial aquifer recharge is currently applied in Holland and the United States, among other countries *(Stuyfzand & Mosch, 2002),* and has the potential to contribute to wetland restoration. However, artificial recharge often implies a change in water quality, due to the different nature of local and imported waters *(Fdez. Escalante, 2005).*

This paper presents a method for wetland classification attending to their capacity to be regenerated through artificial aquifer recharge. The application of this methodology to a

set of wetlands in Spain is described in detail. The paper arises from the PhD of the first author *(Fdez. Escalante, 2005).*

OBJECTIVES

This paper assesses the current state of some of the Coca-Olmedo wetlands. Approaches to wetland characterization based on specifically-designed artificial parameters have been applied.

After such characterization, a brand new method for wetland classification is presented and applied. This classification indentifies the suitability of wetlands for regeneration by means of artificial aquifer recharge.

(i) Characterization and inventory

Characterization based on the new classification has been carried out in three of the 17 wetlands with bibliographical references *(Rey Benayas, 1991).* In all the cases (those 17 and 68 additional inventoried in Fdez. Escalante, 2002 and 2005), field measurements were taken for morfometric characterization, with the ultimate objective of generating numerical data to allow the study of their future evolution.

Wetlands have been classified according to three approaches:

A) Those that are under legal protection, like the lagoons of Caballo Alba (SG-1), La Iglesia (SG-3) and Las Eras (SG-2).

B) Those that maintain a certain “lavajo” (a local name for a type of wetland) in spite of human attempts of drainage. This is the case of the Valderruedas or Valdeperiñan wetlands, both of which present significant alterations.

C) Those that have been deeply transformed (plowed areas, urbanized or with an undue use).

The objective of the inventory and characterization is to study the viability of regenerating of the wetlands by means of artificial aquifer recharge, provided that technical and socio-economic conditions are favorable.

Table 1 shows the characterization approaches and their application to a given wetland. This is intended as an example of how all the necessary knowledge can be integrated in a single table, so that coordinated action can be taken, particularly in regard to environmental issues.

Data presented in table 1 refers to august 2003, and is partially based on Gonzalez *(1988 and 1989)* ideas on environmental evaluation.

(ii) A brand new wetlands classification proposal

The inventory of the previous section has been incorporated to a documental database of wetlands potentially elligible for artificial recharge (provided that economic, environmental and political conditions allow).

This classification keeps in mind the conservation state and functioning of the system in natural conditions, that is, before anthropogenic impacts occur *(Fdez. Escalante, 2002, 2005; García, 2003)* (Table 2).

Four wetlands typologies have been identified according to their functioning. Each of these is assigned one color:

- Red. Currently extinct wetlands, detected by means of indirect techniques: old aerial photographs, interviews to local population, tests detected in field, etc. These have been termed “indicial wetlands”.

- Orange: Strongly degraded wetlands. Recovery is difficult because due to the variety of impacts.

- Yellow: Wetlands associated to net runoff. These are generally endorreic, and unrelated to groundwater: their origin is not conditioned by the phreatic level of aquifer, but rather to superficial drainage networks. These wetlands may remain dry during the drought periods and hardly lose their ecological value (high resilience). Their recovery is relatively easy if artificial recharge water does not have a significant impact on water quality.

- Blue: Groundwater-dependent wetlands *(Custodio, 2000).* Their recovery is more complicated than in the previous case, since they require a qualitative modification of recharge water, using techniques to replicate the processes of soil-water interaction.

Suitability of wetlands to be restored by means of operations of artificial recharge corresponds in general to blue or yellow types.

Given the importance of water availability for recharge, each colour is accompanied by a relative index to the presence of water and of agricultural data.

The presence of water is largely conditioned by the date the inventory was carried out, as well as by the type of hydrological year. Nevertheless, regenerative works are envisioned for the wetlands degraded due to the disappearance of their natural water sources (though irrigation, drainages, derivations of streams, canalisations, etc.), and not due to the absence of precipitations during dry periods.

Weights assigned to each type of wetland in relation their state of conservation are based on the following criteria:

1) Absence of water for most of the year. Very strong affection. The wetland and their surrounding land have been subjected to changes in use.

2) Total absence of water. Affection is substantial. Derived impacts of the terrain ploughing and drainage, cropping activity is usually present in the area.

3) Widespread absence water. Affection is remarkable. Recovery is feasible by increasing water inputs to the system and correcting certain additional significant impacts (drainages or undue uses). Agricultural activity usually present in the area.

4) Absence of water. Wetland recovery is possible by increasing water inputs to the system. Additional environmental impacts are of scarce intensity. No agricultural activities in wetland perimeter fringe nor in the influence area. Hydrochemical quality conditioned by the presence of manure in the surroundings areas.

5) Presence of water the whole year. No agricultural activity. Narrow variation in water quality. Suitability for protection perimeters, legal protection, etc, in order to safeguard their current state and to avoid deterioration.

Types 1 and 2 correspond to indicial wetlands in most cases. Techniques fo detection are diverse. Chemical composition of soils generally prevails, except in the case of wetlands associated to the superficial hydrology, whose preservation index is variable.

Types 4 and 5 correspond to reasonably well preserved wetlands, while type 3 corresponds to an intermediate state.

An application of the new classification is presented in Table 3. Most of the inventoried wetlands classified as "blue" are susceptible of a rational regeneration by means of induced artificial recharge. In contrast, red and orange wetlands correspond to a high degree of deterioration.

CONCLUSIONS

A significant part of the wetlands in the area of study present a fair degree of conservation and a low ecosystem value. Some wetlands are quite well preserved and in many cases they are under legal protection.

Implementation of artificial recharge would allow the use of excess water for environmental restoration. The abundance of degraded wetlands suggests this may be one of the most recommended uses for excess water. However, it is necessary to devise a system to prioritize which wetlands should be regenerated in the light of their own technical and political viability.

Within the Coca-Olmedo wetlands, there is a second typology that corresponds to unrecoverable cases. These refer to wetlands that have been dramatically modified, generally due to anthropogenic action. These wetlands, classified as ‘red’, have been excluded from table 3.

Although there is a degree of subjectivity in assigning weights to 'state of conservation', wetland characterization and monitoring in time will allow to appreciate the changes and act accordingly.

Most wetlands tend to experience an increase in their numerical index with time, although not necessarily all end up with an index 5. Legal protection could be aimed at achieving a degree of connectivity, so that wetland regeneration may have a positive impact on the rest of the system Rey Benayas (1991).

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Table 1. An example of characterization suitable for a set of wetlands:

CHARACTERIZATION TEMPLATE: "LA IGLESIA" WETLAND. AUGUST OF 2003.

IDENTIFICATION	**CHECK-UP**
WETLAND CODE	Nº 57. SG-3
TOPONOMY	"LAGUNA DE LA IGLESIA"
ADMINISTRATIVE UNIT	COCA
AUTONOMY REGION	CASTILLA-LEÓN
TOWN/ MAP 50.000	VILLAGONZALO DE COCA/ 455 ARÉVALO
BASIN	DUERO
SUBASIN	2229 CEDEX. Eresma Duero (Voltoya-Adaja)
UTM COORDINATES (Huse 30): X:	367434
Y:	4562545
Z:	798,1
TYPE	ENDORREIC AND SALINE
FIGURA OF PROTECTION	WETLAND CLASSIFIED AREA SG-3
AEREAL PHOTO	8726 (1957); 428F (1987)
ORTOIMAGEN	428 S-3 (JCL 2000).
IMAGE SATELLITE	Spot ORBIT 031, Spot 2 de orbit 032 y Landsat 202
PHOTOGRAFY	57.jpg (annexes 4.1.2. y 4.2.2.).
RESOLUTION MDT AVAILABLE	1 METER
ACCESS	JUST BESIDE COCA TO VILLAGONZALO RD
CHARACTERISTICS	
GENETIC ORIGIN	TOPOGRAPHICAL BASIN
HYDRODEPENDENCY	NO
RELATED AQUIFERS	NO
OVEREXPLOITATION YES/NO	YES
CONNECTION WITH FLUVIAL NET	NO
SOIL ENVIRONMENT	LOAMY AND SALINE LAND
HYDROCHEMICAL FACIES	DURING 2002 AND 2004 WAS DRY. SMALL PUDDLE OCASSIONALLY
CHEMICAL ANALYSIS	NO
PERÍMETER OF PROTECTION	NO
VULNERABYLITY	HIGH

LANDSCAPE ASSESMENT	4
PRESENCE OF HIDROFILIC VEGETATION	HALOPHITIC
PRESENCE OF NITRIC VEGETATION	YES. PERIMETRAL FRANGE
MORFOMETRY	
BIGGER AXIS	482.6 m
SMALLER AXIS	227.5 m
LIMNIMETER	NO
LIMNIMETER BENCH MARK	NO
MÁXIMUM DEPTH OF RECIPIENT BASIN	1,4 m
MÁXIMUM DEPTH	0 (2004)
Maximum perimeter (m)	1209
Maximum wide (m)	227.5
Longitude Maximum (m)	482.6
Maximum Surface (km^2)	0,794
References	Rey Benayas, 1991
NATURAL PROTECTED AREAS (ENP)	
LIC (PLACES OF UE INTERES)	NO
Spanish Historical Patrimony	NO
ZEPA SPECIAL AREA OF BIRD PROTECTION	NO
RAMSAR	NO
OTHER	CLASSIFIED HUMID AREA SG-3
WETLAND PERFORMANCES	
(TYPE OF AFFECTION)	DOWNDRAWN OF WATER LEVEL DUE TO EXTRACTIONS BY IRRIGATION PURPOSES
FILLED (YEAR)	
DRAINAGE (YEAR)	YES/ NO
CROPS	NO
SURRONDED by	CEREALS.
DAMMED (YEAR)	NO
DUG	NO
DREDGED (YEAR)	NO
ARID EXTRACTIONS	NO
REGULATION	YES. DREIN IN SOUTH AREA
WATER EXTRACTIONS	NO
SUSCEPTIBILITY TO WASTES	
URBAN	NO
INDUSTRIAL	NO
AGRÍCULTURAL	YES. DIFFUSE CONTAMINATION
AGROCHEMICAL	YES.
PESTICIDES	YES BY LIXIVIATE
USES	
SHEPHERDING	OCCASIONAL
WATER FOR CATTLE	NO
CITIES SUPPLY	NO
EXTRACTIONS AND OUTLETS	NO
IDUSTRIAL USES	NO.
OTHER USES	AESTHETIC, LANDSCAPE
PÚBLIC USE	
RCREATION	NO
ACUICULTURE	YES (NEGATIVE)
URBANIZED	NO

HUNTERY	YES
FISHERY	NO
EDUCATIONAL	NO
RECREATIONAL	NO
MEDICINAL	NOT AT THE CURRENT TIME
VEGETATION USE	NO
OTHERS	NO
OBSERVATIONS	SALINE SOIL WITH POSIBLE INTERES
ADMINISTRATIVE DATA	
PROPERTY	COCA TOWN HALL
ADMINISTRATION	JCL
CONSERVATION DEGREE	4/BLUE TYPE (Fdez. Escalante, 2005)
INSTRUCTOR/SOURCE	Fernández Escalante, 2005
OBSERVATIONS	IMPROVEMENT BY MEAN OF MAR

Table 2. Classification:

- Conservation state:

5. Water. It can improve easily.
4. Without water. It can recover. No agricultural activity nearby.
3. Without water. Affected. Agricultural activity nearby.
2. Without water. Substantially affected. Ploughed, cultivated.
1. Without water. Substantially affected. Changes in use.

- Operation:

Hydrodependent wetland.
Wetland in connection with the net of surface runoff. No Hydrodependent /endorreic.
Wetland strongly damaged with difficult recovery.
Indicial wetland missing.

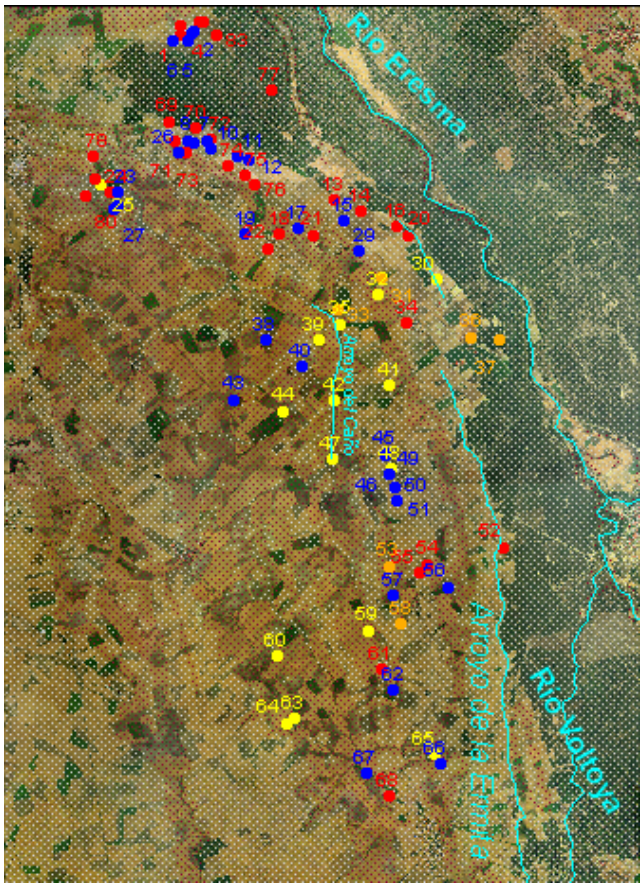

Figure 1. Location of the wetlands inventoried of the Coca-Olmedo Complex and application of the classification for their regeneration by means of artificial aquifer recharge techniques. Scale (aprox): 1:150.000

Table 3. Inventory:

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