# LAND USE AND TECHNOLOGICAL CHANGE IN THE SEDIMENTARY RECORD: THEIR RECORD IN A TEMPERATE WETLAND (CENTRAL SPAIN)

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## Introduction

Land use change produces clear disturbances in the natural systems that can be identified by means of the analysis of the sedimentary record. Such changes are evident since agriculture development, but on the contrary to climate, for which there is a "compromise" agreement among the different factors implied in its cycle, less attention has been paid to the controls on human-induced change.

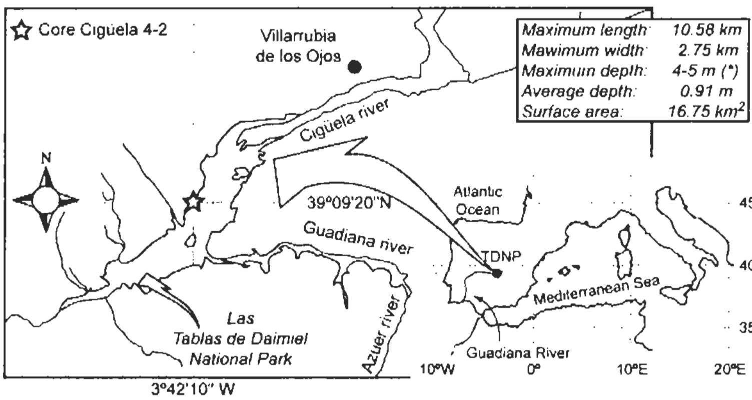


Figure 1. Studied area, location of core Cigüela 4-2 and morphological characteristics (from Alvarez-Cobelas et al., 1996) of the wetland vase. (*): artificial values due to the presence of dams.

Recognition that political (as colonization, introduction of new species, etc.), economical (migratory movements) and technological changes (industrialization, machinery, etc.) are some of the controls on human-induced change introduces new "rules" on the global change scenario that do not follow the "natural" mechanisms and, therefore, must be analyzed under other set of premises that can, or cannot, be easily modelled.

In this paper, we present the geochemical and pollen record for the last millennium of such human induced changes in a temperate wetland (Las Tablas de Daimiel National Park – LTDNP-, Fig. 1) which was fed by surface and ground waters (mostly carbonated-sulphated) since recent times.

## Sediments and history

To present the ideas above expressed, we have chosen a single core (core 4-2, Fig. 1) for which the sedimentary record of the last millennium is exclusively represented by carbonate laminae composed by charophyte oogonia and stems, accumulated in the open water areas of the wetland, interbedded with millimetre-scale laminae composed of vegetal remains, mainly *Phragmites* and *Typha* leaves, that represent the wetland margins. Both facies present sparse gypsum microcrystals and clayey matrix. Consequently, we have chosen organic and inorganic C (heliophytic vegetation and charophytes, respectively), S (gypsum: water salinity) and Al (siliciclastics: external inputs) as the most representative elements of this environment (Fig. 2) plus N (nutrients and fertilizers). These elements have been measured in contiguous samples (average thickness of 7 mm) (Santisteban et al., 2004) as well as pollen content. We have chosen *Pinus* and evergreen *Quercus* in the arboreal strata as "natural" temperature sensitive taxa, Oleaceae and Cerealia as representative of farming, and Chenopodiaceae-Amaranthaceae as indicative of soil salinity. Depth-age calibration of the core has been achieved by $^{14}C$ AMS, $^{239,240}Pu$, and $^{210}Po$ dating, and identification of historical events.

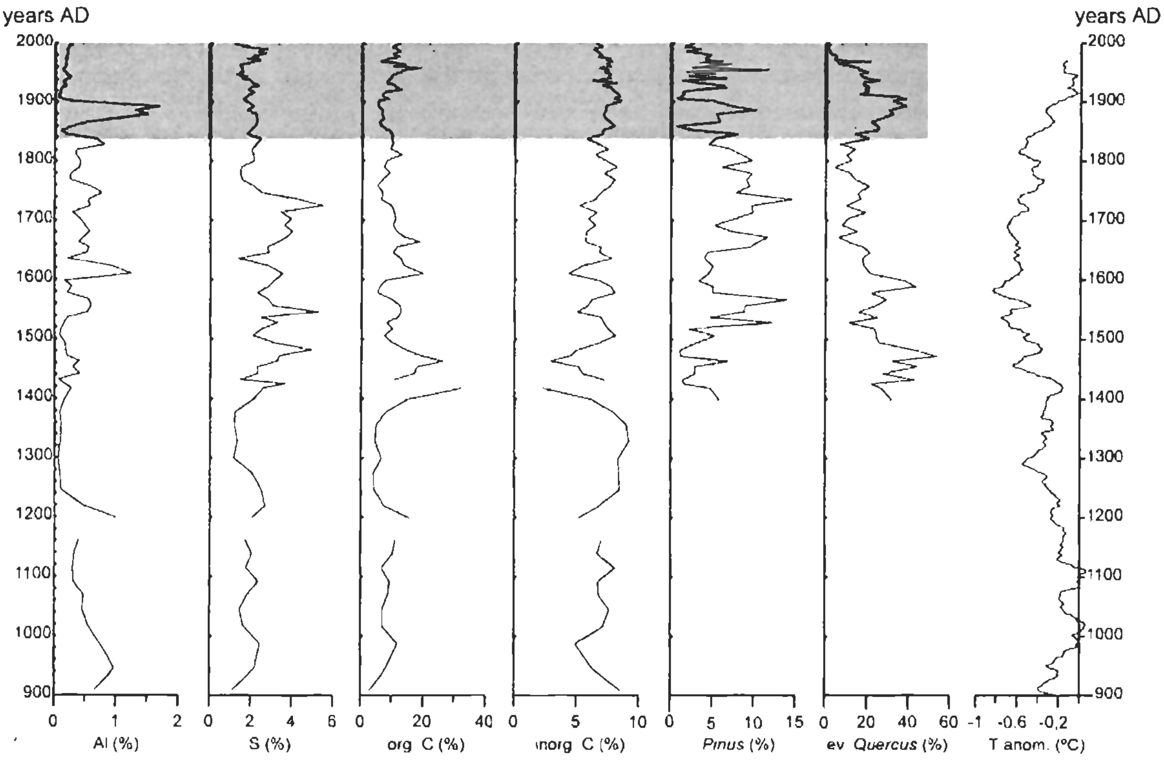


Figure 2. Geochemical parameters for the last 1100 years. These elements, plus Pinus and evergreen Quercus records for the last 600 years (continuous record), show a remarkable similitude to Moberg's et al. (2005) curve.

## The "quasi-natural state"

The lower part (from ca. 10$^{th}$ century up to middle 19$^{th}$ century) (Fig. 2) shows a remarkable reverse coincidence in peaks and trends among organic C, S and Al and inorganic C and of those with the temperature reconstruction of Moberg et al. (2005). This fact reveals the close relation between the environment dynamics and climate, but a closer inspection reveals two different orders of cyclicity:

1) Short-scale cycles (interannual-decadal). During arid (and warm) periods, the water table dropped and charophytes retreated towards the centre of the wetland (diminution of inorganic C), whereas the fringe of emergent vegetation expanded (increased organic C). As a consequence of drier conditions the soils became more saline (increase in S), degraded and were eroded easily (increase in Al). During wet periods the relations were

the inverse.

2) Long term cycles (century scale). The relations changed considerably as sustained arid conditions made soils too saline to support terrestrial and emergent vegetation (decrease in organic C). On the other hand, charophytes were in the aquatic media and they were better adapted to increased saline conditions (increase in inorganic C background).

There are few documentary references for this period in the area. The Muslims, after entering the Iberian Peninsula in 711 A.D., call the region "La Mancha" (from the arab Al-Manxa, meaning a flat, arid and deserted area). In the 10th century, an arab traveller, Al-Razi, wrote that climate in the area was mild and favourable for grain growing. From 11th to 13th centuries, the area was subjected to continuous small fights between Christians and Muslims. After this period, the land was owned by the Calatrava military order and, until middle 19th century, by the nobility and the church.

Land use was on a basis of rental of small portions of land worked by families for self-consume and local or small scale commerce. Main cultivations were vineyards, olive trees, orchards and cereal. But an important part of the economy was based on nomadic shepherding (the so-called "Mesta" constituted by royal regulation in the 13th century and abolished in 1836). That means that an important part of the land was used as pasture. grasslands. Despite this apparent intensive use of land, most of it remained uncultivated.

Some attempts to modernize agriculture were tried during the 18th century, but the "immobility" of land owners caused that such attempts had only punctual results.

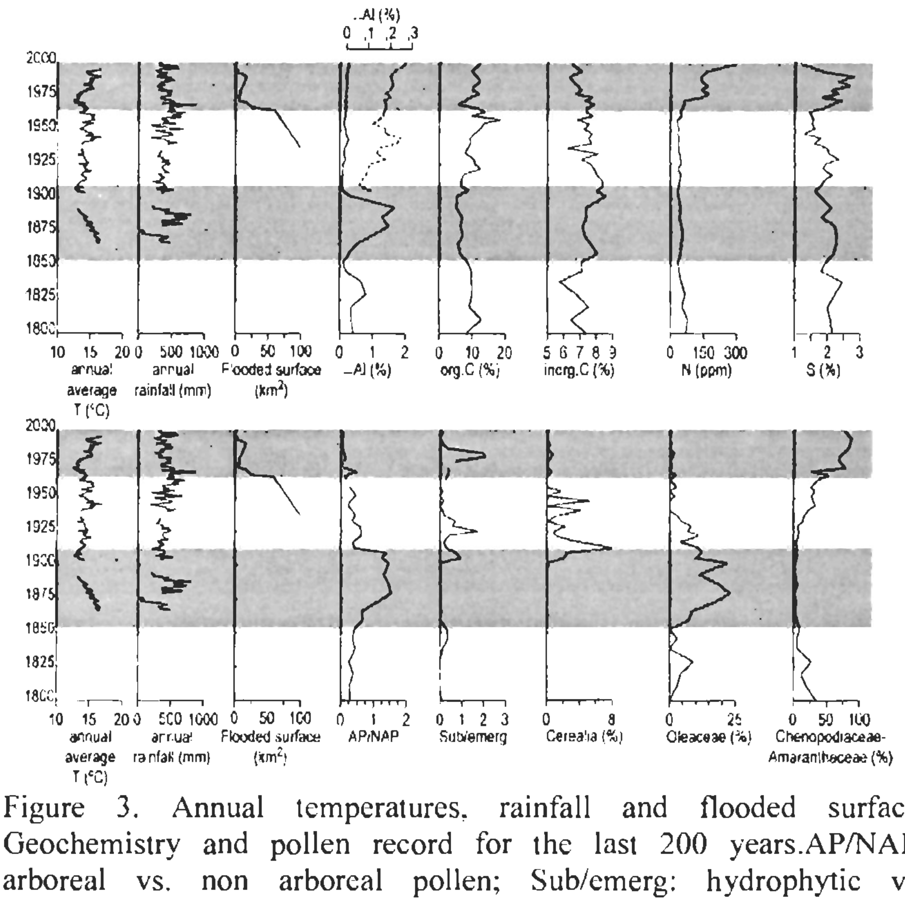


Figure 3. Annual temperatures, rainfall and flooded surface. Geochemistry and pollen record for the last 200 years.AP/NAP: arboreal vs. non arboreal pollen; Sub/emerg: hydrophytic vs. heliophytic vegetation.

## Disturbances of the "natural" system

The more obvious change to the top of the sediments is the disappearance of the previous relations among elements and among them and climate (Fig. 3).

The first evidence of change is observed during the second half of the 19th century (Fig. 3, event 1) when there is a sudden increase in Al. This event is coincident with an increase in trees (notice the increase in *Pinus* and evergreen *Quercus*, Fig. 2) and, in the aquatic domain, emergent vegetation (heliophytes) spread whereas submerged taxa (hydrophytes) almost disappear (Fig. 3 lower). Coevally, there is a sudden increase in Oleaceae and, a little later, in Cerealia (together with other farming species not represented).

This period coincides with a political redistribution of land (Mendizabal's and Madoz's land privatisations) which took the lands not cultivated (mainly owned by nobility and church) and sold them to the middle classes (mainly from outside the region). This change implied a sudden increase in ploughing (increase in Al) plus clearance of lands (removal of grasses and bushes that led to "artificial" percentages of arboreal pollen). However, the agricultural techniques remained as centuries before (use of animals for ploughing, traditional irrigation by channels and shallow wells, etc.).

The increase in water turbidity (siliciclastic input) in the wetland caused the inhibition of the aquatic vegetation and this reflects in the relative sudden increase of marginal vegetation pollen content. However, the low values in organic C and the subtle decrease in inorganic C during this period point to a decrease in wetland productivity that could be related to the increase in turbidity mentioned above and clearance of the margins of the wetland in order to expand the farming lands.

The sudden decrease in Al content at early 20$^{th}$ century marks the beginning of a relatively stable period. During this period (early to middle 20$^{th}$ century) the long-term relations among elements seem to recover (Fig. 3) and a slight increase in Al is followed by organic C while inorganic C and S show a slight decrease. Anthropogenic taxa are still noticeable (mainly Cerealia) but the main feature of the pollen record is the gradual increase in Chenopodiaceae-Amaranthaceae.

Despite the apparent return to "natural" conditions, what really happened was that after reorganization of lands, agriculture spread gradual but irregularly (observe the values of Cerealia in Fig. 3) with some crises related to the loss of the Spanish colonies (1898), the introduction of cereal from Russia and America (early 20$^{th}$ century) and the Spanish Civil War (1936-1939). The parallel increase in Al and organic C, coeval with an increase in annual rainfall, implies an increase in soil erosion plus a higher input of particulate organic matter derived from land, while the gentle decrease in inorganic C is related to increase in turbidity and the decrease in S (water salinity) can be related to the increase in runoff. In addition, the increase in farming implies an increase in water demand that reflects in soil salinization as evidenced by the progressive increase in Chenopodiaceae-Amaranthaceae (Fig. 3).

The next evident change was around the 1960s and it is recorded by a sudden increase in S together with a break in the increasing trend of the organic C and, in the vegetation, the most evident change is an abrupts increase in Chenopodiaceae-Amaranthaceae (Fig. 3). These changes are followed later by a decrease in inorganic C and increase in N and a decrease in heliophitic (emerged) wetland taxa (Fig. 3).

The increase in water and soil salinity (revealed both by S and Chenopodiaceae-Amaranthaceae) together with the decrease in inorganic C were result of the drop in the water table due to the desiccation attempt of the 1960's that caused the sudden drop of the flooded surface of the wetland (Fig. 3). The introduction of water pumps and industrial fertilizers (notice the increase in N) allowed the extension of irrigated cultivations that led to the overexploitation of the water resources (notice the increase in S) and the definitive disconnection of the groundwaters to the surface. The decreasing trend of S in the uppermost part of the record is due to the artificial supply of surface waters, but despite this, salinization of soils (as recorded by the high values of Chenopodiaceae), and loss of flooded surface (around 85 %) became permanent.

## Conclusions

The comparison of changes during "natural" and "anthropogenic" periods allows the characterization of changes in the environment.

First of all, independently of the origin of the change (natural or human-induced), local total variations are small compared to the values for the whole section (Table 1). "Natural" changes show a greater range of variation (Table 1, Fig. 2) than human-induced changes and they are directly related to climate fluctuations (Fig. 2).

But the main difference between natural and human-induced changes is the ability of the system to recover from changes. Climate-driven changes show a cyclic nature that correlates well, despite small time lags (response time), to temperature change in short-term (annual-decadal) and non-lineally in the long term (century scale) (Fig. 2). On the other side, land-use and technological human events are short-term changes that break the environmental relations and a non-lineal behaviour with a fast response and, once surpassed a threshold, slow recovery (Fig. 3).

Table 1.- Minima, maxima and average values of the main geochemical parameters.

| | | Al (%) | | | S (%) | | | inorg. C (%) | | | org. C (%) | | | N (ppm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | min. | max. | av. | min. | Max. | av. | min. | max. | av. | min. | max. | av. | min. | max. | av. |
| Anthropogenic | 1965-2002 * | 0.17 | 0.27 | 0.20 | 1.22 | 2.76 | 2.13 | 6.32 | 7.82 | 7.02 | 5.68 | 12.35 | 10.26 | 52 | 295 | 139.36 |
| | 1910-1965 | 0.07 | 0.25 | 0.15 | 1.28 | 2.35 | 1.76 | 6.22 | 8.36 | 7.53 | 6.59 | 18.70 | 10.83 | 30 | 49 | 40.33 |
| | 1855-1910 * | 0.06 | 1.68 | 0.74 | 1.62 | 2.26 | 2.00 | 7.15 | 8.55 | 7.75 | 5.10 | 8.65 | 6.44 | 32 | 53 | 42.67 |
| | 1855-2002 | 0.06 | 1.68 | 0.32 | 1.22 | 2.76 | 1.94 | 6.22 | 8.55 | 7.43 | 5.10 | 18.70 | 9.52 | 30 | 295 | 72.06 |
| Natural | 1000-1855 | 0.06 | 1.24 | 0.37 | 1.18 | 5.44 | 2.57 | 2.29 | 9.21 | 6.69 | 4.03 | 32.31 | 10.76 | 22 | 208 | 69.87 |
| **Total** | | **0.06** | **1.68** | **0.35** | **1.18** | **5.44** | **2.34** | **2.29** | **9.21** | **6.96** | **4.03** | **32.31** | **10.30** | **22** | **295** | **70.67** |

Changes linked to human activity depend on the location (direct or indirect impact) and intensity of the impact. During the land-use changes of the late 19th century, activity was external to the area of the wetland (indirect impact) and its intensity was medium, so the system was able to recover in about 50 years. The wetland was mainly affected by collateral effects of this activity (debris carried to the wetland by runoff), but its internal mechanisms were able to react in some way to recover previous state.

However, draining and water overexploitation broke the hydrological balance of the wetland in less than 30 years and there is still no recovery. Under those circumstances, despite human actions to prevent desiccation, the loss of the flooded surface and salinization is still running.

This is an example of how humans have destabilized one ecosystem and further inhibited the system's sustainability. Different ecosystems have different resistances to outside impacts, but the Mediterranean wetlands are very fragile due to the climatic characteristics of this area. Additionally, the common lack of water in these regions results in the human attempt to modify the water cycle which could strongly impact terrestrial-aquatic ecosystems such as this.

## Acknowledgements

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