DETECTION OF CHANGES IN LAND COVER AND THEIR ENVIRONMENTAL IMPACT ON AQUATIC ECOSYSTEMS: WESTERN LA MANCHA (CENTRAL SPAIN) CASE STUDY

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I. INTRODUCTION

In some semi-arid regions, traditional agriculture has been replaced by another more profitable one but which badly adapts to the local environmental conditions. At some point in time, these allochthonous models collapse, causing environmental impoverishment and socio-economic problems due to their unsustainability. This is the case of the geographical area of Western La Mancha and Las Tablas de Daimiel.

To govern these territories, the states are increasingly demanding modern and reliable environmental information. The result of this has been the design of geographical information up-dating strategies, particularly with reference to land coverage because it is one of the most dynamic in the short term.

The major importance of evaluating land cover changes which have taken place over time is self-evident for appropriate planning of intervention policies in the territory. There are emblematic projects in the international field which have penetrated this problem (Land Use and Cover Change). Validation techniques of the modellers of land use and cover change have been developed within this framework (Pontius *et al*., 2004).

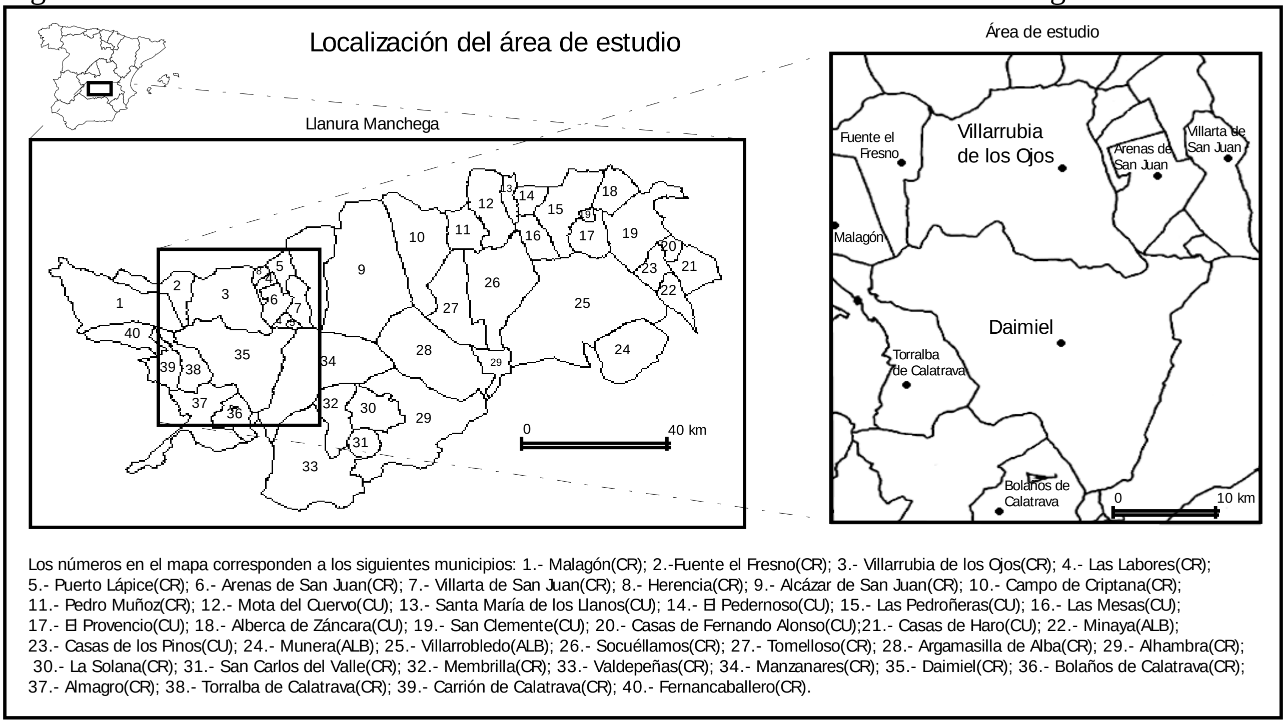
Within this setting, the Geographic Information Systems (GIS) and satellite images, thanks to their global coverage and repetitiveness, are tools of great value for quantitatively and objectively examining the transformations suffered by a territory, taking into account its occupation, and for carrying out predictive models, thus guiding the planners in the decision making process. Eastman

(2007) recently introduced the concept of the vertical GIS and designed a modeller of land use changes.

II. RESEARCH AREA

The area under research is Western La Mancha, located in central Spain. This consists of 40 municipalities in the provinces of Ciudad Real, Cuenca and Albacete and covers a surface area of 5,126 km^2 (figure 1). It is delimited by the Aquifer 23 polygon. The most sensitive area is the one bordering on the Tablas de Daimiel, where the majority of the wetlands are concentrated.

Figure 1: Location of the area under research: Western La Mancha or the Manchegan Plain



Source: Romero *et al.*, 1997

Its topography varies from an altitude of 500 to 1,100 metres. Plains and gentle slopes predominate. It is a morpho-structural depression filled with tertiary materials, mainly covered limestone, in some areas, by plioquarternary and quarternary materials. The limestone materials are essential for the surface and ground-water hydrology, giving origin to the aquifer 23 and reducing the flows which cut across its surface.

Two overlapping aquifers may be distinguished, with 260 hm^3 as an annual average value of the available renewable resources. The upper one gives rise to the Tablas de Daimiel, the Ojos del Guadiana and the irrigated lands developed during the eighties. The majority of wells supplying the irrigated lands in the area are to be found here. The lower aquifer, a continuation of the aquifers of Campo de Montiel and Sierra de Altomira, runs for a length of around 3,500 km^2 in the central and western area of Western la Mancha. The upper aquifer is replenished by means of rain water infiltration, water loss from the rivers circulating around its surface area and irrigated water back-flow.

The climate of the area under research is temperate Mediterranean, with a hot and dry summer. Average rainfall is moderate and varies between 400 and 600 mm. The average annual temperature is between 12° and 16° centigrade. The possibility of frosts exists during a period of at least 2 months. There is a 5 to 6 month deficit in the water balance of the region, reaching maximum levels during the month of July. According to the Martonne dryness index, Western la Mancha forms part of an arid area. There is rotation between wet and dry periods, the latter chronologically coinciding with a greater spread of irrigation. The most common lands found in the region are the Regosols, Cambisols and above all Calcisols. The folic Fluvisols and Histosols are the same as the Guadiana peat bogs. The climatic vegetation are quercineas. With regard to marshy and submerged vegetation, the saw-edge, reeds, bulrushes and chara water meadows abound.

According to the 2006 census, Western la Mancha has over 323,100 inhabitants, accounting for 16.7% of the Castellano-Manchegan population and recording an average density of 37,20 inhab./km^2 which may be low in absolute terms but is, in fact one and a half times the regional demographic density.

III. TRADITIONAL UNDISTURBED LAND COVER SYSTEM

If the 1956-57 national aerial shots are analysed, a still very traditional agricultural landscape may be observed. In the Northern area, in the mountain foothills just above the plains, there was predominately natural autochthonous vegetation. Small gall and holm oak groves were frequently found – always in shady areas – and also in some areas of undergrowth. Forestry exploitation consisted of extracting wood and firewood from these areas. In the little valleys cutting across the mountain interior, large expanses of forest and undergrowth, which had remained beyond agricultural uses due to their location and their limited soil conditions, were ploughed up. They were used to grow cereals crops, mainly barley and oats.

Olive groves also grew on the mountainous ridges with their sometimes steep, sometimes moderate slopes. They were most abundant in a south-easterly-north-easterly strip. These places were doubly propitious for olive-growing: firstly because since they were situated above the level of the hilly inclines, beyond the plains, frosts resulting from frequent temperature inversions did not affect the olives; secondly because the heavy stoniness of the ground provided it with humidity whilst preventing the existence of arable crops at the same time. Here, where the stoniness and slopes were less pronounced, large pasture areas were introduced.

Arable and permanent crops growing on small low ridges and troughs were rotated in the triangle formed by the National Park, Villarrubia and Daimiel. The most common arable crops were barley and wheat. Vines were one of the emblematic crops of the area. During this period, a major increase in vineyards took place owing to the high profits obtained.

Small family market gardens and fields of irrigated arable crops could to be found along the river beds and lowest lying land – depressions, fissures and dolines. These were fed by the water from the Guadiana, Azuer and Gigüela rivers and the shallowness of the water table, where the necessary water resources could be extracted with a small water-wheel or oil generated pumps. These lands were much more intensively used, both space and time-wise.

The wetlands and marches of the Ojos del Guadiana and the Tablas de Daimiel National Parkland represented the main water-channels to the west of Western La Mancha. The regular flow of the Guadiana was used as the main force for the watermills and small electrical plants existing along its course. Together with these, there were temporarily swamped areas, some of which were dried out by means of ditches and drainage channels.

As is apparent, there was a whole diversity of interlinking developments, enriching the Manchegan agrarian landscape. It could be said that there was a certain under exploitation of groundwater resources, as was thought at the time (Alvarado and Hernández-Pacheco, 1934). Notwithstanding, it goes without saying that sustainable agriculture was practised, fostering the replenishing of aquifer 23 and the survival of the major wetlands of the region. At this time, there were already designs to drain them and convert them into agricultural lands, although this had not yet been realized.

IV. FROM MEDITERRANEAN TRIOLOGY TO UNSUSTAINABLE IRRIGATION

IV.1. Transformations occurring between 1956 and 1990

The most radical change was that of the irrigation systems used. Irrigation using small waterwheels was quickly replaced by the distribution of water using spray or drip systems (figure 2.)

The vine plays an important social role in the region, strongly linked to traditional family cultivation. For this reason, in some municipalities, it has expanded, complemented by a progressive intensification, improvement and implementation of irritation. In little over ten years, the spread of the irrigated Manchegan vineyard increased from 5,000 hectares in 1977, to over 25,000 in 1990. Vineyards have been completely transformed at the same time, the older stock being uprooted and replaced by new plantations. Varietal improvements were introduced, making it easier to harvest and increasing output, whilst technological improvements produced drip irrigation, a new plantation framework, trellis training.

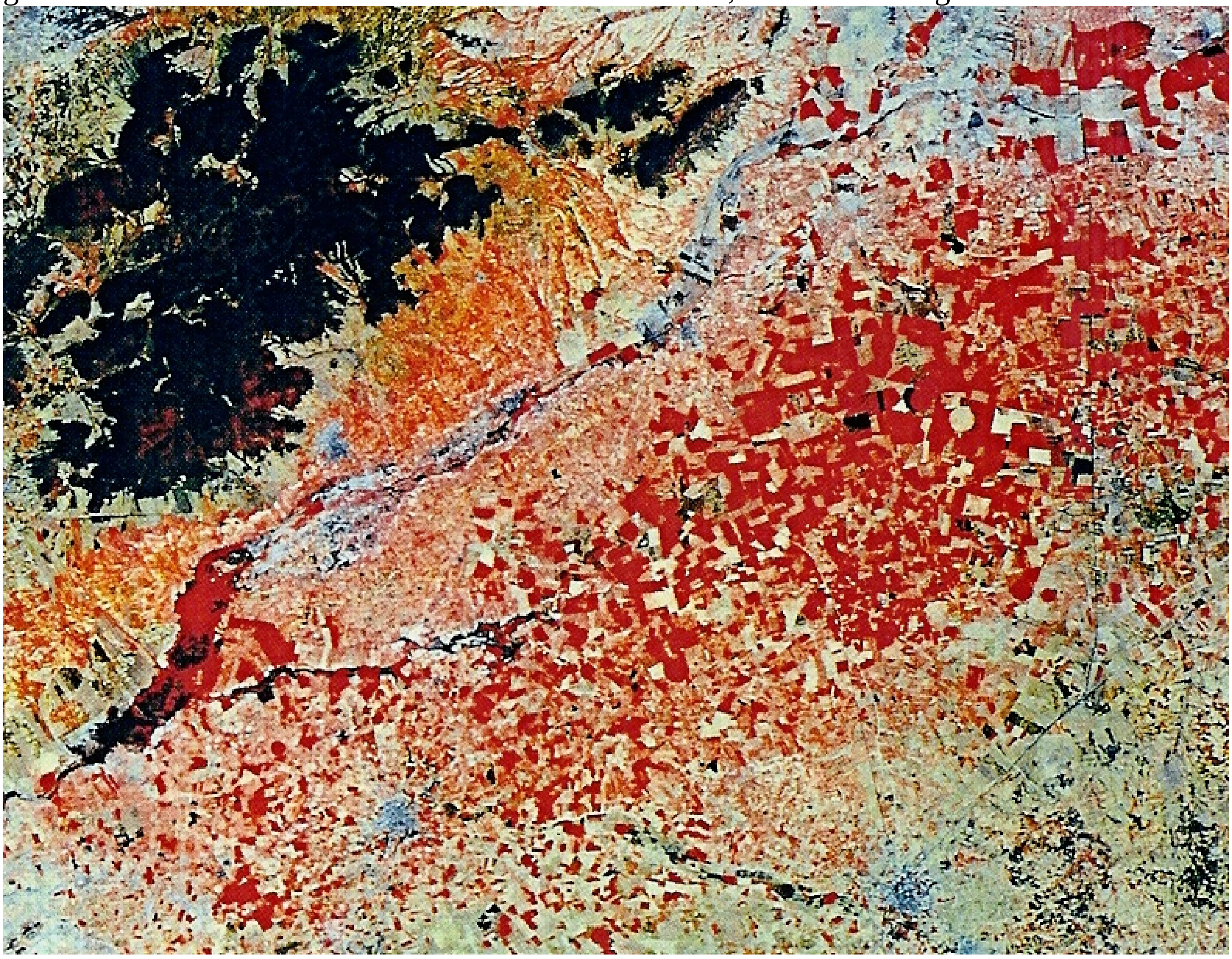
Figure 2: From waterwheel to pivot

Photographs: JAC and JMV

The main arable crops were barley, sunflower, alfalfa and corn. There has been a considerable increase in land given over to irrigated arable crops in central Western La Mancha since 1982. Particularly in the areas of Alcázar de San Juan, Membrilla and Socuéllamos. Over 70% of the area occupied by arable crops became irrigated in less than 10 years. In Villarrubia and Daimiel, following an excessive increase, crop cultivation of this type was stabilised in these areas at the beginning of the eighties. In general, irrigated arable crops cultivation has remained above 25,000 hectares since 1981, surpassing the 49,000 hectare mark in 1990. Figure 3 shows the distribution of irrigated crops and the marshy vegetation in the central-western sector of the Manchegan Plains in a deep red colour.

Industrial irrigated crops consist of beetroot, cotton and oleaginous crops. There was a spectacular reduction in irrigated beetroot cultivation from a surface area of 14,000 hectares in 1982 to 6,000 hectares in 1987. Farmers' dependence on sugar crops and state regulation in allocating productive quotas by area and in fixing prices, are factors which explain the variations both in cultivated area and in the location of the same (Baraja, 1989). Furthermore, a major increase in fodder crops has been recorded during the last few decades, during which their expansion has duplicated. Alfalfa was prominent in the region, increasing from over 6,000 hectares in 1982 to close to 12,000 in 1983. It later maintained its surface area with slight interim ups and downs until the nineties.

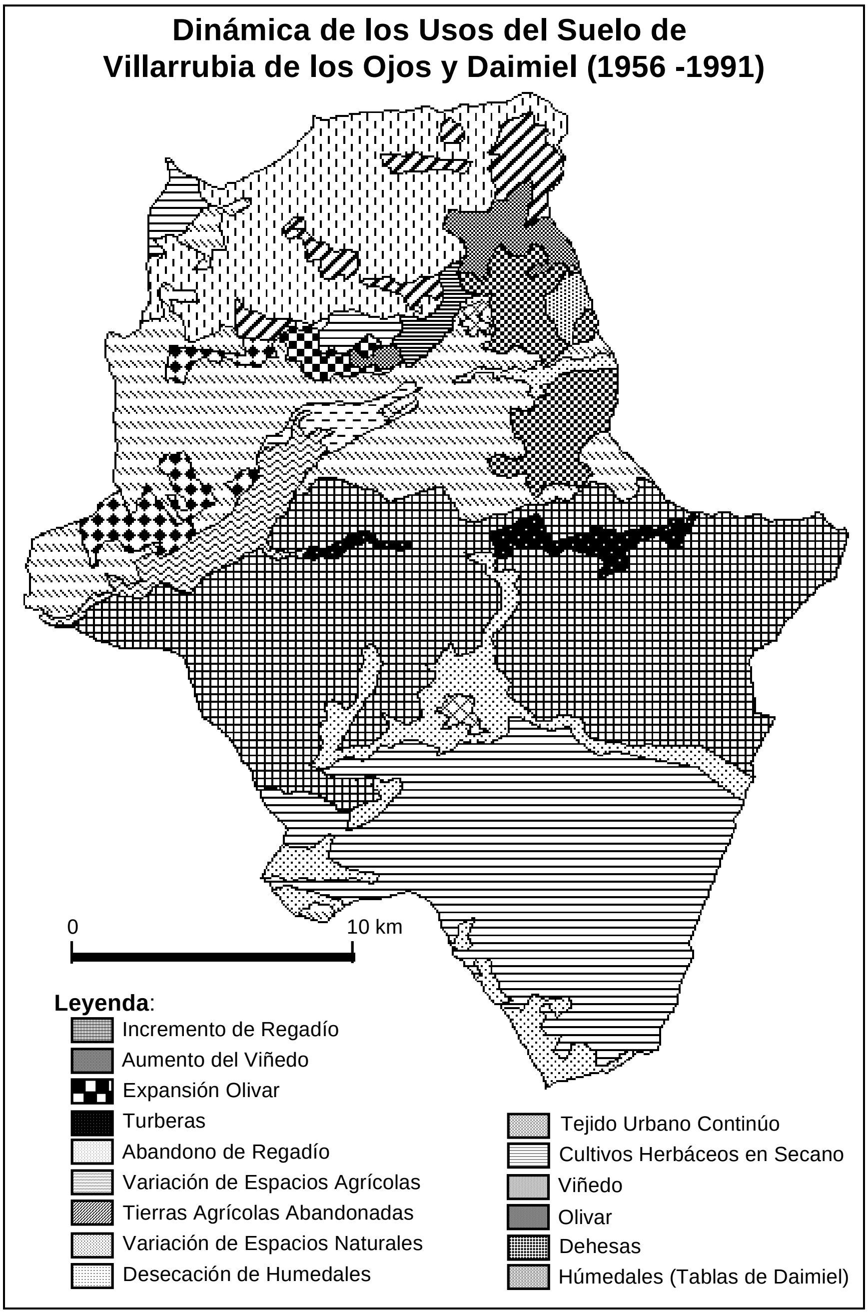
Figure 3: Scene 201-033/2 from the Landsat 5 TM satellite, recorded in August 1988



The expansion of root vegetable crops was parallel to that of irrigated crops, with a steady increase reaching 20,000 hectares. A scaled rise in surface area given over to the cultivation of melons, tomatoes, peppers and aubergines could be appreciated in the area. The most important crop was the melon, which expanded considerably. At the beginning of the eighties, cultivation was increased to around 11,000 hectares in 1984, the time when its growth was moderated with marked ups and downs – from somewhat less than 10,000 hectares in 1985 to close to 13,000 in 1988.

Irrigated crops were not only to be found in the most topographically depressed areas or in the riverbeds, but throughout the arable lands. In figure 4, Romero *et al.*, 1997 gives an example of the dynamic of uses occurring in the National Park service area of the Tablas de Daimiel, comparing the national aerial view of 1956-57 with a 1991 Landsat-TM image.

Figure 4: Dynamics of land cover in the National Park service area of the Tablas de Daimiel



Source: Romero *et al*., 1997.

IV.2. Detection of changes between 1990 and 2000

In order to analyse the changes which occurred during this decade, we must make use of the findings from the CORINE-Land Cover project. Although for a more meticulous analysis another product on a larger scale would be needed, this cover offers us a view of the whole of the aquifer 23 and the development of its land cover between 1990 and 2000.

A large part of the irrigated arable crops and of a mosaic of mixed dry farming crops and irrigated crops were maintained during this period, to a scale of 1:100.000 and considering the size of the minimum cartographable unit, it is impossible to separate them, given the large mix of different uses in a complex land divided into plots. Both types of use were still covering a total of 49,063 and 96,516 hectares respectively in 2000, which means close to 10% and 18% of the overall territory of aquifer 23. As may be appreciated in figure 5, the larger part of the irrigated lands are to be found in the central Western sector of the aquifer, from Socuéllamos to Torralba de Calatrava, maintaining major pressure on the Ojos del Guadiana and the National Park of las Tablas de Daimiel. A second nucleus is to be found to the East of the aquifer, around Villarrobledo.

In figure 6, the changes which occurred in ground use over these ten years is outlined. Despite the fact that over 1,000 hectares of irrigated lands were abandoned (0.20% of the aquifer) affected by a return to dry farming or a process of urbanisation and reconversion in infrastructures, a large part of the changes detected was due to the increase of irrigated lands which increased by almost 11,000 hectares, constituting a gain of 2.14% of the total surface area of the aquifer. These were old dry farming lands which had been transformed into irrigated farming territory. These plots were located in Daimiel, Alcázar de San Juan and, in the Western area, between Villarrobledo, Las Pedroñeras, San Clemente, Casas de Fernando Alonso and Casas de Haro.

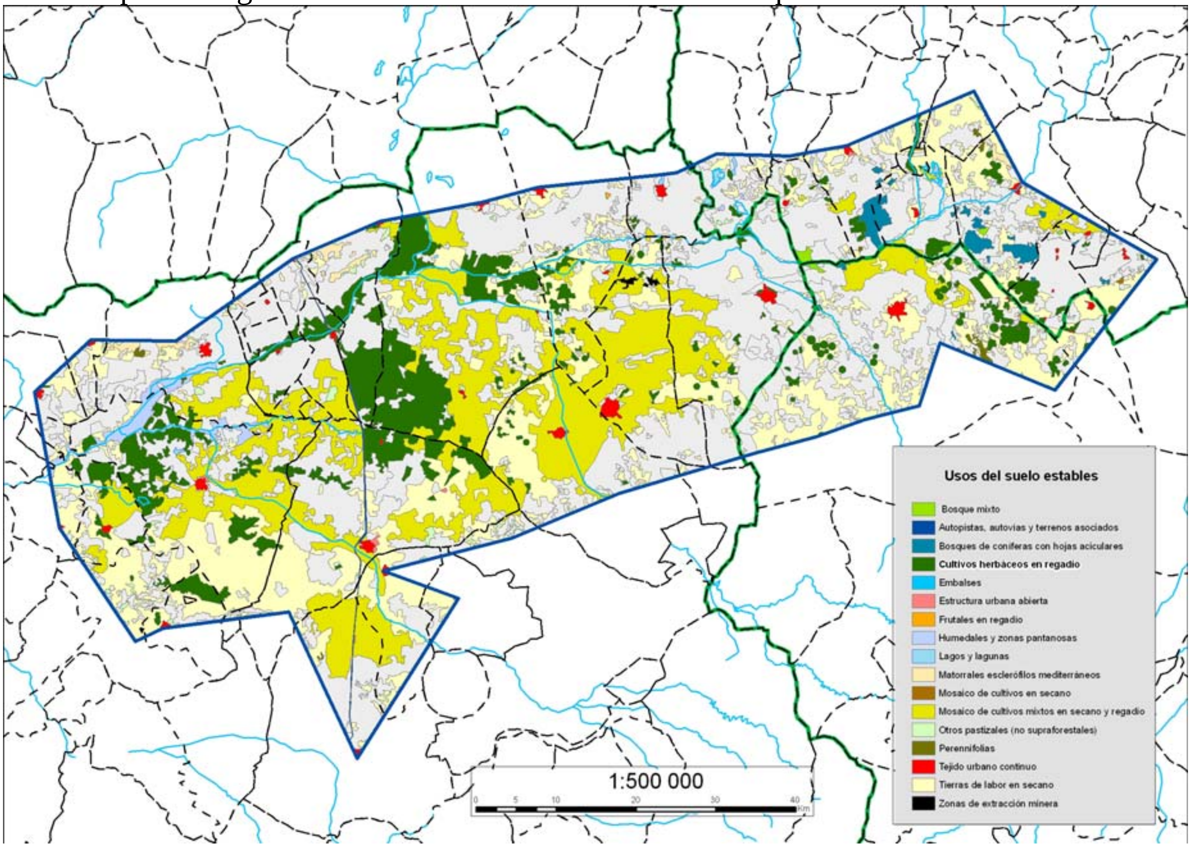
VI. EFFECTS OF THE CHANGES IN LAND COVER

The environmental consequences of this model of agrarian development, based on the overexploitation of water resources has been dealt with by other authors (Aranda *et al*., 1993; García Rodríguez y Llamas, 1993; López-Camacho, 1987, Sancho *et al*., 1994; Sanz Donaire *et al*., 1994). We will sum up the impact incurred.

The increase of irrigated surface area in the region has led to a rise in the volume of the water abstracted from the aquifer. From 1977 to the mid eighties renewable resources from the aquifer (260 hm^3, all but duplicated. This accumulated overexploitation of the aquifer, stemming from changes in ground usage, led to the final pronouncement of the irrevocable overexploitation of the aquifer.

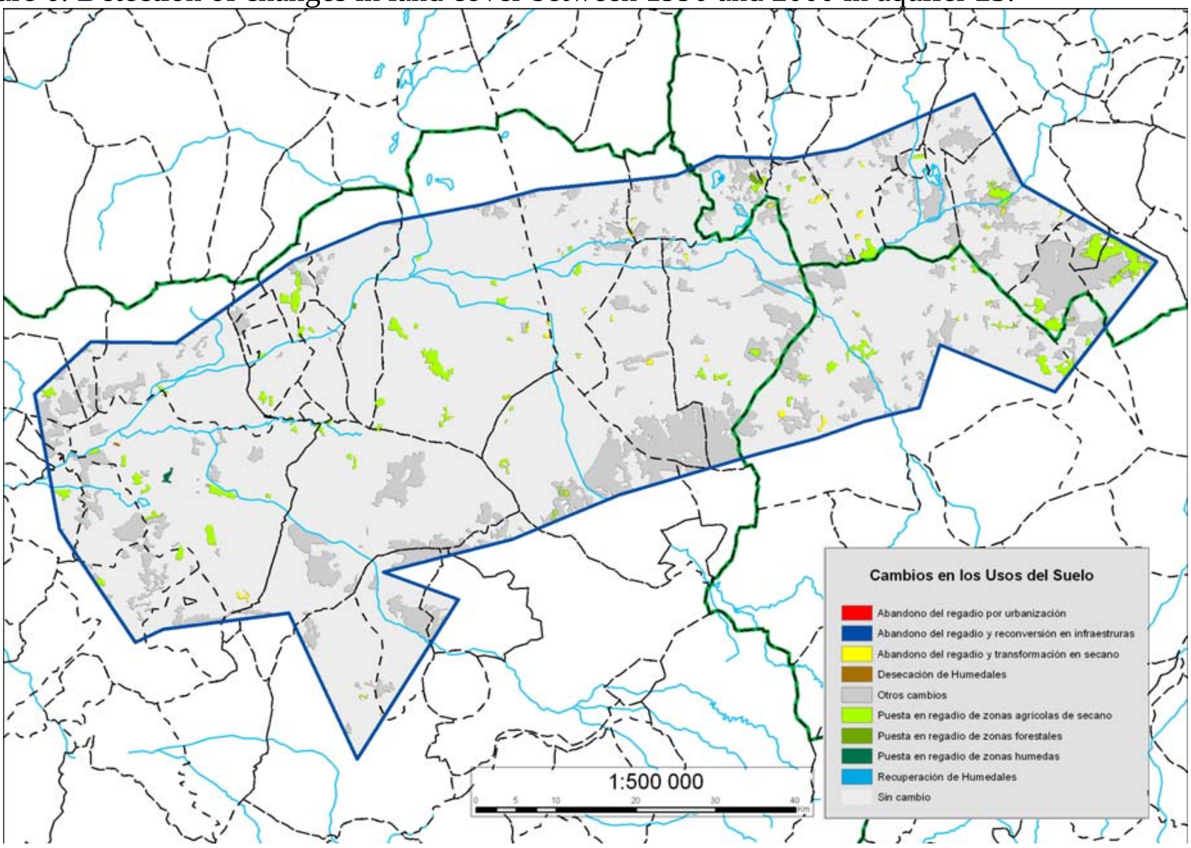
The direct consequence of the process of exploitation of groundwater resources has been the lowering of the aquifer 23's piezometry (Figure 7). From 1974 to 1994 a total average decrease of 22 m throughout aquifer 23 occurred, although in several areas – between Damiel, Manzanares and Argamasilla de Alba - this was higher than 35 m. The immediate socio-economic effect was an increase in costs to be paid by the farmer for introducing irrigation. Environmentally, however, this had other more serious effects.

Figure 5: Map showing stable uses between 1990 and 2000 in aquifer 23.



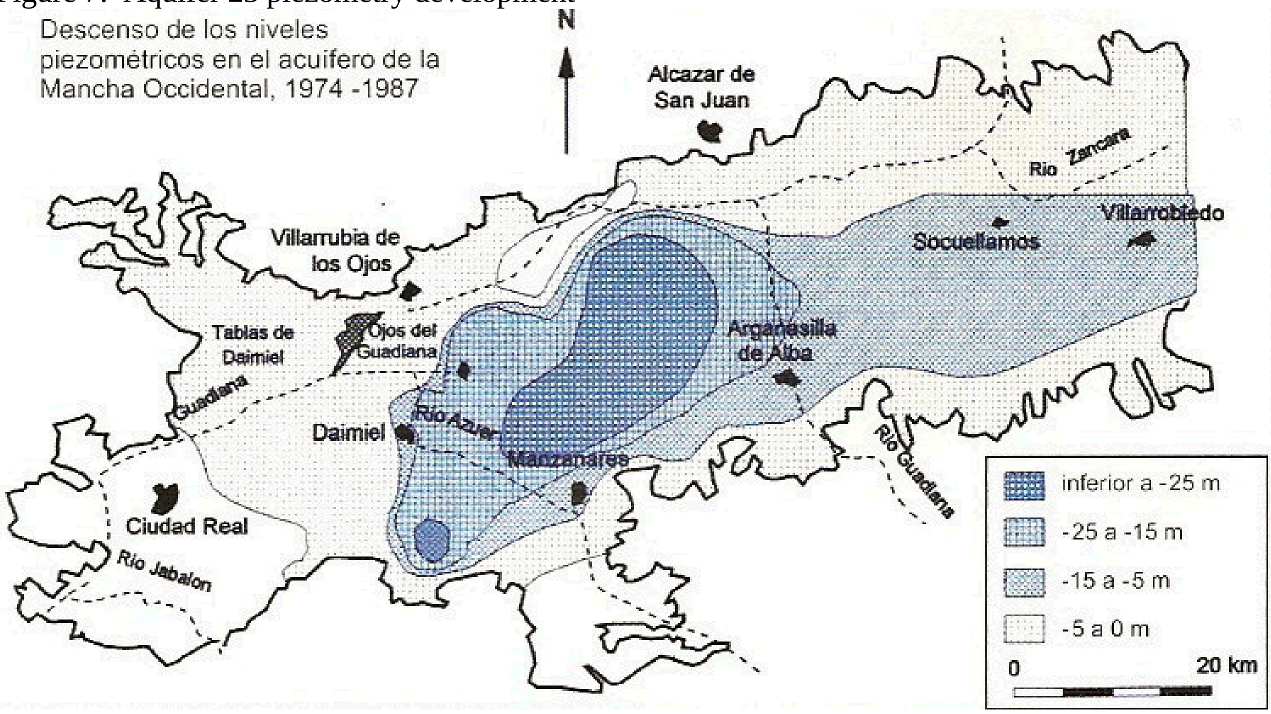
Source: CORINE-Land Cover 1990 and 2000. Production: Pilar Echavarría (CSIC).

Figure 6: Detection of changes in land cover between 1990 and 2000 in aquifer 23.



Source: CORINE-Land Cover 1990 and 2000. Production: Pilar Echavarría (CSIC).

Figure 7: Aquifer 23 piezometry development

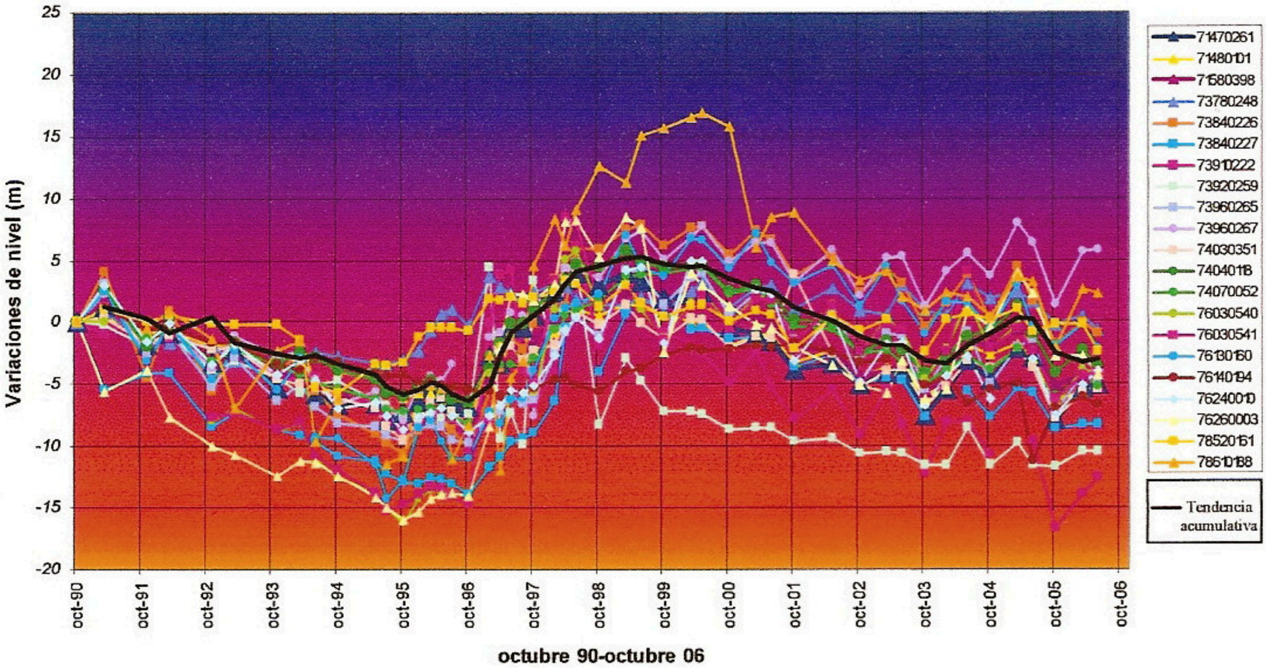


Source: EFEDA Project bulletin: "Impact of the changes in land cover, extraction of groundwater and variability of precipitation in the upper river basin hydrology of the river Guadiana"

Since the mid nineties, the Hydrographic Confederation of the Guadiana (CHG) has been monitoring the hydro-geological development of Western La Mancha from an observation of 21 points, distributed homogeneously throughout the aquifer, with piezometric information being available from October 1990 to the present day. These data have revealed that in terms of an overall balance, no real replenishment has taken place during recent years. On the contrary, the trend towards draining has continued (Figure 8).

Moreover, in a report made by the Spanish Geological and Mining Institute (IGME, 2004) the CGH data were confirmed. It was concluded that during the 1980-2004 period, there was an average decrease in aquifer levels of 22.59 m and it was estimated that, during this same period, a fall in reserves of 2,800 hm^3 could have taken place, resulting in a fall of 3,750 hm^3, during the 1980-1995 period, a recuperation of 1,750 hm^3 between 1995-1999 and a new fall of 800 hm^3 during the 1999-2004 period.

Figure 8: Piezometric development in aquifer 23 from 1990 to 2006.



Source: CHG, (2007): Special plan of the upper *Guadiana. Synthesis document page*. 25.

One of the most visible impacts was the reduction of the swamp area in the Tablas de Daimiel, the drying up of lakes and wetlands, the disappearance of riverbeds and the Ojos del Guadiana and lastly the loss of the Guadiana peatbogs.

An examination of the development of the flooded surface area in the Las Tablas de Daimiel area brings to light two different periods: one of a natural regime lasting until 1987, during which the ecosystem suffered the consequences of overexploitation of the aquifer; and a second one, from 1988, where the Tablas de Daimiel were subjected to seasonal variations, from the addition of water from the Tagus-Segura diversion and its loss – by evaporation and infiltration. This alteration is sufficiently expressive proof of the pressure under which the aquifer 23 has been placed and the search for solutions to the resulting problems. The National Park has suffered the loss and reduction of fauna and flora. However, flow by-passes from the Tagus river basin have contributed to nest-building and the return of several birds. It has also led to the water table levels, around the Tablas de Damiel being higher than those of the aquifer, as they act as an infiltration basin.

The draining of the lakes to the west of Damiel, which are hydrologically connected to the aquifer is more obvious. Their transformation into farming land may give us some idea of the true scale of the ecological damage which the changes to land cover have set in motion.

The Manchegan rivers traversing the region (Gigüela, Záncara, Azuer, Jabalón, among others) are characterised by having rather light flows, most of them being seasonal, linked to more or less abundant rainfall and/or the aquifer surplus. The light flow of these rivers and streams has decreased due to the intense development of the Manchegan agriculture. The duration of low waters since the seventies has become increasingly prolonged over time, not so much due to lack of rainfall as to the abuse of water resources. When the rivers carry water now they quickly surrender a large part of their flow to the depleted aquifer. The case of the river Guadiana is conspicuous and dramatic. Its flow, which had been very regularized due to its karstic origin, has disappeared, due to the fall in piezometric levels of aquifer 23.

The disappearance of the Ojos del Guadiana and the destruction of its peatbogs is even more drastic, should this be possible. Its current state is one of the most disastrous expressions of ecological repercussions this area has suffered. What was before the Ojos del Guadiana and Zuacorta wetlands are now vast areas of non productive lands, their ecological singularity and value having been lost forever. The peatbogs which were used not so long ago around Zuacorta, have now disappeared, a result of the phenomenon of spontaneous combustion.

The intensive use of chemical fertilisers and phytosanitary products has had a heavy impact on the natural environment. Widespread pollution of the water table is augured, with regeneration being of difficult and disturbing proportions. If the water levels are recovered in the medium term, this problem will become palpable when the water comes into contact with the ground, saturating it with chemical products. In order to mitigate this agro-environmental problem those farmers who have been covered by the Income Compensation Plan, are committed to reducing the application of these products.

From the socio-economic point of view, it is obvious that these transformations of the Manchegan countryside have led to an increase in agricultural profits, despite the high investments farmers have had to make with their subsequent debts, to provide individual irrigation infrastructure which the state has refused to take responsibility for.

To sum up, the structural and morphological changes we have examined display the determining role which farming intensification has had in the ecological deterioration of Western la Mancha. The Tablas de Daimiel serve as an “observatory” for evaluating the general situation experienced by the Aquifer 23. They have been the key example of the powerful force suffered by the whole of this Spanish region and the unfolding from a balanced or “sustainable” system to an “unsustainable” agriculture in less than 50 years. Notwithstanding, the most serious impact is that in such a short space of time and owing to the intense pressure on the environment, the Manchegan landscape is already showing signs of this deterioration, due to a lack in planning and poor control over the natural resources.

VI. REACTIONS TO THE LANDSCAPE DYNAMICS AND THEIR IMPACT

Martínez Vega *et al* (1995) said that the solutions to imbalance between supply and demand for water resources should be entirely focused upon two routes which other authors recommended in similar situations. The first solution advocated intense state interventionism via the construction of large infrastructures (reservoirs, basins) to adapt the offer to the increase in foreseeable water demand (0.83% annually between 1992 and 2012 in Spain) and restore the unequal spatial distribution of the resource. This highly costly programmatical idea, is the one underlying several versions of the National Hydrological Plan (Segura, 1994). The second possible solution, possibly with public investment, emphasized control, adapting the demand to the supply of the available water resources and not the reverse (Moral, 1994; Aureli, 1990). This line of argument calls for re-planning of land uses since agriculture is the heaviest water consumer. It also insists on the restriction of enormous hydraulic projects, the utility of which are dubious, and even that the most direct users defray part of the infrastructural costs by means of taxes or levies, although for this to occur, greater participation in the Hydrographic Confederations of the users would be necessary. According to Llamas (1994), in the case of groundwater, the said participation of users is a prerequisite.

The solutions to the problem put forward in this study case have come, co-incidentally, from both routes although, as is logical, emphasis has been placed on the measures relating to the second route. Our next point will now briefly go over some of the actions put into practice and discuss their effectiveness.

VI.1. The Water regeneration plan of the Tablas de Damiel National Park

Faced with the situation being suffered by the Park, the only effective solution for its survival was to replace the waters abstracted for irrigation in Western la Mancha. The Cabinet requested that the MOPU (Ministry for Public Works and Urban Planning) undertake a viability study for a water regeneration plan for the Tablas de Damiel National Park.. Only two of the proposed alternatives were carried out: the design of two well networks within the park limits, the flows of which could be kept subterranean between 1,200 hectares in winter and 600 hectares in summer; the derivation of water volume from the Tagus basin was approved by the Spanish Courts (Law 13/1987), despite protests from several different groups.- This law tentatively authorised a hydraulic diversion through the Tagus-Segura aqueduct.

On 29.II.1988 the first diversion was made from the Tagus-Segura transfer installations through the Valdejudíos stream, affluent of the Gigüela. The alleged effectiveness of the Water Regeneration led to the extension of water volume derivation for a period of three more years, authorised by Royal Decree 6/1990. According to the Government, the results of this plan had been fully satisfied (Parliamentary session minutes, 18.1.1991 and official state bulletin of 29.XII.1990). This led to a further extension on two more occasions: Royal Decrees 5/1993 and 8/1995.

During the 1988-1996 period, a total volume of 110,5 hm^3 of water was diverted, 47 hm^3 of which reached the National Park (1988-1995). Diversion operations apparently achieved the purpose intended, flooding 1,675 hectares –of 1,700 maximum – on 10.I.1990, which even caused the flooding of the Puente Navarro dam. However, evaporation, low rainfall and low water determined the minimums –30 flooded hectares – 25.VIII.1994 and 31.X.1995. Temporary pumping from the network of wells in the Park therefore became necessary. 20 hm^3 were transferred between February and June 2002 Despite this, only 40 flooded hectares were to be found in 2003, i.e. just 2.35% of floodable surface area.

VI.2. Private initiatives or those organised by farmers

At the beginning of the eighties and throughout the nineties there was a spontaneous and modest replacement of crops for other less water dependant ones (cereals and vines), particularly to the west of the aquifer where the first signs of depletion became evident. According to data from the CHG, a considerable growth in vineyards was recorded, from 28,000 hectares in 1993, to 4,000 hectares, in 1995, and over 50,000 hectares en 1999. Despite this increase in its surface area, this transformation has been judged in a positive light by some since, as is well known, vines consume little water in comparison with other crops because their gross demand for water is 2,564 m^3/hectares/year. On the contrary, the fall in surface area used for more water dependent crops has been notable. In 1987, fodder crops occupied 13,000 hectares whilst in 1996, the area dedicated to these crops was lower than 1,000 hectares. This fact may be considered positive if we bear in mind that their gross demand for water is that of 9,320 m^3/hectares/per year. In short, always according to this source, after the 1987-89 period when the maximum groundwater abstractions in Western La Mancha occurred, the gross demand fell during the nineties to figures of between 200 and 300 hm^3/per year.

At the same time, the farmers felt the need to group together in user communities aimed at promoting rational water management and good usage. At the beginning of the nineties, Western La Mancha began to form diverse Groundwater Water Users' Communities (CUAS). Doubtless these organisations, similar to French associations, or to Italian irrigation consortiums (Pérez, 1990), effectively contribute to the preservation and rational management of water resources.

VI.3. Income Compensation Programme (PCR)

This measure, which was introduced in 1993 by the regional government of Castilla-La Mancha and commented upon in previous articles (Sancho *et al*., 1994; Martínez Vega *et al*., 1995; Rosell and Viladomiù, 1997; López Sanz, 1999; Fornés *et al*., 2000), was the starting point of an agroenvironmental income compensation programme (PCR) in exchange for disuse of irrigation and reduction in phytosanitary product application. The grants from the programme during the five year period from 1993-1997 were co-financed by the EU (75%), General State Administration (12,5%) and the Autonomous Administration (12,5%). The established subsidies oscillated from 156 to 360 €/hectare/per year provided that the farmers had reduced the irrigated surface area by 50 or 100%. The aim of this programme was to reduce groundwater consumption and help to recuperate the piezometric levels of the aquifer. In Exchange for the said compensation, farmers were contractually bound to install flow meters in their wells so that the CHG agents could directly and objectively control the reduction in water abstractions. In December 1997, the European Commission extended the programme for the 1998-2001 period incorporating Northern la Mancha and the Sierra de Altomira within its geographic area.

VI.4. The Western La Mancha aquifer exploitation regimes

The state put into practice, as a complementary measure, the so-called "Western La Mancha aquifer exploitation regimes" for a series of years. In accordance with the water legislation in force, the 1994 exploitation regime, for example, established a normal water volume used of 4,278 m^3/hectares for each holding, save in vineyard irrigation usage where it was lowered to 2,000 m^3/hectare. Usage of the water resource limitations have been imposed in direct relation to the size of the holdings. In the broad sense of the word we could consider this measure as a mixed solution propitiating the intervention of the state regulating the aquifer exploitation regime with the aim of saving water, whilst at the same time searching for a rearrangement of land cover by avoiding crops which would be unviable under this new plan.

VI.5. Complete advisory service to the water user of Castilla-La Mancha (SIAR)

The final pronouncement of overexploitation of aquifers 23 and 24 in Castilla-La Mancha are two examples expressing the need for good water usage with appropriate programming of irrigation and effective, well designed and well controlled irrigation systems. For this purpose the Agricultural Board of Castilla-La Mancha established the Complete Advisory Service to the Water User in June 1999 (SIAR). The overall goal of this service is to help farmers achieve effective usage of the means of production, with special emphasis on water (Ortega *et al*., 2005).

A multidisciplinary team is responsible for collecting agricultural data, providing the farmers with information and evaluating the irrigation systems. Around 500 farmers with holdings of approximately 120,000 hectares, which represents 25% of the total irrigable area in Castilla-La Mancha who are attached to the scheme, make use of the advisory service. There are 23 pilot areas spread across the whole region, strategically distributed so as to have a demonstrative effect and the major part of them may be found in semi-arid areas with a scarcity of water. Aquifer 23 is divided into 4 pilot areas, integrated into the SIAR.

This service supplies the climatic data from the agroclimatological seasons. There are different levels of information to farmers, from the calculation of reference evotranspiration and of a specific crop to the determination of a gross film of water to be applied, depending on the proposed irrigation programming. To sum up, this is a technology transference initiative and one of farmers' knowledge which attempts to contribute to shaping and creating decision-making abilities in the area of farm holding management and the planning of crops within an environment of limited available resources.

VI.6. The Special Plan for the Upper Guadiana (PEAG)

In October 2007, the Co-operation Protocol between the Spanish Ministry for the Environment and the regional government of Castilla-La Mancha was signed, one of the starting points for putting into practise the so-called Special Plan for the Upper Guardiana (PEAG). Its geographical area covers 169 municipalities and it services a population of around 600,000 inhabitants. In total, it incorporates aquifer 23 and the rest of Western La Mancha. It has a budget of 3,000 million euros and an execution period up until the year 2027.

Its aim is to achieve a good state of groundwater masses and associated surface waters for promoting the improvement of the ecosystems of Castilla-La Mancha and for complying with the demands of the Water Framework Directive (CHG, 2007 before 2015. Its aim is also to correct the existing structural water deficit, guaranteeing the preservation of the wetlands, together with the socio-economic development of the region. The PEAG does not deal with the use of external resources from other catchment areas.

The PEAG includes a wide combination of measures for the obtainment of its ambitious aims. Among the general measures, we would emphasize those aimed at rearranging the water usage rights by means of instruments such as usage right transfer or administrative acquisition of water and land usage rights, to be particularly developed within the service areas of the affected protected natural spaces. It also includes the Regularisation Plan, regulating the Annual Abstraction Regimes. Other general measures introduce modifications in the exploitation regime of the existing wells. In addition, an Accompaniment Measures Programme for hydrological and agrarian management was envisaged to provide support to the water user communities, in education and environmental recuperation, socio-economic reconversion and water storage and purification (CHG, 2007).

VII. ARGUMENT

It is assumed that the transformation of dry to irrigated farming has led to an increase in income for Western La Mancha farmers and revitalised the region's economy. However, Martínez Vega *et al*. (1995) argued that in some case, even typical comarca holdings received negative net margins and that the economic viability of this type of agriculture was based on PAC subsidies and those coming from agroenvironmental programmes of an occasional nature. The positive gross margins did not calculate the real costs of the water nor account for the environmental damages made by this type of agriculture.

This scenario led to a very intense social debate, questioning every one of the measures taken by public bodies and those which spontaneously appeared. We are now going to look at some of the arguments put forward with respect to each one of these initiatives.

VII.1. The Water Regeneration Plan of the Tablas de Daimiel National Park

According to some experts, this type of measure has been proven to be ineffective or partially and temporally inefficient because the solution is not final. It does not fight against the origins of the problem. However, the National Park authorities state that there has to be a transitory situation – using diversions and wells - to avoid the definitive loss of the ecosystem, even if it is manmade, since it would fulfil its traditional function of providing an area for over-wintering birds.

All parties involved acknowledge that part of the diverted water does not reach the Tablas de Daimiel. Part of the flow evaporates or is infiltrated into the river bed along the 150 km flow from the Tagus-Segura aqueduct to the National Park. Another part of it is illegally taken by the farmers of the holdings along its sides for irrigation. It has been estimated, for example, that the outcome of the diversion made in 2002 was 40%.

Besides, apart from the quantity of water, its quality must also be taken into account. The water which has been diverted from the Gigüela is not good quality because it drags waste emptied into the river. Moreover, since the sill of the Guadiana dried up in1989, there is no longer a mix of fresh and semi-brackish waters in the environs of the Tablas, which is what traditionally gave birth to this singular ecosystem.

Llamas (1988) focuses attention on the probability of this Plan not fulfilling expectations since recharge or infiltration from the Tablas de Daimiel to the aquifer was underestimated by official reports. The CEDEX (1994) also acknowledges that the diversion through the Cigüela river is not the appropriate way of carrying water to the Tablas de Daimiel national park.

Diversions cause confrontation between the users and the inhabitants of the surrendering catchment areas. Co-ordination between the catchment areas and the regions affected would be necessary, as would some kind of compensation from the receivers to the donors, raising production costs or indemnities paid by the state. Furthermore, this combination of solutions instil an increasingly questioned allochthonous agronomic model into semi-arid land, since neither water saving is encouraged nor is it in keeping with the surrounding biophysical conditions

VII.2. Individual initiatives and those organised by farmers

In spite of efforts made by the farmers and the CUAS to transform crops the fact is that this initiative is insufficient on its own for reverting this process of degradation. It may be concluded that instead of reducing the irrigated cultivated surface area, the latter has moderately increased. This fact confirms the growing trend in emptying the aquifer indicated by the IGME and the CHG, especially from 1996 onwards. The detection of changes only emphasizes the PCR's poor results.

It is also true that, despite the 1985 Water Law which established user participation in water management as one of its leading ideas, Hernández-Mora (1998) indicates that, in the case of Western La Mancha, participation of water users and the CUAS has been neither effective nor representative, provoking a situation of extreme social conflict and the continuous deterioration of the aquifer and the wetlands. Several reasons for its failure have been quoted, among which are: lack of social consensus; the absence or minority representation of certain interest groups; predetermined rules governed by the law in force without recourse from users to define institutional amendments that respond to their needs; lack of human, technical and financial resources for making users into proactive participants in water management; the complexity of the regularisation process of water rights; the absence of an appropriate information and education programme; the lack of an effective follow-up system; control and implementation of control criteria; lack of conflict solving mechanisms, and lack of user organisation prior to 1985. In sum, the minor role placed by the CUAS in aquifer control is the result of their youth and inexperience and the rigidity of state institutions.

VII.3. The income compensation programme

The PCR seems relevant, undoubtedly better than previous ones, because it tackles the true problem of the Tablas and provides a response to the environmental and socio-economic problem. However, it suffers from serious deficiencies, such as the delay in flow-meter installation, the opening of new wells, difficulties of legalisation and lack of effective control granting credibility to the programme. Proven control mechanisms exist, based on real, not calculated observations. Had they been used the state would have had to have been provided with enough human and technical resources to have complied with this social commitment.

Despite the fact that when it was established, expectations boded well and that there have been authors (Rosell and Viladomiù, 1997) who have been in favour of the PCR, when indirectly estimating the recuperation of aquifer levels from declared irrigated land surface reductions over time, analysis of the reality has not been so promising.

It is a programme with a high financial cost –higher than that of the diversions – and the environmental profits of which would be obtained in the medium and long term. Despite its interest, it has been disputed by many farmers who regard it as a provisional financial compensation, preferring higher levels of diverted water which allows them to fill the aquifers and return to irrigation. According to the monitoring made by the CHG itself, in 1995, 26% of the users using this programme, particularly the large land owners, cheated. (López Sanz, 1997). This led to the possible alternative of central control over local control, which may have been more effective but which the water users themselves do not wish carry out. Control of the abstractions through the installation of flow-meters has caused certain difficulties because since the wells are located in private properties, there is limited access to them for control by the staff who exercise the role of policing the waters. Appeal is made for solidarity, one of the three basic principles for proper water management according to Llamas (1994).

López Sanz (1999) states that the results of this programme have been fairly limited due to the fact it is based on economic incentives but no sustainable alternative for the future has been considered. He points out that the compensation payments have been directly related to the irrigated area and the major farmers have therefore monopolised the grants. He also argues that the water user communities have not been actively and responsibly participative in programme control and that they have not dedicated financial resources to the programme for agroenvironmental tutoring of farmers.

VII.4. The aquifer farm holding regimes of Western La Mancha

This measure may be a response to the strategy for adapting demand to restricted water supply which seems reasonable in this case study. It is apparent that this idea implies a restructuring of agriculture... At present, no overall crop plan, adapted to the biophysical conditions of the land, has been designed. Even further restrictions on irrigation surfaces must be made. Future campaigns must reduce to a minimum the land occupied by corn, alfalfa and beetroot, replacing them with other higher performance crops which are less water dependant (garlic, vines, cereals, oil-yielding crops, etc), due to individual requirements or the irrigation system efficiency (melon). These are the alternatives with the best gross margins. per m^3 of water consumed (Rosell and Viladomiú, 1997). Martínez Vega *et al.*, (1995) voted for a return to dry agriculture, with the increase of more technified cultivation tending towards olive growing, wine growing or herbaceous crops. There are positive net or gross margins to be had with these crops. The difference of profitability compared with irrigated crops could be compensated for by the state as an incentive for environmental and social well being.

It is also worth considering that other non agrarian uses could be made, capable of bringing both financial as well as environmental benefits. The Tablas de Daimiel national park is able to bring in funds through its recreational function. Contingent evaluation methods (Júdez *et al.*, 1997) and travel costs (Sources Pila *et al.*, 1997) have been applied to calculate the possible annual profit from this new usage, compatible with the preservation of this protected area. The PEAG (CHG, 2007) itself, includes a programme on socio-economic reconversion which promotes the diversification of the economy in the area by promoting other sectors of activity (renewable energies, industry and services).

VII.5. The complete advisory service to the water user of Castilla-La Mancha (SIAR)

If we take into account the low cost of the service per surface area unit (Ortega *et al*, 2005), its results appear satisfactory (SIAR, 2007). Assessments made by the SIAR, in Western la Mancha during the 2006 irrigation campaign indicate that the follow-up level of recommendations is high , to such an extent that the water contributions received by the crops in accordance with the irrigation applied by the farmer and precipitation is quite in keeping with the water needs recommended by the service technicians. Consistency in the project has increased the interest shown by farmers and in the growing level of adherence to recommendations, which has had a positive effect on the irrigation system management and water saving that is estimated to be between 10 and 20% (SIAR, 2007). This appears to be a highly interesting initiative for water saving making its contribution to the recuperation of aquifer 23 and the aquatic ecosystems linked to the same highly relevant. This service is to be increased by the PEAG. Ecologist associations are also in favour of its promotion.

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VII.6. PEAG

The ecologist groups (WWF *et al*., 2006) put forward a series of proposals and recommendations which detail or dispute the measures contained in the PEAG. They insist on the need to introduce more efficient control systems for the plan to be credible. They argue that flow-meters should initially begin to be installed in 2008 by the heavy consumers with immediate expansion to the rest of the users. They also recommend that the control system combines the flow-meters with monitoring via satellite images and other technologies which correctly assess water usages and the situation of the catchment area. The administrative acquisition of water rights is also considered to be a priority for the obtainment of the plan’s environmental goals, particularly in the area servicing the Tablas de Daimiel and the Ojos del Guadiana. Land acquisition with water rights is only supported in areas of environmental interest. They do not consider the acquisition of water rights through the CHG Rights Exchange Centre to be effective, since the establishment of a water market in their opinion would solely benefit those who had economic resources. They consider the replacement of water abstractions for irrigation with waste waters inappropriate since it may encourage new concessions. Neither do they agree with grants for the restructuring of trellised vines since, although it is a social crop and its consumption per hectare is lower than others, as a whole it is the crop which consumes the most water in the area. In their opinion these grants should be reconverted into other agro-environmental measures or rural development for contributing to the socio-economic viability of the area.

VIII. CONCLUSIONS

It is a proven fact that at the middle of the last century, due to the lack of technological resources, man lived more in harmony with the environment. The introduction of intensive methods and technological improvements in agriculture, without planning its development and widely surpassing the limit of what the environment is capable of sustaining, has led to the destruction of the balance between man and his environment, precipitating the processes of overexploitation of the aquifer and the environmental impoverishment of the aquatic ecosystems associated with it.

As we have seen, there are many initiatives, programme and plans for resolving the environmental impacts induced and for maintaining a socio-economic development in the research area. However, there is neither consensus nor unanimity with regard to the opportunity and efficacy of these actions. Different opinion groups hold different viewpoints and it s therefore still necessary to seek common ground and cooperation between the different parties in order to seek compatible and final solutions.

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