INTENSIVE AGRICULTURE AND QUARRIES IN THE CAMPO DE DALÍAS (ALMERÍA, SPAIN)

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ABSTRACT

The intensive agricultural activities that have developed over the last fifty years in the Campo de Dalías have required large quantities of gravel and clays as basic materials for the substrate over which the crops are raised. With this motive, numerous gravel pits have been opened which have extracted several million cubic metres in recent years. Clays have been extracted from the distal sectors of the alluvial fans that descend from the Sierra de Gádor, and from within a large endoreic basin; several million cubic metres of these clays have been extracted as well. In the latter quarries some wetlands have developed due, very possibly, to the rise in the water table level in the aquifer over which they lie. The gravel pits are situated in the apical sectors of the alluvial fans, overlying hydrogeological units that are widely overexploited, for which reason the gravel pits could be used for artificial recharge. In addition to increasing the availability of water in the aquifer, this would also reduce the risks of catastrophic flooding

INTRODUCTION

Today, about 20,000 ha of extra-early market produce is grown under plastic in the Campo de Dalías. Their economic significance is so great that they constitute the principal generator of development in the Almería region. It is estimated that the economic activity related to this extra-early agriculture accounts for more than 1.5 billion US dollars per year. These agricultural activities have been achieved at great environmental cost and due to enormous efforts on the part of the farmers and the administrators, being founded on the use of groundwater which is basically derived from infiltration in the Sierra de Gádor.

Given that the average precipitation in the Campo de Dalías only slightly exceeds 200 mm a year, the exploitation of the aquifers that form this hydrogeological system has been greatly superior to their recharge. The total surface area of the Campo de Dalías is around 320 km^2; the southern face of the Sierra de Gádor covers an area similar to that cited for the Campo. Fifty-five ramblas (dry river beds) draining areas of

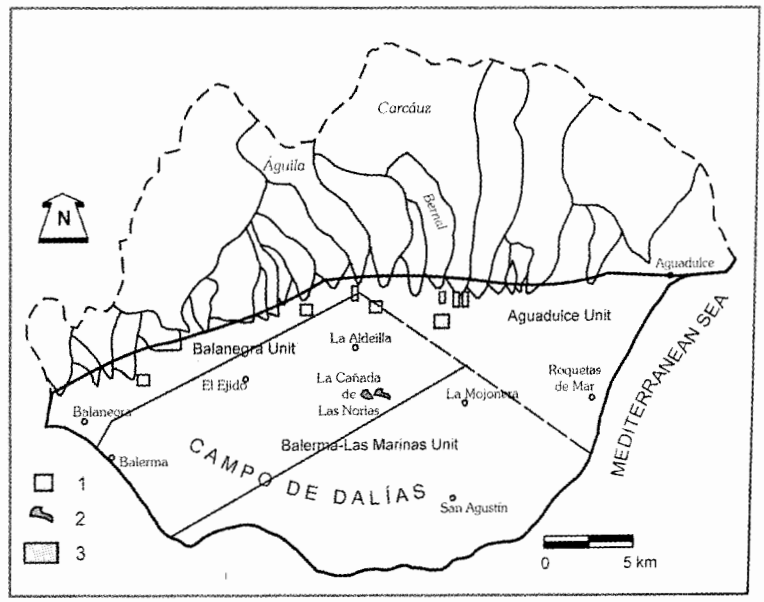

Figure 1. Hydrogeological scheme of the Campo de Dalías and its geographical situation. The location of the principal gravel (1) and lutites (2) pits are shown.

variable size, of between 54.1 and 1.1 km^2 run down from the Sierra de Gádor, and of these, only the five largest are able to discharge directly to the sea. The rest discharge their water in the central part of the Campo de Dalías which, for tectonic reasons, constitutes an endoreic basin (Figure 1).

The oldest rocks outcropping within the study area are metapelites and Alpujarride carbonates, which cover almost all of the southern edge of the Sierra de Gádor. These materials belong to two tectonic groups, namely Gádor and Felix, the first of these being much more widely-represented than the Felix one. It is worth highlighting that the Gádor carbonate rocks can reach up to 1,000 m thick, though there may be intercalation of calcoschists and marly limestones. Over the Alpujarride materials, which are of Permian and Triassic age, lie Miocene materials, consisting of calcarenites in the outcropping sectors, and marls with gypsum beneath the Plioquaternary fill. Locally, the Miocene strata are represented by conglomerates comprising large boulders of volcanic rock. The Pliocene materials are widely developed throughout the whole of the Campo de Dalías (Aguirre, 1999); the base comprises up to 700 m of blue marls, with sandy bands occurring with greater frequency towards the top of the series. The Pliocene series culminates with a cap of calcarenites with a maximum thickness of 120 m. The Quaternary sediments are represented along the entire southern edge of the sierra, comprising large alluvial fans which, locally, exceed 150 m in thickness. The deposits of both former and contemporary beaches, together with the fine terrains of the distal parts of the large alluvial fans complete the body of materials that occupy the Campo de Dalías.

These lands have a very complex tectonic structure which, in turn, confers a great complexity to the geometry of the three most important hydrogeological units that can be differentiated: Balerma-Las Marinas, essentially composed of Pliocene calcarenites; Balanegra, which occupies the western half and which is basically consists of Gádor carbonates; and the Aguadulce unit, which is situated in the eastern half, consisting of the rocks of the nappes of Gádor and Felix, in an extremely complex geometric disposition (Rodríguez et al., 1993).

ORIGIN OF THE QUARRIES

Intensive agriculture began its development in the Campo de Dalías at the end of the forties (Navarrete, 1992), though it was not until the seventies that it acquired more economic significance. The cultivation system is highly unusual in that it does not require favourable edaphic conditions. Effectively, it consists of the following: after levelling the ground as well as possible, a silty-clay substratum is laid and over this a layer of animal manure or compost, which is then covered by a layer of gravel. In this way, the raw materials include, in addition to manure, lutitic materials and gravels (Figure 2).

The lutitic materials are derived, for the most part, from a series of pits excavated in the distal parts of the alluvial fans

Figure 2. Preparation of the ground for cultivation under plastic.

described earlier. These are highly-developed in the vicinity of the area of maximum endoreism (Las Norias, La Mojonera, La Aldeilla, San Agustín), called La Cañada de Las Norias (Castro et al., 1999). It is estimated that the quarries cover a surface area of more than 150 ha. The volume of material extracted, basically lutites, is in the order of 8 million m^3, and this give some idea of their importance.

The gravels initially came from the beach areas, but the prohibition of extractive activities by the competent authority dictated that new extraction points be found, especially in the apical parts of the alluvial fans. There are pits at other points within these fans, notably the large gravel pit lying between the ramblas of Bernal (Figure 1) and Aguila (Figure 3), which has a capacity of close to 1 million m^3 and a depth of more than 30 metres. Thus, more than 5 million m^3 of these materials have been extracted. Figure 1 shows the principal sectors of extraction. As a consequence of all this, a series of pits, of very uneven development, has arisen which confers a significant impact on the landscape.

Figure 3. View of the gravel pit between the ramblas of Bernal and Vícar. The machine in the distance gives an idea of scale.

THE EXTRACTION PITS AND HYDROGEOLOGICAL FUNCTIONING

One of the most unusual aspects related to the extractive activity is concerned with the hydrogeological implications that the pits for lutitic materials have had since being abandoned. In effect, the greater part of these pits is situated over what we have called the Balerma-Las Marinas Unit, which basically comprises Pliocene calcarenites. The waters of this unit (Pulido Bosch et al., 1989 and 1990; Navarrete, 1992; Molina, 1998) have traditionally been exploited very little, since they usually exhibit high salinity. However, a significant proportion of the agriculture is realised over these rocks, and this is the reason for the continuous rise in the water table in this unit, due to the return of irrigation water. This is in contrast to what happens in the other two units (Domínguez and González, 1995), where the level is situated below sea water level over wide areas.

The rise in the phreatic level of the Balerma-Las Marinas Unit has been such that, over the last few rainy years, the bases of the pits have begun to flood. Currently, they cover a surface area of close to 140 ha, with up to 2 m depth of water in places. The Junta de Andalucía, aware of the ecological interest of these wetlands, examined the possibility of declaring them protected areas, despite their singular location and curious origin. The large quantity of debris that the agricultural activities generate have converted these holes into very suitable repositories for these wastes. Many are filled to the brim with inert wastes whilst others are full of degradable materials. This is to say that in the base of the pools may exist a certain amount of pesticide containers, as well as every sort of agricultural debris and/or rubbish from the greenhouses (plastic, cables, construction materials etc.). In addition, in one of the pits a secure tip has been installed into which substances which are more toxic than domestic waste or conventional agricultural waste are tipped, although a series of special precautions were taken when the tip was constructed.

Figure 4. Panorama of the western sector of the wetland of Cañada de las Norias.

THE GRAVEL PITS

Due to the high energy developed by the periodic spates in the ramblas that drain the southern margin of the Sierra de Gádor, the granulometry of the transported sediment is extremely heterogeneous, ranging from boulders of several m^3 volume, to lutite-sized particles, although, in keeping with the fact that we are dealing with an area away from the apical zone, the granulometry is more homogeneous (Figure 5).

Figure 5. View of one of the gravel pits situated in the Carcáuz rambla

On the other hand, cemented and encrusted sections exist which impede their use as materials for the greenhouses. As a consequence of this, in these gravel pits one can find extraction spoil that can be large blocks and fragments of encrusted strata. It is necessary to specify that the hydrological functioning of these ramblas is essentially determined by the intensity and quantity of precipitation, by the slope, and by the permeability and lithology of the terrains that constitute the catchment.

As was indicated earlier, a considerable part of the Campo de Dalías lacks a direct outlet to the sea so that, in the event of floods, all of the endoreic sector could be left under water, including the wetland zone. In these, the water depth in an extreme flood could reach a maximum depth of 18 m (Gutiérrez, 1996), before being able to start draining towards the sea.

As a complement to the above, we can specify that 107 ditches exist along the length of the southern edge of the Sierra de Gádor, of variable size and characteristics variables, having been constructed by the central and regional administrations since 1977 (Martín Rosales, 1997). These ditches fulfil three potential purposes: to reduce erosion, to smooth flood flows, and to facilitate aquifer recharge where the channel lies over permeable materials.

On the other hand, the intensive exploitation to which the Campo de Dalías has been subjected, has had diverse consequences which can be summarised as follows: a continue

decline in the piezometric levels which, in some areas, are situated at more than 20 m below sea level; the appearance of processes of marine intrusion, especially evident in the Aguadulce Unit; and mobilization of waters of elevated saline content retained within the sediments (Molina, 1998). Bearing in mind the intensive exploitation and the risks of floods, it seems appropriate to utilise some of the existing gravel pits on the alluvial fans to undertake artificial recharge, contributing at the same time to reduce the risk of catastrophic floods. This option is relatively in-keeping with the environment, its impact is minimal, it could be highly efficient, and its cost would be low.

Consequently, in 1991 we took the opportunity to witness a storm during which the elevated infiltration potential of the gravel pits in the Águila rambla was highlighted. Logically, this option does not solely bring advantages given that, the requirement of continuous maintenance, especially after each flood which would deposit a muddy layer, it may be that the efficacy would be progressively reduced; it is well-known that the small operating and maintenance costs are sometimes more difficult to obtain from the Administration than the large investments for infrastructure. This potential use of the gravel pits could be complemented by establishing a network of strategically-placed infiltration ditches over the length and breadth of the alluvial fans (Pulido Bosch et al., 1998).

FINAL CONSIDERATIONS

The Campo de Dalías constitutes a singular example of the possible applications of abandoned gravel pits. It would take advantage of its position at the head of the alluvial fans that punctuate the Sierra de Gádor. Artificial recharge to the gravel pits would contribute towards mitigating the marked water deficit that exists in the area as a consequence of the overexploitation of the aquifers. In addition, it will permit a significant reduction in the risk of catastrophic floods caused by the high-intensity rainfall events which have a return period of around 50 years (Martín Rosales et al., 1996).

Another unusual feature of this area is the appearance of wetlands related to the extraction of essentially clayey materials, exploited in the endoreic sector of the Campo for a substratum for greenhouse crops grown under plastic.

The particularly problematical hydrology and hydrogeology in this region (risk of catastrophic floods and the overexploitation of the aquifers) allows us to conclude that both results of the extraction activities, apparently so degradative, could turn out to provide a significant positive environmental role.

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