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1.1
Evaluation and management of groundwater — sustainable exploitation

title: **Evaluation of the agricultural development impact in an arid-semiarid region of the Argentine Republic**

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INTRODUCTION

The dimension of irrigation in Argentina is turning into something noteworthy. It is considered that 75% of its territory belongs to arid and semi-arid conditions.

Groundwater plays an important role in the total of system of public supplying in a large part of Argentina, particularly throughout the rural population and in a mixed way in major cities.

Groundwater has especially contributed to an agricultural expansion and to industrial park in the inner country. Nevertheless overexploitation and mismanagement have contributed to non desirable troubles like decrease of groundwater levels and to get damaged the quality of groundwater in urban areas. The word overexploitation intends to qualify a concerning evolution from certain points of view, but has no precise hidraulic meaning (Custodio, 2002). One of the most important changes which are now generating in Argentina is to establish the racional use of water both in the agricultural economy and to suply human needs. This last one is extremely related to its development generated in vast urban centres. The current paper analizes some changes which were produced in a north-eastern Argentinian region, named "sistema serrano" (Fig. 1), which takes part of the map of basins and hydrologic regions in Argentina. This region is located in the arid and semi-arid area over a surface of 181,000 km^2, where productive agricultura is only available under irrigation.

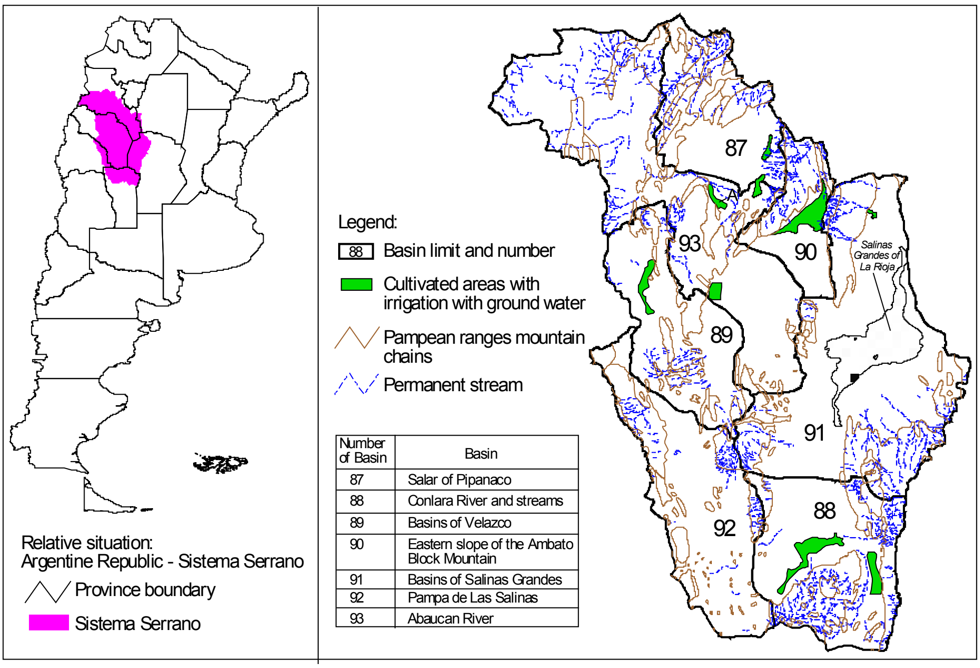

Figure 1. Situation of the "Sistema Serrano" and areas cultivated with ground water.

Based on historical non systematic data, and governmental decisions led to determinate the sustainability of the intensive exploitation; this paper aims to announce a prospect about the present development of groundwater use and to advice how to stength further studies with the pourpose of achieving the mayor benefits to its use. To that end it will be necessary to carry out control observations and to intensify the knowledge of system. Everything should be done within a framework of political decisions and set up tasks in order to be taken into account environmental, social and economical issues. It is, then, necessary a joint work of scientists, politicians and public in order to achieve sustentability, development of water policies and water resource management to satisfy the future demand of water, and to avoid unacceptable impacts (Grabert, 2006).

The explotations of ground water as a result of the expansion of the cultivated surface under irrigation are supposed to have a decrease in the storage during the analysed period. This current analysis will enable to take decisions about the degree of overexploitation, whether it is aceptable or advisable. Evolution of pressurized irrigation in different regions in Argentina, points out a total surface of 61,406 hectares. This surface will clearly have suffered a certain growth with the incorporation of equipments of pumping in this area; and therefore in humid areas or sub-humid ones as complementary or supplementary, irrigation, due to long periods of drought in regions of dry land. It is currently estimated that these ones will exceed 77,000 hectares under irrigation and it keeps constantly growing.

At about the late 1980's, in Argentina, modern systems of pressurized irrigation with groudwater begin to be incorporated to. Since that period a very fase growth of the irrigated surfaces began over the whole Argentinian western (Chambouleyron, 1993). The agricultural development through these systems has been motivated by political decisions of tax benefits for the mention systems and the development of modern technologies. It proves that the development of these mentioned methods have played a predominant role which has been accompanied by governmental decisions led to the execution of hydrological studies with the purpose of determining the degrees of sustainability. This last topic was supported in the last constitucional reform held in Argentina in 1994. It determinates that natural resources belong to each jurisdiction. Thanks to these taken actions, in the current paper, different areas under pressurized irrigation in the region are shown and analysed, moreover the effects that they have caused in the aquifer-systems.

The hard anthropic pressure over this zone, because of water consuming for irrigation added to a narrow dependence of the ground water systems during the last 20 years, turns the knowledge of the extractions into a main issue for the suitable treatment of the resource and the entire satisfaction of the demands. It also arises the need to develop knowlegde about the availability of the aquiferous systems, so as to be properly exploited to the implementation of complementary irrigation, will be able to improve the availability of surfaces for farming uses.

STUDY AREA

"Sistema Serrano" corresponds to a basin with endoreique characteristics where all ground water ends its cycle in Salinas Grandes of La Rioja (Fig. 1). There it will be shown the areas developer ander irrigation with intensive exploitation of groundwater.

AQUIFER SYSTEMS

The study area is included in the geological province Pampean Ranges. All of them make up a geological unit which is characterised by mountain ranges where the crystalline metamorphic basement, migmatic and intrusive Precambrian-Paleozoic, separated by wide depressions covered by Quaternary deposits. This mountain chains line up predominantly north to south, although many ones change its direction dramatically. Practically, it is considered that these rocks take part of the hydrological basement of the subterranean water basin. The main recharge of the aquiferous comes through from the infiltration of superficial runoffs which flow into the mountain area, and the area which generates the main contribution to the recharge which is situated out of the limits of the reservoir.

Sedimentary fill of intermontane valleys includes two geological units of subsoil: a lower one named Fine Clastic Formation which develops itself straightaway over the crystalline basement and an upper one named Coarse Clastic Formation.

Fine Clastic Formation which probably belongs to Tertiary Superior-Quaternary Inferior. It is composed by an alternated sequence of clay silt, silty clay, clays, sands, gravel and pebbles. The largest part of the formation consists on fine material. Silty clay becomes the most frequent component whilst the isolated layers of sand and gravel are generally thicker than 1 m. Predominant colours are brownish-yellowish slightly reddish; occasionally red-a shade of violet, dark brownish, yellowish, blue-greenish and white. Clays are generally plastic and coarse can be frequently found. Coarse Clastic Formation is displayed over the Fine Clastic Formation previously described and is equivalent to the set of units of Quaternary age; conforming units of decreasing age since Pleistoceno till Holoceno. It is generally composed by an alternated sequence of silty clay, silt, sandy silt, silty sands, sand and gravel. It is frequent to find coarse. This Formation, which is integrated into materials of medium to high permeability, contains the most important aquiferous system exploited nowadays. It is worth pointing out that the proportion of coarse grained beds in the Fine Clastic Formation is around 10 % whilst in the Coarse Clastic Formation varies from 50 to 70%. This characteristic evidences an important element of decision in well design.

EFFECTS OF GROUNDWATER DEVELOPMENT

The results displayed in (Tab. 1), have been elaborated with discontinuos data which begin in 1965 up to date.

Table 1. Areas under irrigation and volume extracted of groundwater.

Number of Basin	Basin	Total surface (km^2)	Exploited surface (ha)	Pumped volume (Hm^3)
87	Salar of Pipanaco	18029.57	1000000	146.06
88	Conlara River and streams	22977.44	2008500	140.63
89	Basins of Velazco	17877.74	1323100	132
90	Eastern slope of Ambato	9732.71	1720000	122.04
91	Basins of Salinas Grandes	44506.77	0	0
92	Pampa de las Salinas	24800.08	0	0
93	Abaucan River	43091.95	1448900	143.1
Total		181016.25	7500500	683.83

In most of the studied areas, these parctices have not caused decrease of groundwater levels which may indicate that we are in the presence of overexploitation if we compare with historical registers from seventies. In the areas located in the basins Nº 89 and 93, where there is no more data available than the recent one, they show a decrease of the piezometric water levels. This can be explained if the pluviometrical registers are observed at (Fig. 2). There it is possible to observe that from years 1974 and 1975 a remarkable increase of these registers is produced. Even though they show that from year 2000 on, it might be attending to a decrease of rainfall pluviosity.

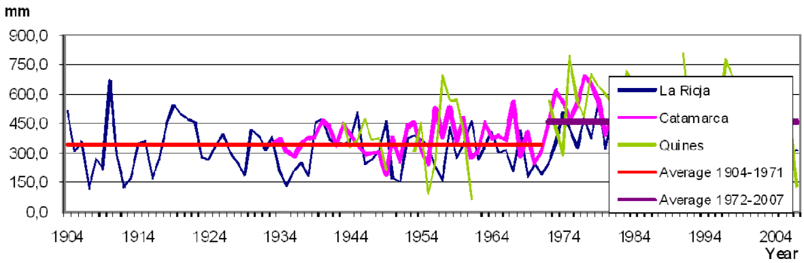

Figure 2. Annual precipitation. La Rioja, Catamarca and Quines (Northern Plain).

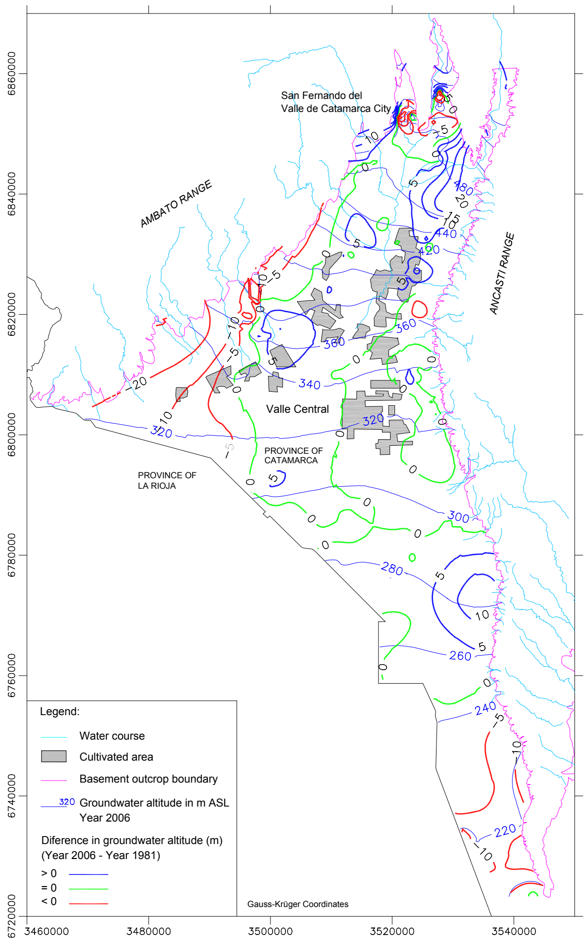

Figure 3. Groundwater level altitude difference. Year 2006 – Year 1981. Catamarca Central Valley.

The mathematical models of aquifer systems carried out in some of these regions (Bucich, 2009) advise the continuous implementation of these techniques so as to follow up on the growth of the agricultural demand and to turn it compatible into systems of potable water supply. In the (Fig. 3, 4 and 5) it can be shown some of the analysed areas as an example of previously indicated. (Fig. 3) represents the current area under irrigation in the Catamarca Central Valley and its variations of levels from 1981 to 2006. It is shown overall that they have suffered an increase at about 3 m, except for the area of San Fernando del Valle de Catamarca city where it is focused the largest drops (nearly 15 m) by intensive exploitation with the purpose of stocking up of potable water.

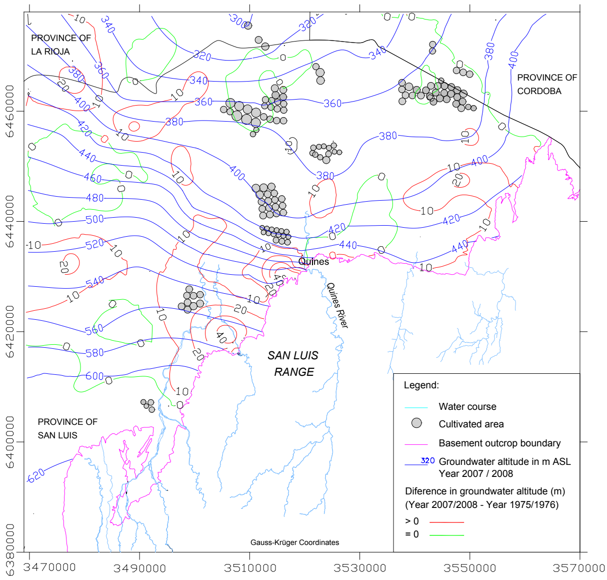

Figure 4. Groundwater level altitude difference. Year 2008. Year 1976. Northern Plain.

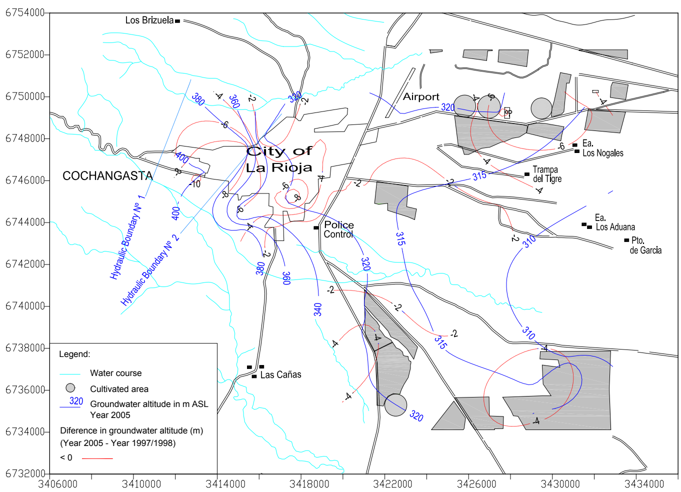

Figure 5. Groundwater level altitude difference.Year 2005 – Year 1998. La Rioja.

In the same way than in the previous area, in the area of Northern Plain, province of San Luis (Fig. 4), with 17,000 hectares under irrigation, groundwater levels compared between the years 1976 and 2007 have suffered an average increase of 7 m.

In the area Cono Aluvial in the province of La Rioja (Fig. 5) it is show, on the contrary a reverse effect where the groundwater leves have suffered a maximum drop of 10 m in the area of capitaline tissue for water extraction for human consumption, roughly 6 m in some areas of agricultural undertakings where water for irrigation is extracted. According to what we have written before, these results should alert the authorities to take measurements of managements in these areas, plus the proteccion of the systems and its consequences.

CONCLUSIONS

The severe antropic pressure over this zone, as far it is concerned to the consumption of water to irrigate, and the almost dependence on the subterranean water during the last 20 years in the study area, means that the knowledge of the extractions, a fundamental issue to the appropriate management of the resource and hoe to satisfy the demands.

The observed decrease in the pluviosity from year 2000 should be monitored onward the continuity of the measurements in order to verify its evolution and to foresee its impact.

Authorities should be alerted about the areas where some decrease of levels have been observed, in order to set up measures of management and the protection of the systems, plus its consequences.

The mathematical modelling of the aquiferous systems, which was made in some of these regions, recommends the continuous application of these techniques with the purpose of controlling the growth of the agricultural demand; and make it compatible with the systems which provide potable water.

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