Water table fluctuations: an indicator of hydrological behaviour in the northwest region of Buenos Aires Province (Argentina)

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Abstract The northwest region of Buenos Aires Province is a great plain with a small topographic slope (0.1 m km^{-1}). There is no fluvial network and the ponds located in the depressions are important. The water table fluctuations are indicators of hydrological behaviour. In wet periods, the water excesses generate a rise of the water table and an increase in the pond areas. The water table is shallower (depth: 1–2 m) and usually produces overflows and negatively affects the agricultural production. In a dry period, the water table falls and some existing depressions become dry. The water table depth (3–4 m) shows a relationship with the reduction of the pond areas. The falling water table makes satisfaction of agricultural demands for water difficult.

Key words Argentina; flatland; hydrological behaviour; water table; wet and dry periods

INTRODUCTION

The social and economic activities (mainly agriculture) in the northwest of the province of Buenos Aires are strongly influenced by the availability of water resources. The most noticeable impacts in the region are the alternating dry and wet periods. The study of their variability is an important issue for the analysis and prediction of the behaviour of the production system.

The selection of indicators that allow us to detect symptoms of overflowing and drought cycles is of extreme importance and is a base for the planning and management of the water resources.

The objective of this work is to analyse the utility of the water table variations as an indicator of the hydrological state of this region. In this work brief descriptions of the regional characteristics of the area and the data available are made. In addition, the results of the relationship between the water table, precipitation and water excess variations and their influence in the hydrological situation are analysed and discussed.

REGIONAL CHARACTERISTICS

The main features of the northwest region of Buenos Aires Province (50 000 km^2) are its small topographic slope, the lack of a drainage network and the presence of permeable sediments near the surface. As a consequence of these factors, there is no fluvial network and the ponds located in the depressions are important.

The area is a plain with a small topographic slope of about 0.1 m km^{-1}. Minor topographic forms that are important hydrologically can be differentiated within the general morphology. There are slightly noticeable elevated areas alternating with depressions that give a subdued relief representing the typical form of paleodune environments. The region shows elongated ridges with a prevailing southward direction. They are 10 km long and 2 km wide.

From a hydrogeological point of view, the region is covered by recent permeable sediments, fine sand and silts forming the dunes where several superimposed aeolian cycles have been recognized (Aiello *et al*., 1995). In the interdune area, finer sediment with lower relative permeability has been found. It is an arreic environment and flooding occurs in the low lands during humid periods (Kruse *et al.*, 1993). At the surface, sandy aeolian sediments with thicknesses that range from a few centimeters up to 4 m were found. They overlie silt with variable proportions of sand and clay, and usually calcareous materials, known as “Pampean Sediments” (Fidalgo *et al.*, 1975). The mean annual rainfall in the region is about 850 mm $year^{-1}$ and the mean temperature is 16°C. The long-term rainfall pattern in the region exhibits an alternation between dry and humid periods, with the first half of the 20th century being drier than the second half.

METHODOLOGY AND DATA AVAILABILITY

The water balance, in which inflows must equal outflows plus/minus any changes in storage, is fundamental to understanding the hydrological problems of the region. A characteristic of this flatland is the low morphological energy of its terrain. As a consequence, the natural storage (depression and groundwater storage) and vertical movement of water (evapotranspiration and infiltration) dominate over horizontal movement (surface and subsurface runoff).

According to these characteristics, the primary inflow in the area is the precipitation and the primary outflow is the evapotranspiration. The change in water storage includes groundwater storage and depression storage. Groundwater storage represents the volume of water that it is possible to store between the water table and the surface of the land (nonsaturated zone). This is important because of its areal continuity and the sediment porosity, and variations in the water table variations represent variations in groundwater storage.

Depression storage corresponds to the volume of storage water in the lagoons and ponds. In the region, precipitation data are available from the end of the 19th century, but data concerning other hydrological variables are only very recent. Since 1998, a monitoring network has been operated to include monthly water table levels in 21 wells and also daily precipitation data. Also periodic determinations of the surfaces covered by water are made from Landsat satellite images.

Daily precipitation data recorded by the National Meteorological Service (SMN) and the National Institute of Agricultural Technology (INTA) for the period 1941–2004 at a total of 20 stations in the region were used in the present study. Potential evapotranspiration according to Penman was obtained from Damario & Cattáneo (1982). The estimation of the daily evapotranspiration employed a specific field capacity for each locality, considering the effective capacity of each zonal soil

(Forte Lay & Spescha, 2001), and assuming a cover of a prairie of perennial grasses growing during the entire year. From the precipitation and evapotranspiration data an estimation of daily water balance and water excess was made. An excess in the water balance may lead to infiltration and water table variations.

RESULTS

The annual series of precipitation in the region shows a tendency for an increase in precipitation since the 1970s. Figure 1 shows the distribution of annual average precipitation in the period 1941–1970 and in the period 1971–2004. The increase in precipitation in the northwest of the Province of Buenos Aires surpasses 150 mm year^{-1}.

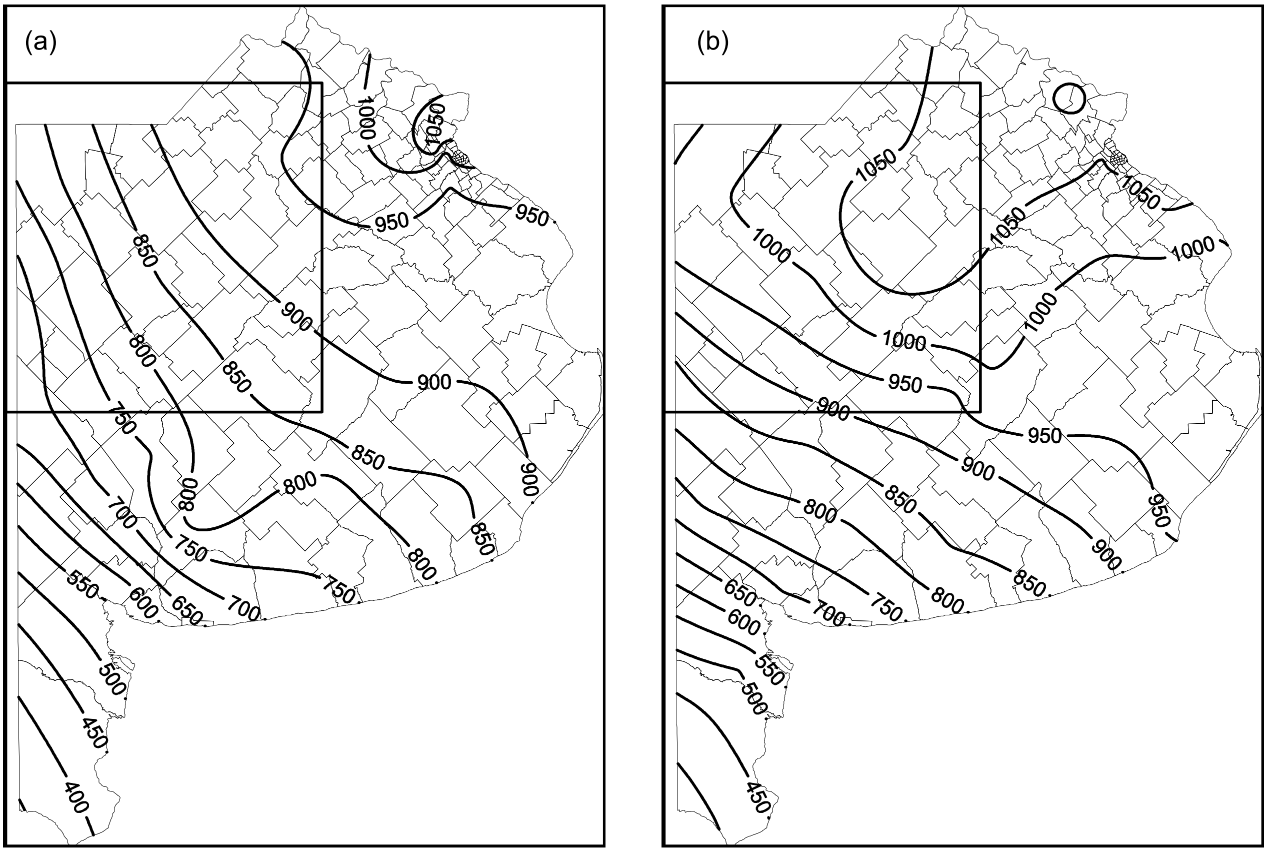

Fig. 1 Average precipitation in Buenos Aires Province during (a) 1941–1970 and (b) during 1971–2004. The smaller rectangle shows the study area (northwest region).

As a result of this increase in precipitation, the water table is often very close to the surface and the waters (ponds) and groundwater are strongly related. The period 1997–2004 is included within the regional humid cycle that has been registered since 1970, and it is possible to define minor cycles of humidity and drought within this humid period.

Figure 2 shows the water table fluctuations at characteristic sites. The water table depth oscillates between 0 and 4 m, and fluctuations vary between areas and are not cyclical. In consequence, the extent of the water bodies shows periodic expansion or reduction coincident with the rise or fall of the water table.

The effect of one extreme event was recorded in March, 1999. Figure 3(a) shows the areal distribution of precipitation and indicates a maximum at Pehuajó (450 mm). Water balance calculations reveal water excesses during this event (Fig. 3(b)) which exceeded 200 mm. Figure 3(c) portrays the rises that took place in the water table, which in some areas exceeded 1.2 m. This event also generated a very important increase in the areas of ponds.

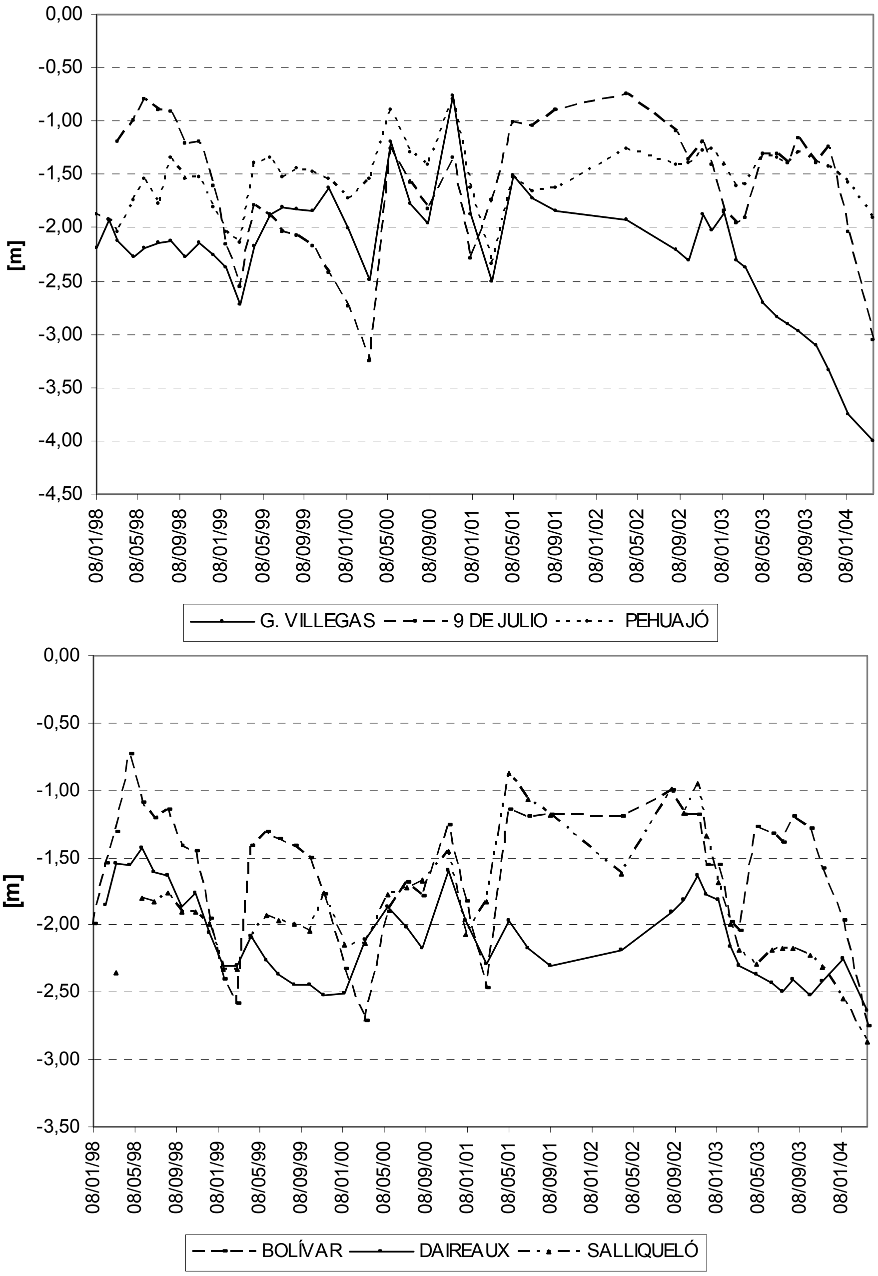

Fig. 2 Water table fluctuations (1998–2004) at characteristic sites

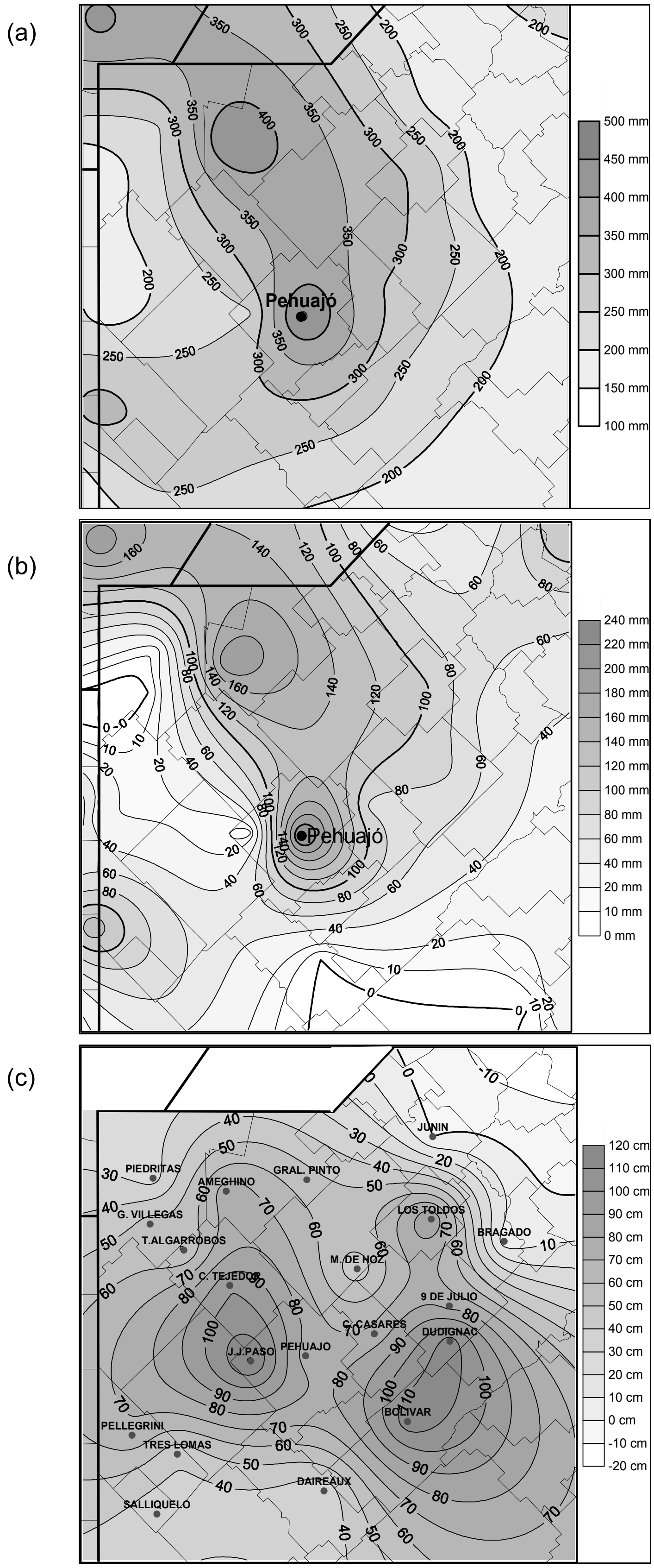

Fig. 3 The hydrological situation in March 1999 with respect to: (a) precipitation**,** (b) water excess, and (c) water table fluctuations.

In the period 1997–2004, periods of low precipitation were also recorded in which water excesses do not exist. An example of these conditions is represented by the period January–March 2004. Figure 4(a) shows the areal distribution of precipitation in January–March 2004 in which, as a consequence of low rainfall and high evapotranspiration, the water excesses were null. Figure 4(b) portrays the extent of water table lowering in this period that in some areas exceeded 0.60 m. The water table depth shows a relationship with the reduction of the pond areas and some existing depressions became dry during this event.

This behaviour allows us to establish different hydrological responses, according to the analysis in wet and dry periods.

(a)

(b)

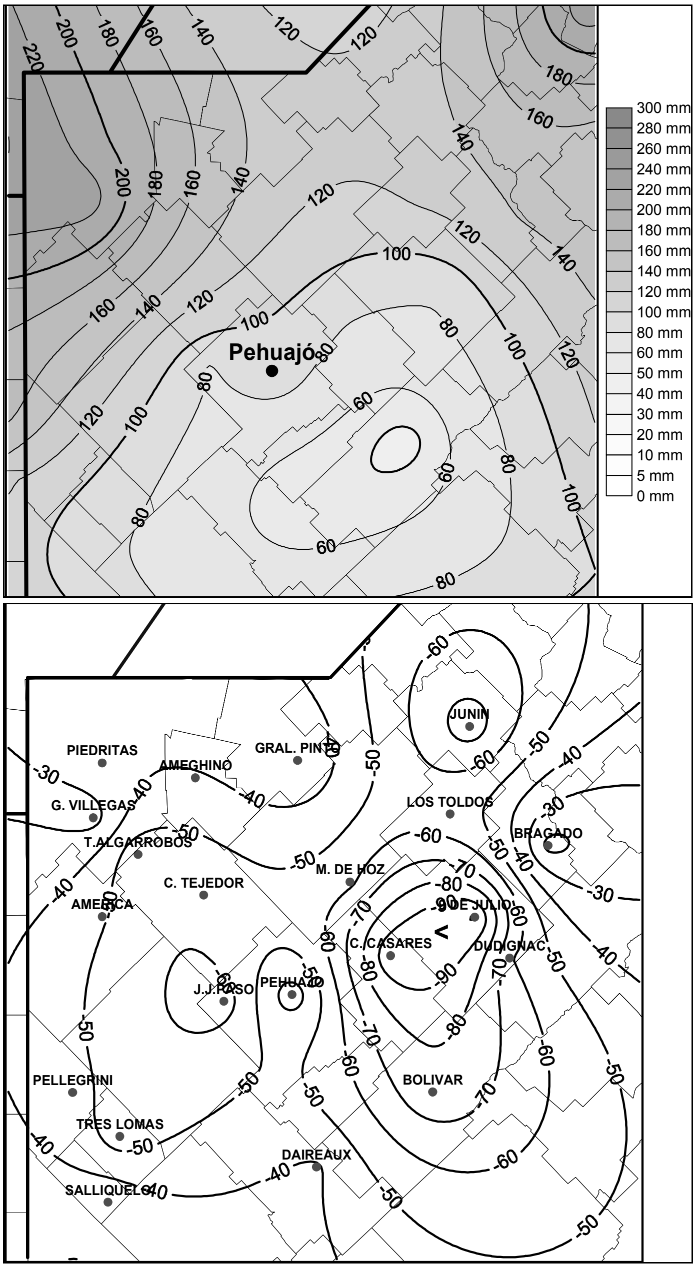

Fig. 4 The hydrological situation in January–March 2004 with respect to: (a) precipitation and (b) water table fluctuations.

DISCUSSION AND CONCLUSIONS

The water table variations are related to precipitation and water excesses. As a consequence of increases in precipitation, the region has seen a tendency to more agricultural land use over the last 30 years. However, this wet period has led to innumerable overflow areas, which reduce the area available for agriculture and cause damage to the road and urban infrastructure.

In a wet period, the rise of the water table can generate surface water in the depressions, which makes agricultural use difficult. The presence of the water table near the surface (at a depth of between 1 and 2 m) as occurred in March 1999, is indicative of a high danger of overflowing.

Lower precipitation and reduced excess water causes the water in depressions to retract or disappear, and the lowering of the water table is maximized (to a depth of between 3 and 4 m), and the danger of overflowing is low.

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