Water **2011**, *3*, 132-145; doi:10.3390/w3010132

OPEN ACCESS

water

ISSN 2073-4441

www.mdpi.com/journal/water

Article

Soil Water Surplus in Salado River Basin and Its Variability during the Last Forty Years (Buenos Aires Province, Argentina)

Olga Eugenia Scarpati [1,2,*], Liliana Beatriz Spescha [3], Juan Alberto Forte Lay [1] and Alberto Daniel Capriolo [1]

[1] National Council of Scientific and Technical Research, Avenue Rivadavia 5485, Buenos Aires, 1424, Argentina; E-Mails: jaflay2004@yahoo.com.ar (J.A.F.L.); albertocapriolo@yahoo.com.ar (A.D.C.)

[2] Geography Department, Humanities and Education Sciences Faculty, National University of La Plata, 48 Street, La Plata, Buenos Aires, 1900, Argentina

[3] Faculty of Agronomy, University of Buenos Aires, Avenue San Martín 4453, Buenos Aires, 1417, Argentina; E-Mail: spescha@agro.uba.ar

* Author to whom correspondence should be addressed; E-Mail: olgascarpati@yahoo.com.ar.

Received: 11 November 2010 / Accepted: 30 December 2010 / Published: 18 January 2011

Abstract: Soil water surplus and deficit occur frequently in Buenos Aires province in Argentina. This paper analyses the soil water surplus in a sub-area, the Salado River basin, in the period 1968–2008. This basin is divided in seven drainage areas, delimitated according to the National Water Resources. The series of soil water surplus data were adjusted by means of the theoretical normal cubic-root probability distribution, and the mean areal soil water surplus value of 300 mm was considered as a threshold above which floods can cause severe damage. An increase in the frequency of extreme events and in their tendency exists during the recent years, coherent with the increase of precipitation recorded in the region. The statistical significance of the results was assessed using the Mann Kendall and MAKESENS tests. The results showed a relevant temporal variability, but did not show significant tendencies.

Keywords: Salado river basin; water budget; flood risk

---

1. Introduction

The Salado River is located in the Buenos Aires (hereafter, BA) province, in eastern Argentina, and flows eastwards to the Atlantic Ocean. Its basin is an almost flat region with a mean gradient of 0.25‰ from west to east, and covers a wide region known as the Pampas Plain or Pampean flatlands. The basin is roughly rectangular, and its coordinate margins are: 34°30'S and 38°10'S for the latitude, and 63°23'W and 56°41'W for the longitude. In recent decades, there were several episodes of soil water surplus (sws, hereafter), caused mainly by intense rainfall [1-3].

The goal of this paper is to analyze the evolution of annual sws in the period 1968–2008, considering seven drainage areas corresponding to the Salado River basin (BA province, Argentina), in order to determine the areas with the highest frequencies of occurrence.

The BA province is a large plain with an elevation of less than 300 m. The Tandilia and Ventania hills, located in the southern part of the region, reach 520 m and 1240 m, respectively. The Salado River basin covers 91,505 km^2, and the homonymous river—more than 700 km long—is the most important. Its main affluents are the Las Flores and Vallimanca streams. The drainage system consists of meandering rivers partially connected to permanent and seasonal lagoons. The low regional terrain slope favors the retention and storage of rainwater for long periods, mainly in the soil, over the floodplain and in shallow lagoons.

Historically, this region was characterized by long periods of water deficit, persistent droughts and high temperatures, interspersed with periods of heavy rainfall that cause severe floods. Since grain production in the Salado River basin accounts for 30% of the national production, that of meat for 25% and the agro-industrial products of vegetal origin exceeds 60%, it is evident that these natural phenomena can have a relevant impact on the national economy.

The climate of the area is temperate and humid, with warm summers and cool winters. Mean annual temperatures oscillate between 13 °C and 16 °C. The temperature of the warmest month (January) ranges between 20 °C and 23 °C, while that of the coldest month (July) between 7 °C and 9 °C. Annual precipitation varies from 1000 mm in the north-eastern part of the region to 700 mm in the south-west. The largest precipitation events are usually generated by the contrast between the warm and humid air mass originating from the semi-permanent anticyclone over the Atlantic Ocean and the cold air mass flowing from the south-west.

The sws is the quantity of rainwater that remains over the soil surface when the water infiltration is null because the soil storage capacity is achieved. This water often cannot infiltrate because the water table is too close to the surface, and there are many depressed areas in the Pampean flatlands. Thus, vertical rainfall and evapotranspiration fluxes are more important than horizontal water movements or surface and subsurface flows in flat regions like the study area. The level of the water table is high during periods of sws, eventually rising to the surface, thereby increasing the flood potential as well as the extension of lakes, ponds and surface impoundments. Nowadays, such a situation occurs more frequently over the Pampean flatlands as a result of the increased precipitation, as the studies performed during the last decades [4-6].

According to Barros *et al*. [7] subtropical Argentina, Paraguay and southern Brazil recorded more precipitation during summer in the last decades of the XX century, and the interannual variability also increased. During this season, a low-level convergence area, a high-level divergence area and an intense convection develop in the northern part of this macro-area, forming the South Atlantic Convergence Zone (SACZ), which has a relationship with the interannual precipitation variability in the same area.

Kruse *et al*. [8] described the relationship between precipitation, evapotranspiration, soil water storage, sws, the water table, subsurface and surface runoff under different scenarios in the north-western BA province, finding a good temporal relationship between water table levels and sws.

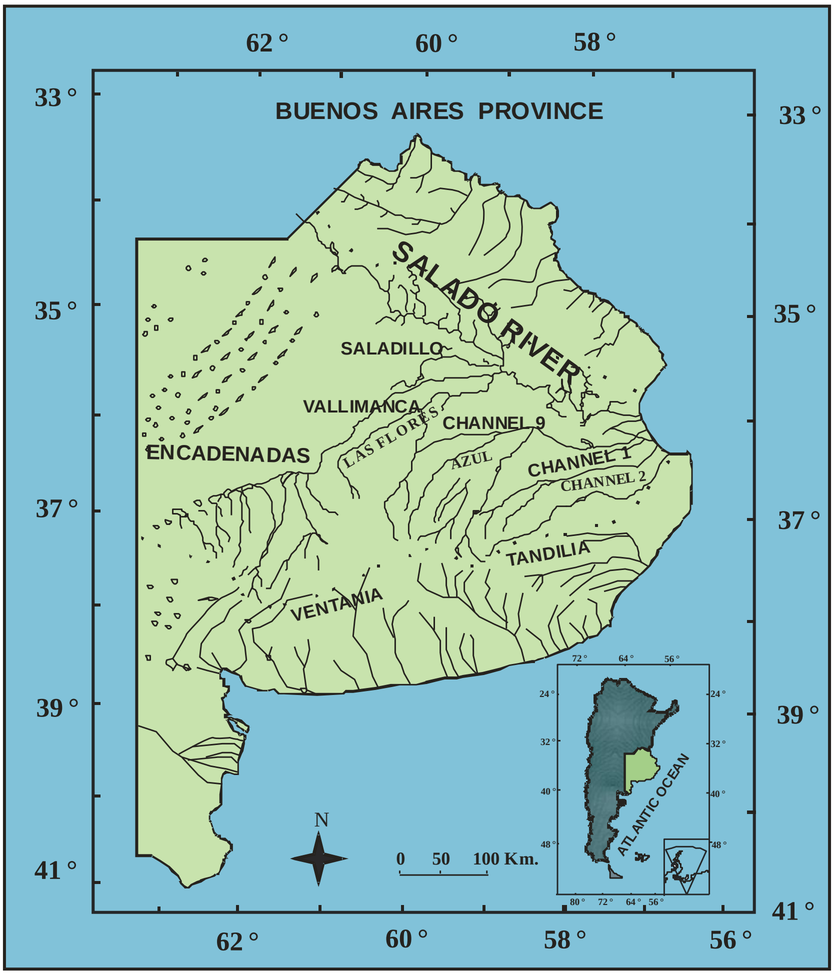
Events of sws occur almost every year, regardless of the ENSO phase, but are particularly intense during the El Niño phase [9]. The differences between the rainfalls in the two ENSO phases appear most evident in the northern BA province, where they reach values of 100 mm, suggesting that the El Niño phase seems to control the magnitude and spatial extent of the sws. In particular, the north-eastern BA reveals high risks of saturated soils and floods in general during the autumn, and in particular during the years characterized by the El Niño phase.

2. Materials and Methods

This section is divided in several parts related to the different sources of information and methodologies utilized in the elaborations.

Figure 1 represents the geographical location of the BA province, and reports also the reticular composition of the basin.

Figure 1. Buenos Aires province and the Salado river basin.



2.1. Data and Meteorological Stations

Daily precipitation data for the period 1968–2008 were provided by the National Meteorological Service—SMN (29 stations) and by the National Institute of Agronomic Technology—INTA (five stations). The meteorological stations were selected according to their long record, homogeneity and historical development.

Figure 2 shows the studied area and reports the position of the meteorological stations used in the work, which are listed in Table 1.

Table 1. Denomination and code of the meteorological stations used in this study.

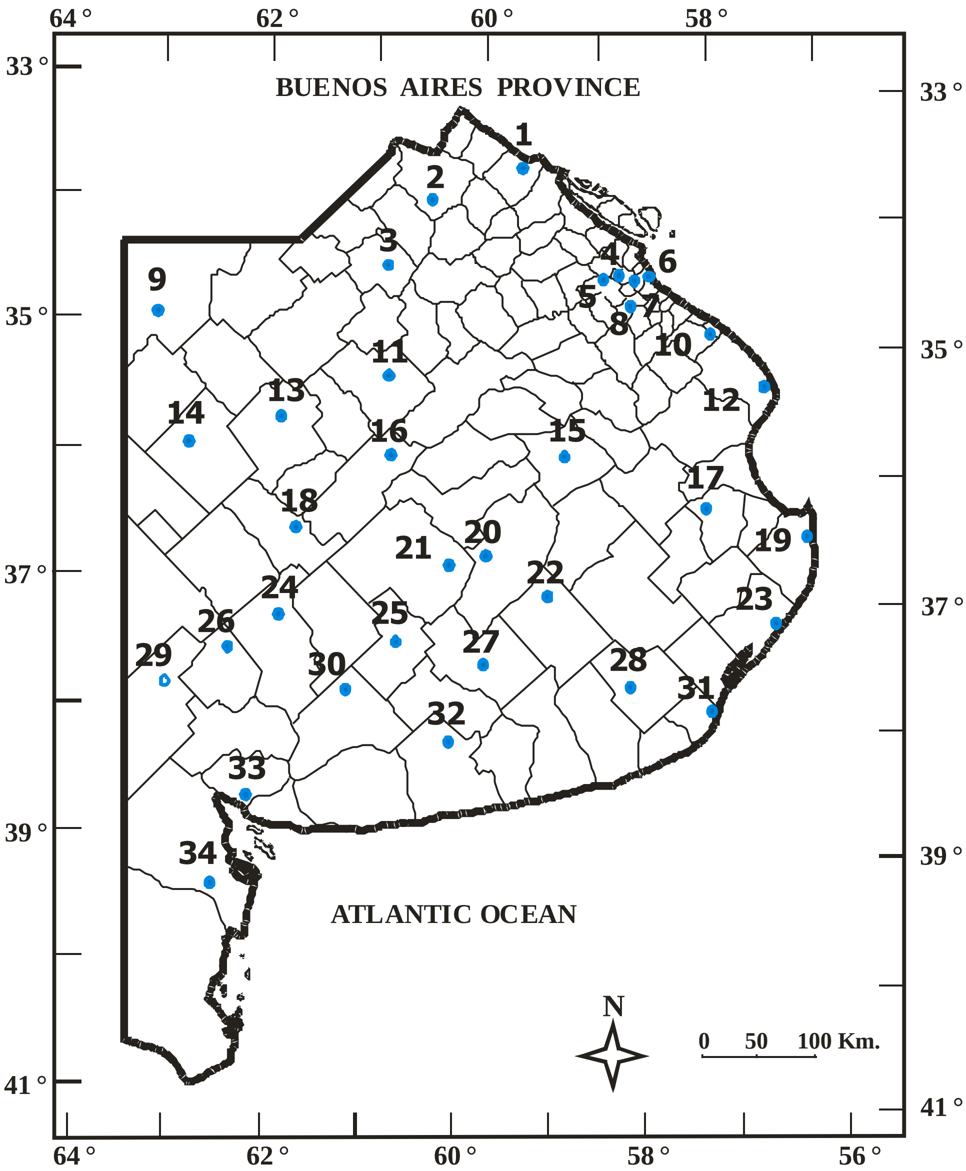
Number	**Station**	**Number**	**Station**
1	San Pedro INTA	**18**	Daireaux
2	Pergamino INTA	**19**	Santa Teresita
3	Junín	**20**	Azul
4	San Miguel	**21**	Olavarría
5	Mariano Moreno	**22**	Tandil
6	Aeroparque J. Newbery	**23**	Villa Gesell
7	Buenos Aires	**24**	Coronel Suarez
8	Ezeiza	**25**	Laprida
9	General Villegas	**26**	Pigüé
10	La Plata	**27**	Benito Juárez
11	Nueve de Julio	**28**	Balcarce INTA
12	Punta Indio	**29**	Bordenave INTA
13	Pehuajó	**30**	Coronel Pringles
14	Trenque Lauquen	**31**	Mar del Plata
15	Las Flores	**32**	Tres Arroyos
16	Bolivar	**33**	Bahía Blanca
17	Dolores	**34**	Hilario Ascasubi INTA

2.2. Basic Hydrological Concepts

The aim of this work is the evaluation of the soil water budget on a daily basis, considering the daily precipitation as input data. The daily mean potential evapotranspiration, two soil hydrologic values (the field capacity and the permanent wilting point) and the corresponding drought levels, evaluated according to the method used by [10,11], were calculated for each station.

Daily sws data were thus obtained using the method of [12] which, in turn, is based on the method of Thornthwaite and Mather for evaluating the soil water balance (Equation 1) on a daily basis. The input data required are the measured precipitation and the daily mean potential evapotranspiration. The latter was estimated using the Penman-Monteith method [13].

Figure 2. The locations of the meteorological stations.



The soil water balance equation used in the model is:

$$PP - EP + \Delta\ St + Su + Def = O \qquad (1)$$

where *PP* is the daily precipitation, *EP* the daily mean potential evapotranspiration, Δ *St* the soil water storage variation, *Su* the sws and *Def* the soil water deficit.

In the following step, the annual values were evaluated by summing the daily soil water balance, and were aggregated in annual areal values; thus, allowing the evaluation of the annual sws on areal basis.

The annual water balance and the sws were then analyzed in order to find the possible tendencies. As the sws values do not have normal distribution, the annual series were adjusted by using an empiric distribution of frequencies (normal cubic-root probability distribution). This operation allowed analysis of the normal distribution of the sws, calculation of the mean value relative to the studied period, and the probability of occurrence of 50% to be obtained.

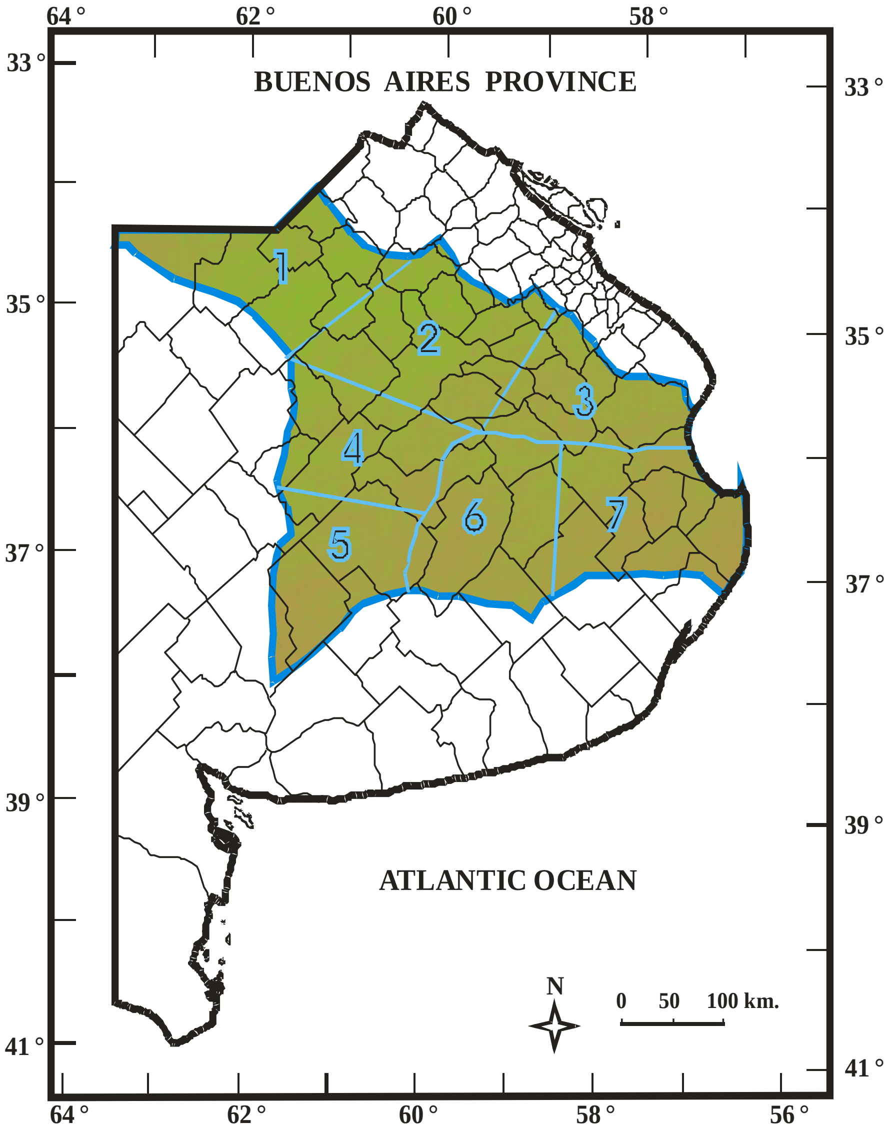
2.3. The Salado River Basin

The Salado river basin was considered subdivided in seven drainage areas, according to National Water Resources [14], as indicated in Table 2 and displayed in Figure 3.

Table 2. Drainage areas studied in the Buenos Aires province.

Drainage area	Name
S1	Northwestern area of the Salado River basin
S2	Central area of the Salado River basin
S3	Salado River mouth
S4	Southern area of the Salado River basin and northern area of Vallimanca River basin
S5	Southern area of the Salado and Vallimanca Rivers basins
S6	Western Channels area south of the Salado River
S7	Channels area south of the Salado River

Figure 3. Drainage areas of the Salado River basin.



2.4. Map Graphical Representation

Maps showing the sws for every year of the studied period were created using the software SURFER 8.0, which allows isoline maps of the sws to be drawn.

2.5. Soil Water Surplus

The obtained maps allowed the spatial distribution of the annual sws to be detailed. The mean areal value was calculated for each of the drainage sub-areas mentioned in Table 2, and the sequence of these annual values of sws was used to study their temporal distribution. An annual mean areal value of 300 mm was considered as a threshold of sws, above which there is a relevant probability that floods can cause severe damage.

2.6. Statistical Analysis

The non parametric Mann-Kendall test was applied to the complete series of data. In addition, an Excel template, called MAKESENS and described in [15], was used for detecting and estimating trends in the time series of annual values of sws. This procedure is based on the nonparametric Mann-Kendall test for the trends, and the nonparametric Sen's method for estimating the magnitude of the trend. In detail, in the first step, the Mann-Kendall test allows detection of a monotonic trend in the time series of data without seasonal or other cycles. Subsequently, the Sen's method tries to fit the data with a linear model, reported in Equation 2, where t is the time expressed in years:

$$f(t) = Qt + B \tag{2}$$

where Q is the slope and B the offset to be determined. Finally, MAKESENS evaluates the test statistical significance using the α levels 0.001, 0.01, 0.05 and 0.1 [16].

The Sen's method gives the following results, depending on the number of years n:

- Test Z for the trend assessment: if the number of samples n is greater than 10, the value of the statistic test Z is displayed. The absolute value of Z is compared to the standard normal cumulative distribution for assessing the presence of a trend at the selected significance level α, while a positive (negative) value of Z indicates an upward (downward) trend.
- Statistical significance: α represents the smallest significance level at which the null hypothesis (absence of trends) must be rejected. If n is lower than 10, the test uses the S statistic, while if n is larger or equal to 10, the test uses the Z (normal) statistic. To show the significance levels, the following symbols are used:

  *** existence of a trend with level of significance α = 0.001;
  ** existence of a trend with level of significance α = 0.01;
  * existence of a trend with level of significance α = 0.05;
  + existence of a trend with level of significance α = 0.1.

- Estimate with the Sen's method of the slope Q in Equation 2: Q represents the annual rate of variation of the areal sws, and is thus expressed in mm/year:

  $Q_{min}99$: estimate of the lower limit of Q with a 99% confidence interval (α = 0.1);

Q_{max}99: estimate of the upper limit of Q with a 99% confidence interval (α = 0.1);
Q_{min} 95: estimate of the lower limit of Q with a 95% confidence interval (α = 0.05);
Q_{max}95: estimate of the upper limit of Q with a 95% confidence interval (α = 0.05).

- Estimate with the Sen's method of the constant B in Equation 2: B represents the mean annual areal value at the beginning of the observations, and is expressed in mm:

B_{min}99: estimate of the lower limit of B with a 99% confidence interval (α = 0.1);
B_{max}99: estimate of the upper limit of B with a 99% confidence interval (α = 0.1);
B_{min}95: estimate of the lower limit of B with a 95% confidence interval (α = 0.05);
B_{max}95: estimate of the upper limit of B with a 95% confidence interval (α = 0.05);

3. Results and Discussion

Figure 4 shows the spatial distribution of the mean areal annual sws for two years (2001 and 2002) in which there were relevant values of sws that caused major floods in the Salado River basin.

Figure 4. Spatial distribution of the mean areal annual sws of the Salado River basin.

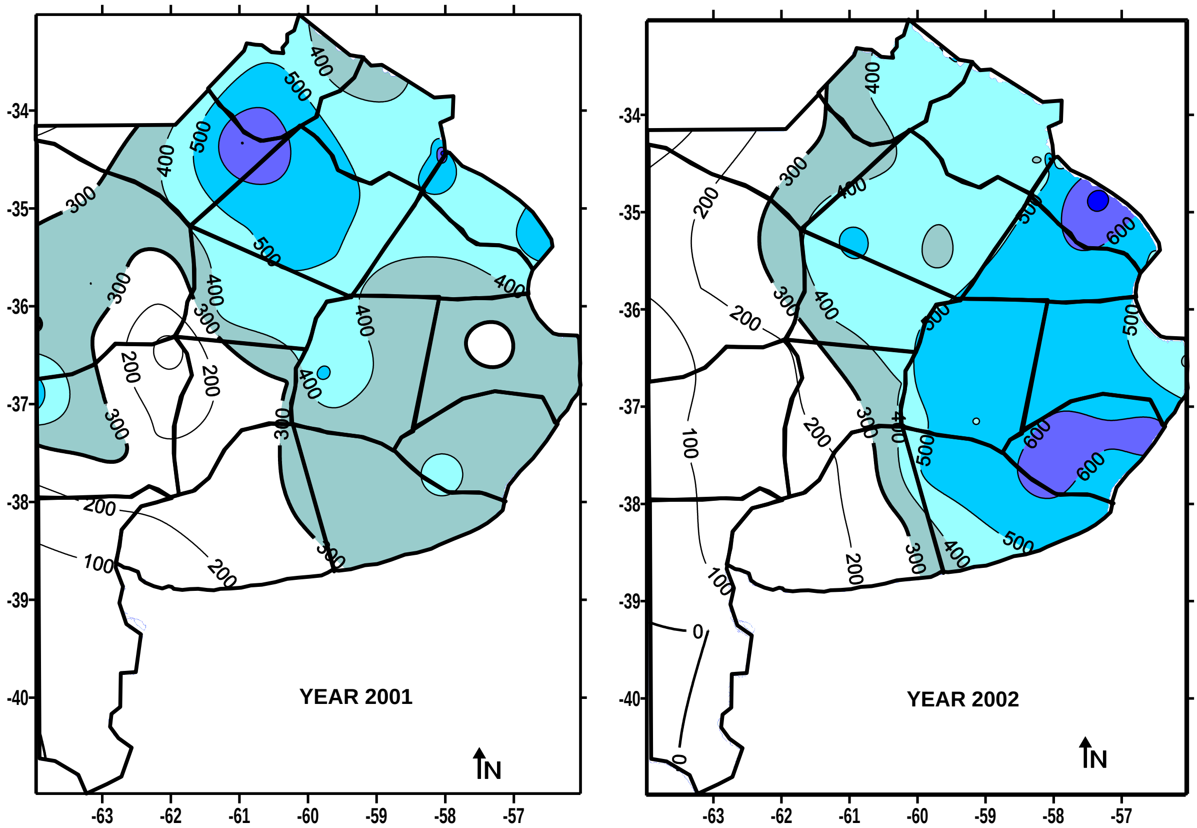


Figure 5 reports the temporal distribution of the annual mean areal values of soil, while Figure 6 shows the mean decadal values, starting from 1969, averaged over each drainage area.

The maximum value refers to the third drainage area (S3) in 1993 (600 mm), and the second maximum to the seventh drainage area in 1980. The former value is in agreement with those found by Scarpati *et al.* [17,18] and Gonzalez and Fernandez [2], who studied the floods of the Salado river basin.

Figure 5. Annual distribution of soil water surplus (sws) in the seven drainage areas.

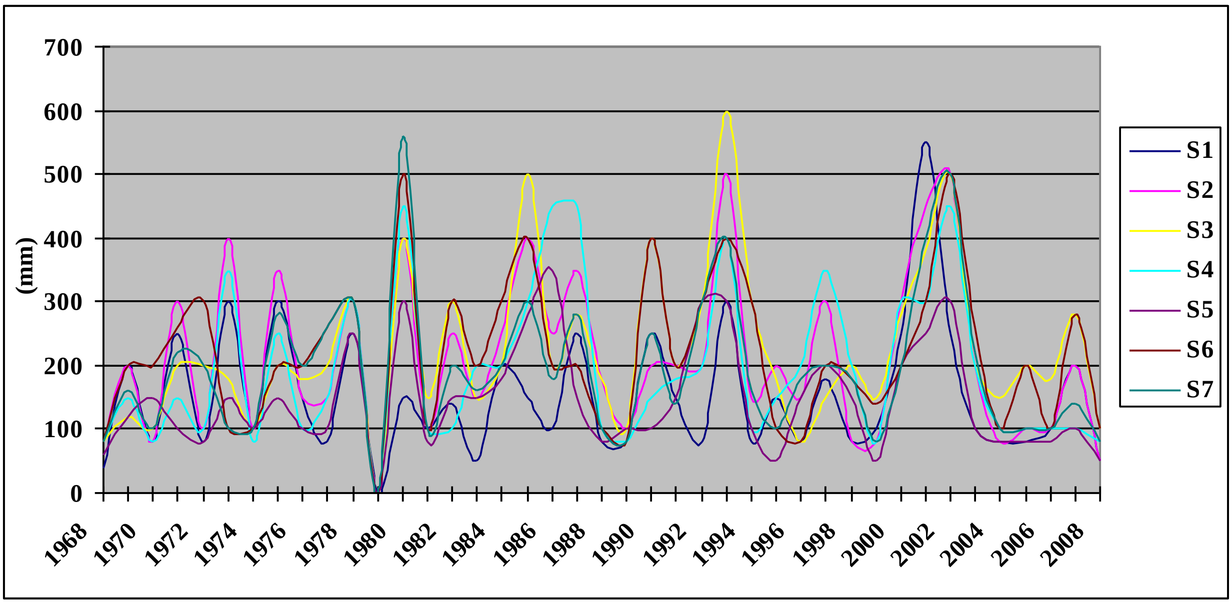
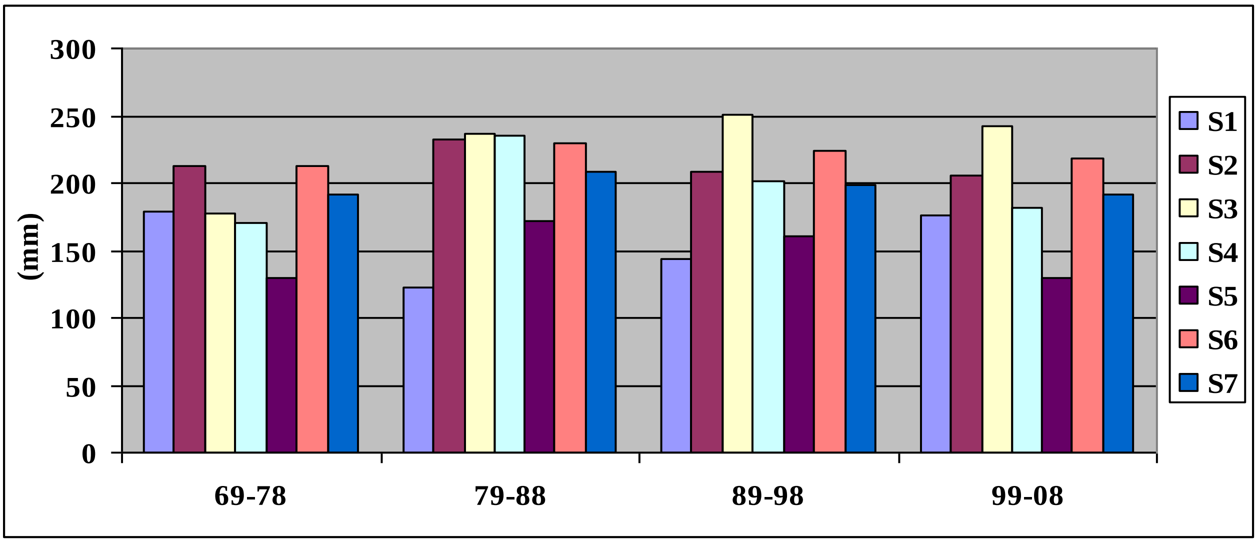


Figure 6. Mean decadal soil water surpluses of each drainage area studied.



The obtained results can be summarized in this way:

1. 1968 to 1980: the values of sws were generally small;
2. 1980 to 1995: in several years, the threshold of 300 mm was exceeded, including the two cases above mentioned;
3. 1995 to 1999: only the second and fourth drainage areas exceeded 300 mm, in 1997;
4. 2000 to 2002: almost all drainage areas, except the fifth, showed large values;
5. 2003 to 2008: the sws values never reached the 300 mm threshold, and are very similar to the first cycle.

Figure 6, grouping the decadal values relative to all drainage areas, can exalt the different behavior of the values during the studied period, which can be summarized in the following way:

- S1 always shows values lower than 200 mm, and the minimum was observed during the second decade;
- S2 always shows values higher than 200 mm, and the maximum was observed during the second decade;
- S3 shows a high value during the second decade, but the maximum corresponds to the third;
- the maxima of S4 and S5 are recorded during the second decade, and high values are also observed in the third;
- S6 and S7 values show the smallest inter-decadal variations among all drainage areas.

Table 3. Annual values of soil water surplus lower than 100 mm (yellow boxes), larger than 300 mm (orange boxes) and larger than 500 mm (grey boxes) for the seven drainage areas. The last column reports the number of drainage areas showing sws larger than 300 mm. The last two lines report the number of stations in which annual sws was larger than 300 mm (last row) and lower than 100 mm (second last row).

Year	**Drainage area**							
	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**N**
1968	40	80	80	80	60	80	80	
1969	200	200	120	150	120	200	160	
1970	80	80	100	80	150	200	100	
1971	250	300	200	150	100	260	220	
1972	80	100	200	100	80	300	200	
1973	300	400	180	350	150	100	100	**3**
1974	100	100	100	80	100	100	100	
1975	300	350	200	250	150	200	280	**2**
1976	150	150	180	100	100	200	200	
1977	80	150	200	150	100	260	260	
1978	250	300	300	300	250	300	300	**5**
1979	0	0	0	0	0	0	0	
1980	150	400	400	450	300	500	560	**6**
1981	100	100	150	100	80	100	100	
1982	140	250	300	100	150	300	200	**2**
1983	50	150	150	200	150	200	160	
1984	200	250	200	200	180	300	200	**1**
1985	150	400	500	300	280	400	300	**5**
1986	100	250	200	450	350	200	180	**2**
1987	250	350	280	450	150	200	280	**2**
1988	80	180	180	100	80	100	100	
1989	80	100	100	80	100	80	80	
1990	250	200	400	150	100	400	250	
1991	150	200	200	180	150	200	140	
1992	80	200	300	200	300	300	300	**4**
1993	300	500	600	400	300	400	400	**7**
1994	80	150	300	100	100	300	160	**2**
1995	150	200	180	150	50	100	100	

Table 3. *Cont.*

Year	**Drainage area**							
	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**N**
1996	80	150	80	200	150	80	180	
1997	180	300	150	350	200	200	200	**2**
1998	80	80	200	200	150	180	180	
1999	100	80	150	80	50	140	80	
2000	250	300	280	300	200	200	200	**2**
2001	550	450	380	300	250	300	400	**6**
2002	250	500	500	450	300	500	500	**6**
2003	100	200	200	200	100	260	220	
2004	80	80	150	100	80	100	100	
2005	80	100	200	100	80	200	100	
2006	100	100	180	100	80	100	100	
2007	200	200	280	100	100	280	140	
2008	50	50	100	80	50	100	80	
Events below 100 mm threshold	**19**	**13**	**7**	**16**	**20**	**12**	**13**	**100**
Events above 300 mm threshold	**4**	**12**	**10**	**11**	**5**	**12**	**6**	**60**

Table 3 summarizes the number of years with low (lower than 100 mm) and high (higher than 300 mm) sws, for each drainage area. The second and sixth areas show the maximum number (12) of high sws, while the minimum value of cases is shown by the first area. Generally, there were a larger number of cases with low values of sws than with high values of sws, but this general distribution was different in the different drainage areas. For instance, the fifth and first areas show a clear prevalence of the years characterized by low sws, while the third area shows a prevalence of years with high sws.

The Mann-Kendall test revealed that the trends observed are statistically significant only for the third drainage area, at the level of 95% (Table 4).

Table 4. Statistical significance of the soil water surplus (sws) trends according to the Mann-Kendall test.

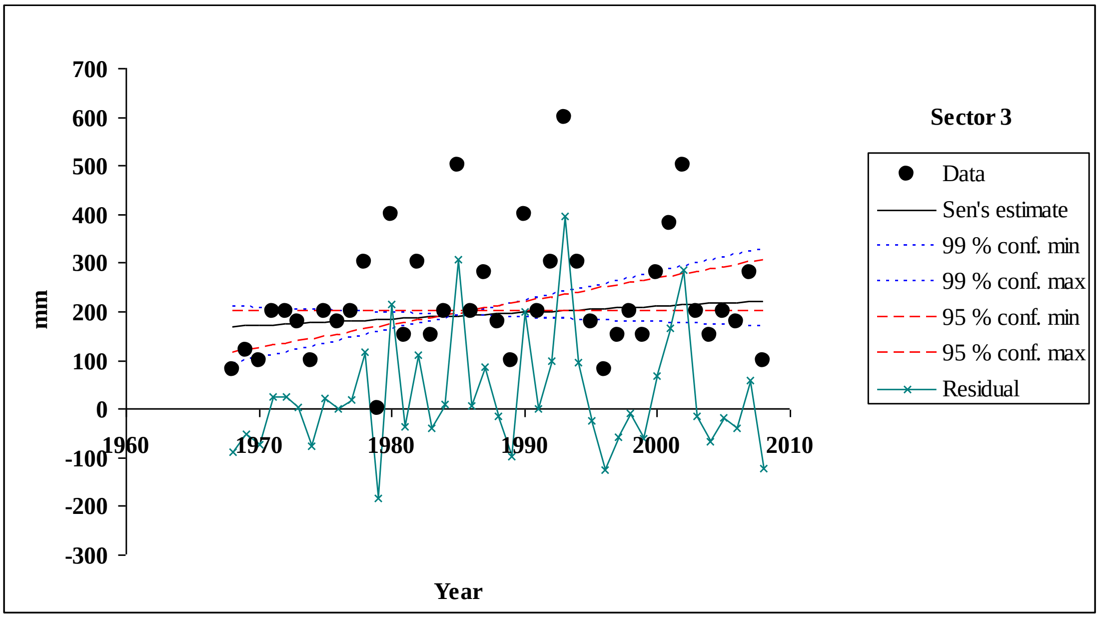
Mann-Kendall test for the trend					
Drainage area	**N cases**	**Confidence Levels p = 95%**		**τ**	**Significance**
S1	41	+0.213	–0.213	–0.015	no
S2	41	+0.213	–0.213	–0.020	no
S3	41	+0.216	–0.216	+0.185	yes
S4	41	+0.213	–0.213	+0.061	no
S5	41	+0.213	–0.213	–0.010	no
S6	41	+0.213	–0.213	+0.010	no
S7	41	+0.213	–0.213	–0.015	no

As the results of the application of MAKESENS test were similar to those of the Mann-Kendall test, only the details relative to the only statistically significant trend, *i.e.*, that of the third drainage area, are reported (Figure 7 and Table 5).

Table 5. Drainage area 3 (S3) results for MAKESENS test.

Name	S3
Test Z	1,27
Significance	> 0.1
Q	1.32E + 00
Q_{min}99	–1.00E + 00
Q_{max}99	5.88E + 00
Q_{min}95	0.00E + 00
Q_{max}95	4.76E + 00
B	1.70E + 02
B_{min}99	2.09E + 02
B_{max}99	9.18E + 01
B_{min}95	2.00E + 02
B_{max}95	1.14E + 02

Figure 7. Trend statistics of annual soil water surplus (sws) using the Mann-Kendall test and Sen's slope.



For sake of completeness, the Sen's estimates for the slope of the linear trends relative to the other drainage areas, considered non significant, are: for S1, 100 mm/year; for S2, 200 mm/year; for S4, 150 mm/year; for S5, 120 mm/year; for S6, 200 mm/year; and for S7, 180 mm/year. The trend of S3 area varies from 169 to 222 mm/year.

4. Conclusions

The soil water surplus relative to the period 1968–2008 was analyzed in seven drainage areas of the Salado River basin. The annual mean areal value of 300 mm for sws was considered as the threshold above which subsequent floods can cause damages. The maximum value present in the series of data was 600 mm. The seven drainage areas in which the Salado River basin has been subdivided show different annual mean sws values, as well as a different number of events, thus the flood or drought risk differs between the different areas.

The decade 1979–1988 showed the highest values in every drainage area, except for S1 and S3. The temporal variability of the sws was evidenced by the choice of five periods related to the cycles visualized through the studied period, and they could be connected to climate change. The behavior of the sws data of drainage area 3 (Salado River mouth) is the only one with statistical significance.

As a general conclusion, an increase of the frequency of sws values above the 300 mm threshold in the period 1968–2008 was identified. The years 1968 and 2008 showed the smallest sws values during the whole analyzed period, and 2008 registered the worst drought in the last 40 years.

The years showing the maximum values of sws were 1983, 1985, 1993, 2001 and 2002.

The third drainage area (Salado River mouth) showed the highest sws value (600 mm), followed by the second area (Central area of the Salado River basin) and the seventh (Channels area south of the Salado River). The sixth area (Western Channels area south of the Salado River) registered the largest frequency of sws values higher than 300 mm (12 events).

Since 1980, the sws values experienced important fluctuations. An increasing tendency during the last years is observed and it is coherent with the increase in precipitation.

References and Notes

1. Forte Lay, J.A.; Quintela, R.M.; Scarpati, O.E. Variación de las características hidrometeorológicas de la llanura pampeana argentina. In *Proceedings of the Memoria Encuentro Meteo 92 (Asociación Meteorológica Española),* Salamanca and Cáceres, Spain, July 1992; Volume II, pp. 142–146.
2. González, M.H.; Fernández, A.E. Floods increasing in Buenos Aires Salado River Basin. In *Environmental Change and Rational Water Use*; Scarpati, O.E., Jones, J.A.A., Eds.; International Geographical Unión: Buenos Aires, Argentina, 2007; pp. 96–113.
3. Quintela, R.M.; Forte Lay, J.A.; Scarpati, O.E. Modification of the water resources characteristics of the Argentine's Pampean subhumid-dry region. In *Proceedings of the 19th Conference on Agricultural & Forest, 9th Conference on Biometeorology and Aerobiology (19th AGMET)*, Miami, FL, USA, July 1989; J-30-J-35.
4. Castañeda, M.; Barros, V. Las tendencias de la precipitación en el cono sur de América al este de los Andes. *Meteorológica* **1994**, *21*, 23–32.
5. Minetti, J.; Vargas, W. Trends and jumps in the annual precipitation en South America on the 15°S. *Atmósfera* **1997**, *11*, 204–221.
6. Rusticucci, M.; Penalba, O. Interdecadal changes in the precipitation seasonal cycle over Southern South America and their relationship with surface temperature. *Clim. Res.* **2000**, *16*, 1–15.
7. Barros, V.; Gonzalez, M.; Liebmann, B.; Camilloni, I. Influence of the South Atlantic convergence zone and South Atlantic sea surface temperature on interannual summer rainfall variability in South-Eastern South America. *Theor. Appl. Clim.* **2000**, *67*, 123–133.
8. Kruse, E.; Forte Lay, J.A.; Aiello, J.L.; Basualdo, A.; Heinzenknecht, G. Hydrological processes on large flatlands: Case study in the northwest region of Buenos Aires Province (Argentina). *IAHS* **2001**, *267*, 531–535.
9. Scarpati, O.E.; Forte Lay, J.A.; Capriolo, A.D. Soil water surplus and ENSO events during the last humid period in Argentine Pampean Flatlands. *Int. J. Water.* **2009**, *5*, 181–193.

10. Forte Lay, J.A.; Spescha, L.B. Método para la estimación de la climatología del agua edáfica en las provincias pampeanas de la Argentina. *RADA* **2001**, *1*, 67–75.
11. Forte Lay, J.A.; Scarpati, O.E.; Spescha, L.B.; Capriolo, A.D. Drought risk in the pampean region using soil water storage analysis. In *Environmental Change and Rational Water Use*; Scarpati, O.E., Jones, J.A.A., Eds.; International Geographical Unión: Buenos Aires, Argentina, 2007; pp. 146-168.
12. Forte Lay, J.A.; Scarpati, O.E.; Capriolo, A.D. Precipitation variability and soil water content in pampean flatlands (Argentina). *Geofísica Inter.* **2008**, *47*, 341–354.
13. Allen, R.G.; Pereira, L.S.; Raes, D.; Smith, M.; Irrigation and drainage. *Crop Evapotranspiration—Guidelines for Computing Crop Water Requirements*; FAO: Rome, Italy, 2004; Paper 56, p. 301.
14. *Atlas digital de los recursos hídricos superficiales de la República Argentina*; National Water Resources: Buenos Aires, Argentina, 2002; Available online: http://www.hidricosargentina.gov.ar/CartAct.html#1 (accessed on 18 January 2011).
15. Salmi, T.; Mata, A.; Anttila, P.; Ruoho-Airola, T.; Amnell, T. Detecting Trends of Annual Values of Atmospheric Pollutants by the Mann-Kendall Test and Sen's Slope Estimates—The Excel Template Application MAKESENS; In *Publications on Air Quality*; Ilmatieteen laitos Meteorologiska Institutet, Finnish Meteorological Institute Painopaikka: Edita Oyj, Helsinki, Finland, 2002.
16. Liu, S.; Mo, X.; Zhao, W.; Naeimi, V.; Dai, D.; Shu, C.; Mao, L. Temporal variation of soil moisture over the Wuding River basin assessed with an eco-hydrological model, *in-situ* observations and remote sensing. *Hydrol. Earth Syst. Sci.* **2009**, *13*, 1375–1398.
17. Scarpati, O.E.; Spescha, L.B.; Capriolo, A.D. The impact of the heavy floods in the Salado River basin, Buenos Aires province, Argentina. *Mitigation Adaptation Strateg. Glob. Change* **2002**, *7*, 285–301.
18. Scarpati, O.E.; Forte Lay, J.A.; Fernandez Long, M.E.; Capriolo, A.D. ENSO influence on soil water balance and temperature in pampean flatlands (Argentina) with special analysis to San Pedro area. In *Environmental Change and Rational Water Use*; Scarpati, O.E., Jones, J.A.A., Eds.; International Geographical Unión: Buenos Aires, Argentina, 2007; pp. 169–183.