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Avaliação de terras sob diferentes cenários climáticos na sub-região Pampa Arenosa, Argentina

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R E S U M O

Desde a década de 70, a sub-região Pampa Arenosa experimentou um aumento do seu regime hídrico, permitindo uma maior área para a agricultura de sequeiro. Diante da intensificação da agricultura, a avaliação das terras com base nas variações pluviométricas é uma ferramenta estratégica fundamental para o planejamento. O objetivo deste trabalho é destacar a importância de diferentes cenários climáticos na determinação do Índice de Produtividade na Sub-região Pampa Arenosa, Argentina. A área de estudo estava localizada no noroeste de Buenos Aires e no leste da província de La Pampa. Foram utilizados dados mensais de precipitação para o período 1921-2020. Cenários climáticos foram determinados de acordo com as mudanças nos valores de precipitação média utilizando o teste de segmentação temporal hidrometeorológica de Hubert. As informações edáficas foram obtidas a partir de cartas de solo fornecidas pelo INTA 1:50000 e do Inventário de Recursos Naturais de La Pampa 1:500000. Recorrendo ao teste de Hubert, foram propostos vários cenários com diferentes pontos de partida para as condições macroclimáticas (H) de Produtividade Índice. Mudanças nos valores médios anuais de precipitação foram detectadas nas regiões do Pampa Arenosa. As terras foram classificadas pelo Índice de Produtividade, que aumentou à medida que as chuvas se tornaram maiores, atingindo sua máxima expressão climática durante o período úmido após uma mudança positiva abrupta. Os resultados da segmentação das séries anuais de chuvas para a Sub-região Pampa Arenosa, utilizando o método de Hubert, permitiram definir subperíodos secos e úmidos, para estimativa de IP. fenômenos têm importantes impactos sociais e econômicos.

Palavras-chave: agroclimatologia, índice de produtividade agrícola, segmentação temporal hidrometeorológica.

Assessment of lands under different climate scenarios in Pampa Arenosa Subregion, Argentina

A B S T R A C T

Since the 70´s, Pampa Arenosa Subregion has experienced a rise in its water regime, allowing a greater area for dryland farming. Given farming intensification, assessing lands on the basis of rainfall variations is a fundamental strategic tool for planning. The objective of this work is to highlight the importance of different climate scenarios when determining Productivity Index in the Pampa Arenosa Subregion, Argentina. The study area was located in the Northwest of Buenos Aires and the East of La Pampa Province. Monthly precipitation data for the period 1921-2020 was used. Climate scenarios were determined according to changes in the values of mean rainfall using Hubert´s Hydrometeorological temporal segmentation test. Edaphic information was obtained from soil charts provided by INTA 1:50000 and the Natural Resource Inventory of La Pampa 1:500000. Resorting to Hubert´s test, several scenarios were proposed with different starting point for the macro climate conditions (H) of Productivity Index. Changes in annual rainfall mean values were detected in regions of Pampa Arenosa. The lands were classified by Productivity Index, which increased as rainfall became higher, reaching its maximum climate expression during the wet period after a positive abrupt change. Segmentation results of rainfall annual series for Pampa Arenosa Sub region, using Hubert´s method, allowed defining dry and wet subperiods, for IP estimation. In the Pampa region, climate variability is represented by the succession of dry and wet periods, and their extreme phenomena have important social and economic impacts.

Keywords: agroclimatology, crop productivity index, hydrometeorological temporal segmentation.

Introduction

The Pampa region is the main farming area in Argentina. It is located in the centre-east region of the country (30°S – 40°S and 56° W- 65° W). The climate is temperate humid, Cf according to Köppen´s classification, revised by Kottek et al., (2006). East winds predominate, driven by a semi-permanent anticyclone from the coast of Brazil. Therefore, sub-tropical maritime air, driven from the Brazilian coast, moves south-east to 40°S latitude in summer and around 30°S latitude in winter. This allows the area to receive sea winds throughout the year with a moisture gradient decreasing from east to west, (Pérez et al., 2015).

Several studies show that the westward advance of agriculture in the Pampean Region during the last quarter of the twenty-first century (Viglizzo et al., 1995; Paruelo et al., 2005; Sgroi et al., 2021), has been favoured by the increase in the rainfall regime (Pérez et al., 2011; 2015; Pérez and Sierra, 2012; Pal et al., 2021), which synergistically interacted with an increase in demand from international markets (Trigo, 2005) and technological innovations (Satorre, 2005).

Considering the high potential impact of changes in the rainfall regime on the farming economy of the region, sustainable management is highly dependent on the knowledge about these changes (Sierra and Pérez, 2006; Veron et al., 2015). Some authors (Suriano and Ferpozzi, 1993; Roberto et al., 1994; Pérez et al., 2003; 2011; Pérez and Sierra, 2012) observed that the Pampa Region is subject to a long-term water cycle with wet and dry phases, and transition periods in between, during which the farming area either advances or recedes (Pérez et al., 2021).

In the Pampa Arenosa sub-region, increase in rainfall allowed farming in dry land, affected by the risk of wind erosion and low moisture- holding capacity (Klingebiel and Montgomery, 1961; Mendez and Buschiazzo, 2010). These lands present soils with scarce development, mainly hapludolls entisols, with sandy texture, permanently limiting their moisture holding capacity and their exposure to erosion. The increase in rainfall in these lands conceals these limitations and allows their use for farming with productivity that varies depending on water availability. Thus, during wet phases, the higher production of dry biomass limited wind erosion (Viglizzo et al., 2003) providing land users with a wrong perception of land fragility. Therefore, farming pressure on these fragile environments increased without a clear understanding of the factors determining that fragility (Irigoin, 2011). Hence, information about the change in rainfall is central to define land use on the basis of dynamic analysis of the climate factor without disregarding the importance of inherited factors.

Farming is the sector with highest vulnerability to those changes and/or climate variations (Irigoin, 2011; Taboada et al., 2020). At regional scale, rainfall is the climate variable with higher influence on grain crop productivity in drylands, due to the incidence in productivity and indirectly in the economy of the productive system. Therefore, rainfall is considered as an indispensable variable (Bert et al., 2007; Penalba et al., 2007) to understand the westward advance of farming in Pampean Region.

Presently, knowledge about climate represents an essential part of environmental assessment, not only as a risk factor but also as a resource. The object of this work was to perform an assessment of lands in different climate scenarios in the Pampa Arenosa Sub region in Argentina.

Material and methods

Data

Monthly precipitation data for the period 1921-2020 in ten districts was used. Three of those districts are located to the Northwest of Buenos Aires Province and the other seven to the East of La Pampa Province (Table 1. Fig.1). These data were provided by the National Meteorological Service (NMS). Tests were applied on annual value series obtained adding monthly values of each year.

Edaphic information was obtained from soil charts provided by INTA 1:50000 (INTA 2005; Cruzate et al., 2010) for those districts located in Buenos Aires Province. For those situated in La Pampa province, the soil chart from the Natural resource Inventory of La Pampa was used, 1:500000

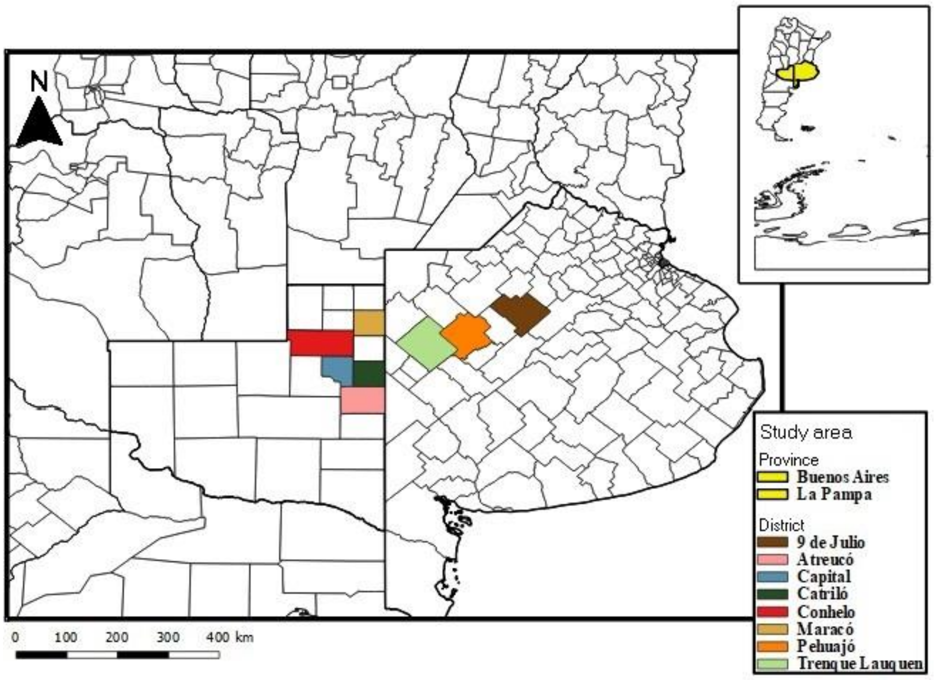

Figure 1. Study area and districts in the provinces of Buenos Aires and La Pampa: Atreucó, Capital, Catriló, Conhello, Maracó, 9 de Julio, Pehuajó, Trenque Lauquen.[1]

Table 1. Study area.

Distric	Province	Latitude (S)	Longitude (W)	Altitude (msl)
9 de Julio	Buenos Aires	35°27′	60°53′	78
General Pico	La Pampa	35°39′	63°45’	143
Pehuajó	Buenos Aires	35°48´	61°54´	84
Eduardo Castex	La Pampa	35°53´	64°17´	171
Trenque Lauquen	Buenos Aires	35°58´	62°43´	80
Winifreda	La Pampa	36°13′	64°14′	139
Catriló	La Pampa	36°26´	63°24´	113
Anguil	La Pampa	36°31´	64°01´	152
Santa Rosa	La Pampa	36°37´	64°16´	175
Macachín	La Pampa	37°08´	63°38´	130

Quality control

Data from the 10 selected districts were subjected to a process of quality control.

All data above the third quartile plus three times the interquartile range and situated above five standard deviations from the means were

[1]Macachín municipality corresponds to Atreucó district, Santa Rosa and Anguil municipalities to Capital district, Eduardo Castex and Winifredo municipalities correspond to Conhello district and General Pico municipality belongs to Maracó district.

treated as atypical values. They were contrasted with climate records from near seasons. If the same record is tagged as out of range during more than two seasons, the value is considered as accurate.

Those months considered atypical and those lacking date were taken as gaps. Both kinds of gaps were filled, but not completed with missing data if there were three gaps in one year. Missing data were estimated from the records of nearer seasons, considering the correlation coefficient among different monthly observation positions.

Homogeneity test

A climate data series is considered homogeneous if "… variations are caused only by variations in weather and climate" (Conrad and Pollak, 1950). A climate series may cease to be homogeneous if the measurement season has been subjected to changes in the instruments, the location, or the observation practices (Wijngaard et al., 2003).

Homogeneity of rainfall series was tested by standard normal homogeneity test (SNHT) by Alexandersson and Moberg (1997), for which AnClim software was used (Štěpánek, 2006).

Detection of changes in the mean

Changes in annual mean rainfall were detected by Hubert´s Hydrometeorological temporal segmentation test. This method divides the series in m segments (m > 1) so that the mean calculated over all the series is significantly different from the mean of neighbouring segments.

Land Assessment System

The Productivity Index proposed by Riquier et al. (1970) was applied, adapted to the Pampean region by Sobral and Nakama (1988) and Sobral et al. (2010):

IP= H * D * Pe * Ta * Tb * As * Na *Mo * T * E

Macro climate Condition (H); drainage (D); effective depth (Pe) superficial texture (Ta); sub-superficial texture (Tb); salinity (Sa); sodicity (Na); organic material (Mo); cation exchange capacity (T); real and potential erosion (E).

IP values were expressed by cartographic units. Those values were grouped into six productive categories: very high (> 80), high (80-61), moderate (60-41), moderately low (40-31), low (30-21) and very low (< 20).

Hubert´s Hydrometeorological temporal segmentation test

Different climate scenarios

Resorting to the results of Hubert´s test for the detection of changes in rainfall regional means, several scenarios were proposed with different starting point for the macro climate conditions (H) of Productivity Index. This was determined from the global moisture index proposed by Thornthwaite (lm) (1948,1955), edaphic moisture regimes (Moscatelli, 1991; Van Wambeke and Scoppa, 1980) and the 16º C isotherme.

Those results were expressed on theme maps using QGIS v3. 10.8-A Coruña (QGIS.org 2021) software.

Results and discussion

Homogeneity test

According to the Homogeneity Test, 8 series of annual rainfall available presented a lower T value than that considered critical (Khaliq and Ouarda, 2007), estimating it was homogeneous at a significance level of α = 0,05 (Table 2). The remaining two series presented a higher T value than the one considered critical, thus being considered non- homogeneous and being discarded from the analysis.

Table2. SNHT results for annual precipitation series for districts belonging to the northwest of Buenos Aires Province and the east of La Pampa Province (* T value exceeds 95%).

	Homogeneity test		
Distric	**Change**	**T Value**	
9 de Julio	1976	9,095	
General Pico	1972	9,734	*
Pehuajó	1972	7,688	
Eduardo Castex	2019	5,412	
Trenque Lauquen	1956	5,254	
Winifreda	1968	18,682	*
Catriló	1990	7,830	
Anguil	1991	6,147	
Santa Rosa	2013	4,089	
Macachín	1928	3,593	

Table 3. Segmentations of annual precipitation series by Hubert's method (Hubert et al., 1989) for Pampa Arenosa Subregion districs.

Distric	Period	Mean	SD
9 de Julio	1921-1955	877,6	161,740
	1956-2020	1031,6	190,831
Pehuajó	1921-1983	841,5	185,388
	1984-2002	1052,4	162,273
	2003-2020	845,1	220,609
Eduardo Castex	1921-1995	639,0	184,252
	1996-2002	1033,4	236,399
	2003-2011	620,6	156,722
	2012-2012	1403,0	0,000
	2013-2020	615,6	221,538
Trenque Lauquen	1921-1962	691,6	157,988
	1963-2011	954,1	234,866
	2012-2012	1838,6	0,000
	2013-2020	713,5	179,675
Catriló	1921-1975	631,8	153,012
	1976-2002	887,2	176,724
	2003-2020	666,3	211,311
Anguil	1921-1975	578,3	145,651
	1976-1995	748,3	180,044
	1996-2002	1017,0	242,495
	2003-2020	680,5	223,331
Santa Rosa	1921-1981	577,5	166,725
	1982-2020	732,4	201,978
Macachín	1921-1989	622,1	159,567
	1990-2000	926,1	226,697
	2001-2001	1638,0	0,000
	2002-2020	645,0	203,327
Zonal	1921-1967	653,0	127,224
	1968-1995	824,5	121,147
	1996-2002	1029,2	152,132
	2003-2020	743,9	185,145
Zone BA	1921-1965	803,4	143,446
	1966-2012	1001,0	155,203
	2013-2020	822,5	140,462
Zone LP	1921-1975	596,5	135,652
	1976-2001	822,0	165,410
	2002-2020	670,1	198,900

Changes in annual rainfall mean values were detected in regions of Pampa Arenosa, using Hubert´s Hydrometeorological temporal segmentation test. Those values are recorded in Table 3.

The average of the Pampa Arenosa sub region (Zonal, Table 3) (Fig. 2) presented two successive positive abrupt changes. The first one raised the rainfall annual average from 653.0 mm, during the 1921-1967 subperiod, to 824.5 mm, during the 1968-1995 subperiod. The second positive abrupt change increased the rainfall annual average to 1029.2 mm during the 1996-2002 subperiod. It is noteworthy that since 2003, after this short six-year wet subperiod, a negative abrupt change diminished the rainfall annual average to 743.9 mm, which is a similar value to that of the 1921-1967 initial period.

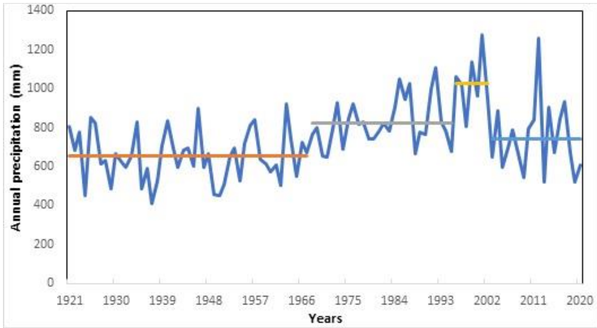

Figure 2. Annual precipitation and averages of the sub-periods defined by Hubert's segmentation, for the Pampa Arenosa Sub region for both provinces (Zonal).

The average in the Pampa Arenosa sub region (Zone BA, Table 3) (Fig. 3) showed two abrupt changes. The first one was positive, taking the rainfall annual average from 803.4 mm, during 1921-1965 subperiod, to 1001.0 mm, during the 1966-2012 period. The last abrupt change, since 2013, was negative as it reduced the rainfall annual average to 822, 5 mm, which was a slightly higher value than the one for the 1921-1965 initial period.

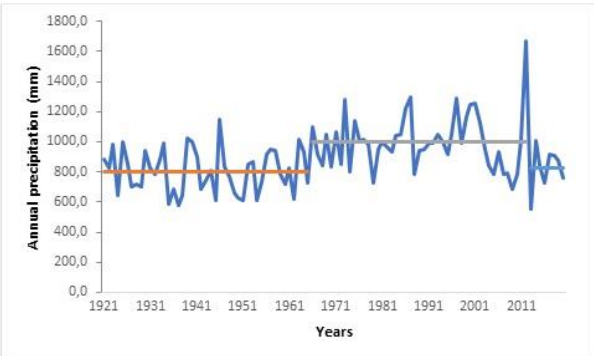

Figure 3. Annual precipitation and averages of the sub-periods defined by Hubert's segmentation, for the Pampa Arenosa Sub-region for Buenos Aires province (BA).

The average of Pampa Arenosa subregion (Zone LP, Table 3) (Fig. 4) showed two abrupt changes. The first was positive, making the rainfall annual average grow from 596.5 mm, during subperiod 1921-1975, to 822.0 mm, during the 1976-2001 period. The last abrupt change, since 2002, was negative making rainfall annual average fall to 670.1 mm.

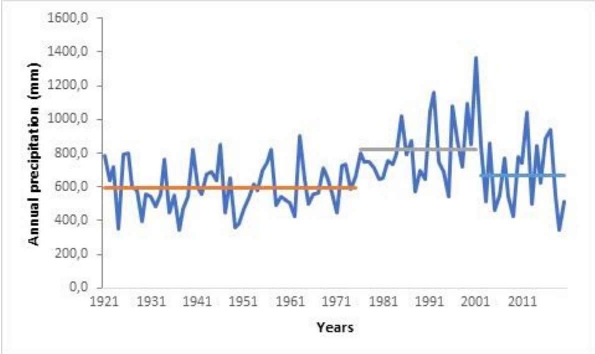

Figure 4. Annual precipitation and averages of the sub-periods defined by Hubert's segmentation, for the Pampa Arenosa Subregion for La Pampa province (BA).

Productivity Index

Segmentation results of rainfall annual series for Pampa Arenosa Sub region, using Hubert´s method, allowed defining dry and wet subperiods, for IP estimation.

Buenos Aires Province Area

Results derived from applying the Productivity Index for each soil cartographic unit in the districts selected in Buenos Aires Province are presented in Fig. 5.

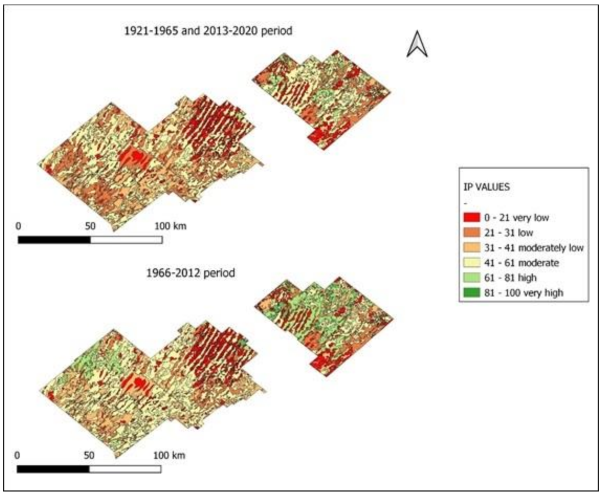

Figure 5. Productivity indices for Buenos Aires area in the different sub-periods according to Hubert's segmentation.

No differences were observed between the dry subperiods (1921-1965 and 2013-2020). All land showed IP values which were moderately low or moderate. Meanwhile, the wet subperiod (1966-2012) presented land with IP values which were high or very high.

La Pampa Province Area

Results derived from applying the Productivity Index for each soil cartographic unit in the districts selected in La Pampa Province are presented in Fig. 6.

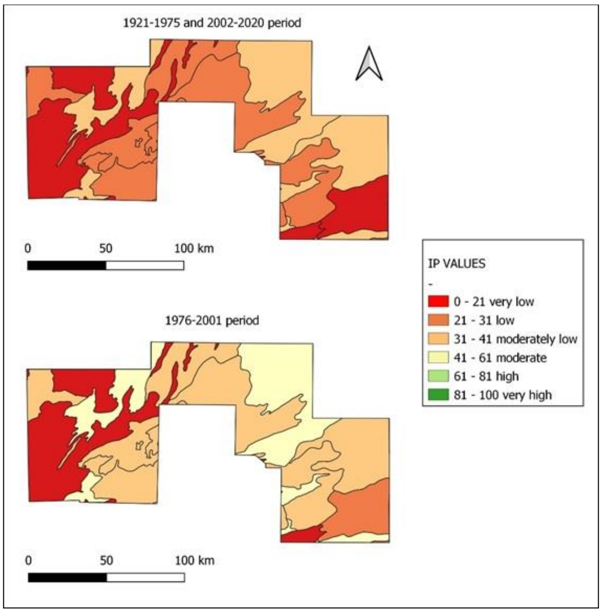

Figure 6. Productivity indices for La Pampa area in the different sub-periods according to Hubert's segmentation.

No differences were observed between the dry subperiods (1921-1975 and 2002-2020). All land showed IP values which were moderately low or moderate. Meanwhile, the wet subperiod (1976-2001) presented higher IP values.

IP values in the Pampa Arenosa Sub region rise in the presence of rain, reaching the highest values in the wet subperiod. Therefore, in the event of different climate scenarios (dry or wet subperiods) and by modifying the macroclimate factor (H), IP may be recalculated and thus assess to what extent climate variation affects land productivity (Irigoin, 2011; Pérez et al., 2011; 2019). This information is highly important as it can be relevant to explain, for example, the advance of farming area (Gessesse et al., 2022), as well as to detect thresholds that show the need to resume uses and/or management which keep soil cover.

In turn, it is necessary to highlight the importance of inherited physical factors which do not present the same temporal dynamics. Particularly, soil texture presents a permanent limiting factor regarding low moisture retention capacity (Haichao et al., 2022) and wind erosion risk in these lands. This is evident, to different extents, depending on changes in rainfall as well as uses and management (Richardson and Sadler, 2022). According to Urrutia Larrachea et al. (2022), it is frequent to observe that the different spatial composition and configuration of the current anthropogenic landscape is not related with the land potential, which may increase the risk of environmental degradation. Hence, just as in wet periods it is possible to extend farming land use in certain districts, during dry periods it is necessary to resume cattle breeding and or recovery periods that allow sustaining soil cover, avoiding wind erosion, as well as recovering physical, chemical, and biological properties to ensure productivity along time (Massobrio et al., 1993; Massobrio and Gutierrez, 1998; Massobrio et al., 2006; Barisio, 2019).

Conclusions

In the Pampa region, climate variability is represented by the succession of dry and wet periods, and their extreme phenomena have important social and economic impacts. There are natural cycles in the atmosphere affecting Pampean rainfall regime during weeks, months, and decades (Forte Lay et al., 2008; Grimm, 2011; Aliaga et al., 2016; Aliaga, 2020)

Applying Hubert´s Hydrometeorological temporal segmentation test (Hubert et al., 1989) to the annual rainfall series for the different districts in Pampa Arenosa, it was possible to observe that the area is subject to rainfall abrupt changes.

The same pattern was observed in different districts, as well as in different regions. This pattern first presented a dry phase, followed by a wet phase which, in time, became dry again. Some districts even presented rainfall values close to those observed in the initial dry phase.

The wet phase started at the beginning of the 60`s in some districts, but it was mostly noticeable in the 70`s when an increase in mean annual rainfall was observed, favouring the expansion of agriculture (Sierra et al., 1995; Solbrig and Viglizzo, 1999; Bernardos et al., 2001; Viglizzo et al., 1995, 1997, 2002, 2003; Manuel – Navarrete et al., 2009). In turn, at the beginning of the XXI century, negative abrupt changes occurred in rainfall annual media, reaching initial values in some cases. Thus, although the land farming capacity had previously increased, a significant proportion was lost, risking production and environment in the area.

This rainfall increase has caused an advance of 100 km westward in the 600 mm isohyet in relation with its medium position during the XX century (Sierra et al., 1994). Other studies relate rainfall with production (Viglizzo et al., 1997), showing a coincidence between agriculture extension and rainfall increase, particularly in drier marginal areas.

Acknowledgments

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