Chapter

Rainfall Trends in Humid Temperate Climate in South America: Possible Effects in Ecosystems of Espinal Ecoregion

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Abstract

In central Argentina, the annual rainfall regime shows increasing since the 2nd half of the 20th century. The aim of this work was to evaluate the long-term changes in the intensity of rainfall in the central-north region of Entre Ríos between 1945 and 2019, based only on daily precipitation records aggregated at yearly, monthly and seasonal levels. We used monthly rainfall data for the period 1945–2019 from 6 localities in Province of Entre Rios, Argentina. The change detection analysis has been conceded using Pettitt's test, von Neumann ratio test, Buishand's range test and standard normal homogeneity (SNH) test, while non-parametric tests including linear regression, Mann-Kendall and Spearman rho tests have been applied for trend analysis. Like the regional results, this study observed a sustained increase in monthly rainfall to the breaking point in the 1970s, but then the annual rate of increase was even higher. The average annual rainfall in the region prior to that date was 946 mm, while after the same 1150 mm, equivalent to 21.5% higher than the 1945–1977 average and 8.5% higher according to the historical average 1945–2019.

Keywords: nonparametric trend tests, climate change, natural ecosystems, biodiversity

1. Introduction

There was a general increase in air temperature worldwide during the twentieth century, albeit with some differences between the hemispheres, corresponding to global warming. Global warming affects the hydrological cycle over land, resulting in observed changes to precipitation frequency, intensity, duration and amount [1, 2]. Although significant attention is paid to how changes in seasonal and annual precipitation sums affect ecosystems, relatively less is known about the ecological impacts of heavy rainfall events [3]. The evaluation of past trends of meteorological parameters at various spatial and temporal scales plays a crucial role in understanding climate change and its impact on food security, energy security, natural resource management, and sustainable development [4, 5]. Detailed analysis of rainfall trend is useful to rainfall forecasting, planning water resources development and management, designing water storage structures, irrigation practices and crop choices, drinking water supply, industrial development, and disaster management for current and future climatic conditions [6, 7].

The analysis of different global rainfall databases shows a change in an anomaly that was positive between 1950 and 1980 and became negative later [8]. While some studies show increasing rainfall, in other regions the evaluations show the opposite results. For instance, in Europe, the rain series show an increase in annual precipitation between 1940 and 1990 [9]. The climate of Italy, in turn, seems to be warmer and drier at the moment with a decrease in rainfall attributed to a reduction in the number of days of rain, as rainfall intensity shows a positive trend [10]. In different regions of South America somethings similar happens and has been studied by several authors. More recently [11] studied summer precipitation variability over Southeastern South America in a global warming scenario.

In central Argentina, the annual rainfall regime shows increasing rates from approximately the 1940s until the end of the century [12–14] with statistical and spectral analysis show that there is significant evidence that rainfall has increased in central Argentina since the 2nd half of the 20th century [15] analyzed breakpoints in annual rainfall trends in Córdoba, Argentina in the period 1930–2006, they observed from negative to positive in the 1950s in the north area of the region, while in the other areas the opposite change occurs in the 1970s. From the mid-1970s, a sharp increase in rainfall regime provided most of the area with a supply of moisture higher than previously reported [16–19]. Recently results in changes annual rainfall in five sub-regions of the Argentine Pampa Region indicate that the Western Pampas are more vulnerable to abrupt changes than the Eastern Pampas [20]. While different indicators in central Argentina reflect a change for precipitation at some sites, the intensity and variability of rainfall show significant long-term trends [21]. The rainfall cycle hypothesis has been supported by recent studies showing an abrupt negative change in the water regime of Pampas Region in recent years [17, 18] as well as by studies linking changes in rainfall with regular or recurring oceanic indices [19–21].

A strong increase in agricultural activity in central of Argentina [22] is a possible cause that would explain the climate change. The central-north region of Entre Ríos (Argentina) had a strong fragmentation of the landscape due to deforestation [23]. These changes are environmentally and economically important, as they have a direct impact on hydrological and soil resources, as well as on the agricultural potential of the region. The central-north of Entre Ríos has a humid temperature climate, Cf in the Koppen-Geiger classification, as revised by [24]. In this way, the Pampa Region (where the province of Entre Rios is located) receives sea winds throughout the year, with a moisture gradient decreasing from east to west [20].

The statistical trend detection in climatic variables and precipitation time series is one of the interesting research areas in climatology and hydrology as it impacts spatial and temporal distribution of water availability across the globe [25]. The parametric or non-parametric method under statistical approach is used to detect if either a data of a given set follows a distribution or has a trend on a fixed level of significance. Various non-parametric tests, including Mann-Kendall test and Pettit's test, are widely used to detect trend and change point in historical series of climatic and hydrological variables [26–28]. To understand the magnitude of trends many techniques have been proposed in the past, including t-tests [29, 30], Mann–Whitney and Pettitt's tests [31] and standard normal homogeneity test [32, 33].

The aim of this work was to evaluate the long-term changes in the intensity of rainfall in the central-north region of Entre Ríos between 1945 and 2019, based only on daily precipitation records aggregated at yearly, monthly and seasonal levels. In more specific terms, the quality of the rainfall series is first analyzed in terms of its homogeneity to assess the reliability of the meteorological information used.

Secondly, the existence of a trend in the indicators of the intensity and variability of rainfall is evaluated during a period showing a generalized increase in atmospheric temperature. Finally, the occurrence of a breakpoint that expresses a long-term trend change in the annual rainfall series in the region is assessed.

2. Material and methods

2.1 Region of study and rainfall data

We used monthly rainfall data for the period 1945–2019 from 6 localities (**Figure 1** and **Table 1**) in the southern of department La Paz (Province of Entre Rios, Argentina): Hasenkamp (HAS), Las Garzas (LGA), Alcaraz Norte (ALN), Bovril (BOV), Hernandarias (HER), El Solar (ELS). This data were collected with

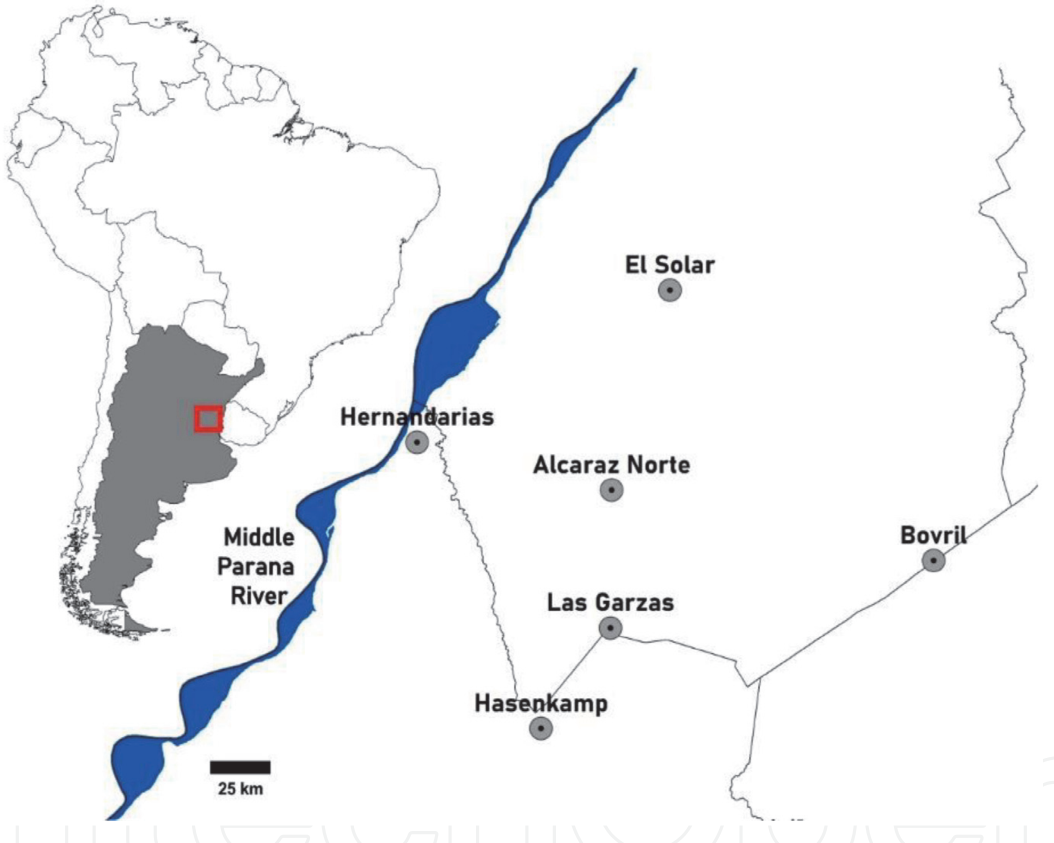

Figure 1.
Location map of southern of department La Paz (province of Entre Rios, Argentina) with localities analyzed.

Meteorological station		Latitude	Longitude	Altitude (m a.s.l)	Period and Entirety (%)
Hasenkamp	HAS	31°30′32.94"S	59°50′9.37"W	88	1945–2019 (93.8%)
Las Garzas	LGA	31°25′43.54"S	59°44′36.09"W	82	1945–2019 (100%)
Alcaraz Norte	ALN	31°19′37.49"S	59°45′15.88"W	68	1945–2019 (98.3%)
Bovril	BOV	31°20′26.89"S	59°26′30.97"W	79	1945–2019 (94.5%)
Hernandarias	HER	31°13′51.34"S	59°59′10.35"W	52	1945–2019 (96.5%)
El Solar	ELS	31°10′32.96"S	59°43′56.73"W	50	1945–2019 (99.2%)

Table 1.
Meteorological station used and the period analyzed.

conventional rain gauges, from the official records of Hydraulic Directorate (Direccion Hidraulica de Entre Rios, in spanish) and Cereal Bag (Bolsa de Cereales de Entre Rios, in spanish) of the Province of Entre Rios.

The data from the 6 locations was subjected to a process of quality control for possible errors. All data above the third quartile plus three times the interquartile range and located more than five standard deviations from the mean was treated as outliers. These outliers were then contrasted climatographically with readings from nearby stations. If the same reading was labeled as out of range for more than two seasons, the value was correct. Months classed as outliers and those without data were treated as gaps. Both types of gaps were filled but no missing data was completed if there were more than three gaps in one year.

Stations with missing data techniques linear regression were used. The filling of missing data by the linear regression technique consisted in using data from neighboring stations that presented coefficients of significant linear correlations with the station to be used in the study [34, 35],

$$P_x = a_o + \sum_{i=1}^{n} a_i P_i \quad (1)$$

where a_o and a_i are the coeffcients of adjustment of the linear model, obtained in the processing of correlation. In this case, stations that presented an R^2 greater than 0.90 were included. The two techniques are widely used to fill gaps in historical series and present low average deviations suitable for climatic studies on monthly and seasonal scales [36].

After the treatment of the time series, the monthly values of all rainfall stations were grouped into scales, according to the following definitions: a) autumn (March, April, and May), b) winter (June, July, and August), c) spring (September, October, and November), and d) summer (December, January, and February). For selecting the change point for a particular parameter, the method presented below has been used [37]: a) no change point or homogeneous (HG), series may be considered as homogeneous, if no or one test out of four tests rejects the null hypothesis at 5% significant level; b) doubtful series (DF), series may be considered as inhomogeneous and critically evaluated before further analysis if two out of four tests reject the null hypothesis at 5% significant level; and c) change point or inhomogeneous (CP) when series may has change point or be inhomogeneous in nature, if more than two tests reject the null hypothesis at 5% significant level.

2.2 Homogeneity tests for change point detection

Homogeneity testing is very crucial in climatological studies to represent the real variations in weather and climate. Inhomogeneity occurs in climate data due to several reasons including instrumentation error, changes in the adjacent areas of the instrument, and mishandling of the human. If the homogeneity is not tested prior to trend analysis, the results will indicate erroneous trends. In this study, the absolute homogeneity tests were performed on individual station records and calculating the ratio of observed series to the reference series. Four widely used statistical tests mentioned below were applied to the data to test for homogeneity. All the following four tests used in this study assume the null hypothesis of data being homogeneous. The change point detection is an important aspect to assess the period from where significant change has occurred in a time series. Pettitt's test, von Neumann ratio test, Buishand range test and standard normal homogeneity tests have been applied for change point detection in climatic series. The details of various change point tests applied in the study are presented here.

2.2.1 Pettitt's test

The Pettitt's test for change detection, developed by [38], is a non-parametric test, which is useful for evaluating the occurrence of abrupt changes in climatic records [39, 40] because its sensitivity. According to Pettitt's test, if $x_1, x_2, x_3, \dots x_n$ is a series of observed data which has a change point at t in such a way that $x_1, x_2 \dots, x_t$ has a distribution function $F_1(x)$ which is different from the distribution function $F_2(x)$ of the second part of the series $x_{t+1}, x_{t+2}, x_{t+3} \dots, x_n$. The non-parametric test statistics U_t for this test may be described as follows:

$$U_t = \sum_{i=1}^{t} \sum_{j=t+1}^{n} sign(x_t - x_j) \tag{2}$$

$$sign(x_t - x_j) = \begin{bmatrix} 1, & if\,(x_i - x_j) > 0 \\ 0, & if\,(x_i - x_j) = 0 \\ -1, & if\,(x_i - x_j) < 0 \end{bmatrix} \tag{3}$$

The test statistic K and the associated confidence level (ρ) for the sample length (n) may be described as:

$$K = Max|U_t| \tag{4}$$

$$\rho = \exp\left(\frac{-K}{n^2 + n^3}\right) \tag{5}$$

When ρ is smaller than the specific confidence level, the null hypothesis is rejected. The approximate significance probability (p) for a change-point is defined as given below:

$$p = 1 - \rho \tag{6}$$

The test statistic K can also be compared with standard values at different confidence level for detection of change point in a series. The critical values of K at 1 and 5% confidence levels for different tests used in the analysis has been presented in **Table 2** [37].

2.2.2 von Neumann ratio test

The von Neumann ratio test has been described by [41, 42] and others. The test statistics for change point detection in a series of observations $x_1, x_2, x_3 \dots x_n$ can be described as:

Number of observation	Critical values for test statistic at different significance level							
	Pettit Test		SNHT		Buishand Range test		Von Neumann Ratio Test	
	1%	5%	1%	5%	1%	5%	1%	5%
50	293	235	11.38	8.45	1.78	1.55	1.36	1.54
70	488	393	11.89	8.80	1.81	1.59	1.45	1.61
100	841	677	12.32	9.15	1.86	1.62	1.54	1.67

Table 2.
Critical values of test statistics for different change point detections tests.

$$N = \frac{\sum_{i=1}^{n-1} (x_i - x_{i-1})^2}{\sum_{i=1}^{n-1} (x_i - \overline{x})^2} \tag{7}$$

According to this test, if the sample or series is homogeneous, then the expected value $E(N)$ = 2 under the null hypothesis with constant mean. When the sample has a break, then the value of N must be lower than 2, otherwise we can imply that the sample has rapid variation in the mean. The critical values of N at 1 and 5% confidence levels given in **Table 2** can be used for identification of non-homogeneous series with change point.

2.2.3 Buishand's range test

The adjusted partial sum (S_k), that is the cumulative deviation from mean for kth observation of a series $x_1, x_2, x_3. \dots x_k. \dots x_n$ with mean ($\overline{x}$) can be computed using following equation:

$$S_k = \sum_{i=1}^{k} (x_i - \overline{x}) \tag{8}$$

A series may be homogeneous without any change point if $S_{k\sim}$ 0, because in random series, the deviation from mean will be distributed on both sides of the mean of the series. The significance of shift can be evaluated by computing rescales adjusted range (R) using the following equation:

$$R = \frac{Max(S_k) - Min(S_k)}{\overline{x}} \tag{9}$$

The computed value of $R/\sqrt{n}$ is compared with critical values given by [37, 41] and has been used for detection of possible change (**Table 2**).

2.2.4 Standard normal homogeneity (SNH) test

The test statistic (T_k) is used to compare the mean of first n observations with the mean of the remaining (n-k) observations with n data points [32].

$$T_k = kZ_1^2 + (n-k)Z_2^2 \tag{10}$$

$Z_1$and Z_2 can be computed as:

$$Z_1 = \frac{1}{k} \sum_{i=1}^{k} \frac{(x_i - \overline{x})}{\sigma x} \tag{11}$$

$$Z_2 = \frac{1}{n-k} \sum_{i=k+1}^{k} \frac{(x_i - \overline{x})}{\sigma x} \tag{12}$$

where, $\overline{x}$ and σx are the mean and standard deviation of the series. The year k can be considered as change point and consist a break where the value of T_k attains the maximum value. To reject the null hypothesis, the test statistic should be greater than the critical value, which depends on the sample size (n) given in **Table 2**.

2.3 Test for trend analysis

All the trend tests in this section assume the null hypothesis of no trend and the alternative hypothesis of monotonic increasing or decreasing trend existence. When the time series are serially independent, the Mann–Kendall test [43, 44] and Spearman's Rho test [45, 46] were applied to test for trends. The magnitude of the trend was estimated using Sen's slope method [47]. Always suggested to apply various statistical tests to analyze the trends in serially correlated data.

2.3.1 Mann-Kendall test

The Mann–Kendall test is a nonparametric test for monotonic trend detection. It does not assume the data to be normally distributed and is flexible to outliers in the data. The test assumes a null hypothesis, H_0, of no trend and alternate hypothesis, H_a, of increasing or decreasing monotonic trend. For a time series $X_i = x_1, x_2, \dots, x_n$, the Mann–Kendall test statistic S is calculated as

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign\left(x_j - x_i\right) \tag{13}$$

where n is the number of data points, x_i and x_j are the data values in timeseries i and j $(j > i)$, respectively, and $sign\left(x_j - x_i\right)$ is the sign function as

$$sign\left(x_i - x_j\right) = \begin{bmatrix} 1, & if\left(x_j - x_i\right) > 0 \\ 0, & if\left(x_j - x_i\right) = 0 \\ -1, & if\left(x_j - x_i\right) < 0 \end{bmatrix} \tag{14}$$

Statistics S is normally distributed with parameters $E(S)$ and variance $V(S)$ as given below:

$$E(S) = 0 \tag{15}$$

$$V(S) = \frac{n(n-1)(2n+5) - \sum_{k=1}^{m} t_k(k)(k-1)(2k+5)}{18} \tag{16}$$

where n is the number of data points, m is the number of tied groups, and t_k denotes the number of ties of extent k. Standardized test statistic Z is calculated using the formula below.

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{var(S)}} & if\ S > 0 \\ 0 & if\ S = 0 \\ \dfrac{S+1}{\sqrt{var(S)}} & if\ S < 0 \end{cases} \tag{17}$$

To test for a monotonic trend at an α significance level, the alternate hypothesis of trend is accepted if the absolute value of standardized test statistic Z is greater than the $Z_{1-\alpha/2}$ value obtained from the standard normal cumulative distribution Tables. A positive sign of the test statistic indicates an increasing trend and a negative sign indicates a decreasing trend.

2.3.2 Spearman's rho test

The Spearman's rho test is a non-parametric widely used for studying populations that take on a ranked order. If there is no trend and all observations are independent, then all rank orderings are equally likely. In this test, the difference between order and rank (d_i) for all observations $x_1, x_2, x_3, \ldots x_n$ can be used to compute and Spearman's ρ, variance $Var(\rho)$ and test statistic (Z) using following equations. The null hypothesis is tested in this test considering the statistic is normally distributed.

$$\rho = 1 - \frac{6\sum d_i^2}{n(n-1)} \tag{18}$$

$$Var(\rho) = \frac{1}{(n-1)} \tag{19}$$

$$Z = \frac{\rho}{\sqrt{Var(\rho)}} \tag{20}$$

3. Results and discussion

Tables 3–8 show the results of the statistical analyzes carried out to know the point of change in monthly, seasonal and annual rainfall in each locality. A marked variability was observed in the months that changed significantly between the localities, fundamentally from January to May, even though the proximity between them does not exceed 40 km. This means, a priori and in subjective terms, that the climatic changes reported worldwide have a direct influence on a microspatial scale, as well as on the temporal window. However, in the region there was no heterogeneity in the breaking point between the localities evaluated for the months of November and December during the study period analyzed.

In relation to the statistical tests used, it is possible to conclude that the Von Neumman's test is more robust when establishing the heterogeneity of the time series, while the Standard Normal Homogeneity test a priori would require less demand from the variability of the time series. to set a breaking point. Based on the results of the SNH Test, it is observed that the month of May presents marked heterogeneity in all localities, but the year that defines the point of change differs significantly. When comparing and analyzing all the tests for each period of time, only Las Garzas and Hernandarias present a significant, but doubtful point of change in the year that followed.

In seasonal analysis, summer is the season of the year that presented marked heterogeneity in the time series in all localities. The year of break point was different by location. However, El Solar and Hernandarias presented significant modifications in the heterogeneity of the time series with breaking points during the 1970s and 1980s, respectively. Both locations are adjacent to the Middle Paraná River, a situation that could be influenced by local atmospheric conditions [48]. There is even greater concern today about the future of rivers worldwide due to a multitude of stressors that impact running waters including climate change [49]. We draw on the growing literature related to climate change to illustrate potential impacts rivers may experience and management options for protecting riverine ecosystems and the goods and services they provide. Regional patterns in precipitation and temperature are predicted to change and these changes have the potential to alter natural flow regimes. One of the key ways in which climate change or other stressors affect river ecosystems is by causing changes in river flow. Rivers vary geographically

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Period	Standard Normal Homogeneity Test				Pettitt's test				Buishand Range test				von Neumann's test		
	T	*p*	*sig*	k	U*	*p*	*sig*	k	R/sqrt(n)	p	*sig*	k	Statistic	*p*	*sig*
JAN	13.94	0.003	**	2018	241	0.885	ns	1958	1.047	0.591	ns	1958	1.374	0.170	ns
FEB	7.55	0.104	ns	1976	504	0.057	**	1976	1.513	0.082	***	1976	−0.373	0.795	ns
MAR	4.44	0.427	ns	1949	218	1.026	ns	1990	0.713	0.969	ns	2007	0.704	0.482	ns
APR	5.23	0.309	ns	1978	500	0.060	**	1978	1.233	0.319	ns	1978	−0.457	0.648	ns
MAY	15.32	0.002	**	2009	448	0.120	ns	1980	1.565	0.061	***	1980	0.311	0.756	ns
JUN	2.42	0.843	ns	2006	316	0.493	ns	1986	0.844	0.871	ns	1974	−1.098	0.272	ns
JUL	1.59	0.968	ns	1968	238	0.903	ns	1987	0.876	0.833	ns	1968	−0.589	0.556	ns
AUG	11.01	0.018	**	2014	198	1.154	ns	2014	0.873	0.845	ns	2014	1.208	0.227	ns
SEP	1.77	0.949	ns	1988	257	0.792	ns	1988	1.036	0.608	ns	1985	−0.039	0.969	ns
OCT	3.49	0.613	ns	1955	526	0.041	**	1982	0.953	0.737	ns	1983	−1.414	0.157	ns
NOV	13.17	0.005	**	1976	740	0.001	**	1976	1.964	0.003	**	1976	−1.993	0.046	**
DEC	8.73	0.056	*	1988	494	0.065	**	1986	1.455	0.116	ns	1988	−0.116	0.908	ns
Summer	10.78	0.020	*	1976	564	0.023	**	1976	1.624	0.044	*	1976	−0.592	0.554	ns
Autumn	6.37	0.186	ns	1997	465	0.096	ns	1974	1.348	0.196	ns	1974	1.519	0.129	ns
Winter	2.74	0.775	ns	2016	172	1.320	ns	1986	0.896	0.814	ns	1986	−0.219	0.826	ns
Spring	4.40	0.438	ns	1977	520	0.045	**	1977	1.106	0.498	ns	1977	−0.404	0.686	ns
Annual	12.92	0.006	**	1977	668	0.004	**	1976	1.784	0.016	*	1977	−0.959	0.338	ns

*References: k: year to shift, sig: * 0.05%, ** 0.01%, *** 0,1%, ns: no signification.*

Table 3.
Results of change point analysis with all test used in Las Garzas location.

Period	Standard Normal Homogeneity Test				Pettitt's test				Buishand Range test				von Neumann's test		
	T	*p*	*sig*	k	U*	*p*	*sig*	k	R/sqrt(n)	p	*sig*	k	Statistic	*p*	*sig*
JAN	16.42	0.000	**	2018	192	1.192	ns	1959	1.009	0.646	ns	1994	1.121	0.262	ns
FEB	5.42	0.282	ns	2006	416	0.176	ns	2002	1.208	0.349	ns	1980	0.709	0.478	ns
MAR	4.11	0.487	ns	2019	221	1.008	ns	1993	0.633	0.993	ns	2007	2.081	0.037	*
APR	5.07	0.333	ns	2015	524	0.042	**	1978	0.965	0.713	ns	1978	−0.526	0.599	ns
MAY	10.37	0.002	**	2017	460	0.103	ns	1973	1.452	0.119	ns	1982	0.849	0.396	ns
JUN	3.11	0.695	ns	2006	320	0.475	ns	1986	1.059	0.572	ns	1975	−1.320	0.187	ns
JUL	1.74	0.949	ns	1948	357	0.334	ns	1988	0.903	0.805	ns	1987	−0.568	0.570	ns
AUG	10.54	0.020	**	2014	172	1.320	ns	2014	0.868	0.847	ns	2014	0.682	0.495	ns
SEP	2.08	0.901	ns	1988	267	0.730	ns	2006	1.036	0.610	ns	1988	0.365	0.715	ns
OCT	2.85	0.754	ns	2010	331	0.430	ns	1999	1.273	0.269	ns	2000	−0.135	0.892	ns
NOV	14.39	0.003	**	1976	718	0.001	**	1976	2.098	0.001	**	1976	−1.983	0.047	*
DEC	7.65	0.101	ns	1976	453	0.112	ns	1976	1.368	0.179	ns	1976	−1.802	0.072	***
Summer	8.85	0.532	*	2004	518	0.046	**	1976	1.464	0.110	ns	1976	−0.357	0.721	ns
Autumn	4.73	0.386	ns	1979	391	0.234	ns	1979	1.143	0.442	ns	1979	1.833	0.067	***
Winter	2.92	0.732	ns	1948	200	1.141	ns	1955	0.880	0.831	ns	1955	−1.339	0.181	ns
Spring	6.93	0.143	ns	2010	400	0.212	ns	1977	1.049	0.591	ns	1999	−0.273	0.785	ns
Annual	10.05	0.003	**	1977	582	0.017	**	1977	1.574	0.057	*	1977	−0.373	0.709	ns

*References: k: year to shift, sig: * 0.05%, ** 0.01%, *** 0,1%, ns: no signification.*

Table 4.
Results of change point analysis with all test used in Alcaraz Norte location.

Period	Standard Normal Homogeneity Test				Pettitt's test				Buishand Range test				von Neumann's test		
	T	*p*	*sig*	k	U*	*p*	*sig*	k	R/sqrt(n)	p	*sig*	k	Statistic	*p*	*sig*
JAN	11.30	0.015	**	2016	199	1.147	ns	1958	0.958	0.721	ns	1958	2.039	0.041	**
FEB	7.17	0.125	ns	2009	477	0.082	***	1999	1.291	0.248	ns	1980	−0.577	0.564	ns
MAR	3.80	0.547	ns	1949	199	1.147	ns	1980	0.721	0.968	ns	1949	2.246	0.025	*
APR	3.56	0.595	ns	1998	442	0.128	**	1978	1.138	0.447	ns	1978	−1.101	0.271	ns
MAY	10.85	0.019	**	2017	392	0.231	ns	1979	1.195	0.366	ns	1979	0.061	0.952	ns
JUN	2.66	0.792	ns	2006	253	0.815	ns	2006	0.959	0.723	ns	1973	−1.321	0.186	ns
JUL	4.19	0.468	ns	1978	400	0.212	ns	1987	1.265	0.283	ns	1978	−0.339	0.735	ns
AUG	12.68	0.006	**	2014	248	0.844	ns	1982	0.927	0.765	ns	2013	1.756	0.079	***
SEP	2.27	0.868	ns	1956	358	0.331	ns	1985	1.192	0.366	ns	1985	−0.926	0.354	ns
OCT	3.19	0.678	ns	1989	447	0.121	ns	1983	1.253	0.291	ns	1989	−1.270	0.204	ns
NOV	9.08	0.051	**	1992	586	0.015	**	1992	1.592	0.051	**	1977	−1.745	0.081	***
DEC	8.09	0.080	***	1989	496	0.063	***	1989	1.394	0.155	ns	1989	−0.765	0.444	ns
Summer	7.58	0.103	*	2008	516	0.048	**	1995	1.236	0.319	ns	1989	−0.248	0.808	ns
Autumn	4.04	0.510	ns	1997	452	0.114	ns	1989	1.040	0.596	ns	1989	0.275	0.784	ns
Winter	3.08	0.711	ns	1968	234	0.927	ns	1968	1.250	0.302	ns	1970	−0.259	0.796	ns
Spring	5.61	0.258	ns	1999	480	0.079	***	1992	1.305	0.232	ns	1922	−1.277	0.202	ns
Annual	10.24	0.026	**	1999	598	0.013	**	1997	1.453	0.118	ns	1997	−0.766	0.443	ns

*References: k: year to shift, sig: * 0.05%, ** 0.01%, *** 0,1%, ns: no signification.*

Table 5.
Results of change point analysis with all test used in Bovril location.

Period	Standard Normal Homogeneity Test				Pettitt's test				Buishand Range test				von Neumann's test		
	T	*p*	*sig*	k	U*	*p*	*sig*	k	R/sqrt(n)	p	*sig*	k	Statistic	*p*	*sig*
JAN	11.12	0.015	**	2018	254	0.809	ns	1961	1.085	0.532	ns	1958	1.501	0.133	ns
FEB	6.49	0.176	ns	1976	466	0.095	ns	1976	1.422	0.138	ns	1976	−0.291	0.771	ns
MAR	3.77	0.559	ns	2014	273	0.703	ns	1980	0.846	0.875	ns	2007	1.047	0.295	ns
APR	5.16	0.319	ns	1980	481	0.078	***	1978	1.302	0.237	ns	1980	−0.112	0.911	ns
MAY	14.09	0.003	**	2012	318	0.484	ns	1973	1.154	0.421	ns	2009	0.180	0.858	ns
JUN	2.55	0.815	ns	2006	416	0.176	ns	1982	0.939	0.750	ns	1982	−0.378	0.705	ns
JUL	1.34	0.985	ns	1958	195	1.173	ns	1988	0.984	0.692	ns	1968	0.160	0.873	ns
AUG	9.86	0.037	*	2014	177	1.288	ns	2014	0.841	0.877	ns	2014	1.410	0.159	ns
SEP	1.68	0.955	ns	1985	220	1.014	ns	1988	0.945	0.746	ns	1985	0.190	0.849	ns
OCT	3.90	0.537	ns	1988	504	0.057	***	1988	1.023	0.623	ns	1988	−1.550	0.121	ns
NOV	8.98	0.049	*	1975	581	0.018	**	1975	1.710	0.024	*	1976	−1.842	0.065	*
DEC	7.58	0.102	ns	2001	403	0.205	ns	1986	1.353	0.197	ns	1988	0.281	0.779	ns
Summer	7.74	0.098	***	2004	492	0.067	*	1995	1.252	0.295	ns	1980	0.302	0.763	ns
Autumn	5.24	0.309	ns	1969	435	0.141	ns	1969	1.162	0.412	ns	1969	0.943	0.346	ns
Winter	2.21	0.880	ns	2016	177	1.289	ns	1986	0.901	0.808	ns	1986	−0.193	0.847	ns
Spring	4.18	0.480	ns	1955	468	0.092	***	1988	1.001	0.664	ns	1976	−0.874	0.382	ns
Annual	12.83	0.006	**	1997	652	0.005	**	1997	1.635	0.041	*	1997	−1.063	0.288	ns

*References: k: year to shift, sig: * 0.05%, ** 0.01%, *** 0,1%, ns: no signification.*

Table 6.
Results of change point analysis with all test used in Hasenkamp location.

Period	Standard Normal Homogeneity Test				Pettitt's test				Buishand Range test				von Neumann's test		
	T	*p*	*sig*	k	U*	*p*	*sig*	k	R/sqrt(n)	p	*sig*	k	Statistic	*p*	*sig*
JAN	19.16	0.000	**	2018	214	1.052	ns	2006	1.148	0.440	ns	2006	0.643	0.520	ns
FEB	9.30	0.044	*	2009	401	0.209	ns	2004	1.200	0.368	ns	2004	−0.187	0.852	ns
MAR	3.85	0.539	ns	1949	190	1.205	ns	1949	0.851	0.866	ns	2007	0.688	0.491	ns
APR	8.29	0.071	***	1980	610	0.011	**	1978	1.501	0.087	***	1980	−0.832	0.405	ns
MAY	12.21	0.010	**	2017	418	0.172	ns	1973	1.279	0.264	ns	1973	0.895	0.371	ns
JUN	2.49	0.827	ns	2006	255	0.803	ns	2006	1.036	0.612	ns	2006	−1.626	0.104	ns
JUL	2.89	0.738	ns	2002	291	0.609	ns	1987	1.045	0.596	ns	2002	−0.234	0.815	ns
AUG	13.44	0.004	**	2014	234	0.927	ns	1984	1.096	0.509	ns	1999	0.561	0.575	ns
SEP	2.36	0.853	ns	1986	295	0.590	ns	1988	1.097	0.509	ns	1986	−1.232	0.218	ns
OCT	3.98	0.516	ns	2000	422	0.164	ns	1982	1.179	0.387	ns	2000	−0.719	0.472	ns
NOV	8.75	0.059	*	1985	560	0.025	*	1985	1.657	0.034	*	1985	−1.415	0.157	ns
DEC	15.81	0.001	**	1989	689	0.003	**	1989	1.948	0.004	**	1989	−1.264	0.206	ns
Summer	15.53	0.001	**	2004	528	0.040	*	1995	1.636	0.042	*	2004	−0.684	0.494	ns
Autumn	8.14	0.081	***	1979	568	0.022	*	1979	1.453	0.114	ns	1979	0.138	0.890	ns
Winter	2.65	0.794	ns	1997	249	0.838	ns	1997	0.977	0.699	ns	1997	−0.841	0.400	ns
Spring	5.89	0.232	ns	1999	481	0.078	ns	1982	1.198	0.356	ns	1983	0.204	0.839	ns
Annual	18.45	0.000	**	1999	767	0.001	**	1982	1.976	0.002	**	1982	−2.087	0.037	*

*References: k: year to shift, sig: * 0.05%, ** 0.01%, *** 0,1%, ns: no signification.*

Table 7.
Results of change point analysis with all test used in El solar location.

Period	Standard Normal Homogeneity Test				Pettitt's test				Buishand Range test				von Neumann's test		
	T	*p*	*sig*	k	U*	*p*	*sig*	k	R/sqrt(n)	p	*sig*	k	Statistic	*p*	*sig*
JAN	23.28	0.001	**	2018	186	1.231	ns	1985	1.036	0.604	ns	2018	0.577	0.564	ns
FEB	7.11	0.129	ns	2009	326	0.450	ns	2004	1.101	0.506	ns	2006	−0.253	0.800	ns
MAR	4.03	0.505	ns	1949	198	1.154	ns	1949	0.943	0.739	ns	1949	1.060	0.289	ns
APR	8.36	0.071	***	1978	614	0.010	**	1978	1.474	0.103	ns	1978	−1.744	0.081	***
MAY	13.67	0.004	**	2017	488	0.071	***	1973	1.421	0.136	ns	1980	−0.274	0.784	ns
JUN	2.75	0.773	ns	2006	341	0.391	ns	1986	0.914	0.776	ns	1974	−1.571	0.116	ns
JUL	2.18	0.086	***	1948	331	0.430	ns	1988	1.024	0.624	ns	1988	−0.425	0.671	ns
AUG	9.98	0.028	*	2014	241	0.885	ns	1966	0.900	0.804	ns	1966	0.447	0.655	ns
SEP	1.24	0.989	ns	1988	307	0.533	ns	1999	0.982	0.683	ns	1988	−1.191	0.234	ns
OCT	4.58	0.407	ns	1983	527	0.041	*	1982	1.343	0.201	ns	1983	−1.700	0.089	***
NOV	13.09	0.004	**	1977	712	0.002	**	1977	2.001	0.002	**	1977	−2.878	0.004	**
DEC	10.00	0.030	*	1996	525	0.042	*	1989	1.542	0.068	***	1989	−0.550	0.583	ns
Summer	10.85	0.018	*	2018	408	0.193	ns	1995	1.193	0.377	ns	1975	0.212	0.832	ns
Autumn	9.16	0.048	*	1985	629	0.008	**	1985	1.535	0.073	***	1985	−0.357	0.721	ns
Winter	2.61	0.803	ns	1948	219	1.020	ns	1992	0.870	0.842	ns	1992	0.009	0.993	ns
Spring	7.36	0.117	ns	1999	562	0.024	*	1977	1.384	0.165	ns	1977	−1.459	0.145	ns
Annual	13.77	0.004	**	1999	636	0.007	**	1989	1.699	0.024	*	1977	−1.476	0.140	ns

*References: k: year to shift, sig: * 0.05%, ** 0.01%, *** 0,1%, ns: no signification.*

Table 8.
Results of change point analysis with all test used in Hernandarias location.

with respect to their natural flow regime and this variation is critical to the ecological integrity and health of streams and rivers and thus a great deal has been written on the topic [50, 51]. The ecological consequences and the required management responses for any given river will depend not only on the direct impacts of increased temperature. Otherwise how extensively the magnitude, frequency, timing, and duration of runoff events change relative to the historical and recent flow regime for that river, and how adaptable the aquatic and riparian species are to different degrees of alteration.

The results resume depicting the homogeneity state of different series have been presented in **Table 9** (See Supplementary Appendix with results of Test's trend). The change point analysis on long-term series in all localities has indicated that a significant change point in the annual rainfall. The breaking point occurred in 1977 for the LGA, ALC and HER locations; year 1997 for BOV and HAS; and 1982 for the ELS locality. **Figure 2** shows the average annual precipitation of all the localities evaluated in each year for the region, as well as the historical annual during the period. On the other hand, since the breaking point occurred in 1977 for most of the localities, it was established that the average annual rainfall in the region prior to that date was 946 mm, while after the same 1150 mm, equivalent to 21.5% higher than the 1945–1977 average and 8.5% higher according to the historical average 1945–2019. In addition, an important piece of information results from the linear model that made it possible to establish that the region's average rainfall increased 4.9 mm per year from 1945 to 2019.

These results are consistent with those obtained in the north of the country where the rainfall change was concentrated in a step change during the 1970s [52]. In this region, half or more of the annual rainfall trend occurred in the months of El Niño phase, with less contribution from La Niña and the neutral phases. However, in the rest of subtropical Argentina and especially south of 30°S, increased precipitation occurred mostly during months of the neutral phase of El Niño/Southern Oscillation (ENSO), with only small trends during months of El Niño and La Niña phases [53]. Accordingly, most of the annual precipitation trends since 1960 in subtropical Argentina can be accounted for by two modes. The first mode, which is positively correlated with precipitation in northern Argentina and with ENSO indices, had a steep increase in precipitation at the end of the 1970s. The second mode, which has a maximum positive correlation with annual precipitation between 30 and 40°S, had a regular positive trend starting in the early 1960s and it is correlated with the southward displacement of the South Atlantic high [53, 54]. In addition, several researchers analyzed the changes in the isohyets, showing that the rainfall regime in Argentina is subject to a positive fluctuation in the 1950s and that it reached maximum values in the 1970s [55], data that coincide with this manuscript.

Average rainfall increased, favoring the expansion of agriculture [16, 22]. This conclusion is obtained primarily because the studies of the time have been hampered by the low significance shown by statistical tests when applied to climatic data, especially precipitation. In the study region mention that one of the factors of change in precipitation is agrarian transformation and claim that the technological innovation of the sector was accompanied by a process of change in the water regime [16]. Furthermore, confirm that the expansion of agricultural structure of Entre Rios, is favored by increased precipitation, generating crops of the marginal territory.

The behavior of historical series of monthly rainfall confirm that November and December, as and summer season, have significant change point in all localities. The annual rainfall in all localities showed a significant increase such as summer season (**Table 9**). November and December showed and significant rise in contrast to the rest of months.

Period	LGA			ALN			BOV			HAS			ELS			HER		
	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
JAN	HG	—	~	HG	—	~	DF	2016	~	HG	—	~	HG	—	~	HG	—	~
FEB	DF	1976	↑	HG	—	~	HG	—	↑	HG	—	↑	HG	—	~	HG	—	~
MAR	HG	—	~	HG	—	~	HG	—	~	HG	—	~	HG	—	~	HG	—	~
APR	HG	—	¿?	HG	—	~	HG	—	~	HG	—	~	CP	1978 1980	↑	CP	1978	↑
MAY	DF	1980 2009	↑	HG	—	↑	HG	—	~	HG	—	~	HG	—	↑	DF	1973 2017	↑
JUN	HG	—	~	HG	—	~	HG	—	~	HG	—	~	HG	—	~	HG	—	~
JUL	HG	—	~	HG	—	~	HG	—	~	HG	—	~	HG	—	~	HG	—	~
AUG	HG	—	~	HG	—	~	DF	2014	~	HG	—	~	HG	—	~	HG	—	~
SEP	HG	—	~	HG	—	~	HG	—	~	HG	—	~	HG	—	~	HG	—	~
OCT	HG	—	↑	HG	—	~	HG	—	~	HG	—	↑	HG	—	~	DF	1982	↑
NOV	CP	1976	↑	CP	1976	↑	CP	1992 1997	↑	CP	1975 1976	↑	CP	1985	↑	CP	1977	↑
DEC	DF	1986 1988	↑	HG	—	↑	DF	1989	↑	HG	—	↑	CP	1989	↑	CP	1989 1996	↑
Summer	CP	1976	↑	DF	2004 1976	↑	DF	1995 2008	↑	DF	1995 2004	↑	CP	1995 2004	↑	HG	—	↑
Autumn	HG	—	↑	HG	—	~	HG	—	¿?	HG	—	↑	DF	1979	↑	CP	1985	↑
Winter	HG	—	~	HG	—	~	HG	—	~	HG	—	~	HG	—	~	HG	—	~
Spring	HG	—	↑	HG	—	~	HG	—	¿?	HG	—	↑	HG	—	↑	HG	—	↑
Annual	CP	1977	↑	CP	1977	↑	DF	1997 1999	↑	CP	1997	↑	CP	1982	↑	CP	1977 1989 1999	↑

Reference: homogeneous series (HG), change point (CP), doubtful point (DF). Trends: ~ none, ↑ increase, ↓ decrease, ¿? Doubtful.
Reference: a- Nature Serie, b- Year shift, c- Trend, LGA- Las Garzas, ALN- Alcaraz Norte, BOV- Bovril, HAS- Hasenkamp ELS- El Solar, HER- Hernandarias.

Table 9.
Results of change point detection analysis and trends of rainfall for all localities.

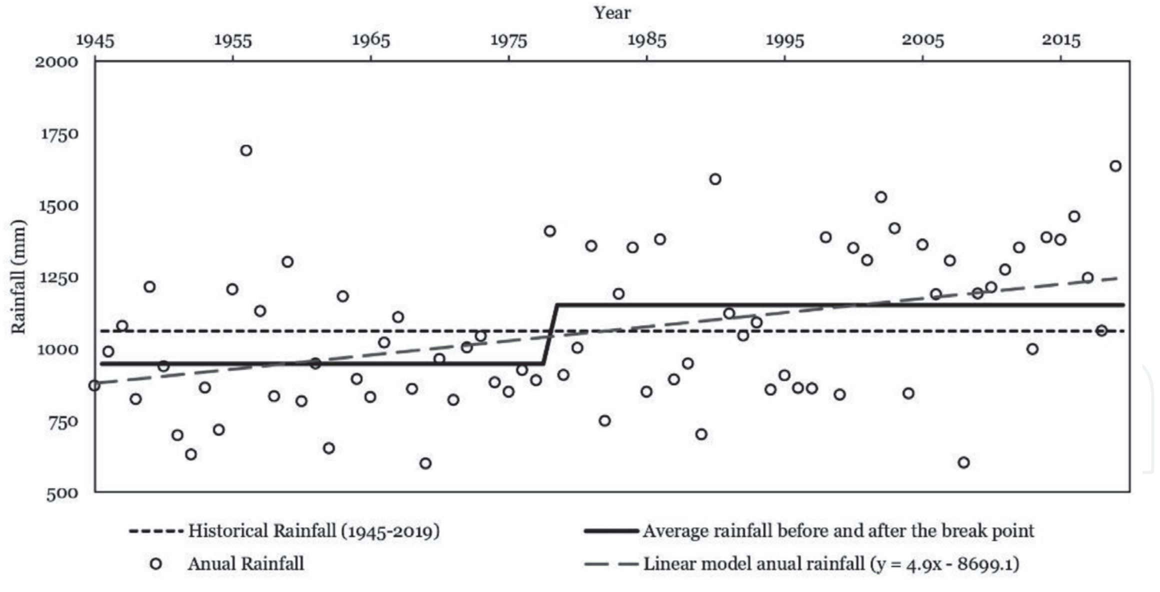

Figure 2.
Variation in the average annual rainfall of all the localities of the analyzed region.

In the last decade, a substantial change in the average climate conditions was observed in many regions of Argentina, particularly in the southern region of Mesopotamian Pampa that showed two abrupt shifts [20]. The first of these was positive, with annual average rainfall increasing from 1062.9 mm during the 1941–1999 sub-period to 1568.9 mm during a short sub-period between 2000 and 2003. The second abrupt change, which began in 2004, was negative, with average annual rainfall dropping to 1108.0 mm, only slightly higher than what it had been in the initial 1941–1999 sub-period (**Figure 3**).

Like the regional results, this study observed a sustained increase in monthly rainfall to the breaking point in the 1970s, but then the annual rate of increase was even higher. In South America [56], observed increasing trends in total annual precipitation values in Ecuador, Paraguay, Uruguay, northern Peru, southern Brazil, and northern and central Argentina. Qualitatively there was a change that indicated a significant increase in summer precipitation, and a decrease in the number of annual frosts, concentrating the winter season (July and August), assuming a "tropicalization of the region". Rainfall tropicalization can be understood as local and regional processes and impacts of climate change, which can be observed mainly by changes in the precipitation regime and the intensification of tropical climatic characteristics [57]. This process is not exclusive of Espinal Ecorregion. It has been observed in other contexts and scales in tropical and subtropical regions that show an important increase in precipitation during the rainy season in tropical regions [58, 59].

Climate change can also indirectly affect organisms by altering biotic interactions, which can have profound consequences for populations, community composition and ecosystem functions [60]. Other aspects of biodiversity management will be affected by global change and will need adapting, including wildlife exploitation, e.g. forestry [61], pest and invasive species control [62] or human and wildlife disease management [63]. Indirect effects may occur: (i) via generation of new biotic interactions, as range-shifted species appear for the first time in naive communities [64]; (ii) by removing existing interactions when species shift out of their existing range [65]; or (iii) by modulating key behavioral, physiological or other traits that mediate species interactions [66]. When climate-driven changes in biotic interactions involve keystone or foundation species, impacts can cascade through

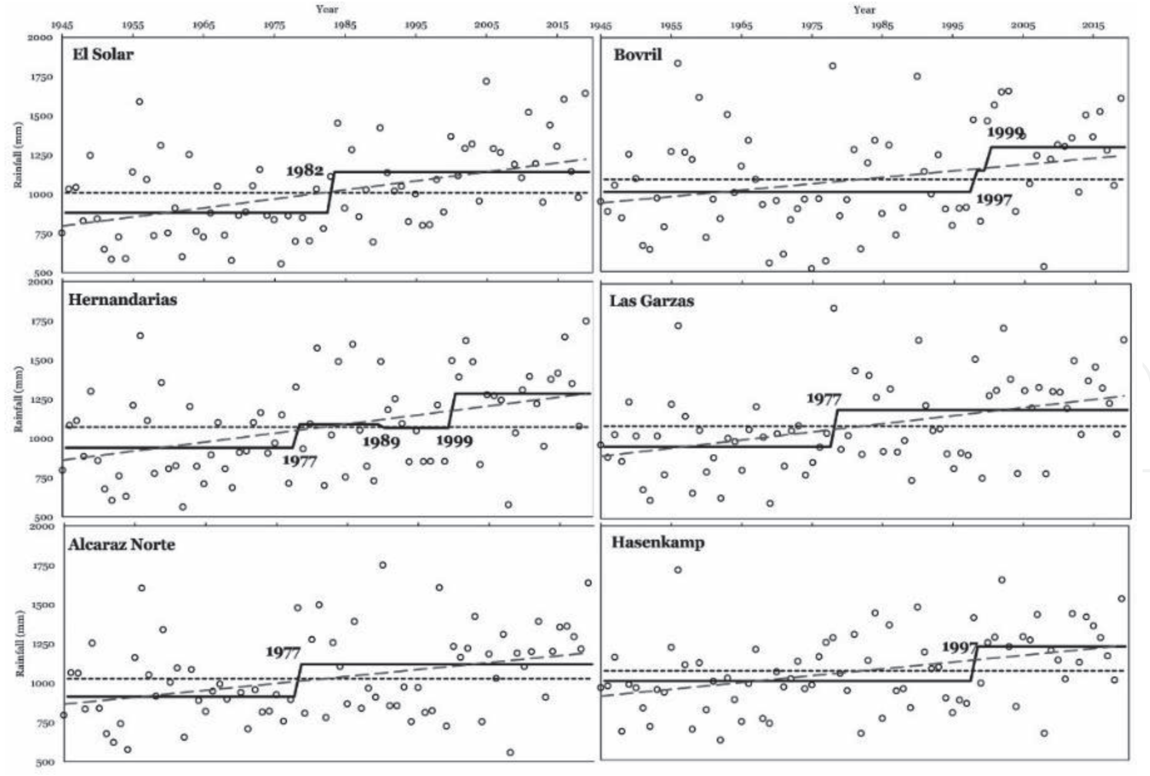

Figure 3.
Variation in the average annual rainfall in each locality of the analyzed region. Reference: Black dash line (——) show historical rainfall (1945–2019), black solid line (—) the average rainfall before and after the break point and gray dash line (——) show a linear model annual rainfall.

the associated community [61]. In this region, studies that have not yet been published for the province of Entre Ríos are showing indications of changes in the productivity of natural grasslands in native forests. Recently reports show that change the growth cycle has change in this ecosystem [67, 68], and mainly attributed to changes in precipitation regimes. These observations are like yields changes of the main crops, were the frequency of extreme weather events constitutes a growing risk.

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Conflict of interest

The authors declare no conflict of interest.

Supplementary appendix

Period	Average rainfall	Spearman's Rank Rho Test			Mann-Kendall Test				
		S	rho	p	z-value	Sen's slope	S	p	tau
JAN	121	70352	−0.001	0.995	0.041	0.008	1.000	0.967	0.004
FEB	131	50419	0.283	0.014*	2.470	1.000	541.000	0.014*	0.195
MAR	142	76056	−0.081	0.485	−0.686	−0.245	−0.015	0.493	−0.054
APR	110	54132	0.230	0.047*	1.880	0.761	0.041	0.060	0.148
MAY	68	51235	0.271	0.019*	2.360	0.576	0.057	0.018*	0.186
JUN	49	76397	−0.087	0.459	−0.778	−0.117	−0.017	0.436	−0.062
JUL	35	72477	−0.031	0.792	−0.357	−0.024	−0.790	0.721	−0.028
AUG	42	66369	0.056	0.634	0.357	0.050	0.790	0.721	0.028
SEP	69	73918	−0.051	0.661	−0.439	−0.108	−0.970	0.661	−0.349
OCT	108	52579	0.252	0.029*	2.140	0.800	0.047	0.033*	0.169
NOV	109	46105	0.344	0.002*	2.946	0.800	0.065	0.032*	0.232
DEC	106	50439	0.283	0.014*	2.402	0.891	0.526	0.016*	0.190
Summer	358	48743	0.307	0.007*	2.657	2.285	0.058	0.008*	0.209
Autumn	320	51593	0.266	0.021*	2.260	1.730	0.050	0.024*	0.178
Winter	126	69514	0.011	0.924	0.069	0.038	1.600	0.945	0.006
Spring	286	50059	0.288	0.012*	2.452	1.355	0.054	0.014*	0.193
Annual	1091	40638	0.422	0.000*	3.449	5.133	0.076	0.001*	0.272

References: (*) test with significant differences of 0.05%.

Table 1A.
Result of trend analysis rainfall at Las Garzas locality.

Period	Average rainfall	Spearman's Rank Rho Test			Mann-Kendall Test				
		S	rho	p	z-value	Sen's slope	S	p	tau
JAN	112	68775	0.022	0.853	0.297	0.154	0.660	0.766	0.024
FEB	119	56223	0.200	0.085	1.729	0.684	0.038	0.084	0.137
MAR	139	77544	−0.103	0.379	−0.883	−0.391	−0.019	0.377	−0.699
APR	102	54987	0.218	0.060	1.866	0.650	409.000	0.062	0.148
MAY	61	50832	0.277	0.016*	2.384	0.557	522.000	0.017*	0.189
JUN	41	78357	−0.115	0.328	−0.915	−0.120	−0.020	0.360	−0.073
JUL	36	76383	−0.087	0.460	−0.679	−0.056	−0.015	0.497	−0.054
AUG	45	65950	0.014	0.598	0.545	0.082	0.012	0.586	0.044
SEP	63	69320	0.103	0.906	0.087	0.007	0.200	0.931	0.007

Period	Average rainfall	Spearman's Rank Rho Test			Mann-Kendall Test				
		S	rho	p	z-value	Sen's slope	S	p	tau
OCT	101	63028	0.103	0.377	0.883	0.313	0.019	0.377	0.071
NOV	108	48056	0.316	0.006*	2.713	0.931	0.059	0.007*	0.214
DEC	99	52013	0.260	0.024*	2.093	0.833	0.046	0.036*	0.166
Summer	330	51074	0.273	0.018*	2.223	2.008	0.049	0.026*	0.175
Autumn	302	56165	0.201	0.084	1.670	1.216	0.037	0.095	0.132
Winter	123	69288	0.014	0.902	−0.091	−0.040	−0.210	0.927	−0.008
Spring	273	55183	0.215	0.064	1.715	1.107	0.038	0.086	0.136
Annual	1029	45357	0.355	0.002*	2.887	4.322	632.000	0.004*	0.228

Table 2A.
Result of trend analysis rainfall at Alcaraz Norte locality.

Period	Average rainfall	Spearman's Rank Rho Test			Mann-Kendall Test				
		S	rho	p	z-value	Sen's slope	S	p	tau
JAN	113	69650	0.009	0.937	0.128	0.043	0.290	0.898	0.010
FEB	119	51962	0.261	0.024*	2.347	0.920	0.051	0.019*	0.186
MAR	117	75068	−0.068	0.563	−0.677	−0.284	−0.015	0.498	−0.054
APR	136	58350	0.170	0.145	1.533	0.729	0.034	0.125	0.121
MAY	61	58123	0.173	0.137	1.491	0.350	0.033	0.136	0.118
JUN	43	76302	−0.085	0.466	−0.750	−0.118	−0.017	0.453	−0.060
JUL	44	82282	−0.170	0.144	−1.611	−0.263	−353	0.107	−0.128
AUG	50	61718	0.122	0.297	1.131	0.184	0.025	0.258	0.090
SEP	70	77711	−0.105	0.368	−0.860	−0.226	−0.019	0.390	−0.068
OCT	114	56116	0.202	0.083	1.752	0.655	0.038	0.080	0.139
NOV	105	49986	0.289	0.012*	2.265	0.804	0.050	0.024*	0.179
DEC	107	53477	0.239	0.039*	2.091	0.923	0.046	0.037*	0.165
Summer	339	51398	0.269	0.020*	2.306	2.054	0.051	0.021*	0.182
Autumn	314	54902	0.219	0.059*	1.876	1.431	0.041	0.061	0.141
Winter	148	74374	−0.058	0.621	−0.572	−0.204	−0.013	0.568	−0.045
Spring	289	55044	0.217	0.061*	1.715	1.215	0.038	0.086	0.136
Annual	1090	49195	0.300	0.009*	2.438	4.451	0.053	0.015*	0.192

Table 3A.
Result of trend analysis rainfall at Bovril locality.

Period	Average rainfall	Spearman's Rank Rho Test			Mann-Kendall Test				
		S	rho	p	z-value	Sen's slope	S	p	tau
JAN	114	71802	−0.021	0.856	−0.156	−0.010	−0.350	0.876	−0.013
FEB	129	51202	0.272	0.018*	2.424	1.029	0.053	0.015*	0.191
MAR	141	77861	−0.108	0.258	−0.910	−0.380	−0.020	0.363	−0.072
APR	114	55361	0.212	0.067	1.784	0.794	0.039	0.074	0.141
MAY	72	58926	0.162	0.166	1.409	0.431	0.031	0.159	0.116
JUN	43	82218	−0.169	0.146	−1.281	−0.184	−281	0.200	−0.102
JUL	33	71809	−0.021	0.856	−0.188	−0.013	−0.420	0.851	−1.523
AUG	41	67234	0.044	0.710	0.334	0.048	0.740	0.738	0.027
SEP	65	73176	−0.041	0.727	−0.371	−0.098	−0.820	0.711	−0.030
OCT	113	52731	0.250	0.031*	2.100	0.822	0.046	0.036*	0.166
NOV	110	50320	0.284	0.013*	2.447	0.840	0.054	0.014*	0.192
DEC	97	54742	0.221	0.056*	1.875	0.724	0.041	0.061*	0.148
Summer	340	50482	0.282	0.014*	2.502	2.032	0.058	0.012*	0.198
Autumn	327	54775	0.221	0.059*	1.844	1.279	0.040	0.063*	0.146
Winter	117	71460	−0.017	0.883	−0.238	−0.075	−0.530	0.812	−0.019
Spring	287	51115	0.273	0.018*	2.250	1.272	0.049	0.024*	0.178
Annual	1071	41184	0.414	0.000*	3.531	4.625	0.077	0.000*	0.279

Table 4A.
Result of trend analysis rainfall at Hasenkamp locality.

Period	Average rainfall	Spearman's Rank Rho Test			Mann-Kendall Test				
		S	rho	p	z-value	Sen's slope	S	p	tau
JAN	119	66804	0.050	0.672	0.435	0.207	0.960	0.664	0.035
FEB	118	58492	0.168	0.150	1.565	0.548	0.034	0.118	0.124
MAR	128	72232	−0.024	0.815	−0.165	−0.083	−0.370	0.869	0.013
APR	107	52121	0.259	0.025*	2.342	0.929	0.051	0.019*	0.185
MAY	56	53917	0.233	0.044*	1.982	0.462	0.043	0.048*	0.158
JUN	52	74096	−0.054	0.645	−0.224	−0.030	−1	0.823	−0.018
JUL	35	77632	−0.104	0.373	−0.865	−0.103	−0.019	0.387	−0.069
AUG	39	63108	0.102	0.382	0.948	0.146	0.021	0.343	0.076
SEP	58	71122	−0.012	0.921	−0.160	−0.026	−0.360	0.873	−0.013
OCT	105	59335	0.156	0.182	1.322	0.460	0.029	0.186	0.105
NOV	98	52646	0.251	0.030*	2.319	0.760	0.051	0.020*	0.184
DEC	95	43704	0.378	0.001*	3.208	1.105	0.070	0.001*	0.253
Summer	332	50288	0.284	0.013*	2.575	2.344	0.056	0.010*	0.203

Period	Average rainfall	Spearman's Rank Rho Test				Mann-Kendall Test			
		S	rho	p	z-value	Sen's slope	S	p	tau
Autumn	291	50852	0.277	0.017*	2.278	1.541	0.050	0.023*	0.180
Winter	126	66250	0.058	0.624	0.526	0.250	0.012	0.599	0.042
Spring	260	54160	0.230	0.048*	1.972	1.195	0.043	0.049*	0.156
Annual	1009	38960	0.446	0.000*	3.925	6.126	0.086	0.000*	0.309

Table 5A.
Result of trend analysis rainfall at El solar locality.

Period	Average rainfall	Spearman's Rank Rho Test				Mann-Kendall Test			
		S	rho	p	z-value	Sen's slope	S	p	tau
JAN	125	60702	0.009	0.942	0.102	0.050	0.240	0.916	0.009
FEB	130	61884	0.120	0.306	1.240	0.547	0.027	0.215	0.098
MAR	135	72915	−0.037	0.751	−0.421	−0.179	−93.000	0.674	−0.034
APR	112	50504	0.282	0.014*	2.314	0.957	0.051	0.031*	0.183
MAY	60	49393	0.297	0.010*	2.571	0.593	563.000	0.010*	0.203
JUN	47	79615	−0.133	0.257	−1.075	−0.125	−0.024	0.282	−0.085
JUL	34	73537	−0.046	0.695	−0.412	−0.041	−0.910	0.680	−0.033
AUG	42	65897	0.063	0.594	0.490	0.066	0.011	0.624	0.039
SEP	62	65597	0.067	0.569	0.590	0.143	0.013	0.555	0.047
OCT	104	56327	0.199	0.087*	1.766	0.608	0.039	0.077*	0.140
NOV	114	45954	0.346	0.002*	2.978	1.067	0.065	0.003*	0.235
DEC	108	50090	0.287	0.012*	2.280	0.939	0.050	0.023*	0.181
Summer	363	54028	0.231	0.046*	1.985	1.888	0.044	0.047*	0.157
Autumn	307	47158	0.329	0.004*	2.763	1.805	0.061	0.006*	0.219
Winter	123	70554	−0.004	0.976	0.009	0.000	3.000	0.993	0.001
Spring	280	48297	0.313	0.006*	2.722	1.700	596.000	0.006*	0.215
Annual	1073	40694	0.421	0.000*	3.778	6.420	827.000	0.000*	0.298

Table 6A.
Result of trend analysis rainfall at Hernandarias locality.

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