Rainfall performance at the Institute of Animal Science in Cuba during the period 1970-2009 as basis for the strategic management of pastures

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Rainfall performance in the farm of the Institute of Animal Science (ICA) in Cuba during the period 1970-2009 was studied with data recorded at the agro-meteorological station. The methodology of analysis of seasonal series was applied and the performance of its components: seasonal variations, trend, cyclicity and random component of the time series were studied. It was confirmed that the seasonal character of rainfall was maintained each year, but showed stability during the last decade, as well as decrease of the minimum and maximum values. There was a very high variability and it was confirmed by the analysis of the coefficients of variation, which reached values above 41% in all months, particularly, in the poor rainy period, with average fluctuations of 200 mm. Also in this stage there was a decrease in the amount of rainfall of 324 mm in the period 1970-1980 to 225 mm presently. It is foreseen that this decrease will continue and that the difference between periods will increase, with a probability of 1105.7 mm for 95%. In general, rainy days also showed a decreasing trend. Regarding rainfall cyclicity at ICA, the duration was variable. It can be concluded that the high rainfall inter-annual variability, the inequality of its distribution throughout the year and the decrease of the rainy days favor the instability of these events at ICA's farm.

Key words: *time series, rainfall, animal production*

Climatic variations that are presently recorded influence negatively on the productivity and quality of agricultural production. This emphasizes the marked effect of the agro-meteorological factors regarding their biological and agronomical aspects (Febles and Ruiz 2009). This problematical together with the high prices of raw materials for the preparation of cattle feedstuffs (Harrison 2002, FAO 2007 and FAO 2011), brings about the need of increasing pasture production, as one of the strategies for uprising livestock productivity for the benefit of the Cuban economy.

The Cuban climatic conditions (abundant solar radiation, high environmental temperature and high photosynthetic rate of the exploited species) make feasible the exploitation of pastures throughout the year by the application of adequate modern technologies. Pastures in Cuba show high productions during the rainy period (May-October) and decrease in the poor rainy season (November-April). In this stage, temperature and solar radiation are low and days short, compared to the months of the rainy period. Water shortage is a climatic factor that, among others, limits pasture production in this period (Suárez and Herrera 1986). Rainfall use and the search for solutions to alleviate its unbalanced distribution is one strategy that Cuba can exploit satisfactorily. Its application represents an advantageous position in regard to other areas of the world under more severe climatic conditions than the tropical ones.

The objective of this study was to analyze rainfall performance in the farm of the Institute of Animal Science (ICA) during the period 1970-2009, as basis for preparing an adequate strategy for pasture management.

Materials and Methods

For the analysis of rain occurrence, rainfall data were collected at the agro-meteorological station of the Institute of Animal Science, located in Mayabeque province at 342 328º of North latitude and 395 418º of East longitude at a height of 80 m above sea level. The study included 39 years (1970-2009). The methodology inserted among the statistical procedures typical of the analysis of seasonal series, was used (López *et al*. 2005). This allows to find out the causes of the experimented movements in a time series, known as components: seasonal variations, trend, cyclicity and random component. The model relating these components is the additive, since it corresponds to that of the best adjustment (Cansado 1966, Freund 1977, Wei 1990 and Willks 1995).

If x1 represents the series considered,

T (xt), the trend

C (xt), the cyclical component

E (xt), the seasonal

I (xt), the irregular

Thus, it is considered that:

$$Xt = T(xt) + C(xt) + E(xt) + I(xt)$$

Rainfall evolution from 1970-2009 was given by the standardization of their annual values. From these, the estimation of mobile means centered in three years considered groups of an odd (2 m + 1) number of consecutive data (xt-m,…, xt-I,xtxt+I...,xt+m), instead of taking into account the chronological series in block and arrange a curve to the whole series. A polynomial was adjusted to each group by least squares and as trend value was taken that of the polynomial, corresponding to the central value. As immediate consequence, there was a "softening" of the original chronological series. The periodicity and cyclicity allowed verifying the existence of some cyclical component in the series. That is, a possible seasonal structure in the rainfall trend by the autocorrelation function (ACF) and the analysis of the graphic representation.

Results and Discussion

The monthly distribution graphs and the integrated graphic representation of the season show the seasonal significance or the performance of the monthly rainfall values in the chronological year (figure 1). Through both analyses, the seasonal rainfall showed a bimodal distribution, with a peak in June, and another secondary in September. Minimum values were in December, January and February. This statement was confirmed on observing the performance followed by the distribution if taking into account the mean value of 150 mm. In the case of the graphic representation, if it is observed that there are two groups of defined values, above and below the central trend line. The statistical analysis confirmed the existence of well-marked seasons with significant differences: a rainy period, from May to October, and a poor rainy period from November to April. The performance characteristics of both and the annual are shown in table 1.

Although this seasonal fluctuations was maintained during the 39 years of observation, when an analysis by decades was made there were modifications of the minimum and maximum values (figure 2). The rainy period had a peak and another secondary in the three first decades, achieving stabilization in its rainfall regime. In the poor rainy season there was also a balance of the rainfall in the last decade, accentuated at its beginning and end.

This result contributes to the adoption of strategic decisions in many aspects of the ICA's farm. However, it acquires more value considering that it can be seen on the performance of the grassland ecosystems and on the productive and health indicators of the animals. For example, this rainfall fluctuation throughout the year provokes a marked seasonal performance in pasture and forage yield (figure 3), deriving a seasonal performance in milk and beef production. In any species, the continuous maintenance of high levels of milk and beef production, with low costs and based on the utilization of the productive potential of pastures and forages, brings about the constant control of the feeding unbalance that could be created by extreme climatic situations.

During the rainy period (May-October) which coincides with temperatures and favorable photoperiod for the development of grasslands, approximately 70% of the total annual forage is produced. As a result, there is half of the year availability with forage surplus which are generally underutilized. There is another semester in which the cattle maintenance requirements are not covered.

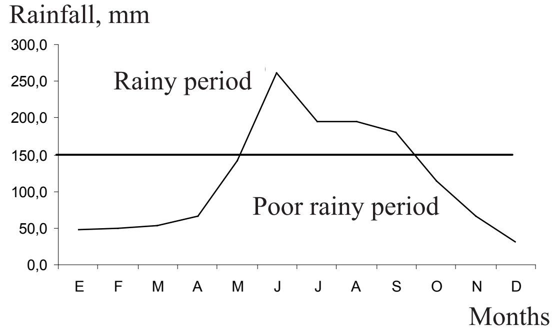
Rainfall distribution also influence on seed production (Febles *et al*. 2009) which agrees with the requirements stated by Hopkinson and Reid (1970) for considering a region adequate for high quality seed production.

Seasonal rainfall fluctuations, together with the variations of temperatures and solar radiation between periods, notably influenced on feed ingestion and water consumption as physiological response of the organism (Alvarez *et al*. 2004). Various authors indicate the direct relationship between environmental humidity, the biological diversity of the grassland (Ferrer *et al*. 2001)

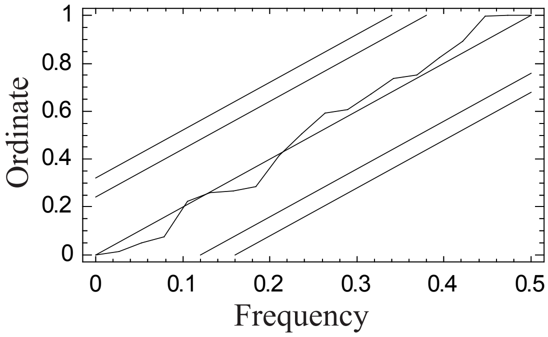
Table 1. Performance of the dispersion statistics of rainfall in the different climatic periods at ICA from 1970- 2009

Period	Min. (mm)	Max. (mm)	Mean (mm)	Variance (S2)	Standard Deviation (SD)	Coefficient of Variation (CV)
Rainy	584.4	1715.7	1094.06[b]	94935.76	308.12	27.55
Dry	8.0	680.0	298.73[a]	21207.66	145.63	48.75
Annual	731.9	2003.2	1382.07	103403.71	321.56	23.27

[a, b]Different letters indicate significant differences (P < = 0.05)



a



b

Figure 1. Monthly distribution (a) and integrated graphic presentation (b) for the mean rainfall at ICA (period 1970 -2009)

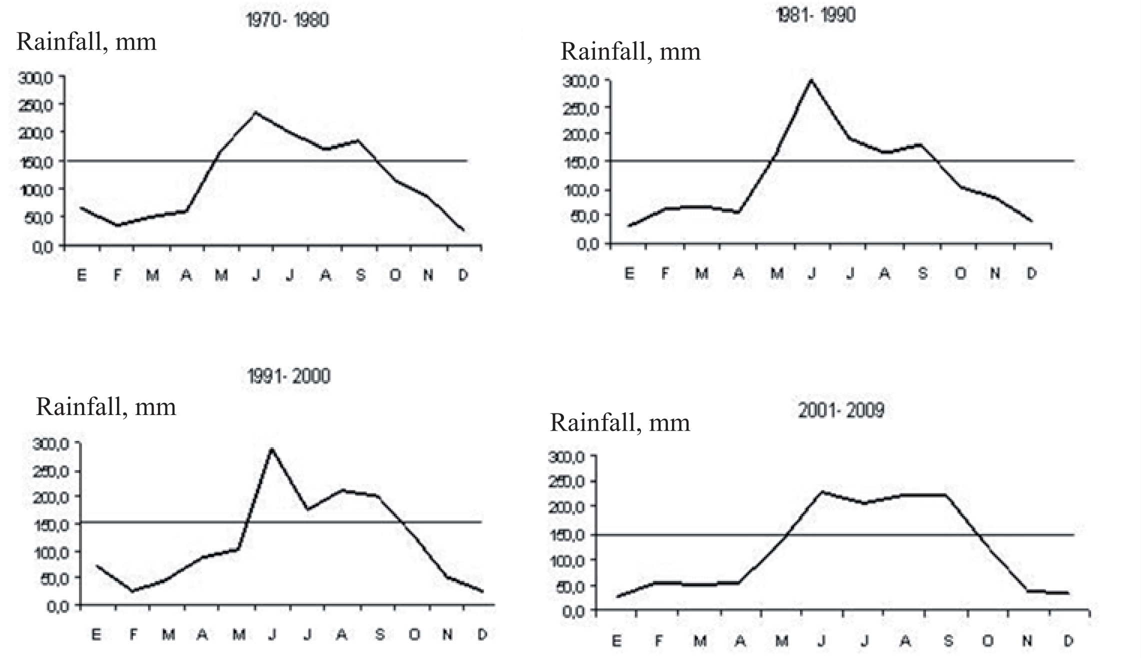


Figure 2. Seasonal index for the mean rainfall at ICA by decades during 1970 -2009

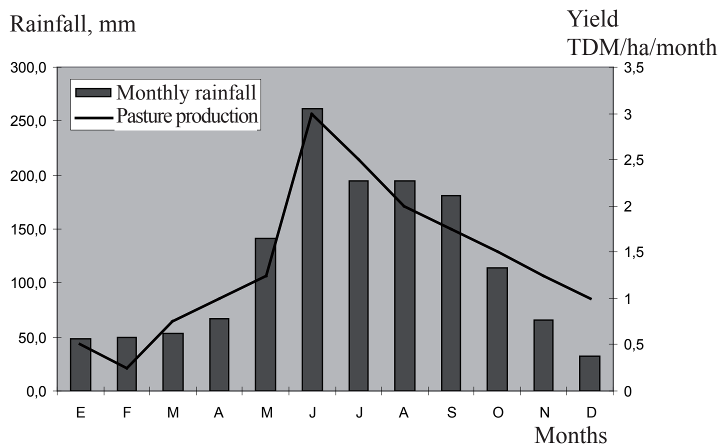


Figure 3. Relationship of rainfall distribution and tropical pastures production at ICA

and soil fauna (Melecis *et al*. 2004 and Quèdraogo and Mando 2004).

In agreement with international studies, Lock and Fraga (2008) demonstrate in more complete experiments that the biological diversity of the soil fauna varies significantly according to the season of the year in silvopastoral grasslands and with multiple legume association that have greater presence of earthworms (*Phylum Annelida*, Oligochatea class).

Herrera *et al* (2008) state that there is a marked difference between seasons regarding the mineral contents of leaves and stems of four varieties of *Pennisetum purpureum* evaluated in the area under study (king grass, Taiwan 146, Cuba CT-115, Cuba CT-169).

Figure 4 shows the high rainfall variability during the studied period. This result is confirmed by the analysis of the coefficients of variation, attaining values above 41% in all months. The highest variability was obtained in the poor rainy period, accounting for this the greater instability in rainfall occurrence during this period. Another important aspect is that throughout the year there was a wide range of rainfall, oscillating in the month between 143 and 398 mm.

Mean rainfall in both periods showed a similar performance to that of the mean annual rainfall, although with contrary trends (figure 5). This result, together with the fact that 78% of rainfall of the year occurs in rainy period, suggests a slight trend to the increase of the mean annual rainfall. Even though rainfall trend in the poor rainy period was to decrease, still there is a 95% probability of media annual rainfall occurrence, ranging between 132.5 mm in February and 228.2 mm in November, for an accumulated total of 997.7 mm.

In the rainy period rainfall from 245 mm in October to 619.8 mm in July for an accumulated total of 2103.4 mm can occur. This means that the difference

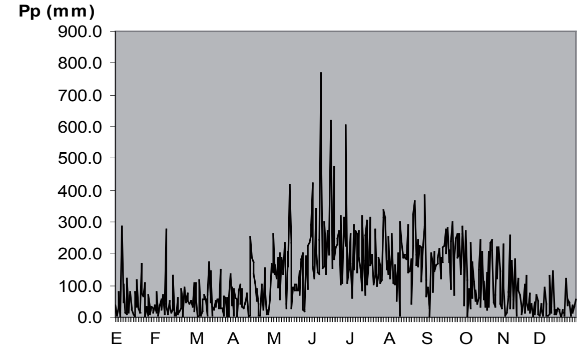


Figure 4. Rainfall variability at ICA during 1970-2009

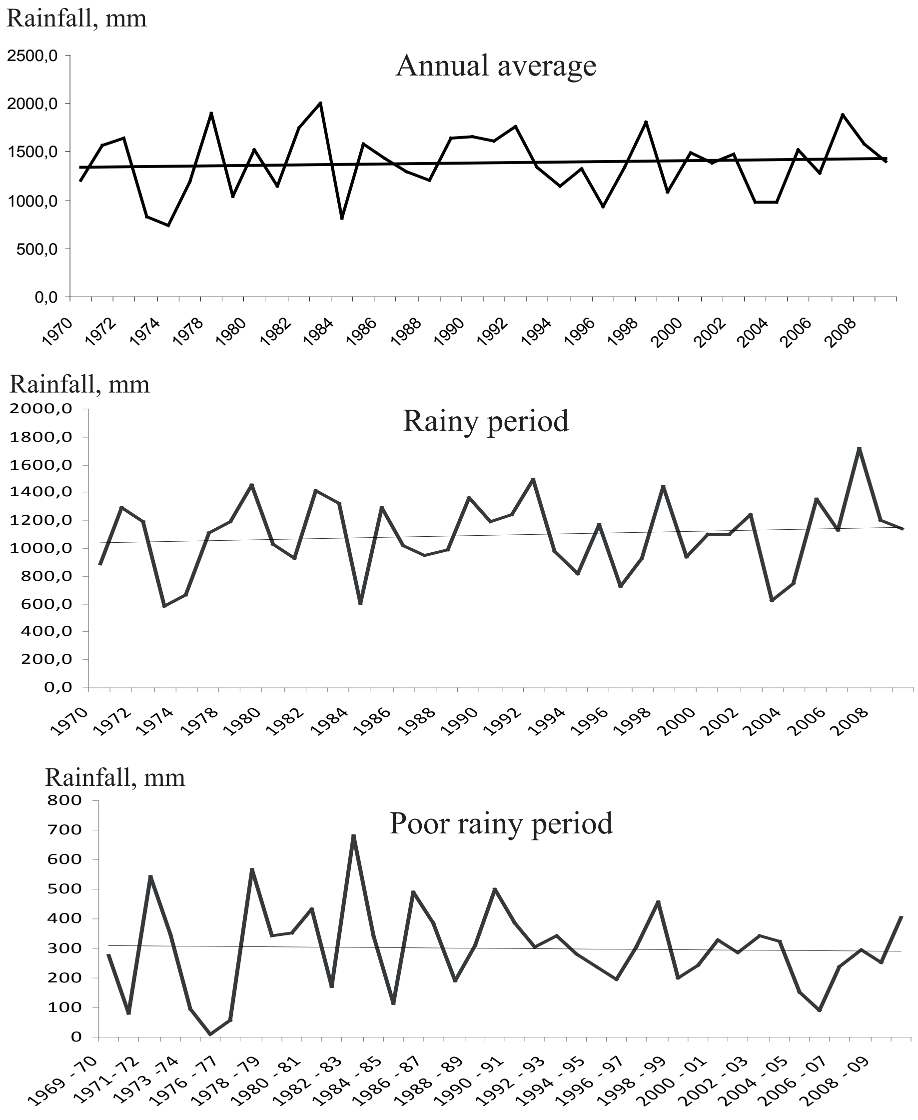


Figure 5. Performances and trends of teh anual and seasonal rainfall series of ICA (period 1970 -2009)

between periods can be increased from 795.33 mm presently to 1105.7 mm in the future. It is important to highlight that if this result continues in the poor rainy period, biomass production in the grasslands of ICA's farm would not be favored.

The analysis of monthly trends was made from the graphs of the monthly series. In table 2 it is marked with positive sign (+) if the curve ascends, and with negative (-) if it descends. Also, if it is slight (S) or almost straight (AS) they are underlined. In the rainy period, in May and June, the rainfall volumes tended to decrease and increased in the following months. There was a significant increase in August. In the poor rainy season this increase coincided with what has been found in rainfall studies for Cuba (Gutiérrez 1992, Lapinel 1997 and López *et al*. 2005). Although rainfall increase could represent greater efficiency in water management in the system and improvements in pasture production during the period, their distribution in everyone of the months showed high variability, which was favored by the presence of cold fronts with rainfall.

Another important result is the decrease in the trend of rainy days, for the annual performance as for both periods. Always its performance coincided with that describing the amount of total rainfall (figure 6).

Regarding the analysis of trends by decades (figura 7), from the 80's referred results regarding the annual trend and by season were stressed. Without reaching to generate a long and typical ecological drought, rainfall performance in the poor rainy period was toward the decrease, recording the 2005-2006 stage the lowest value (92.2 mm).

The first characteristic that outstands in the rainfall cyclicity performance is its aperiodicity (variable duration) (figure 8). This coincides with the results of other studies of climatic regularity (Fernández and Maximota 1990, Gutiérrez 1993, Lapinel 1997 and Lora 1999).

Year variability within a same cycle (figure 3) is around the variability reported by Álvarez (2008) for the sub-basin where the station is located.

Every one of the cycles had two phases: the humid, formed by a set of years of relatively high values, and the least humid, also called dry phase, formed by a set of years with lower values. It was observed that the least humid prevailed.

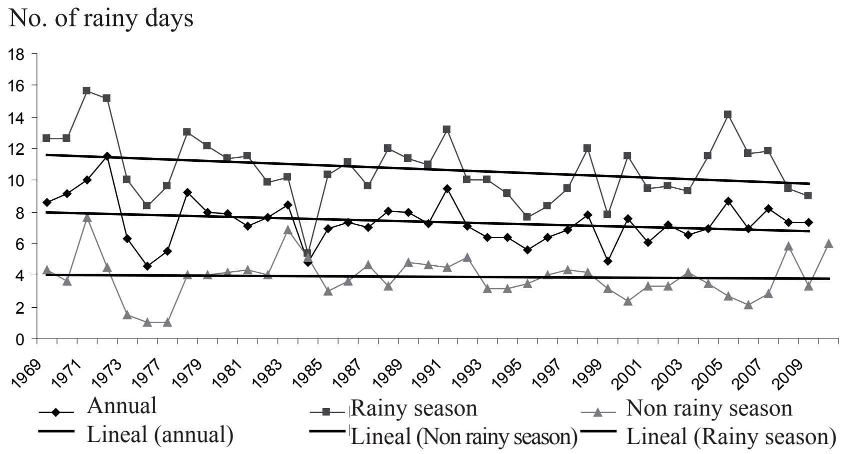
The moments or dates when there were trend changes, from humid to dry, as the curve shows were, approximately, 1979, 1989 and 1999. The inverse moments or of lower inflection corresponded to 1986, 1995 and 2003. The years agree with the final moment of these curves, equivalent to the changing points from one phase to another.

The trend to the decrease of the duration of the cycles

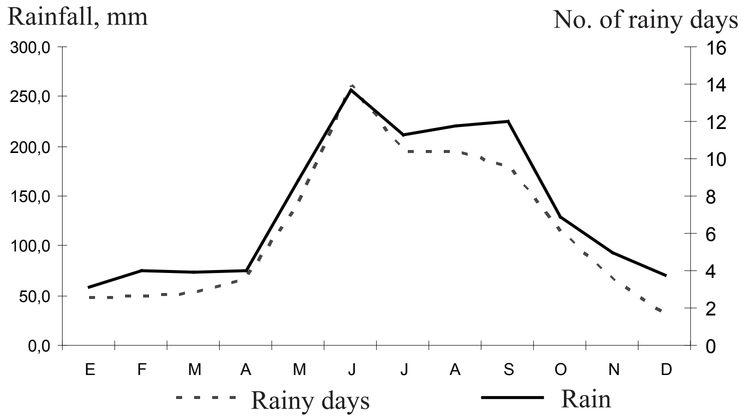
Table 2. Monthly trends of mean rainfall at ICA during 1970-2009

	E	F	M	A	M	J	J	A	S	O	N	D
Pendientes	-0.6[b]	0.2[b]	-0.2[b]	0.02[b]	-1.2[b]	-1.3[b]	0.1[b]	2.6[a]	1.8[b]	1.0[b]	-1.7[b]	0.2[b]
Tendencia	-	+CR	-CR	+CR	-	-L	+CR	+	+L	+	-	+CR

[a, b]Different letters indicate significant differences (P < = 0.05)



a) Annual and per period



b) In respect to the performance of the total rainfall.

Figure 6. Performance of the number of rainy days at ICA (period 1970- 2009)

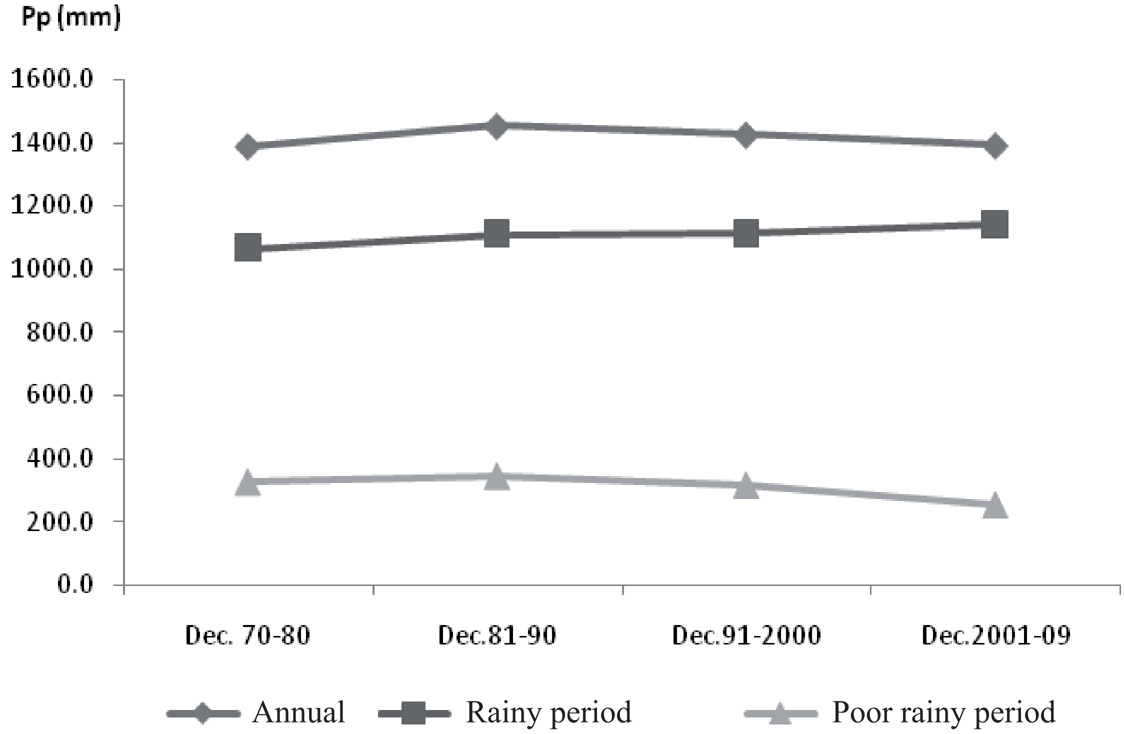


Figure 7. Rainfall trends at ICA by decades during 1970- 2009

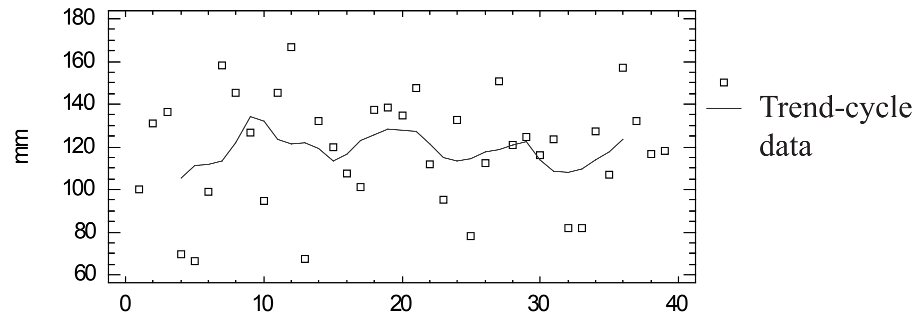


Figure 8. Component trend-cycle for the annual mean rainfall at ICA during 1970 -2009

Table 3. Rainfall aperiodical cycles at ICA during 1970 -2009

Cycles	Duration (No. of years)		
	Cycle	Humid phase	Dry phase
1	1970 – 1986 (17)	1970 – 1979 (10)	1980 – 1986 (7)
2	1987 – 1995 (9)	1987 – 1989 (3)	1990 – 1995 (6)
3	1996 – 2003 (8)	1996 – 1999 (4)	2000 – 2003 (4)
4 (semicycleo)	2004 – 2009 (6)	2004 – 2009 (6)	---

is another important characteristic, that can change if it is taken into account that we are presently in the first semi-cycle (humid phase), with an interval of six years that, when the cycle is completed, can equal or surpass the previous one.

This cyclicity can establish certain regularity in many of the productive and maintenance processes of grasslands, which are of great help to adopt correct decisions. According to Solano *et al*. (2003), rainfall can be a limiting factor for annual cultures, including also pastures. Rainfall influence on production could be positive or negative, and also could act directly or indirectly on the vegetation. The effect of rainfall depends on the height of the rainfall layer accumulated throughout the year, as well as its seasonal distribution, which is vey unequal the whole year, the same as its inter-annual variability.

It can be concluded that in spite that 79% of the rainfall occur in the rainy period, their performance in the poor rainy stage contributes to show in the annual mean trend a discreet growth in time, with 95% probabilities of increasing the difference between periods until attaining 1105.7 mm of rainfall.

The high monthly variability of rainfall, the unequal distribution in the curse of the year and the decrease of rainy days favor the instability of these events in the farm areas of ICA, reflected directly on the productive performance of pastures and forages.

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