International Journal of Economy, Energy and Environment
2022; 7(3): 67-74
http://www.sciencepublishinggroup.com/j/ijeee
doi: 10.11648/j.ijeee.20220703.12
ISSN: 2575-5013 (Print); ISSN: 2575-5021 (Online)

Interaction Between Spatial and Temporal Instabilities of Rainfall on Milk Production in the Brazilian Semi-arid Region

José de Jesus Sousa Lemos*, Elizama Cavalcante de Paiva, João da Costa Filho, Fabricio José Costa de Holanda

Department of Agricultural Economics (DEA), Canter of Agrarian Sciences (CCA), Federal University of Ceará (UFC), Fortaleza, Brazil

Email address:

lemos@ufc.br (J. de J. S. Lemos)

*Corresponding author

To cite this article:

José de Jesus Sousa Lemos, Elizama Cavalcante de Paiva, João da Costa Filho, Fabricio José Costa de Holanda. Interaction Between Spatial and Temporal Instabilities of Rainfall on Milk Production in the Brazilian Semi-arid Region. *International Journal of Economy, Energy and Environment*. Vol. 7, No. 3, 2022, pp. 67-74. doi: 10.11648/j.ijeee.20220703.12

Received: May 11, 2022; **Accepted**: May 26, 2022; **Published**: June 27, 2022

Abstract: The overall objective of the research was to evaluate the synergy between annual rainfall and the defining variables of milk production in the twenty largest producing municipalities in Ceará between the years 1973 and 20209. The research used annual rainfall data taken from the Ceara Meteorology and Water Resources Foundation (FUNCEME) as well as from the IBGE's Municipal Livestock Surveys (PPM) during the investigated period. The rainfall of the municipalities was organized into drought, normal and rainy periods, observing statistical criteria: average and standard deviation. It was used the coefficient of variation (CV) to measure the instabilities of the variables. It was created the instability index (INST) to capture the synergy between the annual precipitation of the municipalities with the number of lactating cows, the daily productivity of milk per cow and the average price of milk received by producers, in each municipality. To construct the INST, it was used the Factor Analysis, with the technique of decomposition in principal components. The results confirmed the high temporal instabilities of rainfall in the municipalities that were also observed in the defining variables of milk production in the studied municipalities. It can also be inferred from the results that, in all municipalities, the estimated INST for the rainy periods were always higher than those observed in the other periods (drought and normal), which confirms the great importance of rainfall for gauge good economic results in milk production in Ceara. The estimated INST confirmed the assumptions that guided the conduct of this research, that there is significant synergy between rainfall, the number of lactating cows, daily productivity and the price of milk received by farmers, in the largest milk producing municipalities in Ceara between the years 1973 and 2020.

Keywords: Brazilian Semi-arid Region, Rainfall Instability, Synergy, Adaptability

1. Introduction

Climate instability affects all states in the Northeast, especially in the its semi-arid areas, and has a significant impact on regional livestock farming, because it reduces the supply and quality of pastures, increasing even more the uncertainties resulting from the seasonality of milk supply over the years [1, 2].

Reis Filho and Carvalho [3] agree with this assertion and add that there are several factors that result in low productivity in milk production in the Northeast. They are: the seasonality of forage supply, the low technological level, the need to strengthen and modernize the industrial park. However, the irregular rainfall have always been, and will continue to be, the major obstacles to be overcome.

Dairy cattle breeding developed in the semi-arid region of the Brazilian Northeast, in its great majority, is constituted by family establishments with low technological level and seasonality in milk production, due to the rainy seasons that occur only in some of the first months of the years. The breeding systems that predominate in the region are extensive and semi-intensive, in which the herd owners use the native vegetation of the caatinga (natural biome which happen only in Brazil semi-arid region) as the main sources of food for their animals [4].

Dairy farming in the semi-arid region of the State of Ceará, as happens generically under this climatic regime, coexists with the problem of rainfall instability, both from a spatial and temporal point of view. This climatic variable affects the dairy cattle herd, mainly in the productivity of lactating cows [5, 6].

In this perspective, this study proposes to answer the following question: Do the variables that define the milk production in the municipalities, largest producers of milk in Ceará, oscillate in synchronized synergy with the rainfall of these municipalities?

To answer this question the study has as a general objective to evaluate the synergy between annual precipitation and the defining variables in milk production in the twenty (20) largest milk producing municipalities in Ceará State between the years 1973 and 2020.

Specifically, the research aims: a) to assess the descriptive statistics associated with the variables that define the milk production in the twenty largest milk producing municipalities between 1973 and 2020; b) to assess the instabilities associated with rainfall and the variables that define the milk production in the twenty largest milk producing municipalities in Ceará State in the investigated period; c) to evaluate the synergy between the variables that define the milk production and the rainfall.

2. Climate Instability in the Semi-arid Region

The semi-arid region of Brazil is marked by rainfall instabilities, both from a spatial and temporal point of view, having a direct influence on agricultural production, as can be seen in the following passage:

“The Brazilian semi-arid region is not homogenous in landscape, natural resources, and floristic covering. One of the convergences that exist in the immense area that makes it up is the climatic instability that is translated into the poor distribution of rainfall, both from a spatial and temporal point of view” [7].

Climate instabilities, mainly in the precipitation of rainfall, being quite frequent the occurrence of droughts that influence milk production, especially in aspects related to the production and productivity of lactating cows both, directly affecting the health of the animal and, indirectly, changing the environment where production occurs [8, 9, 12].

In the Brazilian semi-arid region, the water deficit is a constant, also motivated, in addition to the instability of rainfall, by high evapotranspiration and recurrent periods of drought, which leads to reduced availability of surface water making a challenge to livestock and agricultural activity for this region [5, 10, 11].

According to the IBGE, 2017 [4], in that year the milk productivity in Brazil was 2.14 liters per day per cow, while in Ceará, the Brazilian State that proportionally has the largest area inserted in the semiarid region, was only 1.37 liters/cow. This difference can be justified by several factors, such as the low supply and quality of pasture, breeds and genetics of the dairy herd, animal management, especially in milking, disease control, access to appropriate medicines, infrastructure, rainfall instability [2].

3. Methodology

The Research sought, from the Agricultural Census of 2017, the identification of the twenty (20) largest milk producing municipalities in Ceará State. Based on this identification, the search sought information about the size of the dairy herd, milk production, and average milk USD prices received by farmers in these municipalities. The sources of this information were the Municipal Livestock Surveys – PPM/IBGE (IBGE) covering the same period from 1973 to 2020 [13]. The data concerning the annual rainfall in the municipalities during the studied period were collected from Meteorology and Water Resources Foundation of Ceará [14].

3.1. Classification of the Rainfall Years in the Municipalities

To carry out this study it was decided to create "rainfall periods" to evaluate the situation of each of the twenty largest milk producing municipalities in Ceará State between 1973 and 2020. It would be necessary to find limits for these "rainfall periods" that could be applied to all municipalities, to make spatial and temporal comparisons between them. It was decided to take the State of Ceará rainfall between the years 1950 and 2020 which are available. The average and standard deviation (SD) of these annual precipitations were estimated. Based on these criteria, three annual rainfall periods were defined for the State of Ceará State between the years 1950 and 2020. Thus the annual precipitation observed for Ceará State in 1950 and 2020 are shown in Table 1.

Table 1. *Classification of rainfall average in Ceará State from Years 1950 to 2020.*

Períods	Variation range
Drought	Rainfall < (Average – ½ SD)
Normal	Rainfall = (Average ± ½ SD)
Rainy	Rainfall > (Average + ½ SD)

Sources: FUNCEME [14].
Obs. SD = Standar Deviation.

As data at the municipal level is only available for the years 1973/2020, the periods defined in Table 1 were applied for the municipalities studied.

3.2. Assessment of Stability / Instability in the Variables

To asses instability/stability of each of the endogenous and exogenous variables it was used the coefficient of variation (CV). By definition the CV assesses the percentage ratio between the standard deviation and the arithmetic mean of a random variable. The use of CV allows the comparison between variables of distinct natures and measurements [15-17].

The smaller the CV is, the more homogeneous, or more stable, will be the distribution of observations around the mean. To use the CV as a measure of the degree of instability/ stability of a distribution it may be useful to have some knowledge about the definition of its critical values. Gomes (1985) established limits for classifying CVs in agricultural experiments. These are the references used in this study and are shown in Table 2.

Table 2. *Classification of the CV according to its range.*

Classification of CV	Range of CV
Low	CV < 10%
Median	10% ≤ CV< 20%
High	20% ≤ CV < 30%
Very high	CV ≥ 30%

Source: GOMES [15].

3.3. Measuring the Interaction Between the Variables That Define Milk Production

To assess the interaction that is assumed to exist between rainfall and the variables that define milk production in the municipalities, it is constructed the instability index (INST). This index is used to capture the synergy between observed rainfall with the variables defining milk production in Ceará's municipalities between 1973 and 2020. Thus, it is assumed that instabilities in rainfall, common in the semi-arid region, interact with the defining variables of milk production in the largest milk producing municipalities of Ceará. The INST is constructed in a way that will oscillate with the temporal instabilities of rainfall in each municipality.

There were defined the following variables:

C_{it} = annual rainfall for municipality i (i = 1, 2,..., 20) in year t (t = 1973, 1974,.., 2020);

P_{it} = average price of liter of milk, in USD 2020 values, received by farmers in the municipality "i" in year "t";

V_{it} = number of lactating cows in the i-th municipality in the t-th year;

R_{it} = daily milk yield in liters of milk per cow in the municipality "i" in year "t".

These defining variables observed annually in each municipality are aggregated in the instability index (INST). This aggregation is performed using even the principal component decomposition (PDC) technique of the factor analysis (FA) method.

3.3.1. Brief Summary of the FA Procedure as It Applies to the Study

Factor analysis is a method designed to investigate whether a number of variables of interest $Y_1, Y_2, ..., Y_n$, are linearly related to a number $k < n$ of unobservable: $F_1, F_2, ... F_k$. Each of these new unobserved variables is called a factor, which can be understood as the grouping of variables from established criteria. In this sense, FA is a multivariate technique that seeks to identify a relatively small amount of factors that represent the behavior of a larger set of original interdependent variables [18].

The technical foundations of (FA) are anchored in the linear correlations between the variables that are used. Thus, for the technique to be feasible it is necessary that the correlation matrix between the variables is not an identity] [13, 19–23].

To perform a factor analysis correctly, you must follow these steps: confirm that the correlation matrix of the variables is not an identity, that is, the correlations between them are statistically different from zero; ensure that the Kaiser-Meyer-Olkin (KMO) statistic has a minimum value of 0.5; perform the Bartlett's sphericity test to confirm that the correlation matrix is not an identity; to estimate the percentage of explanation of the accumulated variation of the estimated components.

One or more factors can be generated. When more than two factors are generated, the AF method provides for the possibility of rotating the generated factors. There are different rotation methods. In this study it was choose the orthogonal rotation, varimax method, which will produce linearly independent factors. Once the extraction is done and the number of factors is determined, the factorial scores are generated. These are unobserved variables, which will be used to generate the INST. These unobserved variables gather, through the correlations between them, the information of the original variables [18, 20, 23].

The method used in this study for the extraction of the factors was principal component decomposition (PCD), which has as a characteristic the search for a linear combination of the observed variables in order to maximize the total variance explained by the factors (unobserved variables) generated [18, 20].

3.3.2. Creation of the Instability Index (INST)

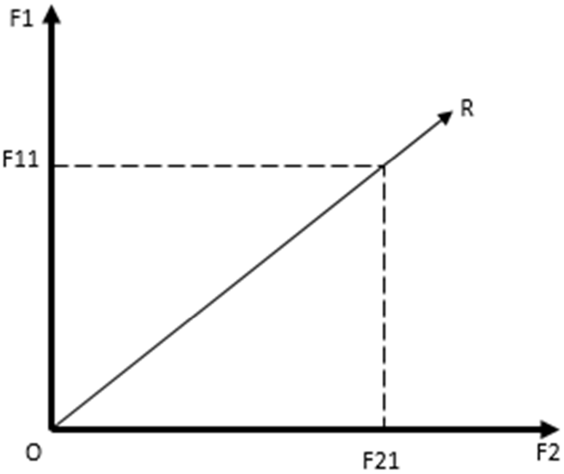
The Factor Analysis method allows the generation of factorial scores and, with them, unobserved variables are created, with a lower number than the original ones, gathered into factors that are correlated among themselves. If two or more factors are estimated, varimax rotation will allow these factors to be orthogonal.

The generated factor scores have values that gravitate around zero average and have standard deviations equal to one. Therefore, they are positive and negative values. In general, indices are constructed on a positive scales. For this reason is feasible to arrange these factorial scores in such a way that they assume only positive values on a defined scale. In general these scales are created in a way that they assume values between zero and one. This is done using equation (1):

$$F_{ij}^{T} = (F_{it} - F_i^{mn}) / (F_i^{mx} - F_i^{mn}). \quad (1)$$

In equation (1) the transformed factorial score F_{jtT} will have values between zero and one; F_{it} is the value generated for the i-th factorial score; Fi_{mn} and Fi_{mx} are, respectively, the minimum and maximum values assumed by F_{it}.

In this research the observed variables are reduced into two orthogonal factors. Being generated in this way, with the observations placed in the first quadrant, they are distributed in two perpendicular axes of a rectangular triangle, as simulated in Figure 1.



Source: Theoretical basis of the search.

Figure 1. *Demonstration of how to construct the INST.*

Figure 1 shows two points observed in F_1 and F_2 respectively, which are the factorial scores generated and transformed with values between zero and one. Based on this geometric formatting it is possible to apply the Pythagorean Theorem [24]. Thus, the segments OF_{11} and OF_{21} can be understood as the skewers, and R as the resultant. The value of the resultant is given by:

$$R = (OF_{11}^2 + OF_{21}^2)^{1/2} \quad (2)$$

The estimated INST in this research will have the size of the "R" for each milk-producing municipality studied in Ceará State, between the years 1973 and 2020. These values are adjusted to be between zero (0) and one hundred (100). This is done by making the maximum value of R equal to 100 and adjusting the other values proportionally. The interpretation of INST is: its values tending towards zero, means that the set of variables that accounts for milk production in the municipality presented greater problems. This is generally expected happen in drought years. Estimated INST values tending towards 100, on the contrary, mean that the variables defining milk production in the municipality presented better results. This is expected to happen mainly in rainy and normal rainfall years.

As a summary, a simple interpretation about what, in fact, the INST is expected to be able to measure in this study. Since it is constructed using the interaction between annual rainfall, total lactating cows, productivity and liter milk prices at the producer level, the index is expected to capture the synergy between these variables.

As the index was built based on rainfall data from the municipality between 1973 and 2020, it is affected by the periods evaluated in the research: drought, normal and rainy. In this way we can estimate the index averages for each period and they can be ranked in descending or ascending order. It is expected that the average INST is the highest in the rainy period, and assume the lowest value in the drought period. To test this hypothesis it is used two "Dummies" variables: D_1 and D_2, which will be the explanatory variables of Equation (3), where the INST is the instability index for the "i-th" municipality studied (i = 1, 2,..., 20):

$D_1 = 1$ in rainy years; D1 = 0 in all other years of the remaining periods;

$D_2 = 1$ in normal years; D2 = 0 in all other years of the remaining periods;

$D_1 = D_2 = 0$ in drought years.

Equation (3) is defined as follows:

$$INST_i = \beta_0 + \beta_1 D_1 + \beta_2 D_2 + \epsilon_i \quad (3)$$

In equation (3), β_0 is linear coefficient that measures the averages of INST when $D_1 = D_2 = 0$. Once this linear coefficient is statistically different from zero, it is inferred that rainfall in the drought period is different from the averages of the normal and rainy periods. It is also expected that this average will present the lowest magnitude. If β_1 is statistically different from zero, it means that the average rainfall in the rainy period will be significantly different from the averages of the normal and drought periods. In this case the average of that period is expected to have the highest magnitude. If β_2 is statistically different from zero, the average rainfall of the normal periods will be different from the averages of the rainy and drought periods. All these coefficients are expected to be positive and can be ranked in the sequence: $\beta_2 > \beta_1 > \beta_0 > 0$. The white noise ϵ_i, by hypothesis, meets the assumptions of the classical linear model of having zero mean, being non-autocorregressive and having constant variance. Therefore the parameters β_0, β_1 and β_2 can be estimated using the ordinary least squares method [25].

4. Results and Discussion

To meet the first and the second objectives of this study we present the averages and coefficients of variations of rainfall of the municipalities, of the sizes of herds in lactation, of the daily productivity of milk and of the prices received by producers in the studied municipalities.

Through the evidences shown in Table 1 it is clear that all municipalities presented rainfall CVs considered "very high", by Gomes' classification (1985). This confirms what was expected about the rainfall in the Ceará municipalities: high temporal instability. It is also observed that Madalena, the second municipality with the lowest average rainfall in the period, also presented the highest temporal instability between 1973 and 2020.

With regard to the defining variables of milk production in the municipalities, it is also found that predominate CVs considered as high, or very high, following the classification of Gomes (1985). In this case, the greatest instabilities are observed in the prices received by milk producers. The prices received by milk producers in Acopiara, for example, had a CV=71.5% in the evaluated period. High instabilities were also observed in productivity and in the number of lactating cows (Table 3).

Table 3. *Averages (Av.) and coefficients of variation (CV) of rainfall, lactating cows, daily milk productivity per cow and milk price in the twenty (20) largest milk producing municipalities between 1973 and 2020.*

Municipalities	Rainfall (mm)		Cows (In Lactation)		Yield (Liters/Cow)		Price (USD/liter)	
	Av.	CV	Av.	CV	Av.	CV	Av.	CV
Acopiara	749.3	38.5	7.488	14.6	1.5	23.6	0.52	71.5
Alto Santo	726.5	40.4	3.944	64.9	2.1	27.7	0.45	55.2
Banabuiú	722.8	39.4	4.475	10.0	2.6	29.0	0.27	27.9
Crateús	718.6	41.5	9.221	26.5	1.8	19.5	0.54	60.1
Icó	759.5	33.9	8.329	29.1	1.5	14.3	0.45	68.6
Iguatu	917.1	31.6	8.183	24.7	1.8	41.1	0.50	67.6
Iracema	820.0	38.0	4.028	49.9	2.5	38.6	0.45	57.1
Jaguaretama	740.8	41.6	9.082	31.4	2.2	16.6	0.41	63.7
Jaguaribe	715.5	41.6	11.603	28.9	2.4	15.1	0.41	63.6
Limoeiro do No	739.4	42.3	4.451	63.9	2.4	26.3	0.45	55.4
Madalena	589.1	47.9	3.976	38.9	2.9	35.1	0.41	67.8
Milhã	722.2	34.3	3.394	43.2	2.4	44.4	0.29	30.8
Morada Nova	712.4	41.5	13.333	42.2	2.3	32.9	0.47	66.1
Quixadá	714.0	42.6	10.857	29.5	2.3	39.7	0.43	61.2
Quixelô	760.5	33.4	3.990	34.6	2.0	37.1	0.33	64.7
Quixeramobim	686.0	39.8	13.590	15.8	2.4	48.5	0.43	61.3
Russas	752.7	43.5	3.303	22.7	2.4	48.9	0.50	60.9
Sobral	714.2	44.9	8.871	23.8	1.6	17.8	0.52	49.6
Solonópole	739.9	35.1	5.007	35.2	2.0	36.8	0.43	59.9
Tauá	509.7	41.6	10.627	27.1	1.8	28.8	0.48	49.7
Average. of Municipalities	725.51	39.67	7.388	32.85	2.15	31.09	0.44	58.14

Sources: Funceme (various years); IBGE (various years).

4.1. Definition of Rainfall Periods for the Municipalities Studied

The study takes as reference. for the definition of the drought, normal and rainy periods, the rainfall observed in Ceará between the years 1950 and 2020. In this period the average rainfall in the state was 793.7 mm, with a standard deviation (SD) of 267.8 mm. These values allow us to create in this study the periods of rainfall for the state. which were applied to identify the situations of the municipalities investigated between the years 1973 and 2020, bearing in mind that it is only for these years that data concerning to variables which define milk production are available at the municipal level. The rainfall definition intervals, which define the drought, normal and rainy periods estimated for Ceará between 1950 and 2020 are shown in Table 4.

Table 4. *Classification of rainfall Periods in Ceará State between the years 1950 and 2020.*

Períods	Range Periods	Boundaris
Drought	Rainfall < (Average - ½ SD)	Lower than 659.8 mm
Normality	Rainfall = (Avereage ± ½ SD)	Between 659.8 mm and 927.7 mm
Rainy	Rainfall > (Average + ½ SD)	Over 927.6 mm

Source: Estimations based on DNOCS information from 1950 to 1957 and from FUNCEME for the period 1958 to 2020.

The application of these limits to the rainfall observed in the twenty largest milk producing municipalities in Ceará State, in the forty-eight (48) evaluated years, allows to generate the values shown in Table 5. In this table it can be observed that the periods of drought average years; normal average years; and rainy average years were 22, 15, and 11 years, respectively.

It is thus clear that, on average, more years were predicted to occur with drought periods, and that in only two municipalities this did not happen (Table 5).

Table 5. *Average rainfall and the number of years of drought, normal and rainy periods in the municipalities from 1973 to 2020.*

Municípalities	Drought		Normality		Rainy	
	Average	Years	Average	Years	Average	Years
Acopiara	498.3	17	774.8	22	1,163.9	9
Alto Santo	476.6	22	813.3	16	1,145.9	10
Banabuiú	497.6	22	769.8	17	1,189.6	9
Crateús	482.7	24	782.8	11	1,104.8	13
Icó	545.8	19	771.5	19	1,144.0	10
Iguatu	564.6	8	7823	19	1,167.0	21
Iracema	497.1	16	771.2	15	1,164.2	17
Jaguaretama	477.8	22	803.7	15	1,186.9	11

Municípalities	Drought		Normality		Rainy	
	Average	Years	Average	Years	Average	Years
Jaguaribe	482.3	23	774.3	14	1,133.5	11
Lim. do Norte	465.8	20	768.0	17	1,195.5	11
Madalena	425.9	31	800.3	13	1,221.3	4
Milhã	527.3	24	779.2	14	1,096.4	10
Morada Nova	489.0	25	802.4	12	1,130.3	11
Quixadá	473.0	22	766.0	15	1,129.9	11
Quixelô	543.6	19	763.4	19	1,145.6	10
Quixeramobim	498.0	27	774.4	11	1,105.3	10
Russas	497.9	23	827.4	15	1,234.2	10
Sobral	470.6	24	791.2	13	1,161.9	11
Solonópole	525.7	20	776.8	20	1,187.6	8
Tauá	423.2	37	711.9	8	1,103.4	3
Municipalities Average	493.14	22	780.2	15	1,155.6	11

Source: E stimated values from Funceme data (several years).

4.2. Estimation of the Instability Index (INST)

The results found in the FA to generate the factors from which the instability index (INST) was constructed are shown in Table 4. As can be seen, two orthogonal factors were generated. From the evidence shown in Table 6 it follows that the statistical adjustment was adequate to use of the principal component decomposition method of Factor Analysis in this study. The hypothesis that the correlation matrix among the four variables is an identity is rejected, as shown by Bartlet's test. The KMO statistic = 0.678, higher than the lower acceptable limit of 0.5, and the total variance explained by the adjusted model of 79.112% consolidate the assertion that one it is adequate to use the factorial scores generated to construct the INST.

Table 6. *Results found in the estimation of factors using the principal component decomposition technique to assess the interaction between rainfall and the variables that define milk production in selected municipalities in Ceará State from 1973 to 2020.*

Variáveis	Factor components after orthogonal rotation		Factor score coefficients	
	F1	F2	F1	F2
Chuvas	0.761	0.300	0.425	-0.008
Vacas	0.103	0.955	-0.292	0.859
Produtividade	0.872	0.002	0.617	-0.331
Preço	0.674	0.599	0.249	0.306
Suitability of Kaiser-Meyer-Olkin (KMO) Test				0.678
Explained variance = 79.112%				
Bartlett's Test		DF = 6	Chi-Square = 69.236	Sig.= 0.000

Source: E stimated values from Funceme data (several years) and from IBGE (several years).

Study made by Paiva et al 2021, confirmed that rainfall instabilities and prices impacted herd size forecasts by dairy farmers in Ceará, however, the unpredictable instability of rainfall affected in a much more elastic way than the instability of milk prices. In this research the data were segregated by municipalities level and by periods classified as dry, normal and rainy (Table 7).

Based on this adjustment was generated the instability index (INST), whose estimated average values for each municipality are shown in Table 7. This Table 7 shows that in all municipalities the average INST are lower during drought periods.

Table 7. *Estimated values for the aggregated INST averages for all municipalities with the breakdowns for the rainfall periods defined in the study between 1973 and 2020.*

Municipalities	Averages	Drought Averages	Normality Averages	Rainy Averages
Acopiara	71.3	57.5	77.5	82.7
Alto Santo	48.7	37.6	46.5	76.4
Banabuiú	23.6	14.3	21.2	50.7
Crateús	78.1	74.7	80.0	82.8
Icó	73.3	64.5	70.5	95.0
Iguatu	84.2	82.4	88.0	97.8
Iracema	46.5	27.2	39.7	70.2
Jaguaretama	52.2	49.0	53.8	56.7
Jaguaribe	62.5	60.0	63.0	67.2
Lim. do Norte	45.8	38.1	39.6	66.0
Madalena	28.2	21.1	26.1	89.1
Milhã	20.0	6.1	25.5	46.2
Morada Nova	73.8	63.1	72.0	100.0

Municipalities	Averages	Drought Averages	Normality Averages	Rainy Averages
Quixadá	65.0	56.1	64.2	84.0
Quixelô	29.9	19.4	23.4	61.4
Quixeramobim	79.5	74.6	83.4	88.7
Russas	41.9	19.3	50.0	82.6
Sobral	81.5	74.2	85.1	93.7
Solonópole	49.7	44.5	48.6	65.6
Tauá	66.1	56.8	60.8	74.0
General Averages	56.1	48.2^C	54.2^B	75.5^A

Sources: Estimated values from Funceme and IBGE data (various years). Note: The super-indices indicate that the averages are statistically different and the hierarchy can be established: A>B>C.

Table 8. *Resultado da Análise de Regressão Para testar se os INST estimados para os períodos chuvoso. normal e seca são estatisticamente diferentes.*

Var. Explicativas	Coef. Regressão	Estatatística "t"
(Constant)	48.151	48.324
D1	27.305	15.528
D2	6.050	3.800
R^2 Ajustado	0.205	

Sources: Estimated values from Funceme and IBGE data (several years).

Table 8 presents the results found using the dummies variables to test whether the estimated INSTs for the rainy, normal and drought periods are statistically different. According to these results it is feasible to write the following rank to the index: $INST_{RAINY} > INST_{NORMAL} > INST_{DROUGHT}$.

5. Conclusions

From the evidences found in the research, it was observed very high instabilities associated to the rainfall of the municipalities that are also experienced by the defining variables of milk production in the studied municipalities, especially prices. This finding suggests that the observed instabilities in municipality's rainfalls have carried over to the production-defining variables in the twenty largest milk producing municipalities between 1973 and 2020.

The correlations between the variables that define the production in the biggest milk producing municipalities in Ceará could be consolidated in a dimensionless index. using the factor analysis method: the instability index (INST), that managed to capture the synergy between municipality's rainfalls and the studied variables, which defined the production of the 20 biggest milk producing municipalities in Ceará State from 1973 to 2020.

From the evidences found in the search it is also concluded that the estimates of INST associated with the drought periods are always lower than those estimated for the normal and rainy periods, as was expected in this work. It is also concluded that in the rainy periods the INSTs of the municipalities are always higher than in the normal and drought periods, also in accordance with the guiding expectations of the research. These are results that confirm the importance of the occurrence of high rainfall to foster better results in milk production in the semi-arid region.

It was shown in the study, as was also expected, but until then not empirically confirmed, that there is an synergy between the variables: rainfall, the number of lactating cows, the daily productivity and the price of milk received by farmers.

In general, as the synergy between rainfall and the defining variables of milk production in the municipalities studied was manifested unequivocally, it can be inferred that the same could be observed in all other municipalities that produce milk in Ceará State.

Thus, it is concluded that the evidence found in the research responded unequivocally to the guiding question of this study which was: Do the variables that define the production of milk in the twenty largest milk producing municipalities of Ceará State oscillate in synchronized synergy with the rainfall of these municipalities? The answer is yes.

As suggestions, the research results point out that to produce milk in Ceará State it is necessary to create technological instruments to adapt to the temporal rainfall instabilities that are important part of the semi-arid scenario. This includes a better interactive action among research, technical assistance, rural extension service and rural development institutions in the State. These recommendations seem obvious, but until now there was no scientific basis to support them. However, it is believed that, with the evidence found in this work, they now have scientific support to be implemented, not only in the 20 studied municipalities, but in all the municipalities of Ceará State.

References

[1] WILLIAMS. S. E. et al. (2008). Towards an Integrated Framework for Assessing the Vulnerability of Species to Climate Change. PLoSBiol 6 (12): 325. Recuperado em 10 de junho. 2021. de. https://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio. 0060325

[2] XIMENES. L. J. F. (2009). Forecasting of Profit per unit change of productive and reproductive traits of dairy cattle in the semi-arid Northeast. PhD Thesis. Universidade Federal do Ceará. Fortaleza. CE. Brasil. Universidade Federal do Ceará. Fortaleza. CE. Brasil. (In Portuguese).

[3] REIS FILHO. R. J. C. CARVALHO. A. P. (2009). Plan for the Development of Dairy Cattle Raising in the Irrigable Areas of the State of Ceará. Fortaleza: ADECE. (In Portuguese).

[4] PAIVA. E. C.. LEMOS. J. J. S.. & CAMPOS. R. T. (2021). Predictions for milk production under rainfall instability in Ceará in the period 1974 to 2 to 2019. Revista de Economia e Sociologia Rural. 60 (spe). e 252091. https://doi.org/10.1590/1806-9479.2021.252091 (In Portuguese).

[5] BURNEY. J.; CESANO. D.; RUSSEL. J.; LA ROVERE. E. L.; CORRAL. T.; COELHO. N. S.; SANTOS. L. (2014). Climate Change Adaptation Strategies for Small holder Farmers in the Brazilian Sertão. Climatic Change 126. 45–59.

[6] GALVÃO JÚNIOR. J. G. B; GUILERMINO. M. M.; MEDEIROS. H. R.; NOVAIS. L. P.; RANGEL. A. H. N. (2015). Profile of bovine milk production systems in Siridó Potiguar. Rev. Holos. 2. Rio Grande do Norte. (In Portuguese).

[7] LEMOS. J. J. S.; BEZERRA. F. N. R. (2020). Interference of rainfall instability in predicting grain production in the semi-arid region of Ceará. Braz J. Of Develop. 5. 9. 15632- 15652. Available in: https://www.brazilianjournals.com/index.php/BRID/article/vie .w/3294/3157. (In Portuguese).

[8] CURI. R. L. C. (2020). Precipitation and temperature effects on inequalities of milkproduction in Brazil. PhD Thesis. Universidade Estadual de Campinas. Campinas. SP. Brazil.

[9] RAGAZZI, F. G. et al. Analysis of the seasonal variation in milk production in the different dairy basins in Brazil. Brazilian Journal of Animal and Environmental Research. Curitiba (PR), Brazil. C v. 4, n. 1, p. 976-988 jan./mar. 2021.

[10] FAO Food and Agriculture Organization of the United Nations. 2018. World Meat Market Overview 2017. Meat Market Review. 1–11. Available in: http://www.fao.org/3/I9286EN/i9286en.pdf

[11] NUNES. L. F. C. V.; MEDEIROS. P. H. A. (2020). Historical analysis of the severity of droughts in Ceará: effects of hydraulic capital acquisition on society. Rev. Gest. Água Am. Lat.. Porto Alegre. v. 17. e18. 2020. (In Portuguese).

[12] THORNTON. P. K.; VAN. S. J.; Notenbaert. A.; HERRERO. M. (2009). The impacts of climate change on livestock and livestock systems in developing countries: A review of what we know and what we need to know. Agricultural Systems. 101. 113-127. Available in https://www.researchgate.net/publication/223601083_The_Impacts_of_Climate_Change_on_Livestock_and_Livestock_Systems_in_Developing_Countries_A_Review_of_What_We_Know_and_What_We_Need_to_Know.

[13] IBGE. Brazilian Institute of Geography and Statistics. Rio de Janeiro (RJ), Brazil. 2020.

[14] FUNCEME. Meteorology and Water Resources Foundation of Ceara. Rainfall calendar for the State of Ceará. Fortaleza, Ceara. 2021. Available in: http://www.funceme.br/app/calendario/produto/municipios/maxima/anual. Access in: 13 dez. 2021.

[15] GARCIA. C. H. (1989). Tables for classifying the coefficient of variation. IPEF. 12. (Circular técnica. 171). dehttps://www.ipef.br/publicacoes/ctecnica/171.pdf. (In Portuguese).

[16] GOMES. F. P. (1985). Course in experimental statistics (13a ed.). São Paulo: ESALQ/USP. (In Portuguese).

[17] SORENSEN. A. T. Equilibrium Price Dispersion in Retail Markets for Prescription Drugs. Journal of Political Economy. Chicago. vol. 108. P. 833- 850. 2000. Available in: https://pdfs.semanticscholar.org/3b1a/6ba76440c8095d7dcc5e07317461ba38923d.pdf.

[18] FÁVERO. L. P et al. (2015). Análise de Dados: técnicas multivariadas exploratórias com SPSS e STATA.(1aed). Rio de Janeiro: Elsevier. 2020.

[19] BROOKS, N. Vulnerability, risk and adaptation: A conceptual framework. Tyndall Centre for Climate Change Research. 2003. Available in: https://www.researchgate.net/publication/200032746_Vulnerability_Risk_and_Adaptation_A_Conceptual_Framework/link/58ac004a458515040205dfb2/download

[20] MCCLAVE. J. T.; BENSON. P. G. SINCICH. T.. Statistics for Business and Economics. Upper Saddle River. New Jersey. Pearson Prentice Hall. 2005.

[21] HAHN. M.; RIEDERER. A.; FOSTER. S. (2009). The Livelihood Vulnerability Index: A pragmatic approach to assessing risks from climate variability and change - A case study in Mozambique. Global Environmental Change. 19 (1). 74-88.

[22] GUILLAUMONT. P; SIMONET. C. (2011). Designing an index of structural vulnerability to climate change. FERDI-Fondation etrecherchessur le Developpement International. 42. France.

[23] CHAN. L. L. (2017). Validity and Reliability of The Instrument Using Exploratory Factor Analysis and Cronbach's alpha. International Journal of Academic Research in Business and Social Sciences. 7 (10). Access in: 15 de april. 2021. in https://hrmars.com/hrmars_papers/Validity_and_Reliability_of_The.pdf

[24] SALLY. J. D.; SALLY JR.. P. J. (2007). A vertical development of mathematical problems. Washington – DC (USA). American Mathematical Society.

[25] WOOLDRIDGE. J. M. (2013). Introductory econometrics: A modern approach. (5a. ed). Mason: South Western Educactional Publishing.