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Climate Resilience Agriculture (CRA) In The Brazilian Semi-Arid Region

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Abstract:
This study aims to evaluate the climate resilient agriculture (CRA) in rainfed crops cultivated semi-arid zone of Ceará a Brazilian State. To do this, it has four specific objectives: a) to classify the rainfall distribution of Ceará State from 1901 to 2020 into three periods: drought, normal and rainy; b) to evaluate the years of occurrence of those periods between 1945 to 2020 because the crops production data are available only in those years; c) to evaluate how the production of rice, beans, cassava and corn in Ceará State behave in each of these periods in the studied years; d) to assess the instabilities/stabilities of rainfall, as well as those associated with the defining variables of studied crops production; e) to assess evidence of the existence of resilience in the production of these crops in rainy or normal years of rainfall following those of drought, as defined in this study. It was used factor analysis methodology to build the synergy index (SIN) to evaluate the gathered variables used to measure the production of crops. All the objectives are achieved and there were found evidences of climate resilience agriculture among the production of rice, bean, cassava and corn from 1945 to 2020 in Brazilian Ceará State.

***Key Word**: Rainfed agriculture; Rainfall instability; Sustainable production; Food security; Brazilian semiarid.*

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I. Introduction

The semi-arid is a type of climate characterized by the prevalence of high temperatures, low relative humidity and with unstable rainfall regimes both, from a temporal and spatial point of view [1,2,3].

In general rainfed agricultural activities, which depend exclusively on rainfall precipitation, prevail in the Brazilian semi-arid region. These are crops of great importance as promoters of occupation, monetary income, and food production for the families of farmers who engage in these activities. The use of technologies that neutralize, or at least mitigate the impacts of rainfall irregularities, which are very common in the Brazilian semi-arid region, isn't accessed by the majority of farmers [4,5,6]. These facts make the agriculture practiced under this climatic regime, in the semi-arid region, difficult to conduct and is an activity very subject to risks: economic, social and environmental [7,8,9,10,11,12,13,14,15,16].

Soil and water management, in areas where rainfed agriculture prevails, are the main constraints in maintaining production, productivity, and income of these crops. Thus, the water scarcity that is caused by the systematic occurrence of droughts plays a crucial role, given that it induces vulnerabilities that rebound in persistent poverty in places that coexist with this difficulty, in addition to impacting on the degradation of natural resources and the environment, thus eroding productivity and weakening coping strategies and their resilience [7,17,18,19,20,21,22,23].

On the other hand, it is known that farmers in general, and those who cultivate rainfed crops in particular, develop strategies of adaptation and coexistence with the rainfall uncertainties that are their rule since they entered the activities, either through the knowledge acquired from their parents and relatives, or by their own experiences. This learning leads them to devise survival strategies in the most critical periods. A behavior that can be identified as self-resilience, because it is independent of the action of external agents, or of public policies. They function as a self-defense mechanism for farmers who cultivate rainfed crops [24,25,26].

In 2010 the FAO presented the concept of Climate-Smart Agriculture (CSA) at The Hague Conference on Agriculture, Food Security and Climate Change. This concept, according to the document produced at that event, would contribute to the achievement of sustainable development goals. The concept would reflect the synergy between three of the dimensions of sustainable development: economic, social and environment, seeking to find food security under the challenge of climate change [27,28].

According to FAO (2013), the CSA concept is anchored on three pillars: 1- increasing productivity growth and income in the agricultural sector; 2- adapting and building resilience to climate variations; and 3- reducing and/or removing greenhouse gas emissions, when possible.

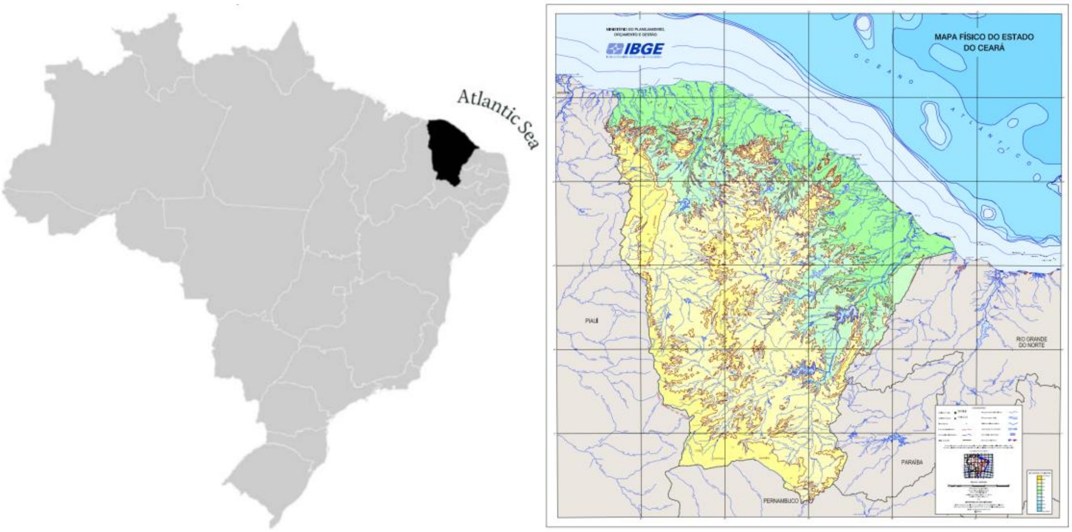
The concept of CSA, as can be seen, is relatively new and is in a maturing process. It involves the search for tools to identify appropriate patterns of sustainable agriculture conditioned to the location and specific situations experienced in certain regions. CSA seeks to identify the technical and economic foundations that can encourage intelligent actions to climate variations. As the concept is still under construction, the FAO document itself recognizes that it may not be possible to achieve at once and simultaneously the three objectives on which it is based. It is necessary to evaluate each specific context, priorities and difficulties to be overcome [28].

According to [29], Climate Resilient Agriculture (CRA) means the incorporation of adaptation, mitigation, and other practices in agriculture that are able to increase the productive system in responding to different climate instabilities, by resisting damage, recovering quickly and ensuring sustainable production. In short, it is the ability of a system to return to its position prior to the occurrence of the stress to which it was subjected. CRA involves increment in management of natural resources, such as land, water, soil, besides genetic resources always seeking better practices. In this way, the concept of Climate Resilient Agriculture (CRA) can be conceived as a step prior to CSA [30,31,32,29,33,34].

The literature depicting CRA practices suggests that some of the strategies to achieve this goal would be: growing drought-tolerant varieties, crop diversification, soil management, developing water harvesting and storage strategies, fostering food security, attempts to conserve soil moisture, proper soil management, crop diversification, using water-constrained tolerant cultivars, growing shorter cycle crops, among other practices [30,35,36,31,29,37,38,39].

In the Brazilian semi-arid region in general, and in Ceará State in particular, which has 171 of its 184 municipalities recognized by the Federal Government as being included in this region, it can be said that there are some practices exercised by the farmers themselves that can be characterized as CRA. These are experiences and adaptations, most of the times spontaneous, without the intervention of public authorities, which lead them, for example, to select seeds and seedlings of the crops that show the best results in times of good rainy seasons and even in those periods when there are rain difficulties [11,40,26]. Map 1 shows the position of Ceará State in Brazil.

Map 1 - Ceará State position in Brazil



Source: Based on Brazilian Institute of Geography and Statistics (IBGE).

Based on these fundamentals, this research was designed and is anchored on the assumption that the instabilities observed in the variables that define the production of some rainfed food crops interact with rainfall instabilities in a differentiated way in each of the periods in which the rainfall occurred in the semi-arid region of Ceará State, between the years 1945 and 2020.

To evaluate this assumption, the work has the following specific objectives: a) Based on the historical series of average rainfall for the State of Ceará between 1901 and 2021, to classify the rainfall distribution into three periods: drought, normal and rainy; b) as the information regarding crop production extends from 1945 to 2020, to evaluate the years of occurrence of the drought, normal and rainy periods, defined in objective "a" in this time span; c) to evaluate how the production of rice, beans, cassava and corn in Ceará State behave in each of these periods in the years 1945 to 2020; d) To assess the total instability/stability of rainfall, as well as those associated with the defining variables of rice, beans, cassava and corn production between 1945 and 2020; e) To assess evidence of the existence of resilience in the production of these crops in rainy years or years of normal rainfall following years of drought, as defined in this study.

II. Material And Methods

Drought definitions

According to [41] drought is a prolonged period when the total precipitation over a defined region is lower than the long-term average, causing problems between water demand and supply in that region. According to [42,43,44] drought is a complex natural phenomenon that affects agricultural activities, water reservoirs used to produce electricity, and other water use needs.

According to [45] there are four types of droughts: meteorological, agricultural, hydrological, and socioeconomic. The meteorological drought is associated with a drop in rainfall due to the behavior of the oceanic-atmospheric system. Or, according to [46], meteorological drought can be defined as the duration of periods in which rainfall occurs below a historical average. Drought is classified as agricultural when evapotranspiration is greater than the total water available for crops in the soil [47]. Hydrological drought, in turn, is related to the inadequate flow of rainwater for the uses already established in the system as, for example, to supply hydroelectric plants [48,44]. Finally, socio-economic drought affects the consequences of water scarcity for economic activities, water shortages for human needs, for animals and having environmental impacts [49].

The work of [50] elaborated a classification for drought periods in Ceará State using the normal percentage index (PIN) which is estimated by the ratio between the accumulated precipitation in a given year and the historical average computed from a longer period.

In this search it is used the meteorological and agricultural concepts together, based on a definition of rainfall in three periods evaluating those effects of agricultural variables which define rainfed crops in Ceará State: drought, normal and rainy.

Database description

The study uses rainfall series provided by two sources, covering the period from 1901 to 2020 (120 years). The sources of information were: Meteorology and Water Resources Foundation of Ceará (Funceme)[51] and National Oceanic and Atmospheric Agency (NOAA)[52].

The data referring to harvested areas, productivity, prices of rice, beans, cassava and corn production were collected from 1945 to 1973 from the IBGE Statistical Yearbooks. From 1974 to 2020 were taken from the documents Municipal Agricultural Productions (PAM) in the reference years. The values were updated for 2020 using the General Price Index - Internal Availability (GPI-IA) from Getúlio Vargas Foundation - GVF.

The selected rainfed food crops were: rice, beans, cassava and corn, because they are cultivated by the majority of farmers in the State of Ceará (IBGE)[53]. From these crops the following variables were analyzed:

A_{it} = Harvested area in hectares (ha) with crop "i" (i = 1, 2, 3, 4) in year t (t = 1945,..., 2020) in Ceará;
R_{it} = land productivity or, simply, productivity ($kg.ha^{-1}$) in the production of crop "i" in year "t":
P_{it}= average price ($USD.kg^{-1}$), in 2020 values, of crop "i" in year "t".

The choice of variables is justified for the following reasons. Besides being the ones that define the production of the crops, they have the following characteristics. Farmers have some power of definition about the areas that they will plant (areas that they have) and the technologies that they will use for the cultivation of crops, which will influence the productivities. However, the areas that will be harvested, as well as the yields, depend on exogenous factors, being the rainfall instability the most relevant in semi-arid region. Thus, these variables are random for the farmers. Prices, on the other hand, are set in markets over which farmers have no control. Thus, the crop prices are also random variables for them.

Classification of rainy years in Ceará State from 1901 to 2020

For the classification of rainfall periods for the State of Ceará, are used historical series of rainfall for the State between the years 1901 and 2020. The average (AV) and the standard deviation (SD) were calculated for these years of observations. Thus the following periods are defined, according to the annual rainfall intensity: Years of rainfall scarcity, called "Drought". Years with excessive rainfall, called "Rainy". Periods when the rainfall levels are in an intermediate position between "Drought" and "Rainy", called "Normal". The definitions of these three periods are shown in Table 1.

Table 1 - Rainfall periods definition in Ceará State from 1901 to 2020

	Periods	Ranges of Variation in milimeter (mm)
Drought Normal Rainy		Rainfall < (AV– ½ SD) (AV – ½SD) ≤ Rainfall ≤ (AV + ½ SD)Rainfall > (AV + ½ SD)

Source: NOAA [52] and Funceme [51].Note: SD = standard deviation.

Once the years that make up each period are defined, the test is performed to verify if the mean of these periods are statistically different. If this hypothesis is accepted, the classification can be used to evaluate the variables used to study the rainfed crops in each period. To perform the test we use dummies variables (D_1 and D_2) defined as follows:

D_1=1 in normal years. D_1=0 in drought and rainy periods; D_2= 1 in rainy years. D_2= 0 in drought and normal periods; D_1=D_2=0 in drought periods Equation (1) is used to perform the test:

$$C_t = \beta_0 + \beta_1 D_1 + \beta_2 D_2 + \eta_t \qquad (1)$$

In Equation (1), the linear coefficient β0, being statistically different from zero, with $D_1 = D_2 = 0$, will be the average rainfall for the drought years; the coefficient β1 being statistically different from zero, with D_1= 1 and D_2 = 0, means that the average rainfall of the normality period is different from the other periods. The coefficient β2 being statistically different from zero, with D_1 = 0 and D_2= 1, means that the average rainfall of the rainy period differs from the other periods.

The random term ηt, by hypothesis, meets the assumptions of the classical linear model, of being white noise. Thus the parameters of Equation (1) can be estimated by the ordinary least squares method–OLS [54,55]. If this model prevails, it will be possible to rank the rainfall periods as follows: Rainy period average > normal period average > drought period average.

Assessment of stability/instability in the variables

To gauge the stability/unstability associated with rainfall, it was used the coefficient of variation (CV). By definition the CV measures the percentage ratio between the standard deviation and the mean of a random variable. The CV is widely used as a measure of variation by the researchers in the applied disciplines like finance, climatology, engineering, risk sensitivity; variability in agricultural experiments. An advantage associated with the CV is that it allows the comparison between variables of different nature and measurement [56,57.58,59,60].

The smaller the CV is, the more homogeneous, or more stable will be the distribution of the variable observations around its mean [59]. To use the CV as a measure of the degree of stability/instability of a distribution, some knowledge about the definition of its critical values may be useful. Gomes [56] established limits for classifying CVs in agricultural experimentation. These are the references used in this study (Table 2).

Table 2 - Classification of the Coefficient of Variation (CV) according to its amplitudes

CV Classification	CV Range (%)
Low	CV < 10
Medium	10 ≤ CV< 20
High	20 ≤ CV < 30
Very High	CV ≥ 30

Source: Gomes [56].

Synergies among the defining variables of rainfed production

The variables assumed to define the production of rice, bean, cassava and corn were aggregated: harvested areas, productivities and prices. As these are variables measured in different units and supposed to be correlated, the aggregation was made through the synergy index (SIN) built in the research. To build this index it was used the factor analysis methodology (FA) thru principal components decomposition.

Brief summary of the AF procedure as it applies to the study

Factor analysis is a method designed to investigate whether a number of variables Y_1, Y_2, ...,Yn, can be summarized into a smaller number (k < n) of unobservable factors: F_1, F_2, ..., F_k. The technical assumption of AF is anchored in the linear correlation between the variables that are used. In order to adequately perform the AF you need to follow these steps: perform the Bartlett's test of sphericity to confirm that the correlation matrix is not an identity; ensure that the Kaiser-Meyer-Olkin (KMO) statistic has a value equal or greater than 0.500; evaluate the percentage of explanation of the accumulated variance by the estimated factors [61,62,10,63,64,65,66].

Being generated more than one factor, the FA method provides the possibility to rotate these factors. There are different rotation methods. In this study it was adopted the Varimax method, which will produce linearly independent factors. This property is used to build the synergy index (SIN). Once the extraction has been done and the number of factors has been determined, the FA possibility to estimate the coefficients associated with the factorial scores [62,67,65,66].

With these procedures the "n" original variables generate "k" (k < n) unobserved variables that have zero mean and unit variance. These are the factor scores (FS) used in the construction of the synergy index (SIN) in a positive scale. The FS has zero mean, so they values gravitate around it are positives and negatives. To make all of them positives, without affecting the hierarchy in which they were generated, the variable (Y_{kt}) is created, which will have values ranging between zero and one. To do this we estimate the maximum FS value (FS_{max}) and its minimum value (FS_{min}) and use the transformation showed in Equation (2):

$$Y_{kt} = (FS_{kt} – FS_{min}) / (FS_{max} – FS_{min}) \quad (2)$$

Generated in this way, because the factors are orthogonals (caused by the varimax rotation), it is possibly to estimate the synergy index (SIN) by the arithmetic average of the Ykt.

$$SIN_t = \Sigma Y_{kt}/k \quad (3)$$

The synergy index will vary between zero and one ($0 \leq SIN_t \leq 1$). The closer to one (1) the SIN value is in a given year, the better the joint behavior of the original twelve (12) variables in that year will have been. This is expected to happen in the normal and rainy years that are defined in the research.

Measuring the resilience in the production of the studied crops

To assess whether there was resilience associated with the synergy between harvested areas, productivity and prices of rice, beans, cassava and corn in Ceará State from 1945 to 2020 (including the extreme years, so there were 76 observations), as summarized in the SIN, the following procedure is assumed. It was computed in sequence, the rainfall years in the drought, normal and rainy periods. When sequences of more than one year occur in the drought periods, the SIN averages of these sequences of years are calculated. On the other hand, when sequences of normal and rainy periods occur, the averages of these periods are calculated in aggregated way. These are the non drought periods. Therefore, it is assumed that resilience would be the ability to recover from the non drought periods that followed drought periods.

Proceeding in this way, the annual sequence of the SIN series, which originally has 76 observations, will be reduced to a number inferior of pairs of sequences in which the values follow each other in a binary manner: drought and no drought periods. This SIN sequence is then assembled into pairs identified as “after” and “before” drought periods. The test to be performed compare the SIN averages in the two groups (“after” and “before” drought). The null hypothesis is: the difference of SIN average after drought ($\mu 1$) and its average before drought (μ_2) is equal to zero as shown in Equation (4):

$$H_0: (\mu_1 - \mu_2) = 0 \quad (4)$$

If the null hypothesis is accepted, it can be ascertained, with the margin of error of the test, that there is resilience in the variables grouped in the SIN. The used test is Student's “t” test with (n-1) degrees of freedom, where "n" is the number of pairs to be tested [68,69].This test was used for the comparison of group means by Monteiro and Lemos [70] to analyze the distribution of resources of the National Program of Strengthening Family Farming between regions and Brazilian States from 1999 to 2014.

III. Results and Discussion

The estimated average rainfall for the period from 1901 to 2020 was 799.5 mm, with a standard deviation of 268.3 mm and CV=33.6%. Based on these values we stipulated the upper limit for the drought period (668.50mm) and the lower limit for the rainy period of 933.7 mm. The normal years were situated between these two extremes. These were the limits used for the definitions of the drought, rainy and normal periods that occurred between the years 1901 and 2020.

It can be seen in Table 3 that the observed rainfall averages for the defined periods between the years 1901 and 2020 were statistically different. The limits established for the periods were applied for rainfall occurring between 1945 and 2020. The statistical test done for this period also showed that the averages are different. Thus, the following hierarchy can be constructed for the rainfall precipitation occurring in Ceará between the years 1901-2020 and between the years 1945-2020 as follows: rainy period > normal period > drought period (Table 3).

Table 3 - Results of the test to evaluate difference between the averages of the three rainfall periods created for Ceará

Variables	**Results from 1901 to 2020**			**Results from 1945 to 2020**		
	Coefficients	**t statatistic**	**Sign.**	**Coefficients**	**t statatistic**	**Sign.**
Constant	524.685	24.830	0.000	552.042	23.994	0.000
D_1	255.148	8.979	0.000	245.546	6.987	0.000

D_2	599.670	19.650	0.000	552.521	14.894	0.000
Adjusted R^2: 0.768				Adjusted R^2: 0.753		

Sources: NOAA [52] and FUNCEME [51].

Table 4 shows the averages and the estimated CVs for the drought, normal, and rainy periods between the years 1901-2020 and 1945 - 2020.

Table 4 - Classification by periods of Ceará State rainfall

Periods	**Years of occurrence (1901 to 2020)**				**Years of occurrence (1945 to 2020)**			
	Total	**%**	**Average (mm)**	**CV (%)**	**Total**	**(%)**	**Average (mm)**	**CV (%)**
Drought	38	31.7	524.7	20.6	28	36.8	552.0	19.1
Normal	47	39.2	779.8	10.5	28	36.8	803.4	11.4
Rainy	35	29.2	1124.4	17.0	20	26.3	1104.6	18.4
Total	**120**	**100.0**	**799.5**	**33.6**	**76**	**100.0**	**777.8**	**33.3**

Sources: NOAA [52] and FUNCEME [51].

It is observed that between 1901-2020 the estimated average rainfall for Ceará was 799.5 mm with CV = 33.6%, and between 1945-2020 the average was 777.8 mm with CV=33.3%, showing the very high instability of rainfall in both analyzed series (Table 4).

Table 5 shows the means and the CV estimated for the variables used in the study. Through the evidence shown in Table 5 we can infer that the rainfall instability observed in the period investigated, was transmitted practically to all variables that define the production of rice, beans, cassava and corn in Ceará. In relation to the periods in which the annual rainfall of the state of Ceará was classified, the greatest instabilities observed in the variables that define the production of the products studied are in the drougt periods, excepting to cassava harvested lands (Table 5).

Table 5 - Averages and variation coefficients (CV) of selected variables, Ceará State (from 1945 to 2020)

	Drought		**Normal**		**Rainy**	
Variables	**Average**	**CV (%)**	**Average**	**CV (%)**	**Average**	**CV (%)**
Rice harvested land (ha)	34677.68	50.28	43226.69	46.45	46990.72	28.32
Rice productivity (kg.ha^{-1})	1771.50	41.21	1973.64	30.95	2203.32	23.26
Rice price (USD.kg^{-1})	806.96	43.34	870.49	20.84	1144.89	37.12
Bean harvested land (ha)	336095.71	43.62	385732.90	44.95	462814.5	28.38
Bean productivity (kg.ha^{-1})	260.48	45.49	431.63	28.05	331.80	31.59
Bean price (USD.kg^{-1})	263.63	48.41	298.07	39.33	305.34	35.57
Cassava harvested land (ha)	87500.61	41.01	88143.69	46.95	97308.41	21.57
Cassava productivity ((kg.ha^{-1})	8843.20	35.93	11571.48	27.12	10242.52	27.36
Cassava price value(USD.kg^{-1})	736.84	50.87	811.38	43.05	921.73	33.40
Corn harvested land (ha)	368959.16	45.04	451570.83	37.92	525755.14	23.33
Corn productivity (kg.ha^{-1})	445.08	49.88	833.51	22.20	698.53	32.70
Corn price (USD.kg^{-1})	145.06	57.91	232.51	29.78	216.53	30.24
Years of ocurrence	28		28		20	

Sources: NOAA [52]; FUNCEME [51] and IBGE [71].

Results associated with the FA to build the synergy indexes (SIN)

The results found for the factor analysis used to estimate the synergy index (SIN) are shown in Table 6. The twelve original variables are reduced to three orthogonal factors. It is observed that the adjustments were all satisfactory, from a statistical point of view, considering that the Bartlet test evidences that the correlation matrix is not identity. The KMO statistic = 0.620 and the total explained variance (77.8%) by the three orthogonal factors, into which the twelve (12) variables studied were summarized, complement the information of the robustness of the adjustment (Table 6).

Table 6 - Results from factor analysis to create the sinergy index (SIN)

Variables	**Rotated Component Matrix**			**Component Score Coefficient Matrix**		
	F_1	F_2	F_3	F_1	F_2	F_3
Rice harvested land (ha.year^{-1})	0.131	0.380	0.670	0.042	0.151	0.240
Rice productivity (kg.ha^{-1})	-0.054	0.723	-0.341	0.051	0.245	-0.112

Rice price value (USD.kg^{-1})	0.034	-0.035	0.676	-0.019	-0.002	0.241
Bean harvested land (ha.year^{-1})	-0.184	0.935	0.202	0.005	0.316	0.091
Bean productivity (kg.ha^{-1})	0.958	-0.083	-0.010	0.289	0.042	-0.043
Bean price value (USD.kg^{-1})	0.433	-0.422	0.674	0.075	-0.108	0.220
Cassava harvested land (ha.year^{-1})	-0.280	0.293	0.764	-0.095	0.091	0.289
Cassava productivity (kg.ha^{-1})	0.843	-0.296	0.109	0.233	-0.039	0.002
Cassava price value (USD.kg^{-1})	0.081	-0.255	0.742	-0.024	-0.075	0.261
Corn harvested land (ha.year^{-1})	-0.056	0.943	0.087	0.050	0.327	0.044
Corn productivity (kg.ha^{-1})	0.879	0.325	-0.219	0.304	0.177	-0.110
Corn price value (USD.kg^{-1})	0.867	-0.245	0.340	0.235	-0.017	0.085
Explained variances	29.001	25.165	23.627			
Cumalitive explained variances						
Approx. Chi-Square: 917.835						
Degree of freedom: 66						
Sig.: 0.000						
Bartlett's Test of Sphericity Kaiser-Meyer-Olkin (KMO)/Measure of Sampling Adequacy (MSA): 0.620						

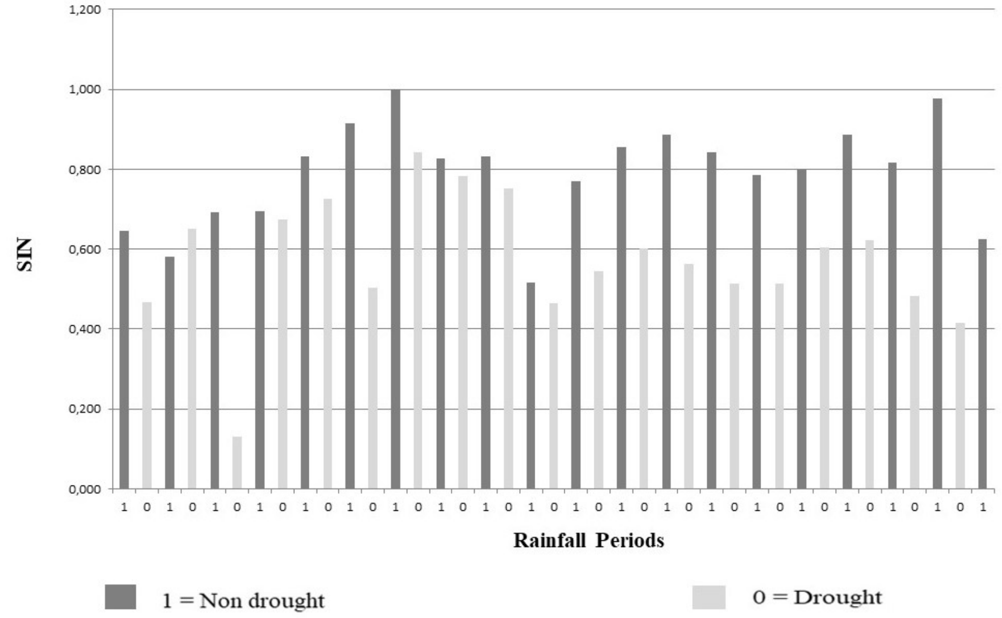
Source: IBGE [71].

Note: Rotation converged in 5 iterations.

Contrast test to evaluate resilience in the rainfed Ceará production

The estimated average of the SIN for the drought periods was 0.572 while its value for the non drought periods was 0,796. The results of the performed contrast test to evaluate the resilience in the production of rice, bean, cassava and corn in Ceará State, between 1945 and 2020, are showed in Figure 1.

Figure 1 - Sinergy index (SIN) and rainfall periods



Source: Own elaboration based on data from NOAA [54] and IBGE [71].

As someone can see in this figure the columns showing the averages of non drought periods (dark gray columns) observed after averages of drought periods (clear gray columns), are almost always greater, suggesting resilience.

To confirm these results, in Table 7 was showed the averages SIN contrasts measuring the differences of SIN average before non droughts periods (0.797) and SIN after drought periods (0.795).The estimated P value for performed "Student" "t" test, used to evaluate the existing statistical significance in the contrasts, showed that there was no significant difference between them. These results mean that the averages aggregated SIN, before drought and after drought periods, are statistically equals. Otherwise they permit to conclude that there were no reasons to reject the hypotheses that exist resilience in production of rice, bean, cassava and corn in Ceará State in the period of 1945-2020.

Table 7 - Contrast test to evaluate difference of SIN before and after scarcity periods in Ceará State from 1945 to 2020

Contrasts	Differences between ranked pairs with 95% fiducial probability					
	Average difference	Average before drought periods	Averageafter drought periods	t Statistic	Degrees of freedom	Sig. 2-tailed
Before – After	0,001	0.797	0.795	0.029	17	0.977

Source: IBGE ^{71}.

IV. Conclusions

The research succeeded in elaborating the proposed classification of the climate years in Ceará State between 1945 and 2020, years in which data about the agricultural production of the state is available. There were created three (3) periods from the annual rain precipitation for that period: Drought, Rainy and Normal. It was made based on an available longer series from 1901 to 2020. The statistical performed test showed that the rainfall averages for the three created periods allow them to be ranked as follows: rainy > normal > drought. Thus, the first objective of the research was achieved.

The research showed that, in general, the rainfall observed in the Ceará State in that period is very unstable, but is even more unstable in the drought years, results that are transmitted mostly to the variables used in the research for the construction of the synergy index (SIN), to evaluate the rice, bean, cassava and corn productions in the State between 1945 and 2020.

The general conclusion of the search is that, despite the difficulties faced by farmers, mostly family farmers, producers of rice, beans, cassava and corn, some of the most important rainfed crops in the Ceará State, these producers managed to develop adaptive capacities by themselves to the rainfall instabilities observed in the last 76 years and exhibited evidences of resilience in the production of these crops, after the occurrence of droughts, which were manifested in 31 of the 76 studied years.

In summary, living with the semi-arid climate in the State of Ceará is a reality that needs to be better planned by public policy makers. The development of low-cost technologies for small farmers, considering the adaptive capacity to the semi-arid climate conditions can be a suggestion for future researches. Another suggestion is to improve resilience of rainfed agriculture to climate change through technical assistance and other public policies, such as make rural credit available at favorable interest rate conditions for family farmers principally.

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